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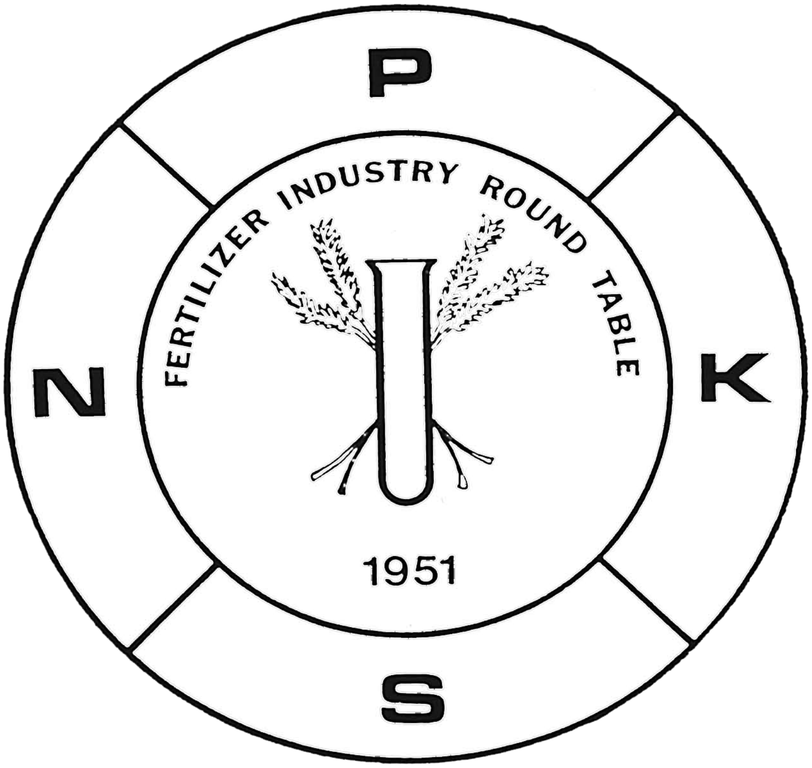
ROUND TABLE
1992



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The Fertilizer Industry Round Table Award of Merit

Presented to William F. Sheldrick
By Harold Blenkhorn

The Fertilizer Industry Round Table award of Merit is an award which recognizes outstanding accomplishments of individuals who have devoted their careers to the fertilizer industry. This year the selection committee and Round Table directors have chosen William F. Sheldrick as the worthy recipient of this award.

Bill Sheldrick has had a long and distinguished career as a chemical engineer working in process technology in industry and development projects on an international scale.

Bill is a native of England. Following a stint in the Royal Navy during 1943-46, he obtained a BSc. in mechanical engineering and a MSc. in chemical engineering from Durham University. He is also a graduate of the Harvard Advanced Management Program.

In 1950, Bill joined Imperial Chemical Industries Limited as a process development engineer, moving on in 1956 to Fisons Limited as chief chemical engineer. In 1961-62, he served as personal assistant to the group chief executive, and was appointed manager of technical services in 1963. In this capacity, Bill had overall responsibility for all production and engineering operations.

In 1975, Bill left Fisons to join the World Bank in Washington D.C., there to fill the newly created position of chief of the fertilizer unit, with responsibility for advising the Bank and member countries on matters relating to fertilizers. Other responsibilties included liason with the international fertilizer industry and acting as Chairman of the World Bank/UNIDO/FAO/Industry Fertilizer Working Group. During his fifteen years with the World Bank, Bill participated in a wide range of fertilizer appraisal projects and fertilizer sector work in many parts of the world. As his colleagues have pointed out-"Bill Sheldrick brought direction and purpose to World Bank fertilizer programs".

Bill retired from the World Bank in 1989 and returned to his native England. He now works as an International Fertilizer Consultant-his current work includes a part time commitment to maintain a fertilizer data base for the World Bank and continues as a member of the Fertilizer Working Group.

Bill is a Fellow of the Institute of Chemical Engineers and a member of the UK Fertilizer Society. Many years a director of the Fertilizer Industry Round Table, he served as chairman from 1988 to 1990. He has been author or co-author of more than fifty papers on chemical engineering and fertilizer topics. In 1983, he was awarded the Francis New Memorial Medal for an outstanding contribution to the Fertilizer Industry.

On behalf of his fellow Round Table Directors, it is with pleasure that I present him with a framed certificate which bears the highly appropriate inscription:

"THE FERTILIZER INDUSTRY ROUND TABLE AWARD OF MERIT"

Presented to WILLIAM F. SHELDRICK in recognition of a lifetime of outstanding services and technical contribution to the fertilizer industry, farmers, and people of the world."

OPENING REMARKS

Paul J. Prosser, Jr., Chairman

Once again, it is my pleasure to welcome you to the annual meeting of The Fertilizer Industry Round Table - this time the forty-second. And, once again, it is my pleasure to welcome you to Baltimore, a cradle of the fertilizer industry in the United States of America.

Today, I am happy to inform you that there are here present representatives of five continents, and it is our hope and belief that our program has something of interest for all of you. Of particular interest this year are the effects that economic changes in the former USSR will have on the world-wide fertilizer industry and we hope that our program will give us some insight there as well as addressing current specific technical issues that are important to all of us.

Again, welcome, we are pleased that you have come, many from very far away, and we do hope you will enjoy a profitable and happy meeting.

Now, I am very pleased to introduce Mr. Bill Sheldrick, Consultant to The World Bank, Past-Chairman and present Director of the Round Table who will introduce our Keynote Speaker.

Monday, October 26, 1992

Session I

Moderator:
Richard D. Harrell

Keynote Address

Investment Opportunities In The Fertilizer Sector In The Former Soviet Union

Dr. Paul Stangel
Stangel and Associated Agricultural Consultants

I. *Introduction*

Leaders throughtout the fertilizer industry are keenly aware that the fertilizer sector world wide is now in the midst of one of its most dramatic changes. These changes are forcing the restructuring of major segments of the sector at national, regional and global levels, not experienced since the end of World War II. The external signs are very clear (Exhibit # 1). Increases in global fertilizer consumption has slowed in the past decade and actually declined over the previous year in each of the past three years and six of the past 11 years. While most of this trend is due to changes occurring in developed countries where consumption is off 15% since 1988, there is increasing evidence that these changes will soon have a major impact on many developing countries as well.

The forces driving this change (Exhibit # 2) and shaping this restructuring are: removal of fertilizer subsidies, scraping of price controls, privatization of state owned monopolies engaged in the production, procurement and distribution of fertilizer and perhaps the most significant, shift from a centrally planned to a demand driven competitive market economy. Nowhere are these forces more operative and changes evident than in what is now known as the Newly Independent States (NIS) of the Former Soviet Union (FSU).

The purpose of this paper is to briefly highlight some of these changes now underway in the republics of the FSU, relate their impact on the fertilizer sector, identify some of the impediments to change and suggest potential areas of investment in the fertilizer sector or related areas.

A. *Background Information*

The FSU is an immense and complex geographic region. A brief review of some of its basic features in terms of overall size as well as trends in agriculture and fertilizer may be useful to understand the potential for investing in the fertilizer sector.

1. *Size* - Prior to its break-up in 1991 the FSU was by far the largest country in the world (Exhibit #3). The FSU, encompassing an area of 8,065 million square miles (greater than Canada and the United States of America combined), stretches 5,700 miles (9500 Km) from the Western edge of the Baltic Sea to the Pacific Ocean on the eastern seaboard and crosses 11 time zones in the process (Figure 1). It is inhabitated by a diverse population made up of at least 112 different ethenic groups and which collectively speak an equal number of languages. The total population of the FSU in mid 1992 was an estimated 284 million (about the size of the US). A majority of this population is located in urban areas (about 67%) with about 60% of it residing in republics west of the Urals (essentially the European side of the FSU). The political break up of the FSU began in late 1990 and was completed by December 1991. Eleven republics have formed the Commonwealth of Independent States (CIS). These are; Russia, Kozakhstan, Kirgizstan, Uzbekistan, Turkmenistan, Azerbaidzhan, Aremenia, Tadzhikistan, Ukraine, Byelorussia,and Moldova. The Baltic States, (Lithuania, Latvia and Estonia) and Georgia while independent republics are not members of the CIS. As a result of this break up, the Russian Federation has emerged the world's largest nation, accounts for 77% of the territory, the majority (70%) of natural resources and 52% of the population of the FSU. These republics, though now independent of each other, have a common infrastructure (rail, airlines, roads, ports, support services), engage in a very large inter-republic trade. Many have a common currency and until changed still attempt to operate under a common set of laws and regulations. However, because of recent changes previously common political and economic policies are no longer acceptable and need to be renegotiated. This poses a major problem to the successful operation of the sub-sectors in the respective republics including agriculture and the fertilizer sector. Resolving these problems will greatly effect the type and volume of foreign investment in the fertilizer sub-sector.

2. *Agriculture* - Agriculture, like other sectors in the FSU has until recently operated under a centrally planned top down command economic system (Exhibit # 4). Production, distribution, and consumption of input and output was controlled by the Central Body (Supreme Soviet) of the FSU. The Supreme Soviet set production targets and established quotas for each republic (State). The republics in turn set targets for the province (Oblast), county (Rayon), collective (Kolkhoz) and/or state (Sovkhoz) farms. Agricultural imputs (including fertilizer) were allocated in accordance with targets with actual quantities adjusted to availability of raw materials and the capabilities and goals of the state owned and operated production and distribution monopolies.

Farms were organized into large scale state owned or collective owned agricultural units.

By 1990, there were about 52,000 large farms in the FSU of which 45% were state farms (sovkhozes) and 55% collective (kolkhozes) farms (Exhibit# 5). About one half of these farms are located in the Russian Federation. While varying substantially from one region to another, these farms are extremely large; the average state farm (sovkhoz) collective (Kolkhoz) has 36,900 acres (15,277 ha) and 14,200 acres (5,900 ha) respectively.

Total employment in socialist agriculture was 24 million in 1989 or 480 workers per farm. While considered by many to be inadequate, the state and collective farms have a large park of farm machinery: as of 1990 - 2.6 million tractors, 600,000 combines and 1.3 million trucks. Together the sovkhozes and kolkhozes accounted for on an average of 75% of the gross value of agricultural output. Private household plots and gardens accounted for between 17-45% of the agricultural production value and did so on only 3-5% of the arable land (Exhibit # 6). Performance in this area may be a good indicator as to which republics will be receptive to private investment in the agriculture and fertilizer sub-sector.

3. *Fertilizer Sector* - The FSU made a huge investment in the fertilizer subsector during the period 1965-85 (Exhibit # 7). This was part of a larger strategy to boost agricultural production and in particular feed grains and forage necessary to support a rapidly expanding livestock sector.

The investments in the fertilizer sector were across the board and included increases in production (plants at 132 separate locations), physical distribution, as well as limited storage facilities to insure the physical availability of fertilizer. Neither financial nor economic cost were of prime concern. The goal was to become self sufficient in fertilizer production and use first, as a means to help assure soviet planners that the USSR could meet its agricultural goals of self sufficiency in food and fiber and second, to eventually out produce the agricultural sector of the western countries.

Centeral to the fertilizer strategy was the abundant supply of raw materials (natural gas, phosphate rock, sulfur, and potash salts) that prevailed particularily in Russia and needed to manufacture fertilizer. The construction of 4 gas lines and a huge ammonia pipeline (2400 km) which stretches from Togleatti-Gorlovka to Odessa, coupled with the existance of a reasonably effective railroad system insured movement of both raw materials and finished fertilizer products to domestic markets (inter republic trade) and/or for shipment to ports for sales overseas. As a result, the FSU became recognized as the world's leading producer and consumer of fertilizer (Exhibit # 8). Due to major shortfalls in agriculture and the failure to consume fertilizer at the planned rate, a significant level of surplus fertilizer went for export. As a result the FSU became a major force in international trade of fertilizer. Today the fertilizer sector is a major factor in generating foreign exchange (about $1.3 billion in 1991). This is particularily true for Russia, the Ukraine and Byelorussia. In 1990 the fertilizer sector accounted for 33% of ammonia, 20% of the urea and 25% of all potash moving in international trade. Five republics (the Russian Federation, Ukraine, Byelorussia, Kazakhstan and Uzbekistan) account for 95 % of the natural gas and 90% of the potash, sulfur and phosphate rock produced in the FSU (Exhibit # 9). Russia is by far the leading republic in the supply of raw materials necessary to manufacture fertilizers.

With the exception of perhaps the Russian Federation (which *technically* is self sufficient in supplies of all raw materials needed to manufacture fertilizer), no single republic is self-sufficient in either the production of raw materials or fertilizers, and each, therefore, is dependent upon *free* movement of fertilizers (and raw materials) across borders. For example, Kazakhstan and Uzbekistan along with Russia are major producers of phosphate rock as well as intermediates like phosphoric acid and ammoniated phosphates. Surplus phosphate is shipped to other republics to be converted to finished products including compounds of NPK. The Ukraine, while a surplus producer of nitrogen, is dependent upon natural gas piped through one of four transcontinental pipelines connected to gas fields in Russia. Most republics are dependent on phosphate from Kazakhstan and Russia, natural gas from Russia and Uzbekistan and the use of the ports at Odessa and Ventspils (Ukraine and Latvia) to meet the full fertilizer needs of their respective sectors.

B. *Recent Policy Changes* (Exhibit # 10)

There are changes now underway in agricultural and fertilizer sectors of a number of republics of the FSU.

1. *Farm Restructuring* - (Exhibit # 11)

The collective and state farms comprise 98% of the farm land in the FSU but are now in the process of being restructured and privatized. This process is following at least four approaches. These are:

a. Create individual cooperatives or private farms within the existing cooperative (kolkhoz) structure.
b. Create "lease cooperatives" as independent units within cooperative (kolkhoz), state farms (sovkhoz) structure.

c. Conversion of the kolkhoz/sovkhoz farms in a joint stock ownership society

d. Separation of individual peasant (private) farms or cooperatives from the kolkhoz/sovkhoz structure.

At present the Russian Federation is pushing all four options and in particular is making major progress in creating private farms (Item #4). An estimated 250,00 private farms were created between July 1991 and October 1992 with 300,000 expected by the end of the year (Exhibit # 12). In addition, major progress is also being made in the creation of independent cooperatives (Items #1 & #2).

The main effects of restructuring the farm system are; huge decrease in farm size, major increase in the number of privately held farms and an increase in demand for a wide range of services and products not now supplied by the sector. Privately held farms are growing at a rate of at least 10,000/month, range in size from 35 acres to 400 acres; large collectives are being converted to independent cooperatives (2,000 acres-4,000 acres) and some state farms are considering the jointly owned "stock" ventures leaving the farm size near 14,000-37,000 acres in size. Clearly the farm sector is changing rapidly and the demands for goods and services in the agricultural sector will become increasingly complex. The fertilizer sector will have to respond accordingly.

2. *Fertilizer Sector Restructuring* (Exhibit #13)

Prior to December 1991, the overall coordination governing the production and movement of fertilizer in the FSU was the responsibility of a state agency called AGR0CHEM, with a separate institution responsible at the individual republic level and Sojuz Agrocham responsible for product imported or exported throughout the union. There was one fully integrated state-owned supply monopoly assigned the task of delivering fertilizer to the farm or the port use in accordance with a predetermined set of targets and quotas.

The breakup of the FSU has made it inappropriate for overall coordination of the fertilizer subsector of the CIS. Neither is it now feasible to have a single distribution system. What has emerged is the equivalent of AGR0CHEM but at the individual republic level and with different functions. As of December 19, 1991, RUSS-AGROCHEM and UKRAINE-AGR0CHEM have been formed for the two largest consumers and prime producers of fertilizer in the CIS. However, the powers of each appear to be much more limited than the case of the previous AGROCHEM. The institutions act as representatives of the fertilizer producers of the respective republics. They are privately held, can arrange for domestic and international sales but do not control the output or sales from individual production units. Each production unit is free to set its own factory gate prices and sell to the association, directly to farms, or through brokers to international and domestic markets. At present, prices of fertilizer raw materials and intermediates are still subsidized although efforts are underway now to change the trade either as movement of raw materials, intermediates or finished product has not been worked out to the satisfaction of all partners making such arrangements uncertain and vulnerable to the political and economic conditions of a specific republic.(Exhibit #14) Prices of finished fertilizer were de-regulated in 1989. Since then, prices have since risen 5-10 fold at the factory-gate and 2-5 fold at the farm level. Prices at the factory level are now somewhere between 60-80 percent of international prices while those at the farm are less than half international rates

The Russian Government has authorized the formation of wholesalers, distributors and dealers of agricultural inputs including fertilizer. This was formally established on December 13, 1991 as Decree Number 232 and was issued by the Ministry of Agriculture. It allows for the conversion of state owned Agro-Industrial Facilities at the Rayon level to be sold and operated as a privately owned enterprise (51% stock by the private sector is authorized). At least 75 such units have already been created.

These changes in policy governing the fertilizer sector, coupled with the down sizing and privatizaton of farms in Russia make it now possible to etablish privately owned and operated fertilizer distribution systems. This could start at the farm level where private cooperatives are being formed, or the rayon level where the agro-industrial complex is being privatized and the demand for products and services by small farmers (private) is on the increase. While this is true in theory, only a small percentage of the system is now privatized and in operation. In actual fact, the old distribution system has collapsed with nothing new to replace it.

II. *Constraints and Investment Opportunities in the Fertilizer Sector* (Exhibit # 15)

Since 1988, there has been a general decline in the performance of the fertilizer sectors of the FSU. The indicators are: a) general decline in fertilizer production, b) drop in fertilizer offtake at the farm level, c) high losses of fertilizer between the point of production and point of end use, d) poor crop response to fertilizer applications, e) insensitivity of the distribution system to shift in farmer needs and demand, f) breakdown of the fertilizer incentives to manage the fertilizer sub sector as a commercial enterprise and h) lack of man power with skills necessary to set up and operate the institutions needed in a free market economy.

A. *Drop in Fertilizer Production* (Exhibit # 16)

Nitrogen Production is down 17% throughout the FSU and 25% specifically in Russia since 1988. Similarly, potash production is down 21% over all in the FSU and 24% in Russia. However, phosphate production is down a modest 5% throughout the FSU but a striking 18% for the Russia. The causes for these declines are: uncertainty of raw material supply, lack of spare parts, and obsolescence of technology. During 1990 and 1991, supplies of natural gas on the pipeline where most nitrogen fertilizer plants are located were diverted from use in the manufacture fertilizer to use for heating and power sectors.

Most of the fertilizer production capacity now in place in the entire FSU was built during the period of 1965-80, before the fertilizer industry placed a premium on energy efficiency. Urea and ammonia technology came primarily from Italy, the United States, and Japan with 25 of 41 such units supplied on a turnkey basis. (This means very little local expertise or equipment was involved in its manufacture or installation; hence, foreign exchange needs for procuring spare parts and other maintainence factors are high). Most of the ammonia plants are high users of energy (1200 m^3 or each ton of ammonia), too high to be competitive in international or domestic markets once competition is allowed.

The technology used in the mining of potash originated from the former German Democratic Republic. Most of this equipment and related spare parts used in mining and processing of potash are no longer available. Furthermore, the production per worker in mining potash is very low – one 20th that for potash mine workers of Western Europe or the North America.

The phosphate technology (mainly for phosphoric acid production) was purchased primarily from companies in Western Europe (France and Belgium) with lesser quantities of technologies coming from the United States and Japan. Much of the technology used to produce liquid fertilizer, ammonium nitrate, ammonium sulfate, single superphosphate, and complex (NPK) fertilizers originated in the various research and development institutes of Russia and other republics of the FSU.

1. *Investment Opportunities* (Exhibit # 17)

There are three specific investment opportunities in FSU fertilizer production sub-sector. These are: rehabilitation of select ammonia/urea complexes built before 1980, retooling of the potash mining operation and the re-introduction of high analysis liquid and suspension operations.

Rehabilitation of Ammonia/Urea Complexes Built Before 1980 - Once energy prices reach international levels and open competition occurs in the domestic market outside capital to up-grade production facilities that are high energy users but which have the potential for rehabilitation. International donors are not likely to finance this demand, but instead will encourage foreign entrepeneurs to join forces with FSU producers and invest their own private capital as part of a joint move is likely to receive wide spread support particularily in the Russian Federation because of its inherent comparative advantage in strategically located raw materials and high demand for nitrogen in domestic and international markets.

Two specific projects have been identified by the Russian Federation. These are:1) rehabilitation of the urea factory at Novomoskovsk where a $15 million investment will increase urea production by 70,000 tpy and 2) Cherepovets Chemical Combine, which needs $13 million to allow an additional 400,000 tpy urea to be produced.

In addition to these, the State Institute of Nitrogen (in Moscow) is surveying existing ammonis/urea complexes throughout Russia to determine which units have the potential for rehabilitation. This should result in the identification of between 25 to 35 ammonia/urea complexes that are currently non-competitive due to high energy usage but could become competitive with the proper investment

Re-Establish the High Analysis Liquid and Suspension Industry – Prior to 1991, approximately 8% of all fertilizer used in the FSU was in the form of liquid and suspension fertilizers. Much of this was made possible by the import of high quality phosphoric acid including super phosphoric acid. Between 300,000-1,000,000 mt of phosphoric acid was imported annually during the period 1983 and 1991. Most of these liquids were used in the Ukraine, Baltic States and Southern Russia. Due primarily to the break up of the FSU, the unfavorable price relationship between ammonia and phosphoric acid and the uncertainty of barter deals, the import of super phosphoric acid has ceased. This has resulted in the closure of 10-34-0 and 11-37-0 production facilities which collectively represents an annual capacity of 1.4 million mt of liquids. It has also reduced the operating rate of many UAN solution plants. This has serious implications for several republics of the FSU. infrastructure is already in place and losses due to handling of liquid fertilizers are only a fraction of that experienced with dry product. In addition, the efficiency by the crop using liquid fertilizer is higher than situations where dry fertilizer are applied.

There is an opportunity for a foreign investor to; a) supply high quality phosphoric acid to this market, b) provide investment for expansion of mixing capacity proper mixing equipment to make fluids, c) set up joint venture companies that produce and market fluid fertilizers and d) eventually invest in domestic production of super phosphoric acid. This could also include the development of local deposits of phosphate rock with properties suitable for the production of super phosphoric acid.

Refurbish the Potash Mining Industry - Both Byelorussia and the Russian Federation are major producers of potash not only for the domestic market but also for export. The mining technology used by each is obsolete and high cost. The potash sector will become noncompetitive in both domestic and international markets when the government de-regulates markets, de-controls prices of basic energy sources and use of infrastructure. A major opportunity exists for modest investments in this area with the potential for very profitable returns.

B. *High Physical Losses in the Distribution System*

(Exhibit # 18) - Fertilizer losses are inordinately high in most distribution systems now functioning in the republics of the FSU. Estimates prepared by the Ministry of Agriculture and the State Nitrogen Institute of the Russian Federation suggest that losses for the Russian Federation alone average 15% of all product shipped. These losses range from 10% to 31%, depending upon the region involved and product shipped.

Losses vary within the distribution system. For example, 10-15% of total losses occur during handling, storage, and transport from the port/factory to the rayon. An additional 30% is lost during off-loading, storage, and reloading at the rayon. However a 55%-65% of all losses occur during transport from the rayon to the farm, storage on the farm, or during handling and transport from the farm to the field.

Approximately 55% of all fertilizer deliveries are made in bulk (including the 7% as fluid fertilizer), Because of shortages of specially designed covered wagons, losses of fertilizer are particularily high when fertilizer is shipped in bulk in open wagons and trucks particularily when the floors of either have large cracks or holes. There is a shortage of on farm storage, thus much of the bulk or bagged fertilizer is stored for many months in the open or at best in very poor quality warehouse facilities.

The losses (Exhibit # 19) occurring in the FSU are at unacceptable levels. In 1991 these were estimated to be 3.24 million mt of nutrients, about the same amount (3.62 million mt) consumed by African farmers in 1991.

1. *Investment Opportunities* - The recent decontrol of prices, introduction of competition and required accountability of fertilizer moved within the system will no doubt over time play a major role in curbing many sources of fertilizer losses now being experienced in the system. At the same time it will require significant investments to actually curb these losses. Four major opportunities for investment are likely to emerge (Exhibit # 20).

Improved Packaging - One of the quickest and most cost effective ways to cut losses is to bag a higher percentage of fertilizer currently being shipped in bulk. Increased bagging capacity needs to be established at the factory port, as well as select units at the rayon level. Serious consideration will have to be given to improve bag quality, and introduce bags of varying sizes (25-50-500-1,000Kg). In addition possibilities of shrink-wrapping of bags on pallets need to be considered, particularily in areas where farm storage is limited and/or of poor quality.

Refurbishment of Rail Cars - This is also a major opportunity for curbing losses. Establishment of companies with expertise in refurbishing rail cars, including repairing of floors, covering open wagons used for bulk shipment and having maximum flexibility in unloading in bulk all would be of major help.

Establishment of Loading and/unloading Facilities – High speed unloading and loading is also required to make most efficient use of the limited number of rail cars that are available.This is badly needed at the Rayon level.

Improved Storage - The shift to bags, shrink wrap of bags on pallets and use of one ton bags will all cut losses and allow on farm storage in the open and/or in poor facilities. However, there is need for good quality low cost storage at both the rayon level and on the farm. This is particularily important as more and more small farm units emerge (15 acres-400 acres in size).

C. *Poor Performance at the Farm Level* (Exhibit # 21)

– Some of the more prominent indicators (in addition to high losses) of poor performance of the fertilizer sector are: a) drop in fertilizer deliveries, b) poor crop response to fertilizer applications, c) insensitivity of fertilizer suppliers to farmer needs and d) lack of incentives and skills to manage farm enterprises effectively particularily in a market driven economy (Exhibit # 22). As examples; fertilizer deliveries to farms in the FSU are off a disturbing 44% since 1988, crop response to fertilizer use is poor often less than three kilograms in crop yield for each nutrient applied, fertilizer deliveries do not come at times or in the condition farmers need the product and finally, few in the present system understand how a free market economy is to function. Therein lies the main problem facing the republics of the FSU. It is here that the investment opportunities are greatest and are likely to be most welcomed by the governments of the FSU. Linking private foreign investments at the farm level with those made in production and distribution is most likely to be accepted.

1. *Investment Opportunities*

Three specific areas of investment appear to be attractive to foreign investors and governments (Exhibit # 23). All are related to operating a fertilizer sector in a market driven economy.

Equipment for Use on Small farms

The breakup of the large collectives and state farms has created a huge demand for farm equipment as well as products and services designed to meet the need of farmers managing land holdings of 35-400 acres in size. The industrial sector of the FSU is not geared to meet this demand. In addition, the economy lacks the capital to finance the development of this technology and create this production capacity. Here lies a major opportunity for foreign investment and one that will be highly welcomed by government policy makers. Investments in trailer type fertilizer spreaders (liquid and dry), nurse tanks, on farm storage, planters with fertilizer attachments and smaller tractors are but a few examples of the needs in this area.

Training in Marketing/Business Skills – Perhaps the one factor that will govern the speed at which the fertilizer sector shifts from a command economy to a market driven economy is the availability of man power that understand how the new system is to work. There is a vast need to train people in the basic skills of business management, financial analysis, agricultural advisory services, marketing, etc. This training will need to take the form of on the job experience in Western market economies, provision of western advisors to work in the FS in managing pilot areas and the establishment of businesses offering these skills on a regular basis.

Establishment of Agri-Inputs Farm Service Centers – All the reforms now contemplated by the Russian Federation and other republics of the FS must have a focal point (Exhibit # 24, also Figure #2). The logical initial focus is at the rayon level and the newly privatized cooperatives and state farms. At each location there is likely to be surplus facilities, extra manpower and a demand for new services that is currently unmet. The establishment of a series of Agri-Input Farm Service Centers, where all the inputs and related services are offered either under one roof or more likely through a series of privately owned businesses, is likely to be the logical next move by the Government as it de-regulates and privatizes the agricultural sector.

The fertilizer component of the agricultural inputs service center is shown in Figure 2. It includes a crop service unit, analytical laboratories for soil and plant analysis, an advisory unit, product mixing center (for liquids and drys), application service unit and an equipment pool. Each of these units could be independently owned and designed to improve services to the farmer (all levels) and assist the farmer in the management of his operation. Services could be provided for other inputs including; seeds, pesticides, farm machinery, animal feed, etc. These would have to be developed on a case by case basis and reflect the agro-climatic, ethnic and economic differences in the regions.

Several international companies are already developing this concept (Exhibit # 25). Monsanto established a version of this concept in 1989 in the Suma District of the Ukraine. Eight collective farms were involved in a program in which Monsanto staff introduced improved equipment, better seeds, plant protection chemicals and practices. Kemera Oy of Finland has introduced a similar concept into the Tula Oblast in Russia (near Moscow) and also in a district in Latvia. ICI of the United Kingdom has looked at ways to introduce their agricultural products as part of the Agri-Inputs Service Center Concept. However good these ideas are, it must be recognized that most of the FSU has no previous experience with these types of systems. Hence, these are in the very early stages of development.

III. *Summary and Conclusion* (Exhibit # 26)

The area discussed in the previous sections have a high potential for investment. Governments of the NIS would particularily welcome foreign joint ventures in these areas. A number of republics will welcome foreign investment in the fertilizer sectors of Russia, the Baltic States, Ukraine, Byelorussia, Kazakhstan and Uzbekistan all represent such potentials. However, the risk of the investment is high and dependent upon the success of the political and economic reforms now underway in these republics (Exhibit #27). The possibility of protecting these investments through guarantees by certain western governments is still unclear. Perhaps the safest move at this time is to invest in manpower development with the specific intent to identify pilot areas which if and when the political and economic environment inproves will prove excellent areas to make the first major investment in physical facilities (Exhibit #27). These investments should start at the retail/distributor levels with linkages to production and distribution established from this point of entry (Exhibit #28).

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Figure 1

Map 1: The Former Soviet Union and the Newly Independent States

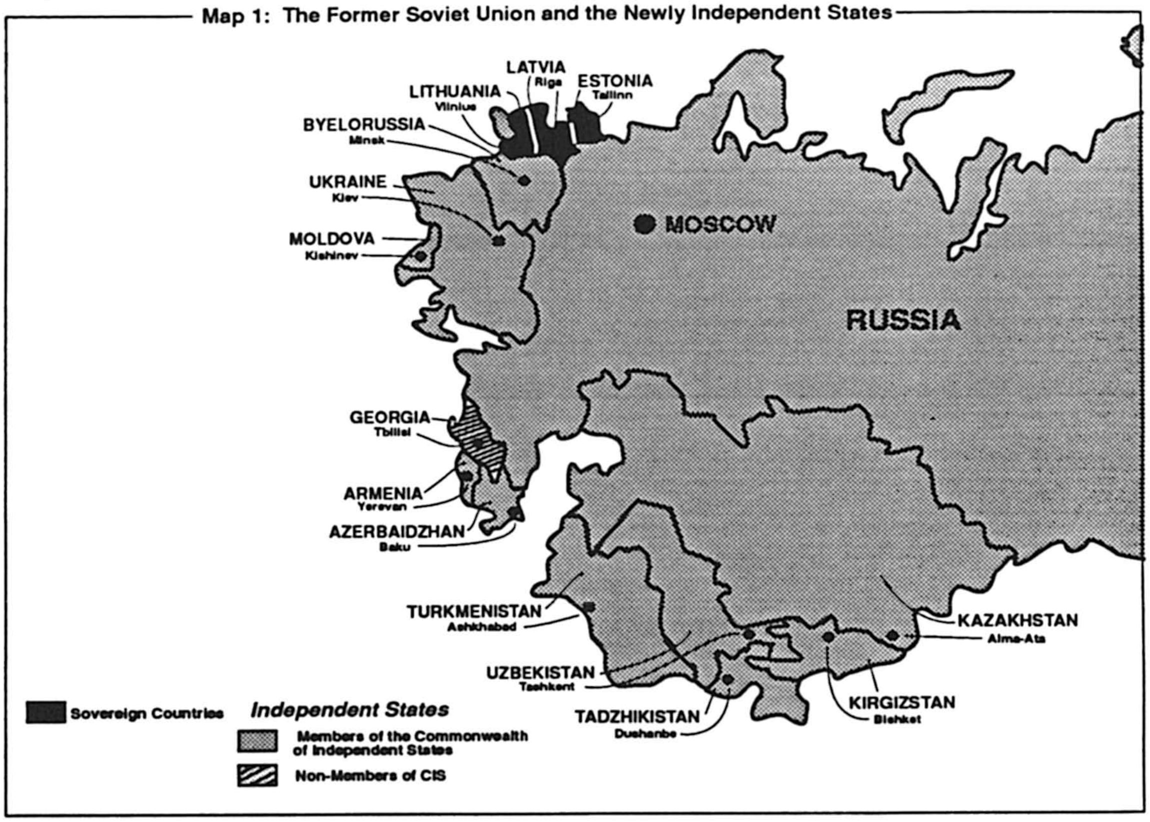
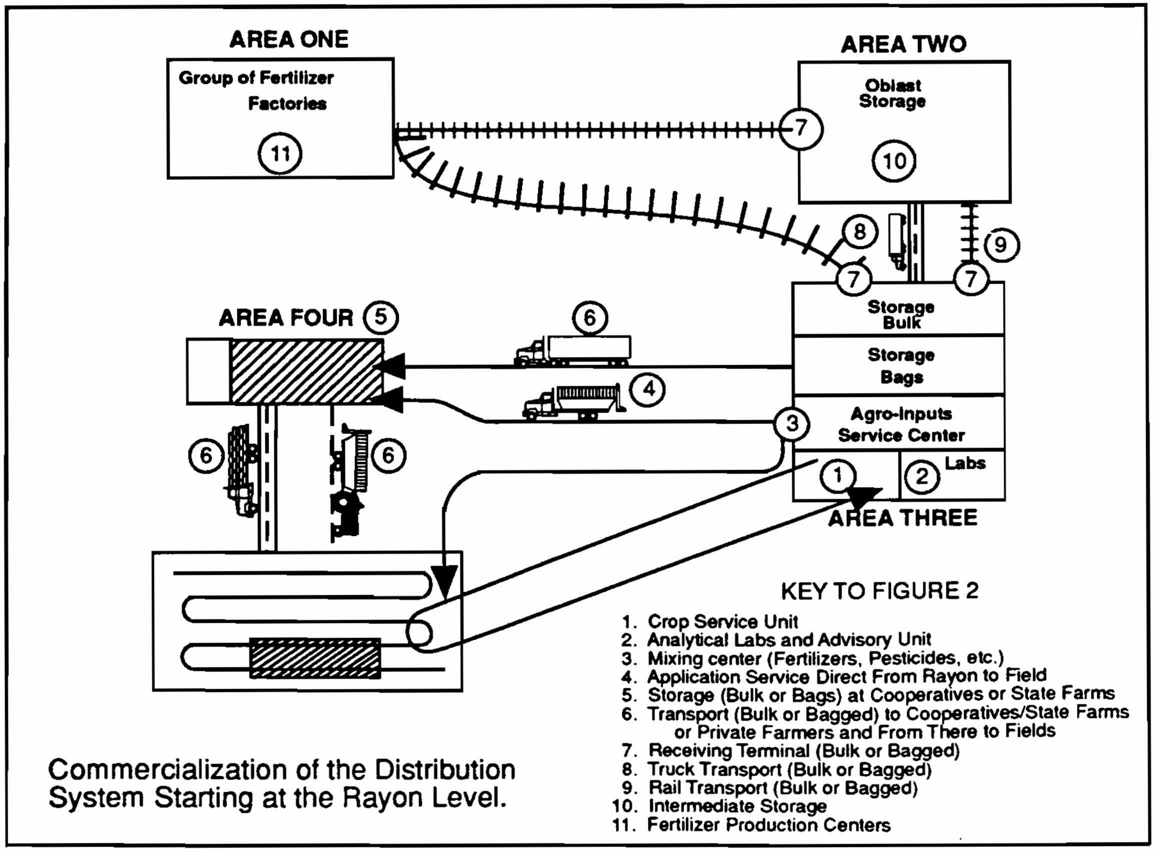


Figure 2



KEY TO FIGURE 2

1. Crop Service Unit
2. Analytical Labs and Advisory Unit
3. Mixing center (Fertilizers, Pesticides, etc.)
4. Application Service Direct From Rayon to Field
5. Storage (Bulk or Bags) at Cooperatives or State Farms
6. Transport (Bulk or Bagged) to Cooperatives/State Farms or Private Farmers and From There to Fields
7. Receiving Terminal (Bulk or Bagged)
8. Truck Transport (Bulk or Bagged)
9. Rail Transport (Bulk or Bagged)
10. Intermediate Storage
11. Fertilizer Production Centers

Commercialization of the Distribution System Starting at the Rayon Level.

Slide No. 1

Recent Years Global Fertilizer Consumption Has Declined

YEAR	DEVELOPED	DEVELOPING	WORLD
	%		
1981	<1	—	—
1982	1.5	—	1.4
1983	2.7	—	<1
1986	<1	3.5	1.5
1990	3.6	—	1.5
1991	10.6	—	4.2
1992 (est)	3.4	—	1.8

Source: Calculated from WB / FAO / UNIDO / IFDC Working Group statistics.

Slide No. 7

Investments in Fertilizer Sector FSU (1965, 1970, 1980, 1988)

— 10^6 mt of nutrients —

	1965	1970	1980	1988
Production	4.6	12.0	24.2	35.8
Consumption	3.7	9.4	21.0	27.1

Source: IFDC Statistical Records

Slide No. 8

Fertilizer Production, Consumption and Exports In FSU and Russia (1989)

10^6mt nutrients

Group	Production	Consumption	Exports
FSU	36.060	27.187	6.093
RUSSIA	20.544	13.848	5.217

SOURCE: Stangel and Associates Agricultural Consultants (SAAC)

Slide No. 9

Five Republics of FSU Leading in Fertilizer Production - 1991

Republic	Production			
	N	P_2O_5	K_2O	Total
		10^6 mt		
Russia	6.51	4.16	4.09	14.76
Ukraine	2.83	1.29	0.13	4.25
Byelorussia	0.75	0.26	5.00	6.01
Kazakhstan	0.41	1.09	0.01	1.51
Uzbekistan	1.11	0.55	___	1.66

SOURCE: Stangel and Associates Agricultural Consultants (SAAC)

Slide No. 16

Problem:
Decline in Fertilizer Production

Nutrient	Changes Since 1988
Nitrogen	Down 17 %
Phosphate	Down 5 %
Potash	Down 21 %

Cause:

- Uncertainty of raw material supply
- Lack of spare parts
- Obsolete technology

Slide No. 18

PROBLEM:
High Physical Losses of Fertilizer

Source	Loss of Total Product %
At Port / Production Site	0.7 — 2.0
To Rayon Level	0.3 — 3.0
At Rayon	3.0 — 10.0
To Farm	1.0 — 5.0
Farm	3.0 — 7.0
To Field	2.0 — 4.0
Total Losses	10.0 — 31.0
Average	15

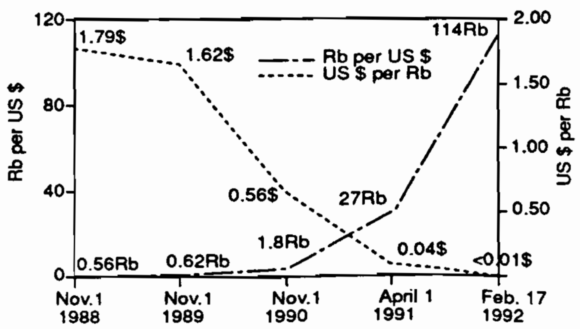
Slide No. 22

Evidence of Poor Performance at Farm (1988-1992)

Source	Indicator
● Fertilizer deliveries	Down 44 %
● Crop response	<3 kg Crop / 1 kg nutrient applied
● Accountability	Little or nonexistent
● Services	Poor and not designed to meet the individual demand

Slide No. 27

The Value of the Ruble, 1988-92



Source 1 Price-Waterhouse Doing Business in the USSR (1991) for 1988-91.
2 *Time* (March 2, 1992) for 1992

The Outlook For Nitrogen

Charles Mcintyre

Arcadian Corporation

The long term future of the Nitrogen Industry,barring any unforeseen natural disasters or catastrophes, additional political upheavals or wars, should remain at about the position we see it today.And that position is one of being in a fairly good balance between supply and demand at both the world and domestic levels.

There will no doubt, however, be continual consolidations and changes as producers and retailers alike continue to try and rationalize their businesses in an effort to control costs and salvage profit margins.

We should never forget that the Nitrogen Industry's health is always determined by the position of supply to apparent demand and when that balance becomes skewed to either side, drastic changes follow.

So on that note I'd like to run through an overview of both the Global and Domestic outlook including supply and demand balances in order to demonstrate why we feel the general outlook for our Industry should be described as "positive".

I. World Nitrogen Fertilizer Outlook

To fully understand the outlook for the Domestic Nitrogen Market, it's important to first have an appreciation for the present position and future direction of the World Industry.The United States, although both a major producer and consumer of nitrogen, is none the less only a minor player in the Global arena.

A.World Population Growth Determines Nitrogen Demand

According to a paper produced for the World Bank entitled "WORLD NITROGEN SURVEY" (number 174) the World population stood at about 5,290,000,000 in 1990 and is estimated to go to 6,260,000,000 by the year 2000.An increase of 18% in ten years or about 1 3/4% per year.

An increase in the population obviously requires an increase in the production of food and therefore an increase in the demand for nitrogen. That's assuming countries throughout the world will strive for maximum economic crop production and there will be no major genetic breakthrough in the development of plants that do not require nitrogen. Both are safe assumptions in the foreseeable future since the world is running out of potential new farmland and the science of genetics is still in its infancy stage.

According to this same paper and one entitled "WORLD FOOD OUTLOOK", as recently as the period 1987-1989 there was serious concern that World consumption of food was far outstripping its production and ending stocks were considered dangerously low. Then in 1990 there was a record World cereal harvest which took the pressure off the stocks. That was also, by the way, the year of record World Nitrogen consumption.

The direct correlation between the projected growth in population, the projected increase in the production of cereal and the increase of nitrogen can be seen in the following chart. (EXHIBIT A)

Cereals by the way, receive the majority of all applied fertilizers across the World and include just about all edible grains that comprise the primary food staples.

The report also pointed out that these projections are very conservative and take into account the increasing constraints and concerns from an environmental perspective, along with an opinion that the on-going changes in Eastern Europe and Former Soviet Union (FSU)will continue to have a negative impact on nitrogen Application levels.

In short, the study is indicating approximately a 2% annual growth in the consumption of nitrogen fertilizer through the year 2000. This annual growth rate could be much more than 2%, but highly unlikely to be less.

Blue, Johnson & Associates also indicates a similar growth rate during this same time period in a study produced in July, 1991 entitled"WORLD SUPPLY-DEMAND-TRADE OUTLOOK TO 2000"(Ammonia Urea).

B. World Nitrogen Production (EXHIBIT B)

As you can see from the chart, the increase in Ammonia capacity during the period 1990 – 2000 represents only about a 10% change, while the increase in operating rates is assumed to climb to 89%. This will be an ambitious objective for producers when you consider that a great deal of the Ammonia capacity in use today was brought on stream during the period 1965-1980. Over a quarter of the World's plants in use today are over 20 years old and well over a third are past their fifteenth birthday, placing these facilities at an efficiency and economic disadvantage to newer construction.

According to the World Bank study, at least an additional 2 million metric tons of 'N' production capacity per year will be required to meet anticipated demand to the year 2000 (equivalentto approximately five plants the size of the Saskferco project). This doesn't even take into account the replacement of an estimated 1.5 to 2 million ton of obsolete capacity which will be lost.

None the less, the demand for Ammonia and upgraded nitrogen will be sufficient to absorb the anticipated increase in production between now and the end of the century.Asia, including China will be the region in which the greatest amount of new capacity is built in anticipation of the greatest increase in demand.Western Europe, on the other hand is expected to loose capacity as nitrogen demand drops in reaction to environmental pressures,loss of grower subsidies and higher fertilizer prices.

In general, it is anticipated that the pace of new construction will slow considerably during the nineties versus the prior twenty years. This slower pace of capacity expansion should have a stabilizing effect on the Global market by reducing the chances for the MAJOR dramatic swings in supply we've seen in past years.

C. Recent World Events Having an Impact on Today's Nitrogen Market

It seems you can never have a discussion about the Nitrogen Industry today without including the impact of the Arab Gulf and the FSU/Eastern Europe Region. The two areas are important because both have historically been major exporters of nitrogen products and as such have had a major influence on the Global market.

Starting with the Arabian Gulf.The war did in fact inflict damage to the Nitrogen Industry in both Kuwait and Iraq.The combined capacity initially affected total led approximately 2.2 million metric tons of Ammonia and approximately 2.5 million metric tons of urea capacity which has since been partially restored and we expect to see completely restored by the year 1995. In fact, all supply balances assume complete restoration of production.

The FSU and Eastern Europe are a much more complicated topic as massive political changes and disorganization within this region have resulted in an economic "free for all" by creating competition amongst themselves for natural gas, transportation and ammonia/urea export business.Severe congestion at their ports during the past year is evidence of the disarray as discounting of nitrogen prices continued even though shipments of previous sales were continually delayed.

Domestic use of nitrogen within these countries has dropped for four consecutive years providing additional product available for export and with it the generation of additional hard currency.The control of the fertilizer export business by the former Central government has been replaced by the fierce competition between individual plants which has resulted in a steady decline in profit margins to the plants and a negative impact to the World market.

Natural gas that was once provided free to production facilities within the FSU and Eastern Europe is now being SOLD to those same plants.The levels at which the feedstock is being priced has yet to reflect real world levels but it does have a negative impact on the economic competitiveness of their entire Industry. Older plants once considered as being borderline efficient by World standards now become candidates for permanent closure.Plants in Romania, Hungary, Bulgaria, Yugoslavia and Poland have all been affected by the new order of things as production and export levels have fallen from historical highs as a result. Environmental improvements, desperately needed by their Industry as a whole, could be placed on hold due to lack of capital should the profit margin picture not improve.

Over the next two to three years,it is believed that some semblance of order will return to this region and that possibly some of the less efficient plants will be mothballed through economic necessity and public pressure to conform to some sort of minimum environmental standards. Domestic consumption should return to former levels as food stock piles become threatened and Domestic tranquillity takes precedence over the pursuit of hard currency. The net result will have a positive and further stabilizing affecton the World Nitrogen Market while simultaneously providing improved financial returns to the Region.

D. Industry Costs

One final point about the Global outlook before moving on to the Domestic.

The costs associated with environmental regulatory compliance are just now beginning to be realized by our Industry, not just Domestically, but on an International scale as well. The costs are substantial and will continue to rise on into the future affecting production, transportation,storage and application of 'N' products.

Cost data relating to compliance has been somewhat scant but the TVA has provided some broadrange estimates for discussion purposes.

Pertaining to non – pressurized liquid containment for operational systems, the costs can range from $20,000 –$50,000 per facility.In addition, secondary containment costs at the same facility can range from $5.00 – $20.00 per ton of storage.

The point to be made is that compliance costs will be substantial and something which will probably not be absorbed in the price of the product.

This will yet be another determining factor which will further weed out the less efficient Industry players across the Globe and at all levels of participation, not just here in the United States.

E. World Outlook Summary

In general, the World supply and demand balance for Ammonia and the market for upgraded nitrogen products will remain steady through the end of the century. Net capacity expansions planned and otherwise expected should increase to meet the rising demand with a small annual surplus.Pricing trends should follow the steady pattern of the supply/demand balance.The overall Global Market place should therefore be relatively stable assuming there are no unexpected natural disasters or wars that could threaten that balance and result in dramatic swings in supply.

II. The Domestic Outlook

A. General Outlook for the U.S.Market

In our estimate, consumption of nitrogen during the current Fiscal period through June 30, 1993 should be flat to slightly down (minus 1-2%) versus last year.The long term outlook for consumption here in the United States should be flat through the year 2000 with minor swings in either direction resulting from changes in the Domestic Ag policy which in turn determines our planting intentions.

Long term, application practices will see a very gradual shift away from the use of direct application ammonia (due to safety and environmental concerns) to the increased use of up-graded products such as urea, ammonium nitrate and nitrogen solutions.

In the long term the cost of doing business at all levels of the Domestic Industry will continue to grow as margins continue to be squeezed prompting further consolidations and rationalization at both the producer and retail levels.

B. 1993 U.S.Crop Intentions

Over the past several years the level of fertilizer application on major crops here in the United States has become fairly flat. According to soil fertility research data published by several universities, application rates through much of the U.S. could not be reduced below present levels without causing major decreases in yield.

Growers have been under a great deal of pressure,trying to simultaneously operate their business in a financially successful manner and coping with an environmentally sensitive public.The end result is that the grower appears to have reached a level of spending as little as possible while still maintaining some level of productivity.

The rationalization behind this trend then, is economic rather than public pressure to use less fertilizer.Regardless of the reason, the point which emerges is that the rate of application appears to be predicable and tends to change only with crop rotation.

The Acreage Reduction Program which determines the number of acres of major crops to be planted then becomes the critical missing variable in determining nitrogen consumption.(EXHIBITS C, D AND E)

And due to the record corn crop the Secretary of Agriculture has already announced a 10% ARP vs last year's 5% which should reduce planted corn acres from 79. 3MM to a projected 75.4MM acres (a 5% drop). Wheat acreage, on the other hand, is expected to increase 5% since beginning stocks last year initially started at levels equal to approximately 50% of this year.It is also anticipated that Wheat exports could get another shot in the arm yet this winter with the increase of export subsidies to the FSU.

Other positive points about this year's crop:

Corn beginning inventories started at levels 28% below last years, Sorghum levels started at levels 63% below last year and Soybeans started below 16% below.

Corn usage is expected to increase long term with the recent Bush decision to support the ethanol program.

The projected corn utilization in excess of 8 billion bushels this year should provide sufficient pressure on stocks to have them in check by next fall, which could simultaneously remove some of the downward pressure on prices.

Acreage of Major Fertilizer Using Crops (EXHIBIT F)

Projected acreage for FY92-93 then will result in a drop in nitrogen consumption from the loss in corn and cotton acres and a corresponding increase in consumption when additional wheat and coarse grain acres are placed under till. The net result, as mentioned earlier, nitrogen consumption should be flat to slightly down versus the past year.

Another point on the positive side about nitrogen consumption next spring.According to Doane's, the average corn yield increased 14% over last year.(1991 Average of 108.6 Bu. verses 1992 Average of 123.8 Bu.)Regardless of the reason for the increase, one thing is certain, the crop pulled considerably more nutrients from the soil than last year. This nutrient draw down then, should require additional inputs beyond crop needs to rejuvenate the soil and return it to last years levels.

In looking at the long term, the year 1995 could have a significant impact on the Agri-business in general and certainly shape nitrogen demand on past the year 2000.During that year there will be a new farm bill which, according to some, could contain language to reduce the amounts of farm chemicals (including fertilizers) that a grower may apply.Environmental groups have been working hard to influence the new bill along these lines.

The second possible change during '95 has to do with the approximately 36 million acres in the Conservation Reserve Program (CRP).The first ten year contracts will expire in the fall of the year and if the contracts are not renewed and the land returned to production, additional nitrogen demand not seen in that ten year period could return.

C. High Costs/Low Margins

As mentioned previously, the high cost of doing business has taken its toll on profit margins at all levels of the Nitrogen Industry. Consequently, producers, retailers, distributors and Co-op's alike have been going through a continual consolidation process that does not appear to be over.With the shrinking of margins and the real expenditures of environmental compliance just starting, it would not be surprising to see another major change at all levels of our Industry as organizations become fewer, larger and leaner.

It is easy to understand the justification for such massive change when you consider that a single outlet retailer can spend as much as several hundred thousand dollars on assets whose costs will not be passed on to their customer. What it will really get down to at all levels of the nitrogen business is that you either commit to the Industry long term and invest, or get out before it becomes mandatory. (EXHIBIT G)

To date, nine states have enacted storage regulations with an additional eight states having their regulations in the development stages. These seventeen states comprise a total of 67% of the total U.S. consumption of the nitrogen solutions. (EXHIBIT H)

Mandatory compliance has already begun.And we think remaining states will quickly follow as the general public becomes less tolerant of even the potential of ground water contamination.

D. Urea and Uran Supply/Demand Balances

The final topic in the overview of the Domestic Industry is the supply and demand balances for urea and Uran.The data presented here is a collection of currently available data from TFI plus Arcadian's own projection based on conversations with domestic customers(both Agricultural and Industrial), along with our present experiences as both an importer and exporter of urea and Uran.

United States Urea Supply/Demand (EXHIBIT I)

The key points to be made about next year's balance: Opening inventories were once again below the previous year.The trend in inventories seems to be that you never buy it till you need it and you always have zero inventory at the end of the season.Unfortunately, there is a level at which inventories can be entirely too low to handle a spring season even if consumption is flat or slightly down.Last year's frantic April wasn't so much a result of an increase in demand as it was in a logistic log jam.

Consumption numbers reflect a very conservative estimate based on rice being flat, wheat and the Industrial sector being up and remaining applications being slightly down.

Production takes into account the loss of Arcadian's Lake Charles production for this spring and an increase in operating rates for the rest of the Industry.

Imports are based on our guess that 225M of new Canadian production will be added to the off-shore material that's historically been brought into this country and that the off-shore material 's arrival pattern will not change over night.

The crystal ball says that the Chinese will have to come into the market in November to cover some major requirements changing the bears into bulls.In general the domestic urea market should be very close to a repeat of last year except for the possibility of maybe more of a logistic problem during the rush periods.

United States UAN Supply/Demand (EXHIBIT J)

The nitrogen solutions balance assumes less off-shore imports, takes into account the increased Domestic capacity and projects a very conservative consumption for the up coming season.It also assumes that there will be several plant turn arounds within the Industry which did not occur last year.Here again we are looking at a lower starting inventory which could cause everybody some heartburn if the weather patterns from last spring repeat themselves.In general the business looks healthy.

III. Summary

In summary, both the short term and long term prospects look good for the Nitrogen Industry. With the additional costs associated with environmental compliance, we think net returns will be squeezed further at all levels of the business through out the world, prompting further consolidations.There will none the less be a growing need for nitrogen and we're confident a healthy Industry to supply it.

Ehibit A

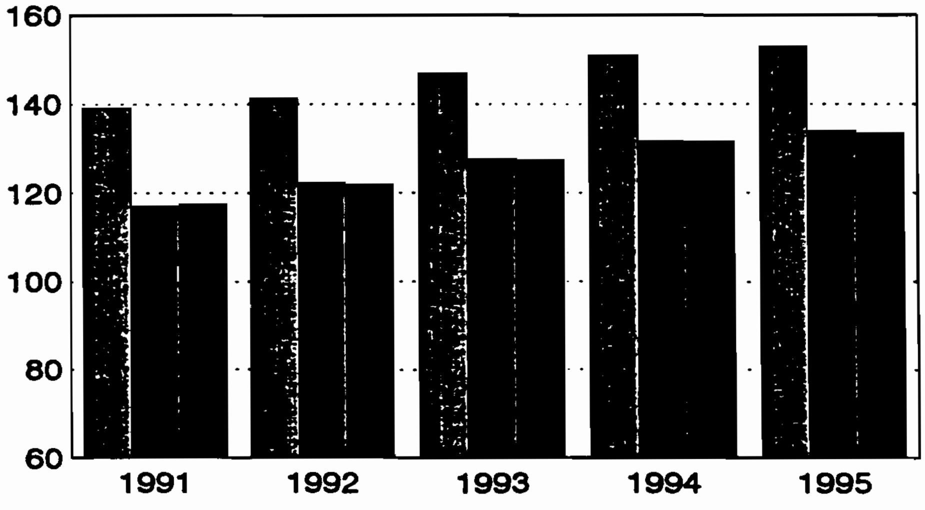
PROJECTIONS OF FERTILIZER NITROGEN CONSUMPTION

Year	Projected World Population (Millions)	Cereal Harvest Required to Maintain 1990 Food per Capita Production (Million Tons)	Nitrogen Application Required to Maintain 1990 Food per Capita Production (Million Tons N)	Nitrogen Demand Forecast by the Working Group (Million Tons N)	% Change
1991	5381	1937	81.39	77.76	
1992	5472	1970	83.47	78.27	1%
1993	5565	2003	85.61	80.12	2%
1994	5659	2037	87.81	81.69	2%
1995	5757	2073	90.11	83.56	2%
1996	5854	2107	92.43	85.37	2%
1997	5953	2143	94.82	87.23	2%
1998	6054	2179	97.30	89.09	2%
1999	6157	2217	99.84	90.95	2%
2000	6261	2254	102.45	92.80	2%

Source: World Nitrogen Survey
World Bank Technical Paper No. 174

Exhibit B

WORLD NH_3 CAPACITY AND PROJECTED PRODUCTION



	1991	1992	1993	1994	1995
Capacity	139.2	141.4	146.9	150.9	152.9
Production	117.1	122.4	127.6	131.7	134
Consumption	117.6	122.1	127.5	131.6	133.6

Expressed in MM TYP NH_3
Source:
Blue Johnson & Associates

▨ Capacity ■ Production ■ Consumption

Exhibit C

CORN

Million Bushels

	OCT (1991-92)	OCT (1992-93)	(% Change)
Beginning Stocks	1521	1100	-.28
Production	7474	8938	+.20
TOTAL SUPPLY	9016	10049	+.11
Less Total Usage	7918	8185	+.03
ENDING STOCKS	1100	1864	+.69

SORGHUM

	OCT (1991-92)	OCT (1992-93)	(% Change)
Beginning Stocks	143	53	-.63
Production	579	853	+.47
TOTAL SUPPLY	722	906	+.25
Less Total Usage	669	810	+.21
ENDING STOCKS	53	96	+.81

Exhibit D

WHEAT

	OCT (1991-92)	OCT (1992-93)	(% Change)
Beginning Stocks	866	472	-.46
Production	1981	2459	+.24
TOTAL SUPPLY	2288	2981	+.03
Less Total Usage	2416	2408	-.003
ENDING STOCKS	472	573	+.21

SOYBEANS

	OCT (1991-92)	OCT (1992-93)	(% Change)
Beginning Stocks	329	278	-.16
Production	1986	2108	+.06
TOTAL SUPPLY	2310	2388	+.03
Less Total Usage	2040	2083	+.02
ENDING STOCKS	278	305	+.10

Exhibit E

COTTON

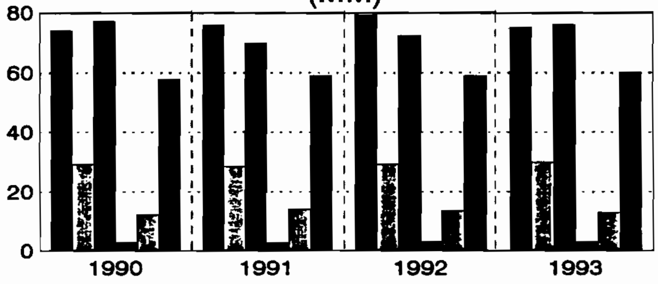
Million Bales

	OCT (1991-92)	OCT (1992-93)	(% Change)
Beginning Stocks	2.3	3.7	+.61
Production	17.6	15.9	-.10
TOTAL SUPPLY	20.0	19.6	-.02
Less Total Usage	16.3	15.7	-.04
ENDING STOCKS	3.7	4.0	+.08

Source: Doane's Ag Serv
Economic Forecast, Oct. 9, 1992

Exhibit F

ACREAGE OF MAJOR FERTILIZER USING CROPS (MM)



	1990	1991	1992	1993
Corn	74.1	76	79.3	75.4
Coarse Grains	29.2	28.6	29.3	30
Wheat	77.2	69.9	72.3	76.1
Rice	2.9	2.9	3	3
Cotton	12.3	14.1	13.4	13
Soybeans	57.8	59.1	59.1	60.1

■ Corn ▨ Coarse Grains ■ Wheat ■ Rice ▨ Cotton ■ Soybeans

Exhibit G

STATES THAT HAVE ENACTED STORAGE REGULATIONS

COMPLIANCE DATE	OPERATIONAL	SECONDARY
WISCONSIN	1-01-88	1-01-88
ILLINOIS	1-01-92	1-01-97
SOUTH DAKOTA	2-01-92	2-01-96
KANSAS	6-14-93	6-14-97
INDIANA	7-01-94	7-01-94
OHIO	1-01-96	1-01-96
MISSOURI	1-13-97	1-13-97
IOWA	2-18-97	2-19-97
MINNESOTA	**Expect stricter regulations by 1994**	

Exhibit H

STATES CONSIDERING STATE REGULATIONS

(Expected Compliance Date)

Kentucky	1995
Louisiana	Draft Stage
Michigan	Draft Stage
Nebraska	1997
North Carolina	Draft Stage
Pennsylvania	Draft Stage
Texas	Proposed
Virginia	Proposed

Exhibit I

UNITED STATES
UREA
SUPPLY/DEMAND

SUPPLY	1990/1991	1991/1992	1992/1993
Opening Inventory	380	369	263
Production	5062	5093	5009
Imports	1979	1682	1905
TOTAL SUPPLY	7421	7144	7177
DEMAND			
Disappearance	6003	5718	5665
Exports	1049	1163	1250
ENDING INVENTORY	369	263	262

Source: Arcadian Estimates and TFI

Exhibit J

UNITED STATES
UAN
SUPPLY/DEMAND

SUPPLY	1990/1991	1991/1992	1992/1993
Opening Inventory	1100	760	598
Production	8430	9050	9080*
Imports	256	207	180
TOTAL SUPPLY	9786	10017	9858
DEMAND			
Disappearance	8579	9023	8920
Exports	447	396	420
ENDING INVENTORY	760	598	518
Assuming Production Capacity of:	91.0%	93.5%	93.7%

*Assumes Turn Arounds, Temporary Outages and Additional Capacity

Source: Arcadian Estimates and TFI

The Outlook For Phosphate

James A. Beck
IMC Fertilizer Corporation

One hundred and fifty years ago, French, German and English scientists were discovering the fundamental facts of plant nutrition; that chemical fertilizers could be used to increase and maintain soil fertility. But it was only after World War II that significant development in fertilizer manufacturing technology and agronomic research stimulated strong growth of the commercial fertilizer industry.

World fertilizer consumption has increased 9-fold since 1950, In 1992, 140 million nutrient tons or 300 million product fertilizers will be used worldwide.

Today I want to discuss with you the primary factors influencing phosphate fertilizer demand, the major producers and markets for phosphates, and the outlook for supply and demand in this global market.

Before focusing on the assigned topic, let me briefly describe what we do and how we do it.

IMC Fertilizer owns or operates eight phosphate rock mines in central Florida. We're the world's largest independent producer of that basic crop nutrient, with an annual capacity of some 23.5 million tons, about 35 percent of U.S. capacity and 12 percent of world capacity. We believe IMC Fertilizer holds the majority of currently unused rock capacity in Florida.

We also operate our own ocean shipping terminal at Port Sutton, near Tampa, Florida.

Another major part of IMC Fertilizer's operations in Florida is our New Wales phosphate chemical complex, largest production facility of its kind in the world. With an annual capacity of 1.7 million tons (P_20_5), New Wales accounts for 15 percent of current U.S. production and about four percent of world capacity.

In early October, IMC Fertilizer announced an agreement in principal to acquire the Conserve Phosphate Chemicals Plant near Nichols, Florida. This acquisition would increase IMC Fertilizer's DAP capacity by about 25 percent.

To support our large phosphate investment in Florida, we maintain a number of in-market warehouses to serve our domestic customers' needs.

Although we're here today to discuss phosphates primarily, it is important to note that our company is also a major producer of a second basic crop nutrient, potash, with three mines. Two are in Saskatchewan, Canada, and a third is near Carlsbad, New Mexico.

We have the ability to mine 5.25 million tons of potash a year, about six percent of worldwide capacity and 23 percent of effective North American production capacity.

As with our phosphate business, we operate a network of potash distribution centers, primarily throughout the Midwest to provide prompt, reliable delivery to customers in that key domestic market.

Over one-half of U.S. phosphate chemicals production is exported. Much of it to the growing Asian market. Wherever we find intensive agricultural production, intensive fertilizer use will be found also.

In fact, the profile of world grains production very closely matches the profile of world fertilizer use. China, the United States, Europe and the Former Soviet Union are world leaders in the production of grains and the use of fertilizer. Overall grains account for 75% of world fertilizer use.

Let's look at the grains situation and how it will impact fertilizer demand.

We believe the fundamentals supporting fertilizer demand are strong

Fiscal 92/93 is expected to be only the second year in the last six when world grain production exceeded consumption. Most of the projected increase in grain output is attributable to the large corn crop being harvested this year in the U.S.

Grain production in the Former Soviet Union is at its lowest level in more than a decade.

Expected output for that region will be 150 million tons, down 26 percent from the previous year.

Eastern European countries have seen their production plummet this year, due in large part to reduced acreage, drought and sharp reductions in fertilizer usage.

Looking at the world grain stocks-to-use ratio, we see that, by the end of 1992/93, world grain stocks are expected to rise only slightly. An increase in coarse grain stocks in the United States will account for virtually all of this gain.

Although stocks in other countries have hovered around 14 percent of world utilization, U. S. grain stocks have varied considerably, and today are near all-time lows.

That means greater pressures on agriculture to increase food production to meet the food needs of an increasing world population.

Farmers will have to continue to be more productive, growing more on about the same amount of planted acreage. They also must be able to operate in an environmentally responsible manner. Much of this responsibility for meeting the world's food needs fall on the shoulders of American farmers. The American storage bins are no longer full.

Despite expected record corn yields this year, previous low output levels will keep stocks from rising much more than into the lower part of the target range.

U.S. wheat ending stock figures are even more dramatic. Despite an 18 percent increase in output this year stocks will rise only marginally, and are expected to remain well below the target range in the coming year.

U.S. soybean ending stocks also offer reason for optimism. Production is up, but demand remains very strong. As a result, stocks are expected to remain in the middle segment of the target range through 1993.

Meanwhile, the most fundamental force driving world fertilizer demand remains the steady, increase in world population.

About 75 percent of the world's people live in developing countries, about 50 percent in Asia where our fertilizer materials are highly competitive.

Let's look at some key developments in world and U.S. phosphate demand.

For 15 years, world phosphate fertilizer consumption increased steadily - at an average of one million tons of P_20_5 per year..

Then consumption declined in fiscal 89/90 and again in '91 and in fiscal '92. The first time consumption has declined for three consecutive years in the history of the industry.

Why did this occur?

Two thirds of the decline is the result of a 70% drop in phosphate use in Eastern Europe due to economic and political dislocations there. Reduced subsidies, higher production costs, and a breakdown in distribution and credit systems were to blame.

A substantial decline in consumption also occurred in the Former Soviet Union during this period.

Over the next five years, these areas should again begin to realize their potential as fertilizer use recovers and grain production returns to more normal levels.

Meanwhile in the Asian market, phosphate fertilizer consumption continued its steady growth. But a strong Asian market could not offset the declines registered in Europe and the Former Soviet Union.

We feel that the growth in world fertilizer consumption must move toward more balanced fertilization in order to significantly expand grain production. In the early 1970's potash and phosphate consumption worldwide was roughly half that of nitrogen consumption. Ten years later this ratio had fallen to 2 1/2 to 1, and it has continued to deteriorate.

Potash and phosphate consumption lagged far behind the increase in nitrogen use in developing countries. This trend began to turn around in the late 1980's but there is still more catching up to do.

China is a prime example. Increasing yields must overcome growing population pressures and limited arable land in order to meet ambitious goals for increasing grain production.

China's already impressive gains in agricultural production have relied heavily on increased nitrogen fertilization but phosphate and potash consumption grew rapidly during the 1980's as well.

While grain production increased more than 40% during that decade, fertilizer consumption in China nearly doubled. But the ratio of N, P and K used did not make much progress towards an agronomically desirable balance.

Contrast the N-P-K ratio of nutrients applied in the more mature markets of the developed countries with that of the developing countries. Despite radically different cropping practices in the developed countries, it is obvious that the demand growth potential in these markets is enormous.

Closer to home, it is important to note that following a downturn in consumption in the early 1980's, fertilizer usage in the United States has been on an upward trend since the mid 80's.

However, there has been a somewhat surprising corollary to those trends in the past 10 to 15 years. It can be demonstrated in how the amount of fertilizer applied per bushel of corn produced has continued to decline.

For example, the keen interest in protecting the environment has caused growers to seek out the most efficient utilization of crop nutrients and other inputs...reducing the possibility of problems that could result from over-application on some types of soils.

Also, in the case of corn, U.S. farmers have been able to dramatically improve the efficiency of fertilizer use.

Part of that improvement has come from technical advances in fertilizer placement and timing of application.

Unfortunately, these advances in crop technology have been so successful, they have masked another serious trend...a significant reduction in the level of nutrients in the soils of this country.

This chart illustrates the amount of P_20_5 contained in phosphate fertilizers applied to the corn and soybean crops in the seven Midwestern states where these crops are commonly grown in rotation.

Notice that the tonnage applied has fallen since the late 1970's as application rates per acre have been reduced.

The amount of phosphate removed from the soil in the harvest of the corn crop has increased over this 25 year period from 600,000 tons P_20_5 to 1.4 million tons as production has more than doubled. Through the Midwest, it has become an accepted cultural practice to count on phosphate carryover from corn fertilization to provide the nutrient needs of the soybean crop in the following year. It is clear that the amount of phosphate remaining for the soybean crop has been declining.

When the phosphate removed in the soybean harvest is considered, we find that through the 60's and much of the 70's, farmers were applying more phosphate than was being removed in the total crop rotation. That excess application built soil phosphate levels. A sound agronomic practice to insure that soil fertility was not the limiting factor in crop production.

However, during the 1980's the trend has been reversed from one which built phosphate levels to one in which the level of that nutrient is being depleted. Since 1980, Midwestern growers have "mined" 2.3 million tons of P_20_5 from the soil in the corn/soybean rotation.

Fertilizer application rates must be increased just to maintain present yield levels and certainly to meet the production goals of the 1990's...

What factors influence farmers in their fertilizer use decisions.

The surveys we do point to the same factors year after year. The most important is fertilizer nutrient carryover from the preceding – year. The amount of carryover is determined by nutrient application and removal in the crop harvest.

Following years of drought, for example, farmers may reduce application rates unless attractive crop prices provide an incentive to maintain or increase use per acre.

The farmer's perception of his overall financial condition ranks high on the list of factors impacting fertilizer use.

The third factor is soil moisture. Either too much or too little will cause farmers to act more conservatively.

A second category of factors are the relationships that exist each year between fertilizer prices and the farmers expectations of crop prices. Progressive farmers are dealing with this issue by forward contracting or hedging to lock in profitable crop prices.

Let's complete our overview of the phosphate fertilizer picture with a brief look at the near-term outlook in the domestic market.

In 1993, planted acreage is expected to be little changed from 1992. With a zero ARP, wheat acreage is expected to increase about four percent next year, but look for a large 1992 corn crop to result in a decrease in corn acreage by three million acres next year.

Because of the record yields and phosphate removal in 1992, a modest increase in per-acre fertilizer application rates are expected.

Overall, fertilizer consumption in fiscal 1993 is expected to be about one percent below use in 1992.

Now, let's focus on the phosphate fertilizer business... first, phosphate chemicals...

The U.S. dominates world phosphate fertilizer trend with a 48 percent market share. Morocco has grown tremendously in the past decade, but still exports only one-fifth as much as U.S. producers.

Looking at the reverse side of this coin, we see phosphate fertilizer as a major commodity growth market.

Asia remains the major growth area, where imports by China and India have increased four-fold in the past 10 years.

The favorable economics of phosphate fertilizer imports also have resulted in increased growth in the mature markets of Europe, but Asia dominates in this aspect of the business.

Meanwhile, the bottom line in any commodities outlook is the supply/demand situation.

Because of unfavorable market economics, the United States' leading competitor, Morocco, recently canceled a large expansion project that had been scheduled to come on-stream in the mid-1990's. Without this expansion, and with modest demand growth, world supply/demand for phosphate chemicals is expected to tighten in the next few years.

Let's look at the U.S. situation.

IMC fertilizer and Agrico produce more than 20 percent of this country's output. As noted earlier, IMC Fertilizer's capacity is concentrated at its New Wales facility, largest of its kind in the world.

Florida remains the world's low cost DAP producer. Recent studies by one of the world's leading fertilizer consultants confirms this- fact. The study also reconfirms that IMC Fertilizer is the lowest cost producer in Florida.

Note that four of the next five low cost producers are also located in the United States. it is this low cost competitive position that gives the U.S. 70 percent of world DAP exports.

In fiscal 91/92, exports of DAP from the United States set a new record, 10.4 million tons, up nine percent from the previous year. China and India continued to be the key buyers. As you can see, Asia is the market for 75 percent of our export DAP.

We expect DAP volumes to continue around the ten million tons level this year. Longer-term, we anticipate the demand for DAP from the United States to continue to increase as our competitive costs allow us to maintain market position.

Looking ahead, we expect a modest increase in P_20_5 shipments to the domestic market in 92/93, but a dramatic difference from last year in the timing of those shipments.

Starting with a good fall season in the wheat-producing area and a promising demand in the corn belt, we expect fall movement of phosphate to be up 8-10 percent from last year's relatively weak showing.

We believe this strong start is key to creating favorable market conditions by avoiding the build-up of excessive inventory in producers' hands. Against this optimism, we must consider the possible negative of late-maturing crops and a later than normal harvest.

Those of you who follow our business are aware that the phosphate chemicals market remains on the brink of shortage despite the low prices that have prevailed in the marketplace. That condition could become even more acute as production potential is reduced in 92/93 with the shutdown of several chemical plants.

Now let's turn to phosphate rock.

Morocco and the United States lead the world in rock exports. The attractive economics of importing phosphate chemicals mentioned earlier have caused a reduction of some 30 percent in rock commerce by the U.S. and Morocco in the past 10 years. Only a few of the smaller producers have been able to maintain export tonnage.

Similarly, except for growth in three developing markets, India, Mexico and South Korea, all of the traditional rock importers have reduced their demand for that basic fertilizer product.

Looking at Florida and North Carolina rock producers, it is clear that IMC Fertilizer remains the dominant player with capacity equal to the next three producers combined.Our company benefits from low-cost reserves obtained over a long period of time in a systematic and strategic program to insure adequate rock to support our production operations.

The supply/demand picture for rock shows that declines in production potential and increases in rock output have boosted the industry shipping rate from 70 percent five years ago to about 86 percent today. The shipping rate for operating mines is currently above 95 percent!

In the past three years, three Florida mines, with a combined annual capacity of some six million tons, have closed as reserves were mined out.

Capacity is expected to remain relatively stable until 1995, but more than 10 million tons of rock capacity are expected to be lost during the second half of this decade, again due to depleted reserves.

It is important to understand the impact of the ongoing depletion, of phosphate rock reserves in Florida and the resulting shutdown of mines.

For example, by 2010, Florida rock production from mines operating today will have fallen to only 1/4 of current production. This means that to just maintain current phosphate rock usage levels, 30 million tons of capacity must start up in the next 15 years. But current market prices do not justify new investment in production capacity.

Finally, I want to discuss the most critical issue facing the phosphate industry – phosphate fertilizer demand in the 1990's.

Earlier I talked about the three-year decline in world fertilizer consumption. The recent interruption in the growth trend for both grains and fertilizer is largely due to the events in Eastern Europe and the Former Soviet Union. It seems unreasonable that fertilizer consumption will continue to drop in these regions, or just stay at its current depressed level.

Given current productions for a world population in excess of 6.2 billion people by the turn of the century, grain consumption will have to exceed 2 billion metric tons just to maintain the current per capita consumption level. Strengthening incomes and improving diets will demand even more grain.

The world's grain producers have responded to this challenge in the past. During the 1960's and 1970's they added more than 400 million tons of grain to world supplies. During the 1980's additional production exceeded 300 million metric tons.

The challenge for the 1990's is even greater productivity from our limited arable lands to generate another 300 million ton increase in grain production to feed our growing population.

On a world-wide basis, current projections by the Agro-Economics Committee of the International Fertilizer Association appear inadequate to meet the task of expanding world grain production while maintaining soil fertility.

Although forecasting a recovery in world fertilizer consumption, the IFA committee's projected rate of increase in fertilizer use is even below the expected rate of increase in the world's population. It is a sharp departure from the growth trend in world fertilizer consumption over the past two decades.

To meet the food production needs, to just maintain per capita food production, historical fertilizer use to grain production relationships must be realized. Phosphate fertilizer use required to maintain per caipta food production would be below the long-term consumption trend but well above the pessimistic concensus forecasts.

There is no practical alternative to the productivity provided by fertilizer. And it must be greater productivity that meets the food demand of more than 6 billion people in the next decade and beyond.

The Outlook For Potash

William J. Doyle

PCS Sales

It is a pleasure for me to join you, for the first time, at the Round Table. I have to tell you that it is not always a pleasure to be the potash speaker at fertilizer outlook sessions. Representing the K in NPK, we inevitably come third and, since many of the factors that affect potash also affect nitrogen and phosphates, a lot of what we have to say has been already said! However, this morning, due to a last minute change in plans, I get to go first, which tempts me to want to speak about the Big Picture.

The Big Picture is any presentation that manages to tie together the significance of European economic union, the exercise habits of Japanese steel workers, the seductive properties of Mexican wages, the fate of the Spotted Owl, and the impact of moving the Redskins to Virginia. One is then driven to the conclusion that the future is not what it used to be.

Due to a lack of expertise on the mating habits of the Spotted Owl, I will spare you the Big Picture today.

What I would like to do is to examine some of the underlying trends that define the fertilizer industry in general and the potash industry in particular. Then, I will cast an eye toward the future and share with you some views on where the potash industry is headed.

First, let's look at where fertilizer has been headed on a global basis. European fertilizer consumption, and this includes all of Europe plus the former Soviet Union, rose from nine million nutrient tons in 1960 to a peak of nearly 60 million tons in 1987. It has dropped off to the 50 million tonne level since. A good deal of the growth in the past decade or two has been the result of the European Community's Common Agricultural Policy. Government-supported prices stimulated overproduction that in turn has led to massive surpluses and, it can be argued, to today's trade wars, which prevent a resolution of the GATT negotiations. However, it is likely that western European fertilizer consumption will taper off further during the decade ahead, while Eastern European and former Soviet Union consumption will rebound to approach the levels that we saw in the late 1980s after a precipitous drop in the past five years.

In 1960, North American fertilizer consumption was six million nutrient tons. Consumption rose steadily until 1980 and has fluctuated considerably in the past decade. With acreage reduction programs and the Conservation Reserve Program, North American fertilizer consumption has settled at around the 20 million tonne level. It can be considered a mature market and little growth is expected in the future.

If we look at the rest of the world, which is almost entirely represented by developing countries, we see a much different picture. Consumption of fertilizers in the rest of the world rose from just under 4 million nutrient tons in 1960 to 70 million tons in 1990. This area still shows significant prospects for growth.

Let us look at the magnitude of change among these three regions. European fertilizer consumption is now four times what it was in 1960. North American consumption is more than double the 1960 level. But, among developing countries the present level is almost 15 times what it was in 1960. And, for fertilizer producers, this is unquestionably the major source of future demand.

On the supply side, fertilizer production has fallen in recent years in response to falling demand. Potash production, for example, peaked in 1988 at around 52 million tons KCI. Since then, production has fallen by about 10 million tons. The two main sources of this drop have been the former Soviet Union and Germany.

In the former Soviet Union, potash production peaked in 1988 at 18.5 million tons KCI. Since then, production fell to 14 million tons in 1991 and is expected to fall further to around 12.5 million this year.

German potash production has plummeted as well, primarily the result of mine closures in Eastern Germany. From 9.5 million tons in 1988, it fell to 6.4 million tons in 1991 and a further decline is expected this year. So, these two areas alone accounted for nine of the ten million tonne drop in production.

That drop in production was precipitated by the virtual elimination of sales from Eastern Germany and the former Soviet Union to what were Soviet satellite countries in Eastern Europe. This volume amounted to almost five million tons. The reduction in sales to former Soviet satellite countries plus a drop of almost four million tons in home deliveries in the two countries represents almost all the decline in potash sales in the past five years.

World potash demand fell to 42 million tones in 1991 and is expected to be at the same level in 1992. Toward the middle of this decade, the International Fertilizer Industry. Association in forecasting potash demand to grow slowly to around 46 million tons, still below the peak of 52 million tons that we saw in 1988.

The dominant feature of the world potash industry continues to be surplus productive capacity. This surplus is anticipated to be a factor over the next five years and, for the near term at least, will be exacerbated by some recent developments.

Recently, the Government of India has eliminated subsidies on a variety of fertilizer products, including potash. In practical terms, this will increase the price for potash at the farm level by three to five times the previous level. It is not surprising that the outlook for potash sales to India over the next six months or so is not rosy. The main suppliers to India have been Jordan, Germany and, recently, the former Soviet Union.

Jordan has traditionally produced at capacity and sold all of its production. It can be expected to aggressively market that product which is not destined for Indian markets. In the case of Germany, the Zielitz mine in Eastern Germany has been the major supplier to the Indian market. With the continued rise of the deutschmark, which has already led to list price increases in Germany of 40 percent, production cutbacks may well be in store. As far as the former Soviet Union is concerned, it is clear that a major objective underlying it's potash exports is the acquisition of hard currency. In Belarus, for example, it is estimated that about 30 percent of its hard currency earnings are derived from potash sales. We can expect to see potash from the former Soviet Union being aggressively marketed, with the predominant constraint being their ability to deliver product.

Turning to North America, potash consumption has been leveling off from a long period of growth that began around 1950. Increases in production will be driven by rising exports, primarily from Canadian producers.

US agricultural potash consumption has leveled off at around the seven million tons KCI level, down from the eight to nine million tonne level that we saw at the beginning of the 1980s. For the fertilizer year ending in June 1992, we estimate that consumption will have been about the same as the previous year and for next year, little change is expected.

This is why.

Agricultural consumption of potash in this country is driven by corn and soybean planted acres. These two crops account for over 50 percent of potash consumption.

But, corn and soybeans receive on the average around 80 pounds of potash per acre, about double the amount that is applied to wheat.

After five years of growing corn acres, next year, we expect to see a small reduction in acres planted to corn. The excellent crop that we have seen this year has pushed corn prices to the $2 level and has increased inventories. And we now know, we'll have a 10 percent acreage reduction program for 1993. However, the outstanding harvest this year will have depleted nutrients from the soil and some increase in application rates is likely - probably enough to cancel out a decrease in consumption resulting from reduced acres.

Soybeans are anticipated to be at around the same level as this year and other crops are likely to show little change. So, we are in store for a repeat of 1992 in 1993.

When I was preparing for this presentation, I was reminded that someone once pointed out that all forecasters suffer from a common character deficiency. They are often wrong - but never in doubt.

The reason that forecasts are often wrong is that they are based on probabilities. Based on what kind of behavior farmers have demonstrated in the past, we kind of know, or feel we know, what they will do in the future.

However, as Peter Drucker pointed out in a recent article in the Wall Street Journal, unique events, such as the dissolution of the Soviet Union, have no probability. And it is these unique or random events, rather than the certainty of 80 pounds of potash being applied on an average acre of corn that, in the words of Walter Cronkite, "alter and illuminate our time."

Drucker goes on in his article to suggest that what is needed is planning for uncertainty and that the best strategy is to match a company's strengths to changes that have already taken place. For example, in the United States, we know that farmers grow crops on the same total number of acres as they did in 1910. We also know that average corn yields, as an example, have risen from 25 - 30 bushels per acre at the turn of the century to around 120. The fertilizer industry has played no small role in this. However, we are not likely to see a five-fold growth in the next 80 years, so our strategy for this market is to promote the efficient use of plant nutrients to sustain this kind of productivity.

In other parts of the world, fertilizer application rates are lower than in North America. Here ample room exists for crop yields to grow so that a rising population, in search of a higher standard of living, can be adequately nourished. The main deterrent is the lack of sufficient income to pay for inputs. The strategy here is to demonstrate that increased food production, greater profit for farmers and heightened environmental protection go hand-in hand. This has certainly been the case in Asia.

However, in Africa, where many people have almost given up on a strategy to increase food production because of many economic and political constraints, there are signs of progress. Dr. Norman Borlaug, the Iowa plant breeder who won the Nobel Peace Prize in 1970 for his role in the Green Revolution, has been directing some highly successful projects. On over 150,000 African farms, yields have increased an average of 2.5 times. In Ghana, maize production is up by 40 percent from 1986. In Sudan, where civil war ended his work, about 800,000 tons of wheat were harvested last March, up from 160,000 in 1986.

So, we have seen great progress in Asia - where China now produces more wheat than the United States and where India has quintupled wheat output since 1967 - giving these two population giants the ability to feed themselves. Now there is hope for similar progress in Africa.

In spite of the progress we have made in Asia and in the face of the opportunities in Africa, we still live in an uncertain world. As far as potash is concerned, the largest single certainty we face is over capacity. How we manage through this over capacity period will determine the future of our industry. So far, the response from the industry has been less than brilliant - pointing to the fact that the enemy often lies within.

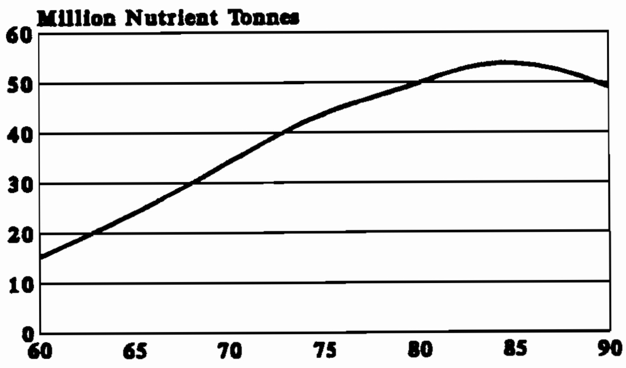
The fertilizer industry has never been known for an abundance of strong managers. In fact, we are plagued by managers who are production driven rather than price or profit driven. These people understand the basics of unit cost of production. They know you can save a couple bucks a ton by running at full capacity. What they fail to understand is when you try to put 20 lbs. into a 10 lb. bag you get a real mess. The couple dollars savings you get by running full out is lost quickly when the market drops - often precipitously.

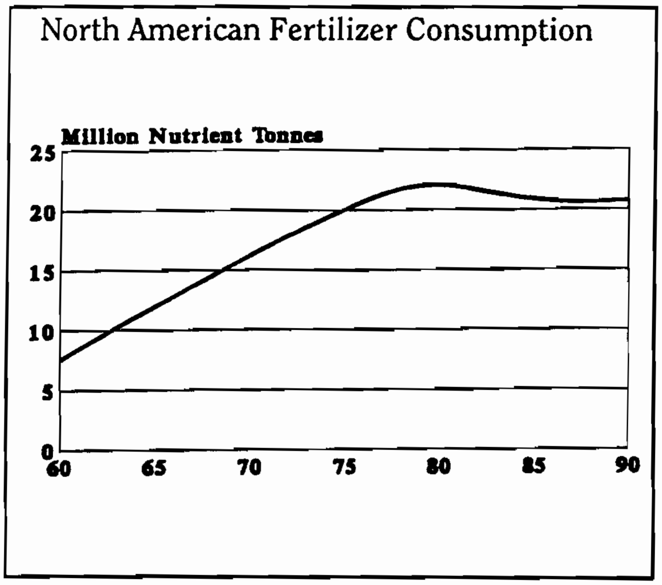
Many of you will know that, outside of the former Soviet Union, most of the surplus capacity in the potash industry resides with PCS. While we also understand the unit cost of production theory, we have chosen a different approach. Our strategy has been to manage our way through this over capacity period by producing only what the market will consume. By managing our inventory, we manage our business rather than having our business manage us.

We are operating this year at less than 40 percent of capacity. This is a production level which will meet market demand and still allow us to be profitable. Unfortunately, other producers have failed to cut back and supply continues to outstrip demand in North America and elsewhere The predictable results are too much potash chasing too few buyers and downward pressure on price.

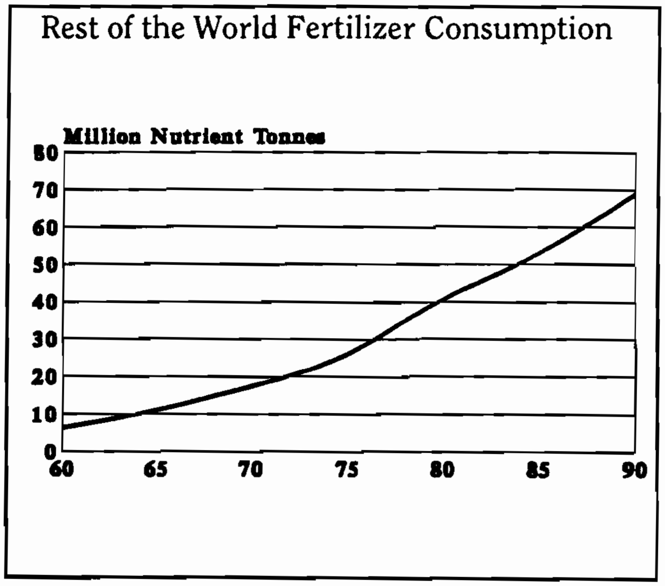
It doesn't have to be this way and I hope to be around long enough to see the change needed for the industry to survive long term. We know, or should know, what our fundamental strengths are in the fertilizer industry. By matching and managing those strengths to the constantly changing developments we see across North America and around the world, we can make the future more stable, which will be to the benefit of both consumers and producers of potash.

European Fertilizer Consumption

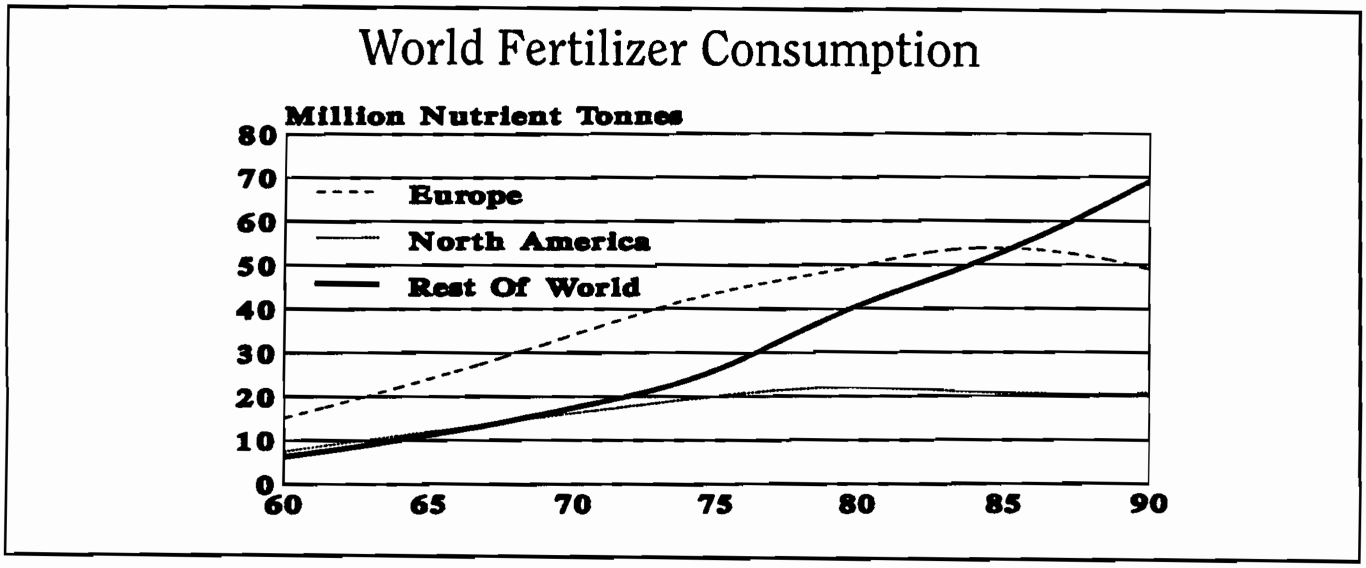




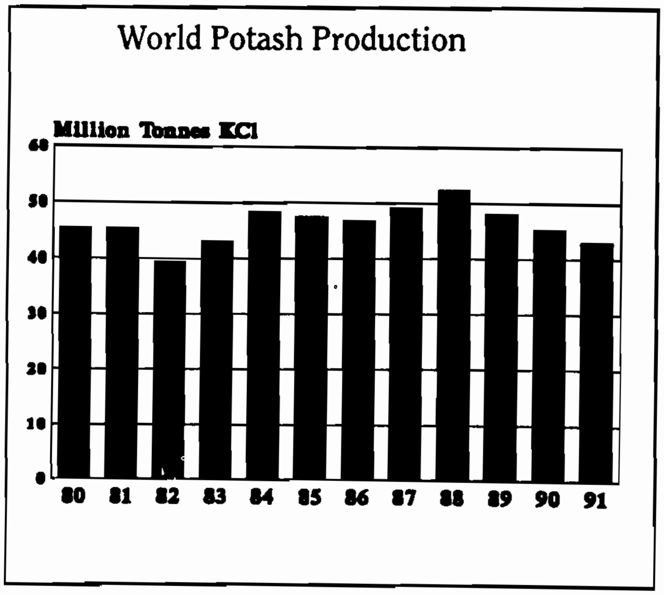
North American Fertilizer Consumption



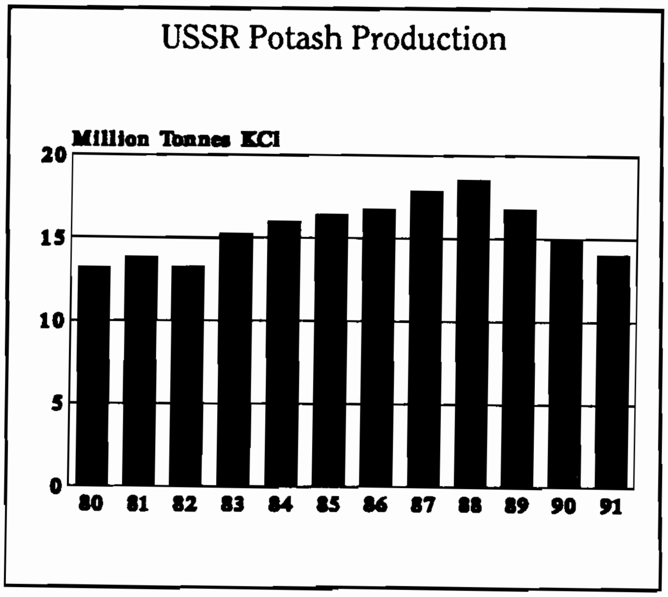
Rest of the World Fertilizer Consumption



World Fertilizer Consumption

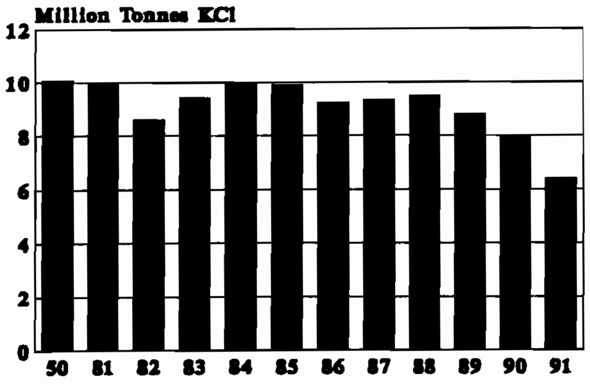


World Potash Production

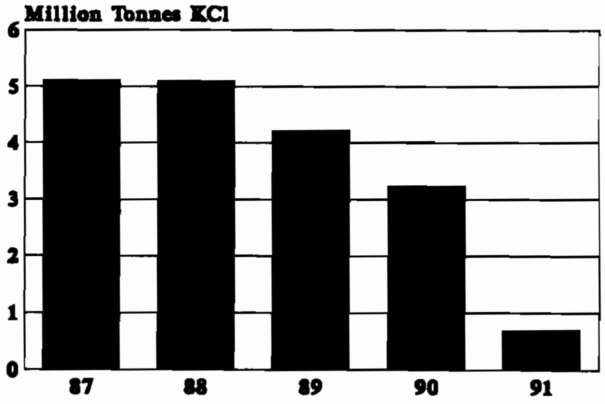


USSR Potash Production

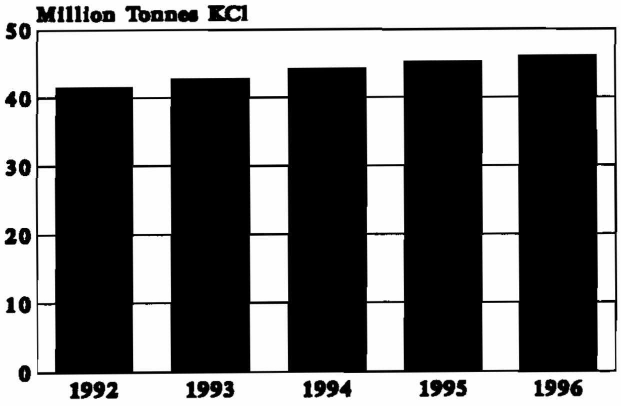
German Potash Production



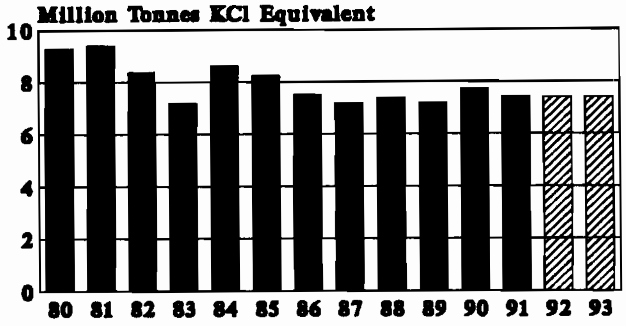
Potash Imports – Eastern Europe



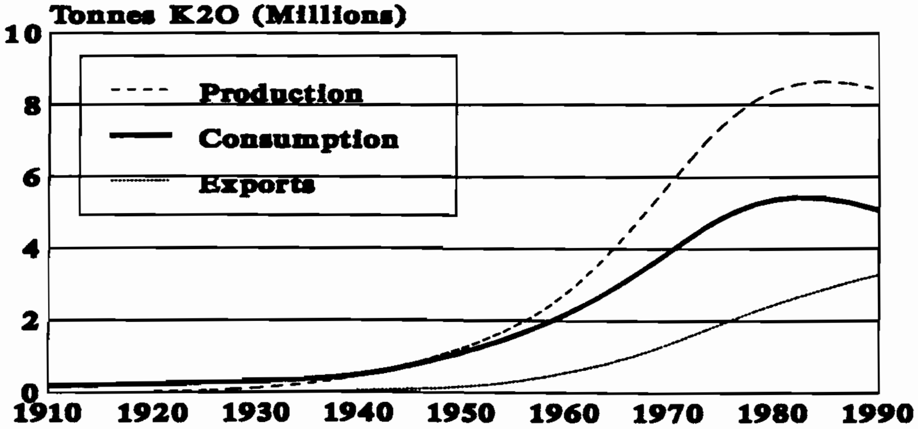
World Potash Demand

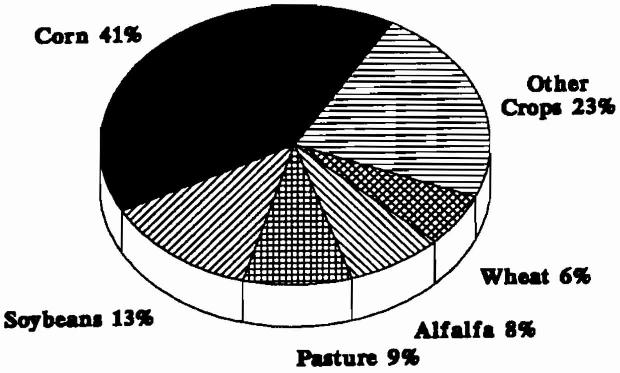


USA Agricultural Potash Consumption

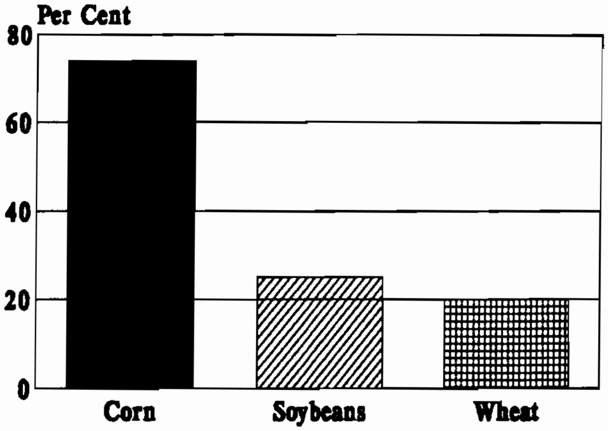


Potash Consumption, Production & Exports – North America

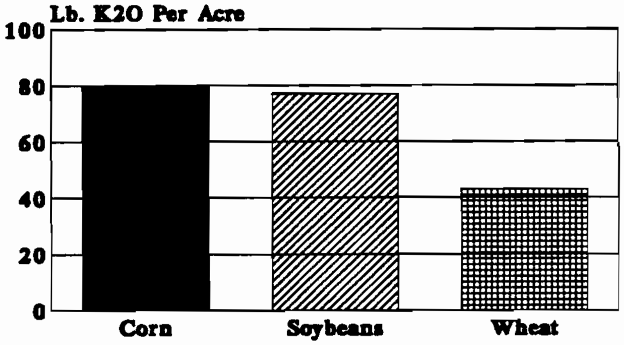




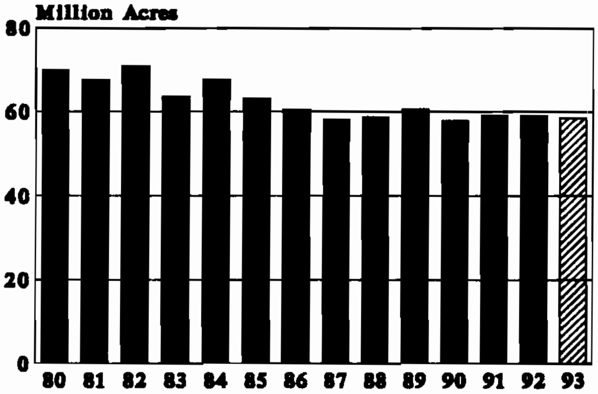
Potash Use By Crop



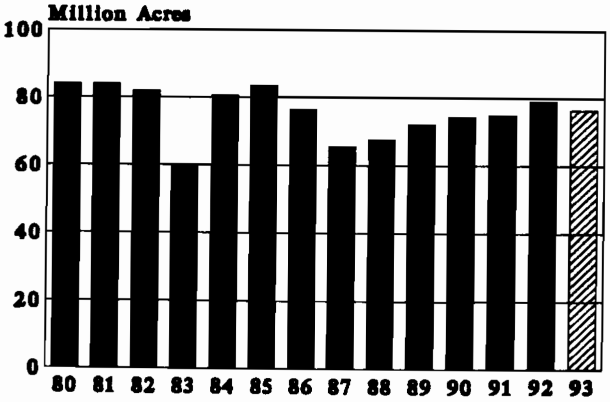
Per Cent Of Acres Receiving Potash



Potash Application Rates



USA Soybean Acres Planted



US Corn Acres Planted

Outlook For Sulfur

T.D. Callaway, Jr.

Shell Oil Company

When I last spoke to this distinguished body on the outlook for sulfur, I admitted to cataracts and a cloudy crystal ball. Today, I must admit that after cataract surgery, my sight has improved; however, my crystal ball is now opaque.

Since many of your market research departments have provided you with detailed assessments of the sulfur market, I have limited my use of statistics and, instead, will concentrate my remarks on my preception of the market. I would like to thank the Sulphur Insititute for its permission to use statistics published in TSI's 1992 Sulphur Outlook. While the figures were compiled and edited by TSI, the opinions formulated in this paper are mine alone.

The outlook for sulfur and, by extension, all agricultural inputs will depend on resolutions of a host of interrelated factors, all of which hold a great degree of uncertainty.

If any on phrase can be used to characterize the current sulfur situation, it is "global change"- in politics, in the economy, and in the environment. The United States is engaged in a heated presidential election where no candidate has been able to articulate clear-cut polices on the economy, on energy, on trade or on agriculture. Germany is unified; the Soviet Union and other Eastern and Central European countries are facing economic collapse while struggling to establish free market economies under less restrictive governments, and Western Europe is attempting to set aside centuries old political/social distrust in order to create a borderless, "unified" economic community. The U.S. , Canada, and Mexico are attempting to consolidate North America into the single largest economic marketplace ever known to man.

Figure 1 presents snapshots of world sulfur supply and demand in 1991, 1996 and 2000. As indicated, a surplus is expected to the year 2000.

During 1991, recovered sulfur represented 70% of all elemental suflur production, and sulfur recovered from natural gas production accounted for 58% of recovered sulfur. Sulfur from natural gas is dominated by only a few countries .At present, Canada has the largest natural gas-based sulfur prodution capability and, by judicious use of the sulfur block that accumulated during the late '60's and early '70's, Canada was reliable supplier to the world.

It is important to remember in any discussion of sulfur simply and demand that everything is interdependent. Agricultural policies, import/export policies, currency strenghts/weaknesses, political goals, and hydrocarbon economics are just some of the host of factors that must be considered.

For example, India has decanalized DAP (DiAmmonium Phosphate), generating a surge in DAP imports while simultaneously causing curtailment of domestic Indian phosphate fertilizer production facilities. Concurrently, this move further depressed the international market for sulfur and phosphate rock.

International sulfur competition has placed pressure on Canadian sulfur netbacks. In an attempt to "prop-up" revenues, Canadian producers are trying to "purchase" market share in the U.S.'s prime phosphate markets. This is generating a defensive backlash from U.S. recovered sulfur producers who must market their " by-product" sulfur to protect their production of natural gas, light oils, and chemical products. Some U.S. sulfur producers are rumored to be seriously considering actions to get the Federal Government to impose "dumping duties" and to get the Justice Department to investigate railroad pricing practices for potential illegalities.

Canada's ability to continue to be a reliable supplier will, in my opinion, depend to a very great extent on the Canadian industry's ability to streamline and rationalize its export-oriented production, Transportation, storage economics, and joint marketing policy. Frankly, I do not believe that the individual companies have the discipline to absorb the financial impact imposed by differing levels of sulfur production, debt service, and cash requirements. It is highly unlikely that any Canadian export consortium will be marketing policy.

Canadian sulfur suppliers have failed to adequately address sulfur competition from Saudi Arabia and other growing sources of sulfur supply. International sulfur and DAP price competition have rippled through the sulfur and phosphate markets, placing economic pressure on sulfur recovery and phosphate manufacturing costs.

Figure 2 shows overall growth in sulfur consumption during the 1981-1991 period.

Sulfur consumption for non-fertilizer use is expected to decline as anti-pollution restrictions are implemented within the pulp, paper, iron, steel, tellurium dioxide, and phosphate detergent industries.

The major demand area for sulfur production in the world is fertilizer manufacturing. Sulfur consumption for fertilizer production totaled 33.5 million tons in 1991

The phosphate industry is in an oversupply position. The U.S. based phosphate industry's posture as supplier to the export market has been eroded by the development of domestic phosphate industries in Mexico, Brazil, India and China, as well as by the continued expansion of the North African and Middle Eastern export oriented phosphate industries. This situation has been exacerbated by the decline of phosphate consumption in both Eastern and Western Europe.

On the surface, severely depressed sulfur prices would appear to be a boon to cash strapped phosphate fertilizer producers, but inevitably, phosphate fertilizer consumers force pass-through of the savings from lower sulfur prices.

Currently, the domestic phosphate fertilizer industry is reportedly operating at or below cash cost recovery levels. The reasons are well known and include agricultural surpluses, the removal or reduction of farm subsidies, limited credit, and environmental pressures. Some phosphate producers have sought the protection of the Federal Bankruptcy Code. A number of others have reported plant cutbacks and curtailments, and several are for sale.

Absent increased utilization of sulfur, Canadian supplies and on-purpose mined sulfur supplies will be at risk. Market conditions are deteriorating to levels where sulfur suppliers producing on-purpose, or co-product sulfur could be at or below cash operating costs.

The supply side for sulfur is not much rosier or more certain. Currently, we do not project that the U.S. growth rate for sulfur in all forms will be robust. Neither will the supply of smelter acid nor sulfur form power plant stacks, coal liquefication and gasification projects yield the quantities of sulfur that were once projected. Stack gas SO2 recovery is likely to increase due to any preceived favorable economic differentrial between using 6 oil, coal, or petroleum coke as a boiler fuel of choice over natural gas. Limestone scrubbing/gypsum throw-away process is used today because there is little economic incentive to recover elemental sulfur. This has been the case for the last ten years. However, environmental contraints could make sulfur recovery an attractive alternative to handling/disposing of scrubber-generated waste products.

There is always the possibility of development and exploitation of known Canadian and U.S. deposits of gas containing such extremely high levels of sulfur that they should realistically be called "sulfur wells". However, the projects are burdened by extremely challenging technological and environmental problems, require long lead times, and are extremely expensive. Given the volatile nature of sulfur prices, it is not possible at this time to project the minimum sustainable sulfur value that would be requided to justify this type of investment.

Further complicating the situation, the world oil and gas markets are oversupplied, and prices are at levels where North American producers are economically unable to replace depleted domestic reserves and are looking to less stable "third world" countries for exploration and development opportunities.

The revenue obtained by a U.S. producer for its natural gas crude oil production has a direct impact on that producer's ability to explore and drill for additional reserves.

The U.S.'s natural gas deliverability bubble finally appears to be deflating as supply and demand approach equilibrium. Fortunately, natural gas prices are approaching levels that could sustain a moderate natual gas exploration program. However, political, environmental, and economic constraints will continue to restrict development of new sour gas reserves in the U.S.

During 1991, U.S. natural gas consumption was approximately 19.3 trillion cubic feet (TCF) ; at the same time, reserve replacements only approached 15 trillion cubic feet. Low oil and gas prices, combined with restrictive drilling/development regulations in North America, have forced activities to be concentrated in geographically remote areas of the world. This relocation will cause an attendant relocation of the production of natural gas based sulfur to third world countries who will use it to generate hard currency or to develop domestic fertilizer industries.

A decision to invest in major sour gas fields to develop new sulfur supplies cannot be easily justified with conditions currently prevailing in the oil patch.

Figue 3. Assuming environmental and drilling permits could be obtained, a major new U.S. sour natural gas field: would typically entail production from deep wells and/or hostile geologic environments; would have "drilling" costs of between 4-6 milion dollars per well; would require and additional 7-10 million dollar investment just to complete each commercially productive well; would require an additional prorated investment per well of approximately 12 million dollars for an amine treating/claus sulfur recovery facility; would entail a total filed development investment of between 1/4 to 1/2 million dollars before the first cubic foot of gas or ton of sulfur was sold.

Compared to deep well developments, the typical sweet on-shore natural gas well drilled in the U.S. is about 5,600 feet deep and required a total investment of about one million dollars compared to an aggregate investment of approximately 27 million dollars for each sour gas well.

It is highly unlikely that new North American, discretionary, deep sour gas fileds will be developed in the foreseeable future. The lone exception is Shell Canada's Caroline Field.

Investments in the Caroline Field were committed some years ago on the basis of a composite revenue stream composed of income from natrual gas, sulfur and LPG. Once the capital was committed and sunk, it became a vitural certainty that the field would be produced. Consequently, sulfur production from the Caroline Field is included in the supply estimates. Without Caroline and production from Freeport's Main Pass mine, the North American sulfur supply picture would be very different.

Unless future oil and gas prices improve in industrialized nations, sour gas developments requiring multi-million dollar investments do not appear to be economically prudent.

The only major new-on purpose-sulfur supply developed in recent years is the new frash mine being developed by Freeport and its partners at Main Pass, Offshore Louisiana. This development should produce enough sulfur to offset reserve depletions at Freeport's other mines, with some incremental production available for sale.

The loss of natural gas based sulfur in North America,(principally the U.S.) will be offset by the recovery of sulfur derived from refining heavier sour crudes—sulfur supply from locations where product must and will move on a daily basis.

A handful of countries dominate the recovery of sulfur from crude oil. The U.S. and Japan are expected to maintain their dominance in sulfur production from crude oil refineries. Growth potential exists in the major oil producing areas of the workd as more countries try to capture additional revenue from their own crude oil production by investing in the crude which in turn yields sulfur and other finished or semi-finished products.

Sour crude economics and strengthening environmental regulation will continue to generate increased quanities of by-product sulfur at refineries which typically have minimal storage and must move their production on a daily basis. Unlike other refinery product streams which need not be produced or can be converted to refinery fuel, sulfur must be recovered and marketed. Failure to do so will cause refinery crude slates and runs to be changed or stopped. This is an economic penalty no refiner is willing to tolerate Refinery sulfur will go to market.

It is unrealistic to assume that the beleaguered North American oil and gas industry will recover its economic health sufficiently to reverse the drilling dislocations or to justify development of new sour gas fileds. Natural gas reserves are available in North America to allow potential production increases will be delayed because of the current gas oversupply and generally poor prices existing in the U.S. market. Development plans will likely be delayed waiting for the natural gas market to reach a more economically rewarding level.

In the long term, absent a better economic climate in the oil patch, the U.S. petroleun industry is unlikely to replace declining sulfur production by developing major new domestic fields.

Ladies and Gentlemen, as I indicated earlier, trying to forcast the future is fraught with risk. Any projection can be overtuned by unforeseen factors. However, absent major political, economic or catastrophic events, I am not encouraged by the prospects for the North American hydrocardon industry and sulfur-supplied phosphate industry.

Figure 4 suggests that total sulfur production will increase through 2000. This forecast is dependent upon:

- Development of Russia's gas and oil fields without interuption by political, social or economic issues;
- A semblance of peace in the Middle East;
- Arabian Gulf sulfur reaching the market;
- Privatization of governmentally-owned sulfur producers moving forward in an orderly manner.

Figure 5 suggests that total sulfur consumption will increase through 2000, However, the increase in consumption will not keep up with the increase in production.

Plant Nutrient Sulfur (PNS) provides one bright spot in an otherwise bleak sulfur demand picture. Despite the current application of 10 million tons of sulfur in the world, North America, Asis (particularly China and India), and Latin America have identified widespread areas of sulfur deficiency. Sulfur deficiencies are now being recognized in all other major agricultural areas of the world. Environmental concerns and controls will increase the deficiency as "FREE" airborne sulfur is recovered or eliminated at the discharge point.

Agricultural research demonstrates that direct application of sulfur improves nitrogen uptake and crop utilization of other fertilizer inputs.

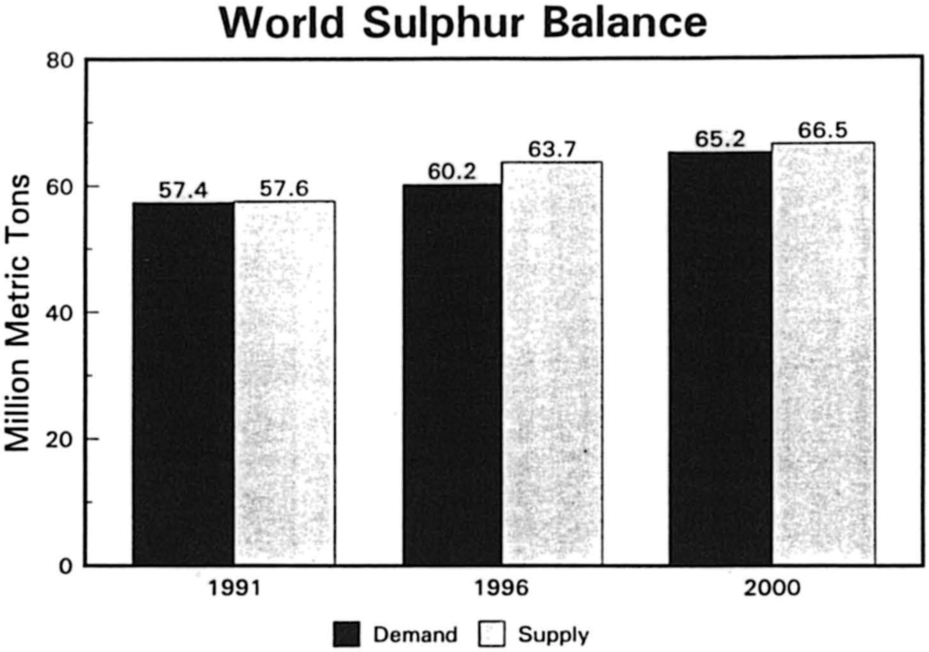
Commercial development of this potentially large PNS market can benefit North American fertilizer manufacturers who develop direct application sulfur products or blended fertilizer products containing sulfur and then aggressively market the products. Failure to exploit the PNS market will increase the gap between sulfur production and consumption.

In summary, I suggest that world-wide sulfur supply will be long to the year 2000.

I believe that sulfur and phosphates have entered a period where the entire "culture" of the industry must change. Those who fail to accommodate the constantly changing market will fail.

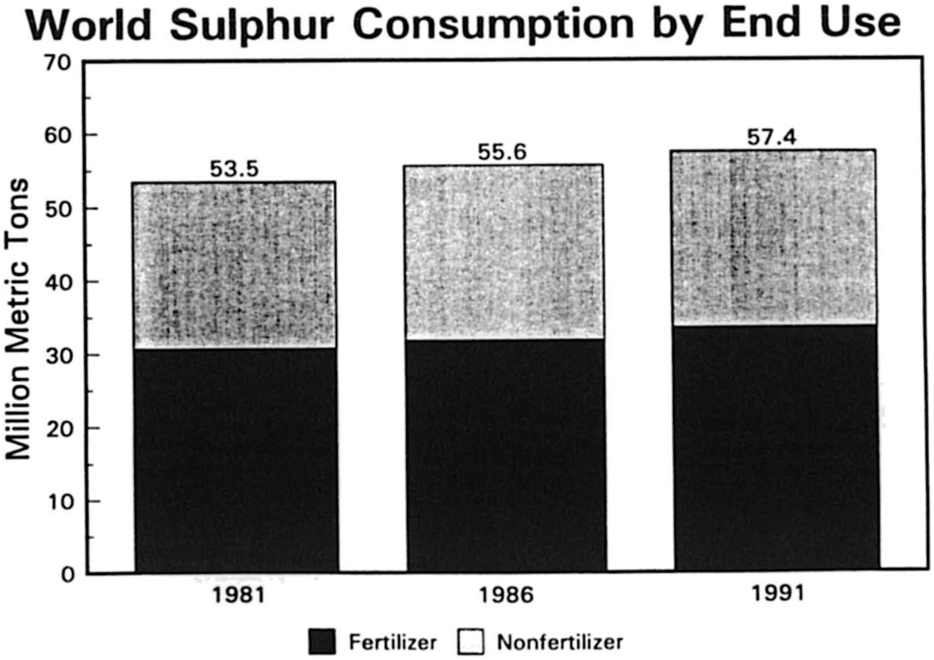
I contend that the economically successful survivors of a market undergoing fundamental restructuring will be defined by innovative trading and pricing practices.

FIGURE 1



Source: TSI 1992 Sulphur Outlook

FIGURE 2



Source: TSI 1992 Sulphur Outlook

FIGURE 3

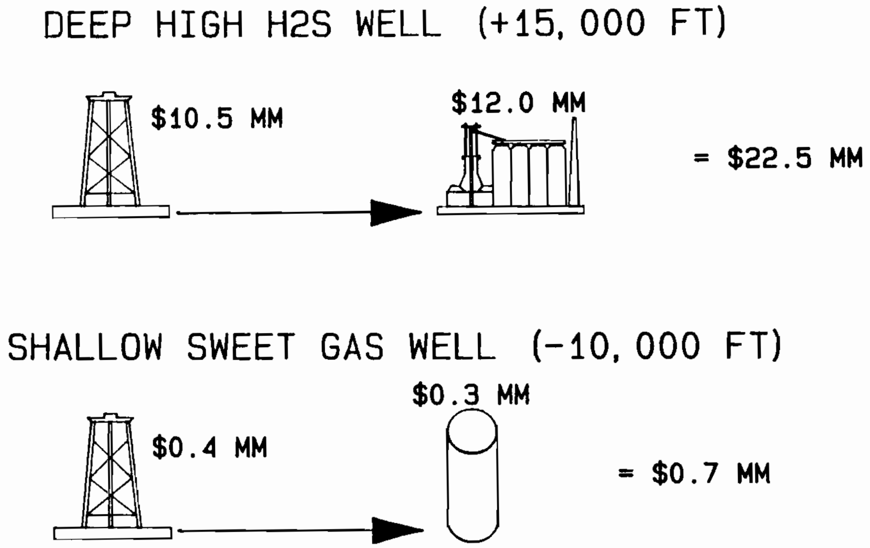
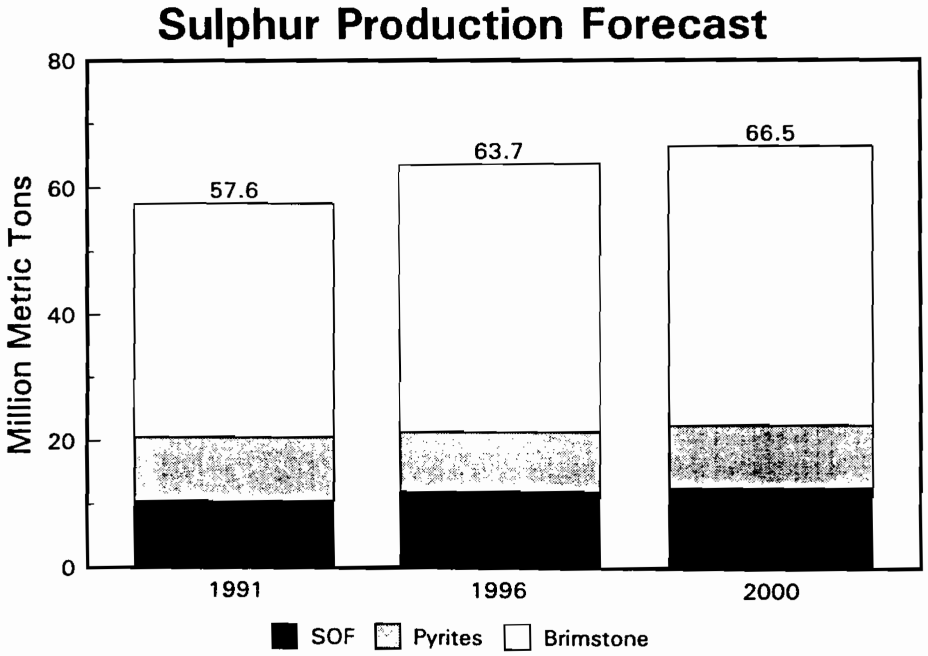
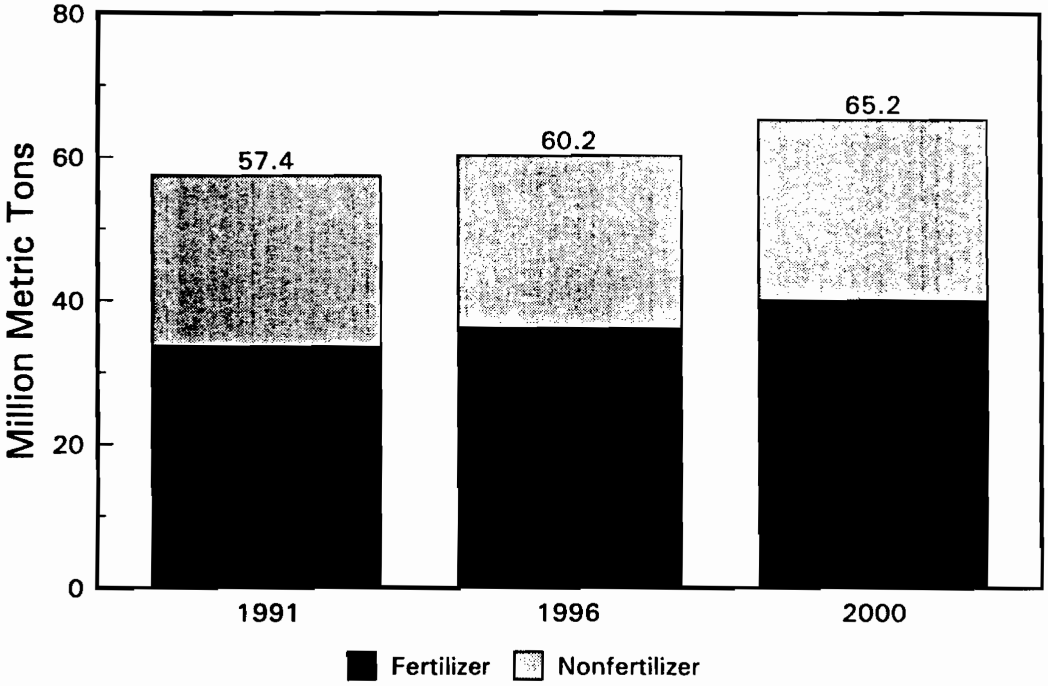


FIGURE 4



Source: TSI 1992 Sulphur Outlook

FIGURE 5



Source: TSI 1992 Sulphur Outlook

Monday, October 26, 1992

Session II
Moderator:
Gary Pigg

Fertilizer Industry Restructuring World Wide Panel Discussion

Asia

Ian Gregory
International Fertilizer Development Center

SUMMARY

The 37 countries of Asia now dominate the global fertilizer industry, accounting for over 40% of total consumption for all plant nutrients and almost 30% of total production in 1991. During the 1980s, fertilizer production and consumption in Asia grew at an annual average growth rate of about 6% compared to a world average of about 2.6%. Over the next 5 years, this differential growth rate in Asia is expected to continue with demand growing between 2% and 3% annually compared to less than 1% for the world average.

The Asian fertilizer sector is dominated by the industry and demand in China and India, and, to a lesser extent, by Pakistan and Indonesia. Together with the declining industry in Japan these countries account for 80% of the Asian fertilizer production and consumption. The past growth in the industry has predominantly been in the public sector for both production and marketing. During this present decade, partial or complete transfer from the public to the private sector, first in marketing then possibly in production, will have a major influence on the industry structure and performance and its trading relationships with the world industry.

Consumption growth between 1991 and 2000 in Asia is forecast at about 8.5 million tons of nitrogen and about 4 million tons P_20_5. This increased production is expected to be met by the Asian countries but this means that the current level of imports (8.2 million tons N and 4.8 million tons of P_20_5 in 1991) will continue through the next few years.

The impacts on fertilizer demand of fertilizer subsidy removal, development of open competitive markets, increasing population growth and food production requirements in Asia, and fertilizer oversupply capacity on the world scene are discussed as factors influencing the structural development of the Asian fertilizer industry over the next decade, with particular reference to China, India, and Indonesia.

INTRODUCTION

In the late 1970's, the fertilizer industry in the developed countries failed to recognize the impact of the momentous developments in the Asian industry both in consumption and production of fertilizer and in rapidly increasing grain production. During the 1980's, the bitter lessons of global over-capacity reverberated through the fertilizer industry in the developed countries. Now, it is known that when China or India sneeze, the world fertilizer industry catches cold. In the 1990's, major events are still taking place in Asia and, combined with the repercussions of the geopolitical changes in the Former Soviet Union (FSU) and Eastern Europe, are creating even more change and more uncertainty, and the global fertilizer industry structure for the twenty-first century is still far from clear. This paper briefly reviews the principal developments that have occurred in Asia and examines the most significant factors that are likely to occur, with particular reference to China, India, and Indonesia.

The World Bank/UNIDO/FAO/Industry Fertilizer Working Group regional classification of West Asia, South Asia, and East Asia is used throughout this paper (Appendix 1). Together, there are 37 countries stretching from Turkey in the west to Japan in the east. The Japanese industry has been declining at about 5% per year since the energy cost increases of 1973/74, with three major reduction and consolidation programs effected by the government. With this exception, Asian countries as a whole have been rapidly increasing their importance as producers, consumers, importers, and exporters of fertilizer.

PRODUCTION, CONSUMPTION, AND TRADE

Production of the primary plant nutrients, N, P_20_5, and K20, in Asia increased from 12% of the world total in 1971, to 20% in 1981, and 30% in 1991 as shown in Figure 1. This represented an increase in production of over 35 million tons of nutrient in 20 years from 8.8 million tons in 1971 to 43.9 million tons in 1991. In product terms, this represents over 130 million tons of fertilizer products.

Increases in consumption have been even more spectacular as shown in Figure 2. In 1971, Asian consumption accounted for 17% of total world plant nutrient consumption, grew to 27% by 1981 and today accounts for 41% of the world total or 56.4 million tons.

Only 5 Asian countries account for 80% of the total nutrient consumption: China (48%), India (22%), Indonesia (4%), Japan (3%) and Pakistan (2%). The other 32 Asian countries together comprise only 20% of the Asian total as illustrated in Figure 3.

In the decade from 1981, exports from the Asian countries have more than doubled from 4.9 million tons of plant nutrient to 10.3 million tons. Most of the increase in exports, illustrated in Figure 4, has occurred in West Asia, particularly in phosphates and potash from Jordan and Israel and in nitrogen from the Arab Gulf countries. Over the same time period imports have also more than doubled from 8.7 million tons in 1981 to 18.5 million tons in 1991. As illustrated in Figure 5, imports of phosphates and potash have increased proportionately more than nitrogen imports although the nitrogen imports alone increased by a total of almost 4 million tons. The major import areas have been and continue to be the major consumers in South and East Asia as illustrated in Figure 6. Discounting potash, South and East Asia represent approximately 28% and 62%, respectively, of both production and consumption of N and P_20_5 while West Asia trails with only 10% of the Asian total.

Table 1 provides a picture of the current product mix in South and East Asia for both production and consumption of nitrogen and phosphate fertilizer. The nitrogen market is essentially urea, particularly outside of China. In China, the production of ammonium bicarbonate (ABC) from the small-scale local plants using coal gasification technology still accounts for over 8 million tons of nitrogen per year or almost 50% of the annual Chinese nitrogen production and is included in Table 1 under "other." Nitrogen production in compounds includes complex nitrophosphates, compound NPKs, and even a small quantity of urea-based NPKs.

Single superphosphate production still dominates phosphate fertilizer production in Asia, mainly due to the production in both India and China. Much of this production is in small-scale plants (less than 50,000 tons annual capacity) and due to the low quality of the phosphate rock used is low in P_20_5 content, often 16% P_20_5 in India and 12% or less in China. There is a significant change evident over recent years towards high-analysis phosphates such as DAP and TSP. In South and East Asian, countries outside China and India DAP and TSP dominate as the primary phosphate materials. Of special interest is the production and use of fused calcium magnesium phosphate (CMP) in China which accounts for around 10% of all phosphate production and use in South and East Asia. Most of the direct application phosphate rock use occurs in China. Several TSP production units in South and East Asia rely entirely on imported raw materials, rock phosphate and sulfur, intermediates, and phosphoric acid. These plants, in common with those in other locations around the world depend entirely on imported raw materials, and cannot compete economically with the low cost imported product from the integrated mining and processing industries in the United States, West Asia, and North Africa.

The trend towards increasing production and use of phosphoric acid based products and the almost exclusive use of urea outside of China as a nitrogen source is leading to increasing evidence of developing sulfur deficiency in many parts of South and East Asia. Current economics preclude the production and use of single superphosphate when distribution distances are long and freight costs high. It, therefore, seems that there is a growing need for plant nutrient sulfur (PNS) that needs to be supplied for the Asian markets.

Statistics alone fail to convey the dramatic changes that have taken place in Asia. Anyone who has visited Bontang situated right on the equator in east Kalimantan, Indonesia, where P.T. Kaltim operates three ammonia urea complexes with an annual production exceeding 1.5 million tons urea and P.T. Pertamina operates an adjoining world scale oil and gas complex, cannot fail to be impressed by the development. A little over 10 years ago, Bontang was a small settlement huddled between the jungle and the sea, with an itinerant population of no more than 3,000 people, engaged mainly in traditional fishing activities. Today, Bontang is a flourishing city of 60,000 inhabitants with all the infrastructure necessary for a city of that size and with state of the art technology, skills and expertise in the work force. Repeat this development story over a hundred times throughout Asia and one begins to appreciate how development of the fertilizer sector has an impact not only on national economies but on the lives of millions of people throughout the region. During this last decade, China and India have maintained a practical level of food grain self-sufficiency for their rapidly growing populations, and Indonesia, once the world's largest importer of rice, achieved self-sufficiency in 1984 and Bangladesh did the same in 1990, an achievement that seemed almost impossible just a few short years ago.

With this development in Asia of the fertilizer sector over the past 20 years has come the development of the associated technical skills and management required to run and maintain modern industrial complexes and the recognition that continuous supply of services is required. In India, capacity utilization in the early years of fertilizer production development was often down around 50%, frequently due to interruptions to the power supply. Today, the average utilization is 85% but as with all averages, this hides the real picture. The large modern complexes are operated at 100% to 110% or more capacity utilization. Notwithstanding that the name plate capacities may be understated to some extent, this still represents major development.

STRUCTURAL CHANGES

With a few exceptions in India, Thailand, Malaysia, Pakistan, Philippines, and Japan and in West Asia, most (>80%) of the production facilities in Asia are in the public sector. Between 1981 and 1991 the number of production companies is believed to have increased from 93 to 224, many operating several production sites and plants. These numbers exclude China. As shown in Table 2, most of the increase has occurred in South Asia, predominantly in India where there has been a large expansion of small SSP producers as shown in Table 3. The share of the public, private, and cooperative sectors in India's total production are 41%, 34%, and 25%, respectively, for nitrogen and 25%, 64%, and 11%, respectively, for phosphate. It must be recognized that the private sector operates under the control of the Retention Price Scheme administered by the government and for all intents and purposes the whole of the highly regulated Indian fertilizer sector can be considered as though it were all in the public sector until recently. During the 1980s, apart from the commissioning of 11 world scale ammonia-urea complexes, the other most significant trend has been the increase in DAP plants reliant on imported ammonia and phosphoric acid. Recent annual import requirements for these plants have been around 1.5 million tons of phosphoric acid and 900,000 tons of ammonia. Morocco, with its specialized fleet of acid tankers, has been the major supplier of phosphoric acid. In 1989, a commercial dispute arising over the price of phosphoric acid led to the temporary closure of much of the Indian domestic DAP capacity and the importation of DAP. Following resolution of the situation, domestic DAP production recommenced but several companies began to explore joint venture investments in Jordan and elsewhere to secure future supplies of phosphoric acid or DAP. Very recent events in India, since August 1992, surrounding the deregulation of the phosphate sector now make the situation very unclear. The reductions in subsidies since August 1991, difficulties with raw material supplies, and long delays in the payments of subsidies to the small SSP plants have reportedly caused considerable problems and reduced output for many of these plants.

The government of China has and continues to administer a policy aimed at self-sufficiency in fertilizer production for nitrogen and phosphate. This has not been achieved to date and although plans were formulated for self-sufficiency to be achieved by the year 2000 it is unlikely, and probably recognized, that this will not be accomplished. Even so, remarkable growth has taken place in fertilizer use and production in China as shown in Table 4.

In the early 1960s China embarked on an ambitious program of fertilizer production capacity based on small-scale local plants producing ABC (17% N) and aqua ammonia (12%-16% N), using outdated coal gasification technology. Many of these plants were built quickly with little regard to availability or quality of raw materials, process technology or training of operators. In the mid-1960s efforts were made to develop standardized designs and plant scale, to set specifications, and train personnel. Until the mid-1970s most of the production was in 1,100 small- and medium-sized plants using anthracite as feedstock and an intermittent air-blow/steam fixed-bed gasification process. The capacities ranged from 5,000 to 25,000 tpy anhydrous ammonia and 20,000 to 100,000 tpy ABC.

Since the mid-1970s, development of the nitrogen industry has followed two avenues: imports of large ammonia/urea plants using international technology and the development of indigenous medium-sized plants (160,000 to 200,000 tpy ABC) based on improvements to the technology of the earlier small-scale plants but still fairly energy intensive. By 1981, China had procured and commissioned 13 large ammonia/urea plants. Not all of these used natural gas as feedstock as they were originally designed to, being converted to naptha or fuel oil. Six more large plants have been constructed since 1981, two locally built plants and four imported plants, the latest one being a nitrophosphate complex with 900,000 tpy capacity. In addition, all of the medium-sized ABC plants have been converted to urea or in a few cases ammonium nitrate (AN) or ammonium chloride (ACL). Approximately 200 of the most energy inefficient small-scale ABC plants have been closed. A summary of the present structure of the nitrogen production capacity is presented in Table 5.

Between 1955 and 1981 about 800 small-scale phosphate plants were established typically producing either single superphosphate or fused calcium magnesium phosphate. These plants are inefficient, increasingly expensive to operate, and about 100 have been closed in the past decade. The remaining 700 plants, however, still contribute significantly to China's phosphate supply providing about two-thirds of total consumption in 1991.

RAW MATERIAL RESOURCES

The availability of fertilizer raw material resources in Asia have dictated the developments of indigenous production facilities to a large extent. The resource situation for natural gas, sulfur, phosphate rock, and potash is summarized in Table 6. The abundant supplies of natural gas in West Asia have allowed for the ammonia/urea production to reach 3.3 million tons of N in 1991, concentrated in the Gulf countries. Good supplies of gas in India, Pakistan, and Bangladesh have allowed the development of ammonia production in South Asia which amounted to 11.2 million tons of N in 1991. In East Asia, while abundant supplies of gas are available in Indonesia, Malaysia, and the Gulf of Thailand, the cost of recovery from new offshore gas fields is increasing. China has limited supplies and future nitrogen production will increasingly have to rely on the abundant coal reserves.

West Asia is also resource rich in sulfur, phosphate rock, and potash. The region can be expected to become increasingly more important as a source of raw materials, intermediates and finished products for South Asia, and

East Asia as well as other regions. South Asia has minimal reserves of phosphate rock and sulfur and no reserves of potash. It will remain extremely import dependent. East Asia also is restricted in sources of phosphate rock and sulfur. Increased supplies of sulfur will be available to Indonesia from 1996 with the development of a large copper smelter but most other countries in the region will remain import dependent. China has abundant supplies of phosphate rock, although much is low quality. The current sulfur supply in China is based on pyrites. Any future large-scale development of indigenous phosphate via phosphoric acid based processes will increase import dependency as the pyrites source of sulfur is very expensive due to logistical and processing problems.

The only major potash resource in East Asia is the Bamnet Narong deposit in Thailand. The ASEAN governments last year placed the development of this mine -an investment of about $320 million with planned production of 1 million tons of potassium chloride per year -high on the development agenda. In view of the current world over supply capacity it would seem unlikely that development will occur in the medium term. China possesses one sizable potash reserve -the Chaerhan Salt Lake in Qinghai province. The development of Phase I of this project with a capacity of 200,000 tpy is currently nearing completion. A further increase in capacity to 800,000 tpy under Phase II is expected to be completed by the late 1990s. This will still leave China very much dependent on imports of potash.

THE FUTURE

The most recent forecasts of world and regional supply and demand balances for nitrogen, phosphate, and potash made by the World Bank/FAO/UNIDO/Industry Fertilizer Working Group indicate world nitrogen fertilizer consumption increasing by only 1.16% annual compound growth between 1990/91 and 1996/97, and phosphate and potash by less than 1%. By contrast the Asian region forecasts are 2.4% for nitrogen and 2.6% for phosphate and potash. Figure 7 illustrates the global and Asian incremental demand growth forecast between 1991 and 1997 and between 1991 and 2002. During the next 5 years, due to the declining European and FSU demand, the Asian markets account for almost all of the increased demand for fertilizer nutrients. In Figure 8 it can be seen that Asia is also forecast to account for most of the increased production of nitrogen and phosphate in the next decade. Combining these data, it can be seen in Figure 9 that while the global surplus supply capacity will remain for the next 5 years the Asian deficit will remain. In summary, the Asian fertilizer sector is forecast to grow by about 8.5 million tons nitrogen and 4 million tons P_20_5. This increased production is expected to be met by the Asian countries themselves. This means that the current level of imports (8.2 million tons N and 4.8 million tons P_20_5 in 1991) will continue through the next few years.

Nitrogen production in China is expected to increase by about 2 million tons by 1997, with the commissioning of eight ammonia/urea plants and capacity improvements to some of the small- and intermediate-sized plants. This is expected to increase supply potential to around 17 to 17.5 million tpy. Consumption, however, should increase to about 21 million tons N, leaving an annual import requirement of around 4 million tons N as urea. In recent years, China has sourced between 50% and 54% of its urea import requirements from the FSU and Eastern Europe and a further 23% from West Asia. It can be expected that in the next 2 years or so this supply pattern will remain as the Newly Independent States (NIS) seek exports for foreign exchange earnings and to offset reduced domestic demand, but as production costs increase, due to economic pricing of natural gas, then China can be expected to diversify its supply sources for urea. The most likely source areas are thought to be West Asia and Indonesia.

The current (8th) 5-Year Plan in India, which is based on grain needs, indicates a continuing gap between production and demand through the mid-1990s, as shown in Table 7. Most observers believe these forecasts to be optimistic. Although consumption in India has been increasing steadily at around 7% per year, apart from the drought affected 1987/88 period, the increased prices arising from subsidy removal are expected to slow growth demand during the next 5 years. Provisional data for 1991/92 indicate no increase in nitrogen demand for instance over the previous year and current expectations are for a 30% fall in phosphate and potash demand following complete removal of the subsidies on these nutrients. Until the pricing situation is clearer, it will be impossible to predict with certainty just how demand will be affected.

In Indonesia, urea production is expected to increase from 4.6 million tons in 1991 to 7.8 million tons in 2000 due to the impact of the current Fertilizer Restructuring Program. This program has revamped much of the urea capacity in Indonesia providing improved energy efficiencies and increased capacities. In addition, the new P.T. Pusri plant at Palembang and the new P.T. Petro Kimia Gresik urea plant at Gresik in East Java will add 979,000 tpy to annual urea production from late 1993. Additionally, a private/public sector joint venture, the Kujang Dua urea plant, is expected to add 542,000 tons to urea production from 1994. This increased production, according to recent forecasts made by the author, increase export availability from 1.6 million tons of urea to 3.9 million tons annually. With its locational advantages in relation to the major South and East Asian markets, Indonesia is well placed to provide an increasing share of the urea market.

CRITICAL DEVELOPMENT FACTORS

The growth forecasts for Asia represent the brightest star in the global fertilizer industry for the next 5 to 10 years. The continuing deficits which need to be supplied by imports represent the largest continuing market opportunities for international fertilizer trade. The forecasts, however, may not reflect some critical development aspects in Asian markets. Some of these factors represent conflicting aspects of the regional supply/demand balance.

Population growth will continue to dominate economic development in Asia. With limited arable land, increased food production has to come from increased yields per acre. When the current fertilizer demand forecasts are compared to the requirements based on food production needs calculated by FAO and IFDC then there is a critical gap. Add to this the current imbalance of fertilizer nutrients used and a picture emerges of reduced growth in food grain production over the next decade. No quantum leap in technology, such as occurred with the Green Revolution, is foreseen either. Improved fertilizer use efficiency through improved management of fertilizer use and water management, pest and disease control, and integrated nutrient management will all be required to improve food production in Asia. Higher grain prices for farmers will also be required as fertilizer subsidies are removed in many countries under pressure from the international finance institutions.

Fertilizer subsidy removal will impact on fertilizer demand in Asia to varying degrees over the next decade. In India, the current chaotic situation is due to the fertilizer subsidy bill reaching more than $2 billion, a level that could not be sustained. As subsidies are systematically removed this is likely to cause short-term disruptions to Asian markets and long-term slower growth than has been experienced in the past. The impact on phosphate and potash is likely to be more severe than on nitrogen and will add to the current nutrient imbalance.

Increasingly allied to the moves towards fertilizer subsidy removal will be moves towards open competitive markets. Not only has the development of fertilizer production in Asia to date been primarily in the public sector but this has also been the case for fertilizer distribution and marketing. Most Asian countries have allocative government controlled or highly regulated distribution systems. Over the next decade, it can be expected to see this change. Examples such as Bangladesh, where private sector open competitive marketing is now firmly entrenched, with resultant cost savings to both the government and farmers, can be expected to be the norm within 10 years. The privatization of the production companies may be next. The deregulation of the Asian fertilizer markets will impact on the international market. It may follow that the strength of the official purchasing agencies in India and China could be diluted by multiple private sector companies importing from the international market.

Table 1. Product Mix in South and East Asia

	Production %	Consumption %
Nitrogen		
Urea	58	59
AN	2	2
AS	3	3
Other	31	25
Compounds	06	11
Phosphate		
DAP/MAP	22	33
TSP	9	10
SSP	37	28
NPK	18	16
Other	10	9
DAPR	4	4

Source: FAO. Fertilizer Statistics.

Table 2. Structural Change in Number of Fertilizer Operating Companies in Asia

Year	West Asia	South Asia	East Asia (Excluding China)
1981	21	31	41
1991	34	133	59

Source: Derived from British Sulphur Corporation, *World Fertilizer Plant List and Atlas,* 1981 and 1991.

Table 3. Number of Fertilizer Plants in India, 1971-91

Year	N Plants'	P Plants'	N Capacity (million tons N)	P Capacity (million tons P_2O_5)
1971	20	33	1.487	0.534
1981	37	52	4.719	1.408
1991	52	101	8.147	2.751

a. NP plants included in both N plants and P plants.
Source: Fertiliser Association of India.

Table 4. Number of Fertilizer Plants in China, 1981-91

		Small	Intermediate	Large
1981	N	1,300	?	13
	p	800		0
1991	N	1,100	54	18
	p	700		1

Source: The World Bank, personal communication.

Table 5. Nitrogen Fertilizer Plants, China

Small-Sized Plants
About 1,100 plants with a total output of about 7-8 million tpy N individual capacity About 5,000-25,000 tpy NH3; 20,000-120,000 tpy ABC
Few plants produce urea, ammonium nitrate, or ammonium phosphate

Medium-Sized Plants
54 plants with a capacity of about 2.5-3 million tpy N individual capacity About 40,000-100,000 tpy NH3; originally 180,000-400,000 tpy ABC
AU ABC plants have been converted, mainly to urea
Some plants produce ammonium nitrate, others ammonium chloride as byproduct of soda ash production

Large Plants
Currently 19 plants with total capacity of about 5 million tpy N
Standard capacity: 300,000 tpy NH3; 560,000 tpy urea (3 locally built plants have capacities around 200,000 tpy NH3)
One NH3 plant feeds a 900,000-tpy nitrophosphate complex

Source: K. M. Constant, "New Developments in the Chinese Fertilizer Sector", *Agro-Chemicals News in Brief*, Vol. XV, No. 1, January-March 1992.

Table 6. Fertilizer Raw Materials in Asia

	West Asia	South Asia	East Asia	China
Natural Gas	Abundant	Good	Limited	Limited
Sulfur				
Production (million tons)	4.0	0.026	3.4	4.8
Import dependency	43%	98%	30%	0%
Rock Phosphate				
Production (million tons)	4.0	0.2	0.3	4.0
Import dependency	25%	81%	87%	2%
Potash				
Production (million tons K_2O)	2.1	0.0	0.0	0.05
Import dependency	0.0%	100%	100%	97%

Source: *FAO Fertilizer Statistics*, British Sulphur Corporation.

Table 7. Future Fertilizer Developments in India
(million tons)

Year	Nitrogen	Phosphate	Potash
1990	8.0	3.2	1.3

8th 5- Year Plan Based on Grain Needs:

1994/95	Capacity	Production	Demand	Gap
Nitrogen	9.9	8.9	10.3	1.4
Phosphate	3.6	3.2	4.5	1.3

Source: Fertiliser Association of India, *Fertilizer Statistics*, various issues.

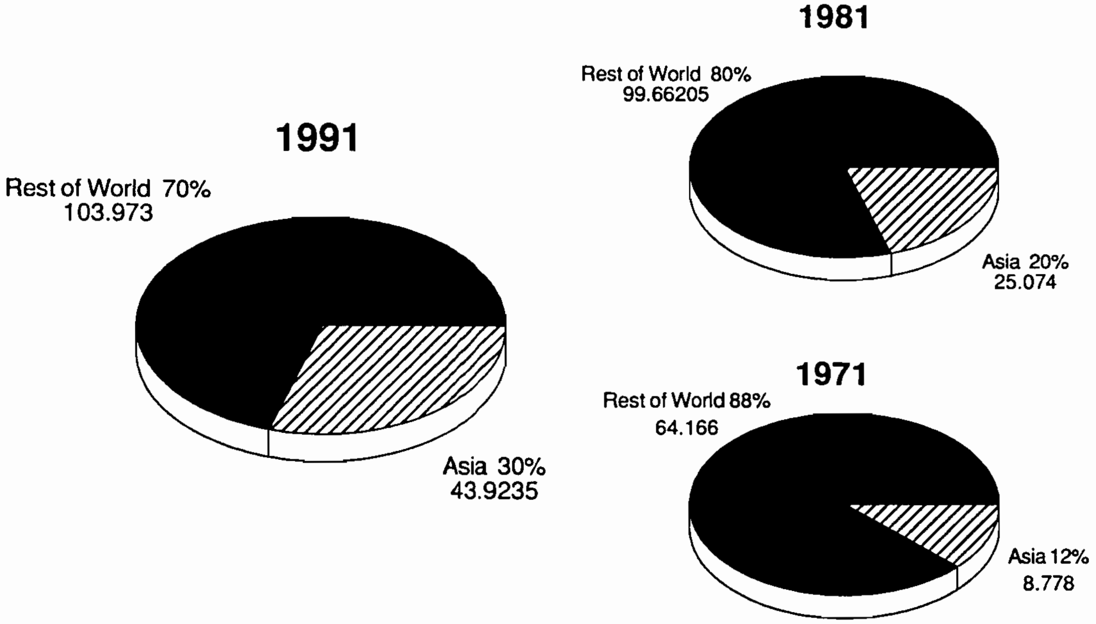
Appendix 1
Asia – Regional Country Classification

West Asia
Bahrian
Cyprus
Iran
Iraq
Israel
Jordan
Kuwait
Lebanon
Oman
Qatar
Saudi Arabia
Syria
Turkey
United Arab Emirates
Yemen

South Asia
Afghanistan
Bangladesh
Bhutan
India
Nepal
Pakistan
Sri Lanka

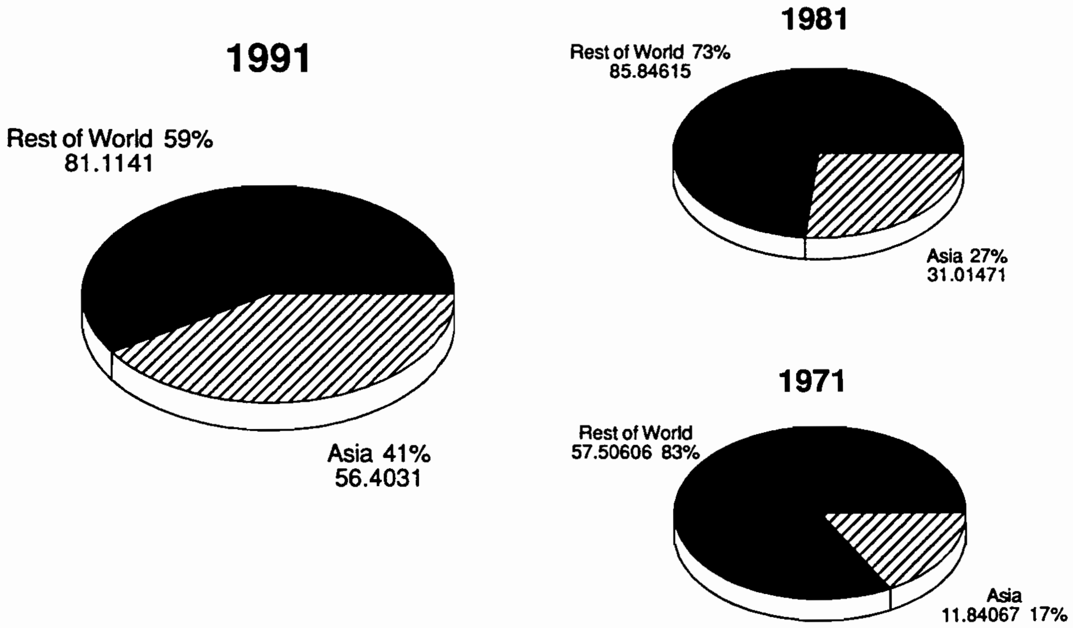
East Asia
Cambodia
China
Indonesia
Japan
Laos
Malaysia
Mongolia
Myanmar
Korea DPR
Korea Republic
Philippines
Singapore
Taiwan
Thailand
Vietnam

Figure 1. Fertilizer production in Asia, 1971-1991, compared to global production (million tonnes nutrients).



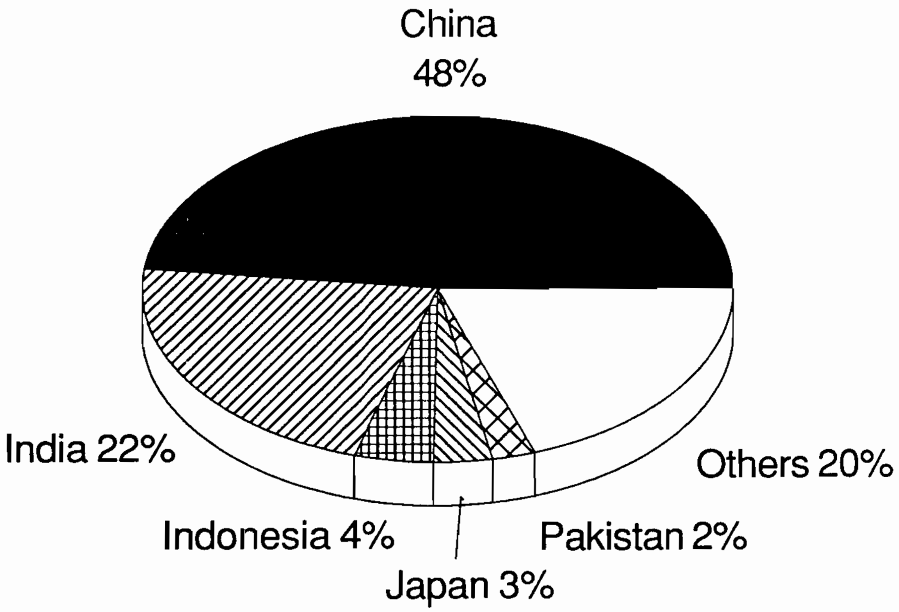
Source: FAO Fertilizer Yearbooks.

Figure 2. Fertilizer consumption in Asia, 1971-1991, compared to global consumption (million tonnes nutrients).



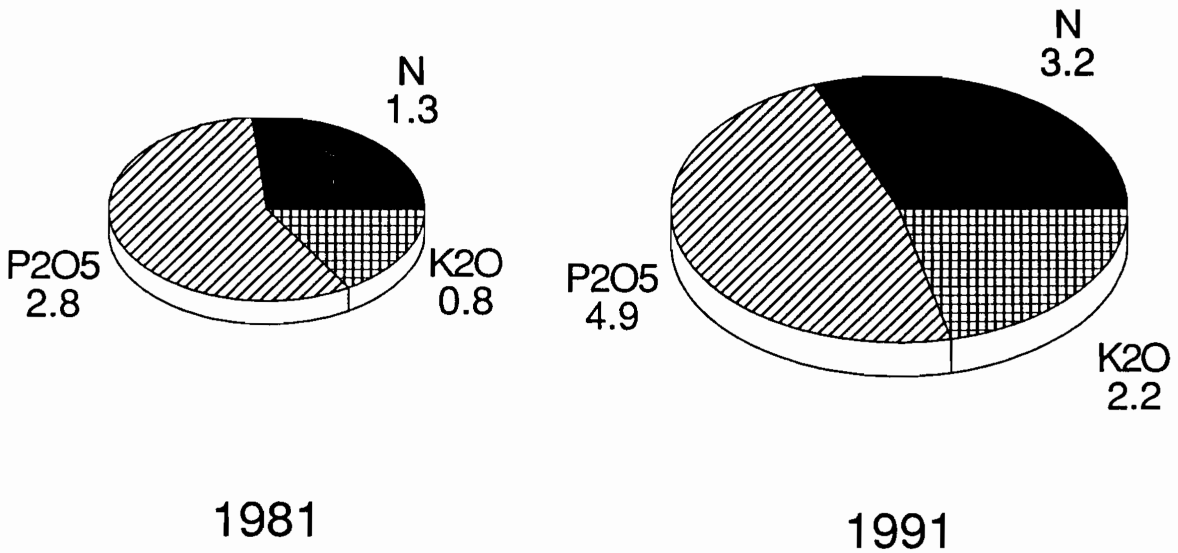
Source: FAO Fertilizer Yearbooks.

Figure 3. The 5 major Asian markets total nutrient consumption, 1991.



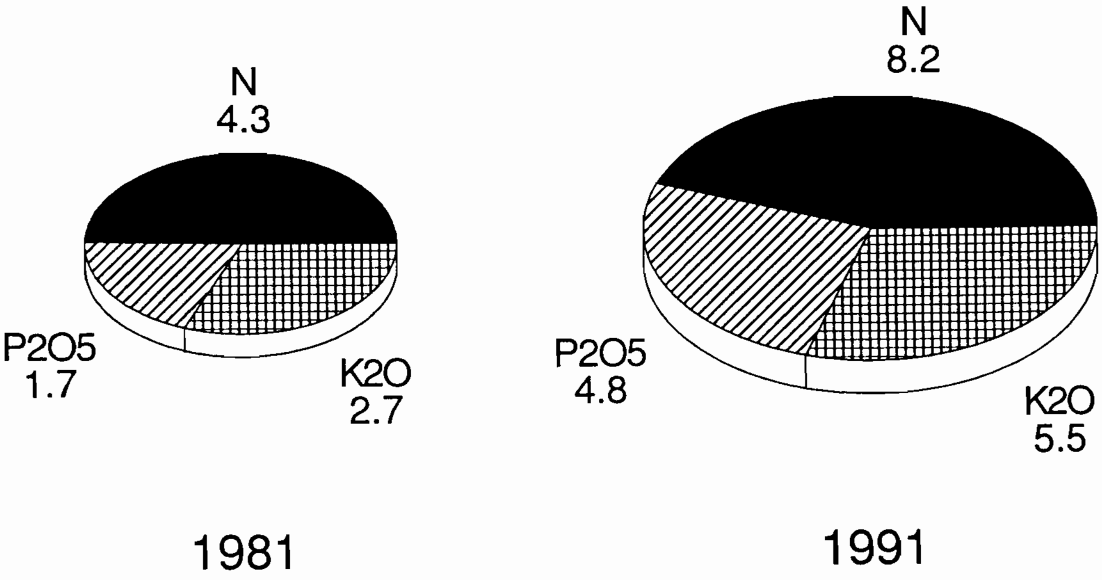
Source: FAO Fertilizer Yearbooks.

Figure 4. Asian fertilizer exports 1981-1991 (million tonnes nutrients).



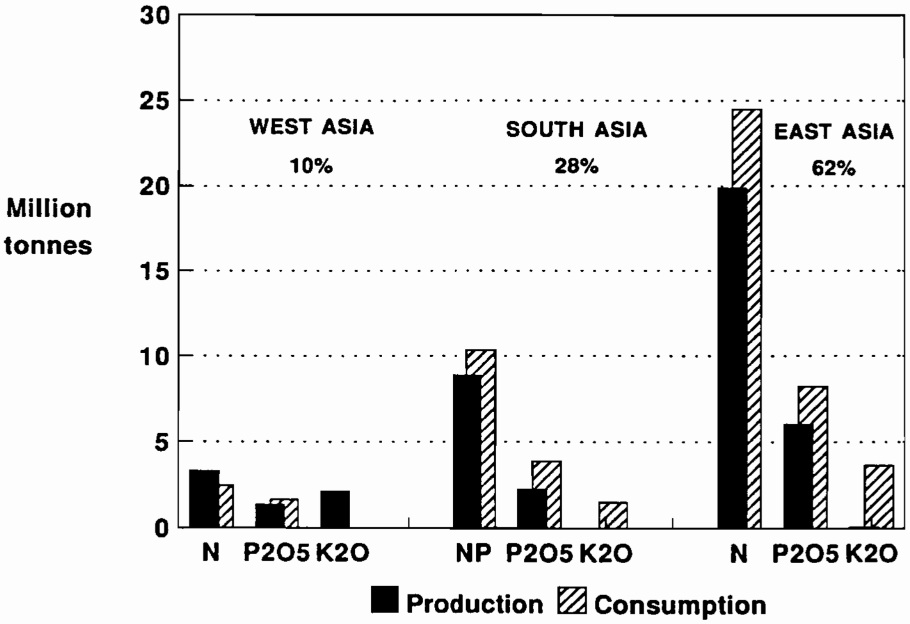
Source: FAO Fertilizer Statistics.

Figure 5. Asian fertilizer imports 1981-1991 (million tonnes nutrient).



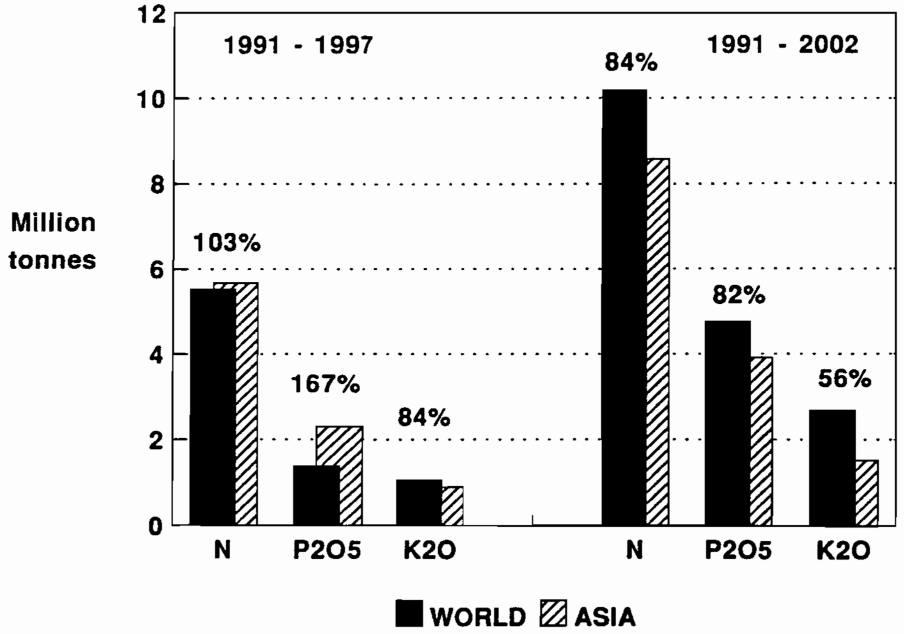
Source: FAO Fertilizer Statistics.

Figure 6. Asian nutrient production and consumption by region, 1991.



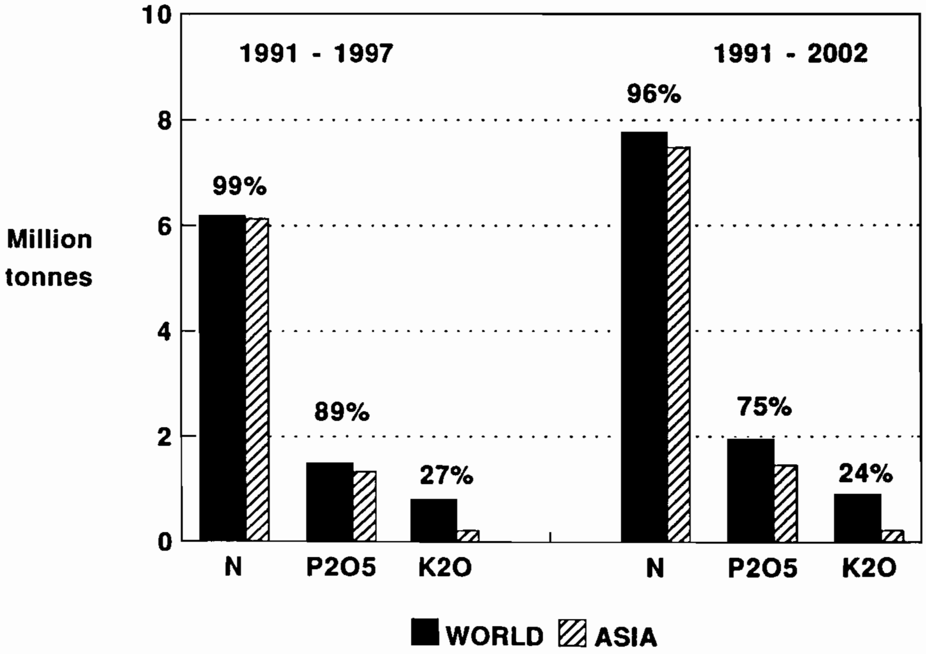
Source: FAO Fertilizer Yearbooks.

Figure 7. World and Asian nutrient demand growth (million tonnes).



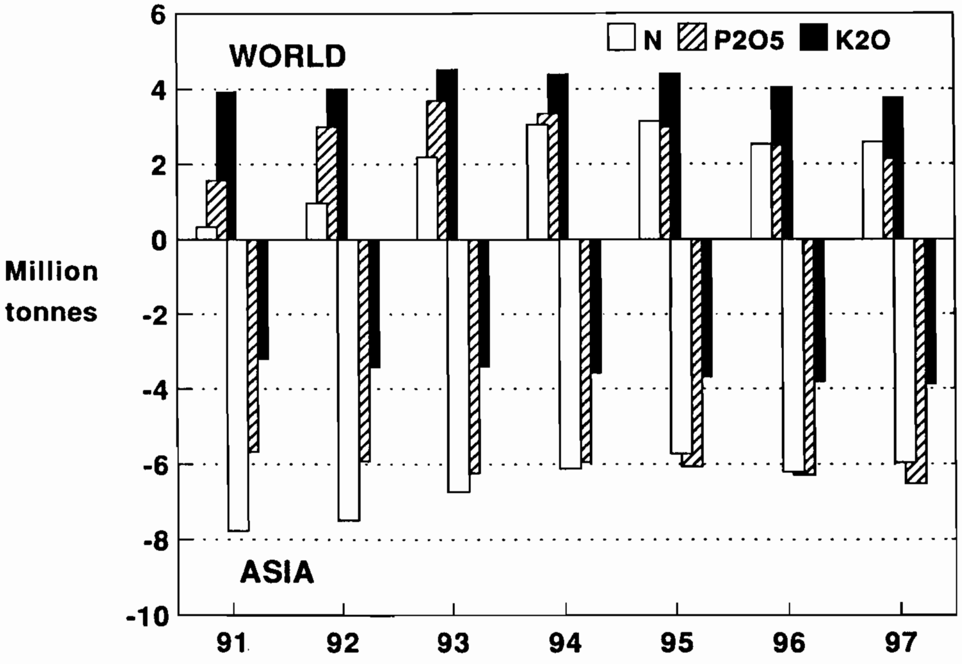
Source: The World Bank/FAO/UNIDO/Industry Fertilizer Working Group, World Bank Technical Paper Number 176, June 1992.

Figure 8. World and Asian nutrient production (million tonnes).



Source: The World Bank/FAO/UNIDO/Industry Fertilizer Working Group, World Bank Technical Paper Number 176, June, 1992.

Figure 9. Global and Asian nutrient surplus (deficit) forecast (million tonnes).



Source: The World Bank/FAO/UNIDO/Industry Fertilizer Working Group, World Bank Technical Paper Number 176, June 1992.

West And East Europe

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1. THE GLOBAL SITUATION

In 1960, 88% of the world fertilizer consumption was accounted for by the developed countries: West Europe, North America, Oceania, East Europe, the USSR, South Africa and Japan. Consumption has tended to stabilize in these regions, except in the USSR where growth continued until 1988. Fertilizer consumption in the developed countries remains large - some 73 million tons of plant nutrients in 1990/91, but its proportion of global consumption is declining. In 1990/91 and 1991/92 there were declines of 10% and 8% (estimated) respectively, due to falls in West and East Europe and the former USSR.

The substantial expansion of fertilizer use in developing countries started in the early 1960's. By 1990/91 the share of world consumption accounted for by developing countries had increased to 47%. Increases in world fertilizer consumption during the next few years will be in the developing countries, essentially in Asia.

In the case of phosphate, the processing of phosphate rock close to its source has increased and this trend is expected to continue. There is also a tendency for processed phosphates to substitute for phosphate rock in international trade. From the mid-1970's to the early 80's, most of the increase in processed phosphate trade was in the form of phosphoric acid. More recently, it is diammonium phosphate which has been responsible for most of the increase.

Natural gas resources are more evenly distributed in the world than are phosphate and potash deposits, although Russia and the Arabian Gulf together account for about 70% of known world reserves. There has been a shift towards nitrogen fertilizer production in developing countries. A substantial increase of production in very large consuming countries such as China and India has been noted. There have also been increases in countries where the opportunity cost for the gas is lower than in Europe, as is the case with associated gas in some major oil producing countries. Developing countries accounted for 46% of world nitrogen fertilizer production in 1990/91, compared with 32% ten years previously.

World potash production is accounted for by the handful of countries with economic deposits. In 1990/91 the USSR accounted for 34% of the world's production, Canada for 28%, Europe for 26% (Germany, France, Spain and the UK), Israel and Jordan for 8%, and the USA for the remaining 4%.

2. WEST EUROPE

2.1 Fertilizer Consumption

Fertilizer use in West Europe peaked at 22.6 million tons nutrient in 1986/87. This was essentially due to the increase in nitrogen consumption. By 1979/80, phosphate and potash had only returned to their 1973/74 levels and in 1980/81 their consumption started to decline. Nitrogen consumption also began to fall in 1986/87. In 1990/91 total nutrient consumption, including the former East Germany, amounted to about 20 million tons. Phosphate consumption was down 30% from its 1979/80 level, potash was down 14%.

Phosphate and potash consumption never recovered from the sharp rise in prices in 1973/74. Nitrogen profited from the considerable increase in cereal production in the EEC countries and from the intensified fertilization of grassland in countries with favourable climatic conditions for this crop. In regions with intensive livestock rearing, large quantities of nutrients, albeit in low concentrations, are contained in imported animal feed and much is returned eventually to the land as manure.

In 1990/91, fertilizer consumption in West Europe fell by 1.8 mill. t or 9%. The fall in fertilizer consumption in the five new federal states of Germany, was responsible for two thirds of the fall. In 1991/92, we estimate that West European consumption will have fallen by a further 1.3 mill. t or 6%. Some 57% of the fall is accounted for by France and Germany but there is a decline in almost every country. Falling prices for agricultural products, deteriorating farm incomes, increased taxation of fertilizers, production constraints such as quotas and set-asides, increasing input costs and a more efficient use of nutrients in organic manures have been reported.

The EEC has agreed on a 29% cut in cereal prices, moderated by direct payment compensation to farmers, a compulsory set-aside for arable land (15% on farms producing more than 92 tons of grain) and restrictions on the number of livestock per ha. Uncertainty about EEC agricultural policies, the impact of the GAT'T negotiations and the criticisms of environmental harm levelled against farmers, have a demoralizing effect on the agricultural sector.

The extent of the falls of the past two years in West Europe is due to exceptional circumstances. However, a gradual trend towards reduced fertilizer consumption can be noted in almost every country. After 1992/93, consumption is forecast to fall at an overall rate of 1.5% per annum, due largely to falling prices for agricultural products. We estimate that nitrogen consumption in West Europe will fall from 10.4 million t N in 1990/91 to 9.3 in 1996/97, a total decline of 11%. Phosphate consumption is expected to decline by 15% over the same period. Consumption is expected to continue to fall at least until the end of the decade, although at a lower rate.

In the world as a whole, the consumption pattern of the different products has changed. Since 1973/74, most of the increase in world nitrogen consumption is accounted for by urea, most of the phosphate by diammonium phosphate and almost all of the potash by potassium chloride. Each of these is a product with a high nutrient content, which offers considerable cost savings in storage, transport, handling and application, compared with otherwise excellent but lower-analysis fertilizers.

In West Europe, however, the product mix has not changed greatly. Since 1973/74 there has been an increase in the consumption of urea and nitrogen solutions in West Europe, but in 1988/89 they still accounted for only 13% and 6% respectively, of total nitrogen consumption. The share of ammonium nitrate and calcium ammonium nitrate has remained unchanged. Among the phosphates, the consumption of basic slag has declined, due to reduced availability, and so has that of single superphosphate. The consumption of potassium chloride in straight form has almost doubled, now accounting for 26% of total potash consumption, compared with 15% in 1973/74. This may partly reflect an increase in bulk blending. In 1988/89, 80% of total phosphate and 67% of total potash were applied as complex fertilizers, compared with 71% and 69% respectively in 1973/74.

2.2 Production and Trade

In 1980/81, West Europe accounted for 20% of world nitrogen fertilizer production, in 1990/91 for 12%. Total N production fell from 12.3 to 10.1 million tons N, although this is still a substantial quantity in world terms.

In 1980/81, the net trade balance for nitrogen fertilizers, regional exports minus imports, was positive at 1570 thousand tons N In 1990/91 there was a negative balance of 649 thousand tons N, excluding ammonia. The negative balance of phosphate fertilizer imports, excluding phosphoric acid, changed from - 205 thousand tons P2O5 in 1980/81 to - 1116 in 1990/91.

In 1980/81, West Europe accounted for 17% of the world production of phosphate fertilizers against 9% in 1990/91, and an increasing share of the production is based on imported phosphoric acid.

The West European market is large, accessible and with the resources to pay cash for imports. In consequence, the market is an evident target for imports. The imports of nitrogen fertilizers from outside the region increased from 0.6 million tons N in 1981 to 2 million tons in 1990, about half of which came from the former USSR and East Europe. Imports from outside the region of the processed phosphates (phosphoric acid, ammonium phosphate and triple superphosphate) increased from 2.2 to 3.7 million tons product, while imports of phosphate rock declined. The prices of imported nitrogen, phosphate and potash products were extremely competitive Export markets have been lost.

2.3 Profitability

Fertilizer production in West Europe is efficient, has a good infrastructure, skilled employees and a relatively stable market. The products are of excellent and reliable quality. However, West European producers are at a disadvantage compared with producers in other regions. Natural gas prices are among the highest in the world.

The fertilizer industry is the largest single consumer of natural gas in West Europe, accounting for about 5% of total consumption. Most of the gas is used as a feedstock for the production of ammonia. The ammonia industry has no economic alternative to gas as feedstock. A competitive gas price is therefore critical for an ammonia producer. But during 1990 the average gas price for ammonia producers in the EEC was about twice as high as in the United States and more than 6 times higher than in the Arabian Gulf.

The FSU accounts for 34% of world ammonia exports, almost 50% of which are directed at the West European market. The price is well below the equivalent natural gas price from the FSU. With low ammonia prices, high production costs and with ammonium nitrate prices under pressure from East European exports, the West European nitrogen industry is under severe economic pressure.

As regards phosphates, the West European fertilizer industry is entirely dependent on imports for supplies of phosphate rock. The USA is the most important supplier of phosphate fertilizer products followed by North Africa. Countries with large phosphate rock resources are able to charge higher prices for the rock phosphate which they export than for the rock which is processed by their own fertilizer industry. This clearly puts the West European phosphate fertilizer industry at an economic disadvantage.

These factors, together with competition from low-price imports, have led to a very low level of profitability. Ammonia and finished fertilizer prices have tended to remain too low to provide a realistic return on investment The return on investment in the fertilizer industry has, since 1985, been much lower than in most other sectors of the chemical industry.

Also, the cost of environmental compliance is increasing. In some countries there are environmental charges on waste water from plants. The gypsum disposal problem has led to the closure of a large proportion of the European phosphoric acid industry. Compound fertilizer plants are being modified to use imported intermediate products.

2.4. Industry Structure

As a consequence of the above-mentioned factors, there has been a considerable restructuring of the industry. Many smaller plants have been closed. The ownership of capacity has become concentrated in the hands of a few producers. In 1983, the fertilizer industry employed around 110,000 people. The number of people employed at present is around 40,000 i.e. a reduction of over 60%.

In the ten-year period leading up to 1990, the number of ammonia sites declined from 74 to 41. Having allowed for investment in new, larger plants and for debottlenecking, total production capacity decreased by 12%. Ammonia capacity is at 90% and urea capacity at 85% of their 1988 level and this includes a significant reduction of capacity in the former East Germany. Total West European ammonia capacity has fallen by 2.5 mill. t. N during the past 5 years. Several ammonia plants have been idled during the past few months and, given the present international ammonia price, their closure is likely to be permanent, and the future of several other plants is uncertain. Hydro Fertilisers in the UK has announced the closure of two ammonium nitrate and nitric acid complexes.

As regards phosphates, the number of phosphoric acid plants has been halved, with capacity and output reduced by some 35%. In 1989, total phosphoric acid capacity in West Europe amounted to 3.6 million tpa P_2O_5. At the end of 1992, it could be 2.1 million tons – a decline of 35% in two years. For example, in 1977, there were 11 wet-process acid plants in the United Kingdom. Now there are none.

Also, a considerable amount of NPK compound fertilizer granulation capacity is being closed. Since 1988, West European producers have announced the closure of about 5 million tpa NPK granulation capacity. Announcements of closures in recent months include Norsk Hydro's plans to close 950 000 tpa granulation capacity in France and the Netherlands, and Kemira's intention to close a 350 000 tpa unit in Finland.

As regards potash, the main change has been the closure of a substantial quantity of uneconomic mine capacity in the former East Germany.

Some companies, such as Hoechst, have withdrawn from the business. Others, such as Norsk Hydro of Norway and Kemira of Finland have sought to achieve the maximum benefits of economies of scale and increased market share by purchasing companies in other countries. The large number of mergers and acquisitions which took place during the ten-year period leading up to 1990 has resulted in eight major companies accounting for more than 80% of European production. These are, in alphabetical order: Agrolinz, BASF, DSM, Enichem, FESA, Grande Paroisse, Kemira and Norsk Hydro.

There has also been considerable concentration in the fertilizer distribution sector. The number of cooperatives and wholesalers has decreased considerably.

Rationalization and modernization within the European industry continues, with a view to improving efficiency, but with little hope of expanding the regional market.

3. EAST EUROPE

3.1. General

Under the centrally planned system, raw materials and utilities were allocated to the plants, and fertilizers allocated to the farms. Prices had little meaning and profitability was rarely a criterion. Countries importing raw materials from others in the former Comecon countries enjoyed favourable prices and barter arrangements. Exports outside the region could be priced arbitrarily, the main objective being to earn foreign exchange. As a result, raw materials, fertilizers and labour were often used very wastefully. Environmental protection was usually a secondary consideration.

Today, producers are increasingly having to pay a market price for their raw materials, often in hard currency. Environmental protection movements are active and, in due course, regulations comparable to those in Western Europe will no doubt be imposed.

However, the full impact of market forces will not be felt for some time. To a greater or lesser extent, depending on the country, the economies of the East European countries are in a very poor condition. In general, production and trade have fallen. Inflation rates are high and in consequence monetary policies are tight, with resultant falls in domestic demand. The agricultural sectors are inefficient and structural change is very slow. Crop prices are rising less than production costs. Agricultural output has fallen, but an increase of agricultural exports has been possible in view of the fall in domestic demand.

3.2. Fertilizer Consumption

Farmers are now faced with economic realities.During the 20 years up to 1980, fertilizer consumption in East Europe increased regularly and strongly. But, from about 1980 onwards, the consumption of all three nutrients levelled off, for much the same reasons as those which led to stagnation in West Europe. At the end of the 1980's, consumption began to fall in the region.

The transition to market economies has led to the removal of high subsidies, high interest rates, shortage of cash and a lack of credit facilities, the need to pay for imports in convertible currencies, increased input prices, higher oil costs and uncertainties due to structural changes in agriculture following attempts at privatization. The demand for certain agricultural products has fallen.

The East European fertilizer markets are characterized by a lack of handling facilities, warehouses, precision spreading equipment and by the absence of credit schemes to farmers. The old inefficient distribution systems, for both inputs and outputs, have collapsed and often have not yet been replaced by adequate substitutes.

It is estimated that fertilizer consumption in these countries fell by 33% in 1990 and 39% in 1991, or 60% over the two years. This represents a reduction of 5.6 mill. t nutrient. Phosphate and potash consumption fell by 71% over the two years. In Poland, it is estimated that consumption this year will average 40 kg nutrients, NPK, per ha compared with 182 kg/ha in the 1980's. In Hungary, in 1991 54 kg nutrients were applied per hectare of cultivated land, compared with over 200 kg in 1989 and 240 kg in 1983. Phosphate and potash consumption in Hungary in 1991 was 15 times lower than in 1989.

Despite the fall in fertilizer use, agricultural surpluses have developed in some countries due largely to a fall in domestic demand and to reduced trade with ex-Socialist countries.

It is hoped that a gradual recovery will begin from 1993 onwards, at least for nitrogen fertilizers, but the 1989 level is unlikely to be achieved ever again. It may take longer for phosphate and potash consumption to recover significantly, and most soils have a reasonable level of these nutrients.

3.3. Production and Trade

At present, East Europe accounts for about 8% of world ammonia and urea capacity and 6% of world phosphoric acid capacity. The countries with the largest ammonia and phosphoric acid capacities are Rumania, Poland and Bulgaria Czechoslovakia and Hungary also have substantial nitrogen capacities but no significant phosphoric acid capacities. Croatia and Serbia have significant ammonia and phosphoric acid capacities.

In 1980 East Europe produced 5.2 million tons of nitrogen fertilizers and had a positive trade balance of 1.4 million tons. In 1990 production was at about the 1980 level, at 5.1 million tons, but was less than that of the previous year (6.5 million tons N). The nitrogen fertilizer trade balance was positive at 1.2 million tons N. In 1990 East Europe imported 0.5 million tons ammonia as N from other regions, compared with a negligible quantity in 1980.

Several countries are significant exporters of nitrogen fertilizers. In 1991 East Europe accounted for about 1 mill. t N or 12% of the world's urea exports and 38% world's ammonium nitrate exports, destined mostly for West Europe. Rumania accounted for 35% of East Europe's urea exports and Bulgaria for 31%.

3.4. The Profitability and the Structure of the Industry

As in West Europe, a key issue for the fertilizer industry is the availability and price of natural gas. The dependence on natural gas varies considerably between countries. Coal dominates as an energy source in the north, whereas natural gas tends to dominate in the south. This partly reflects the availability of resources. Until recently, the East European countries were dependent on oil and gas imports from the USSR. The situation today is that 47% of the region's gas is supplied domestically, 53% imported from the FSU; the latter figure varies from 100% in Bulgaria to 20% in Rumania. Rumania, Hungary, Poland and the former Yugoslavia have a significant gas production of their own, but still require significant imports. Price levels of gas export sales from the FSU to Eastern Europe, for new contracts, have increased to international market levels and they are payable in dollars, but there are still some imports on a barter or countertrade basis. The quantity of gas imported from the FSU has fallen and alternative supply sources are being developed to fill the gap.

The region has no significant resources of phosphate rock or potash. Phosphate fertilizer production is now very limited. Only Poland produces substantial quantities of sulphur.

Except in Poland, which also has the advantage of the Baltic sea ports, and in Croatia, the production of NPK fertilizers is now at a low level in East Europe. As regards nitrogen, to take the example of Rumania, the supply of domestic gas is limited, the price of imported gas is high and payable in hard currency. Most of the plants are old, energy inefficient and polluting. In 1991, a reduction in domestic demand permitted maintenance of the level of urea exports.

In Bulgaria, production of N fertilizers in Dimitrovgrad and Vratsa has been lowered or stopped. In Hungary, production at several nitrogen plants, such as Borsodi, Tisai Vegyi and Pet Nitrogen Works has been reduced or stopped.

The Gdansk phosphoric acid complex in Poland is operating near full capacity, despite the pressure of the public opinion to close the plant due to pollution problems.

Most plants in eastern Europe are still state-owned. Few projects have been made for the privatization of the plants. Hungary plans to privatize the plant of Tiszai Vegyi and hopes western investments will be injected in the plant. In Poland Tarnow may be privatized, as it is not only dependent on fertilizers. But larger plants as Police or Pulawy are unlikely to be privatized for the moment.

In general, the Governments of central and eastern Europe wish to encourage the involvement of western chemical companies by creating a business climate similar to that in Western Europe. Czechoslovakia, Hungary and Poland have taken the most significant steps and are closest to making a transformation from a command to a market economy. However, in the case of the fertilizer industry, Western industries are in any case reluctant to invest in plants which require a great deal of capital expenditure if they are to be competitive in a saturated market.

The economic viability of plants in East Europe will be based increasingly on market prices for the raw materials. Logically several uneconomic plants should close, as they have done in West Europe, but these countries are in great need of the foreign exchange earned by exports. In general, the countries of East Europe, unlike Russia, have few natural advantages as far as fertilizer production is concerned.

4. THE POSSIBLE IMPACT ON WEST EUROPE OF CHANGES IN EAST EUROPE

West Europe has suffered severely during the 1980's from imports of low-priced fertilizers from the countries of East Europe and the former USSR. New plants were constructed in several East European countries in the 1970's and early 1980's with Soviet credits and using cheap Soviet gas, which enabled them to export nitrogen and compound fertilizers at very competitive prices. The East European countries have been seeking to earn foreign exchange In general, they have not followed normal principles of business management.

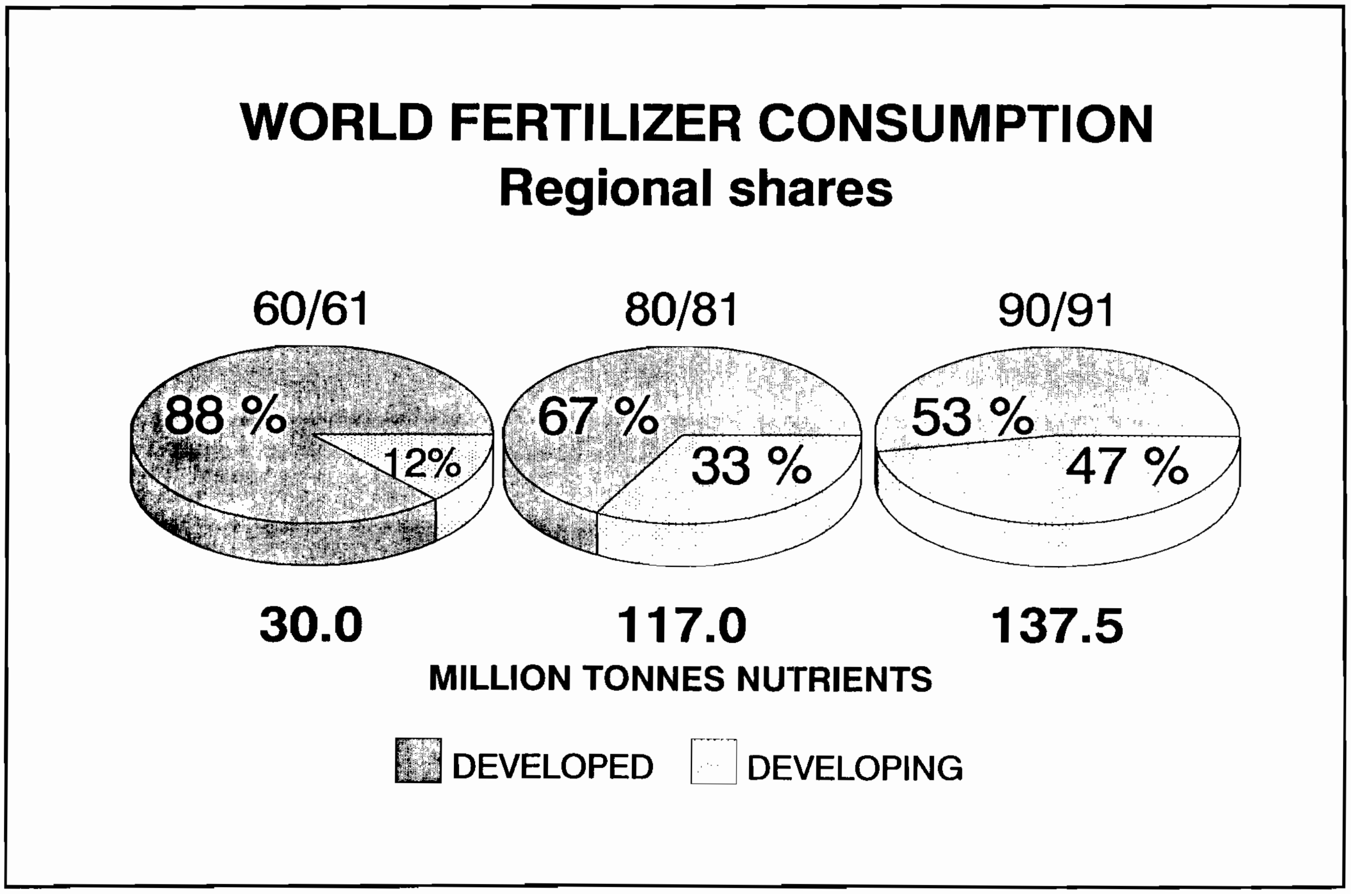
Distortions in the level of competition continue to occur. Government aid in the form of subsidized feedstocks, compensation for losses etc. is likely to continue, in view of the need to earn foreign exchange. The easing of EEC import quotas in 1990 enabled some countries to increase their exports to West Europe at low prices.

Most East European producers are no longer competitive producers of phosphate-containing fertilizers. But the threat to West European nitrogen producers remains for the time being. The total East European ammonia capacity of 9 million t N is not far short of that of West Europe, at 13 million t N.

The economies of the East European countries are moving closer to those of West Europe, but very slowly. The cost of integrating the economy of the former GDR into a united Germany is proving enormous, with financial repercussions throughout Europe. The former GDR had a population of approximately 16 million compared with a total of 124 million for the other East European countries.

As regards fertilizer production, basically the East European countries are even more disadvantaged than those of West Europe. In the longer term the uncompetitive plants should close and agricultural demand and production should return to normal levels. But this will take time. International trade is considered by many to be the most effective way to economic advancement and it is unlikely that these countries will forego exports at present, even if they have to be heavily subsidized.

Given the size of the total European market, in the long run the European fertilizer industry will probably be much healthier than it is today, but this is no consolation for the businesses which cannot wait.



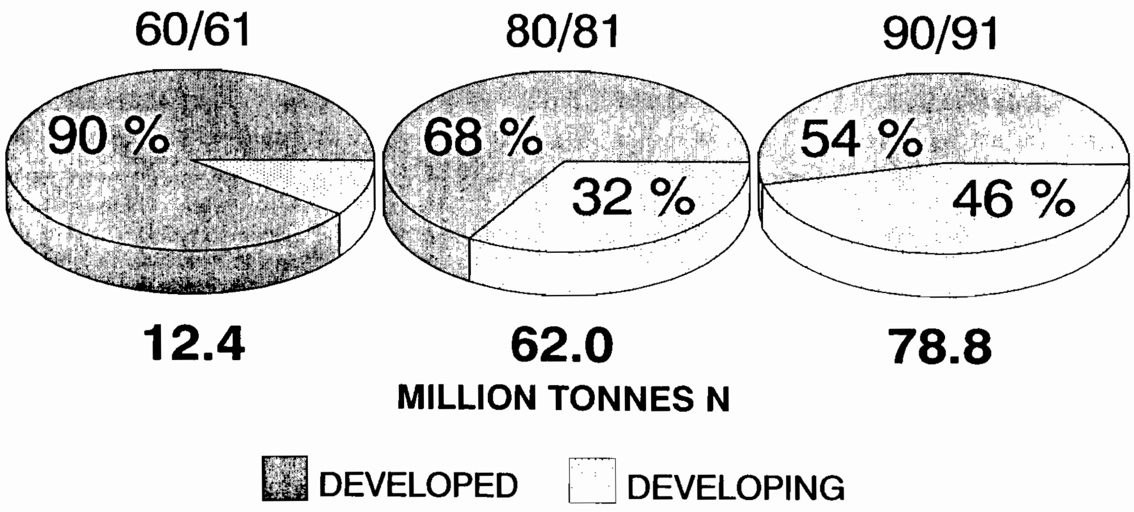
PHOSPHATE EXPORTS

(Million tonnes P_2O_5)

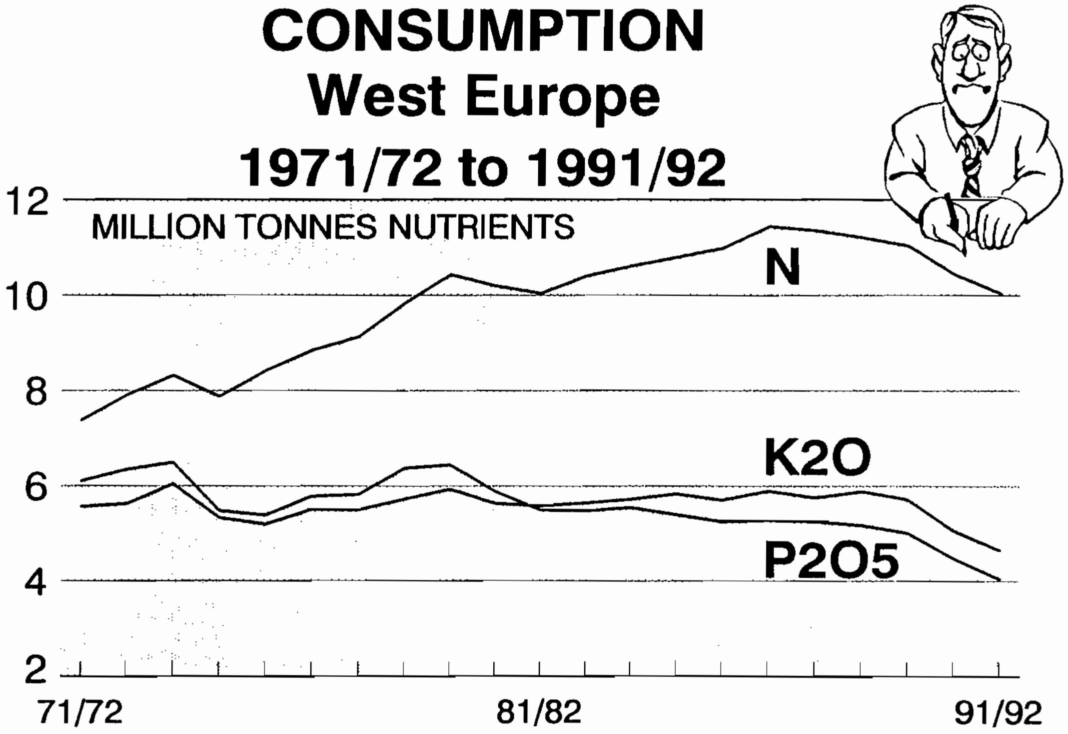
	1980	1990
PHOSPHATE ROCK	17.1 (74%)	11.7 (53%)
PROCESSED PHOSPHATE	6.1 (26%)	10.4 (47%)
TOTAL	23.2	22.1

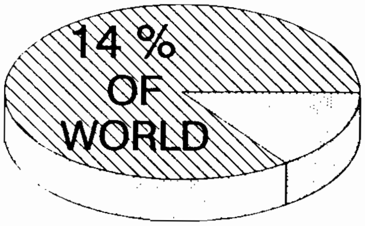
PROCESSED PHOSPHATE : AP + H_3PO_4 + TSP
exports from main exporting countries.

WORLD NITROGEN PRODUCTION
Regional shares



CONSUMPTION
West Europe
1971/72 to 1991/92

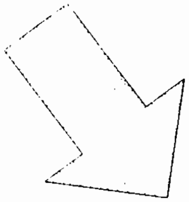




FERTILIZER CONSUMPTION

WEST EUROPE

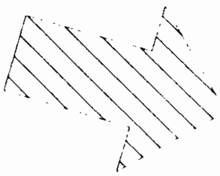
1990/91



-1.8

(-9%)

1991/92



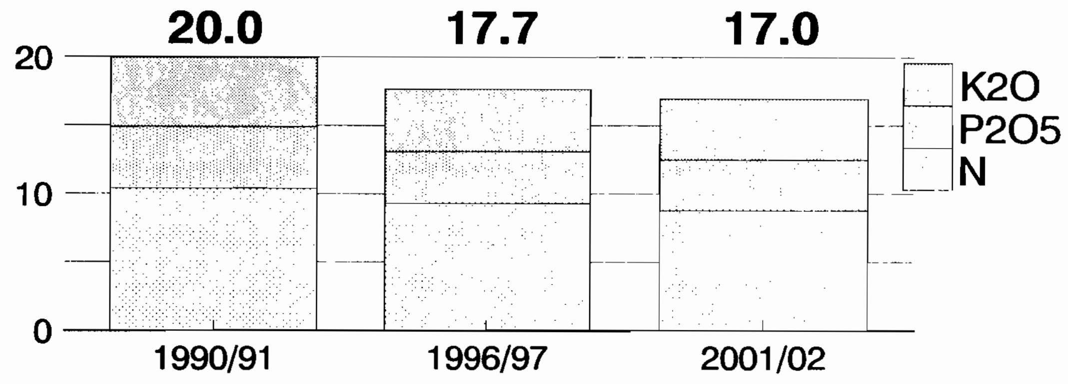
-1.3

(-6%)

MILLION TONNES NUTRIENTS

WEST EUROPE
FORECASTED FERTILIZER CONSUMPTION

MILLION TONNES NUTRIENTS



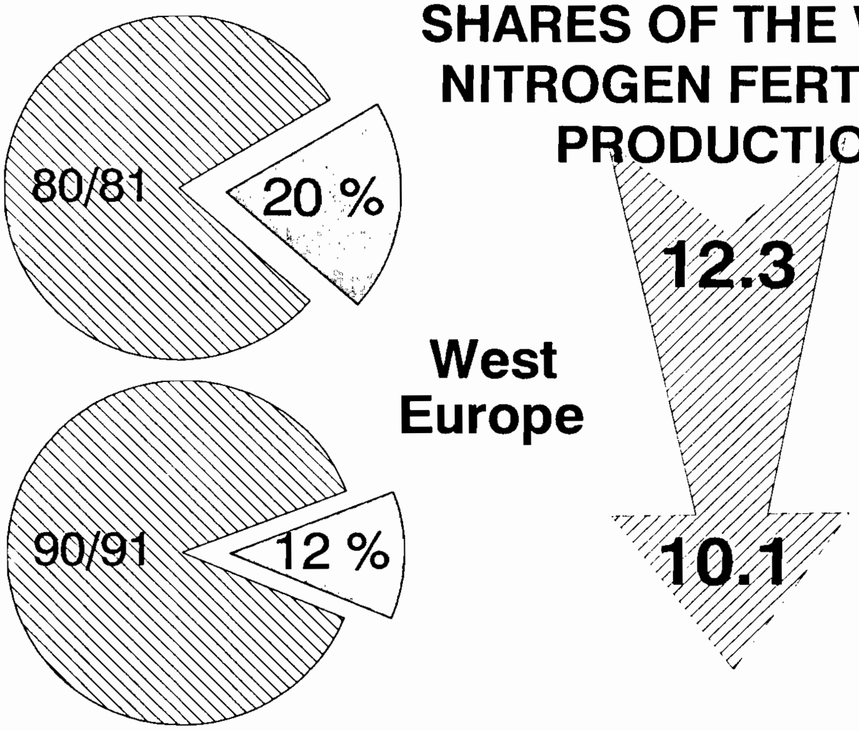
DECREASE : 1990/91 to 1996/87 : -11 %
1990/91 to 2001/02 : -15 %

FERTILIZER CONSUMPTION
Product changes 1973/74 to 1990/91

	WORLD	WEST EUROPE
N TOTAL	+ 37.4	+ 2.1
UREA	+ 21.2	+ 0.9
P_2O_5 TOTAL	+ 10.1	- 2.0
AMM.PHOS.	+ 7.0	+ 0.5
K_2O TOTAL	+ 4.0	- 1.0
POT.CHLOR.	+ 4.7	+ 0.4

Million tonnes nutrients

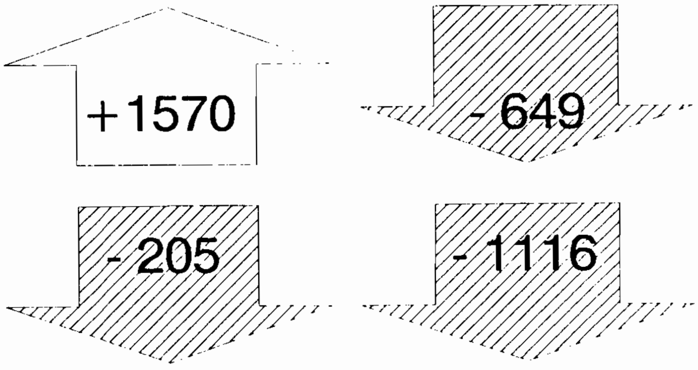
SHARES OF THE WORLD NITROGEN FERTILIZER PRODUCTION



West Europe

Million tonnes N

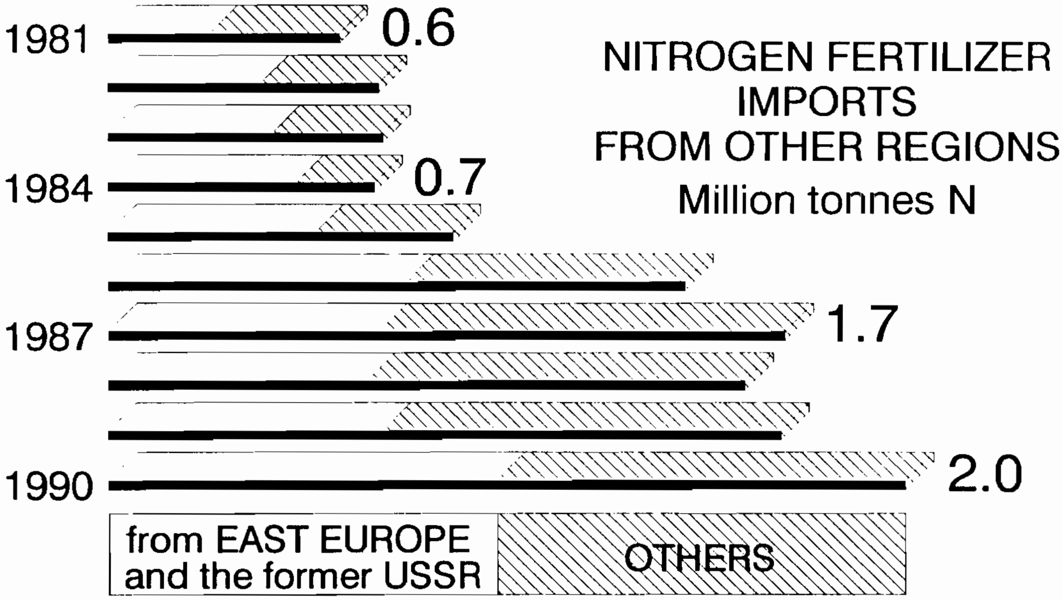
WEST EUROPE TRADE BALANCES



	1980/81	1990/91
NITROGEN	+1570	- 649
PHOSPHATE (Excluding traded phosphoric acid)	- 205	- 1116

1000 TONNES NUTRIENTS

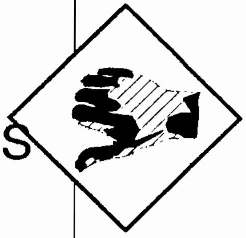
WEST EUROPE



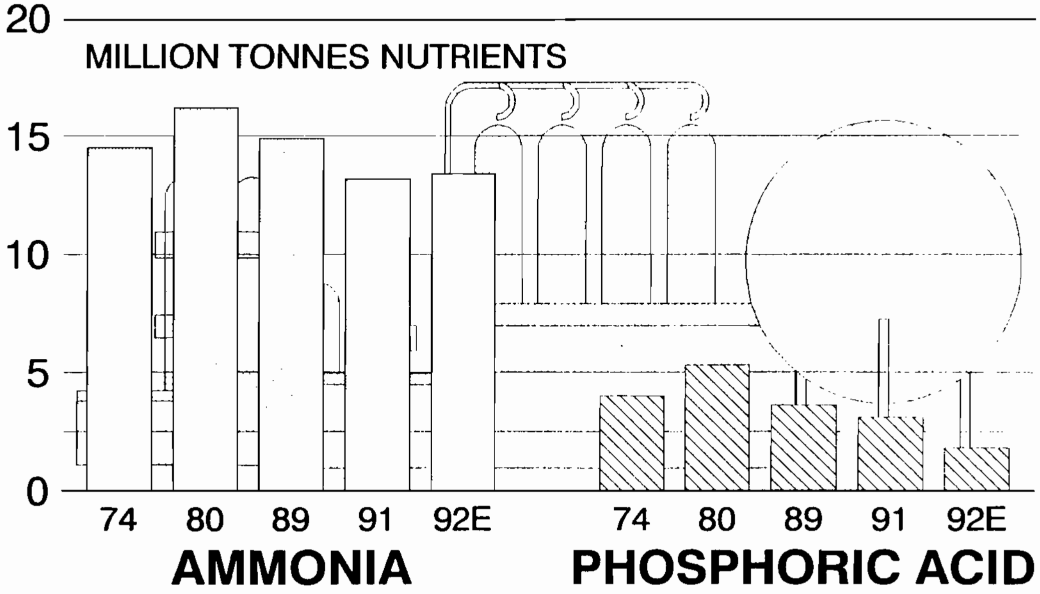
NITROGEN FERTILIZER
IMPORTS
FROM OTHER REGIONS
Million tonnes N

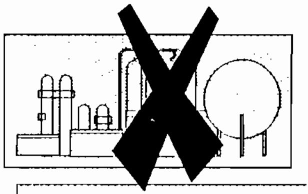
SOME FACTORS AFFECTING PROFITABILITY IN WEST EUROPE

- GAS PRICES
- PHOSPHATE ROCK PRICES
- CHEAP IMPORTED FERTILIZERS
- COST OF ENVIRONMENTAL COMPLIANCE



WEST EUROPE PRODUCTION CAPACITIES

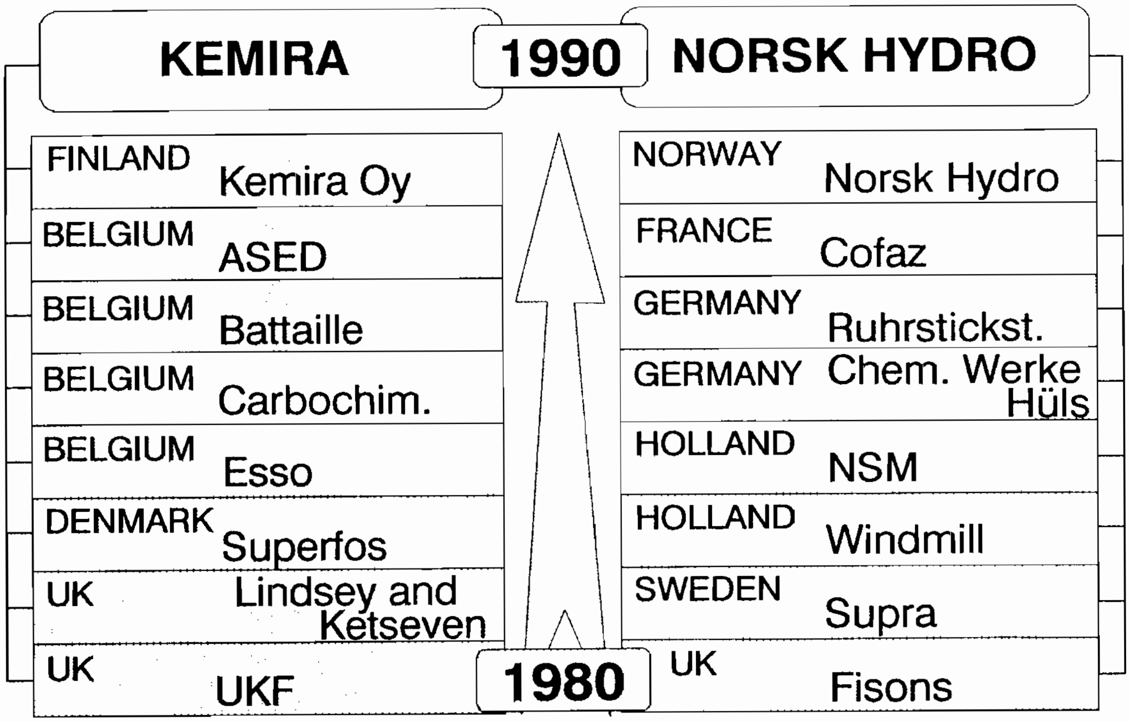




PHOSPHORIC ACID PLANT CLOSURES 1991 AND 1992

(1000 tpa P_2O_5)

BELGIUM	Prayon-Rupel	140
	BASF	75
FRANCE	Hydro Azote	220
	Grande Paroisse	200
	Rhône Poulenc	75
GREECE	Hell. Chemical	65
ITALY	ISAF	132
NETHERL.	Hydro Agri	95
SWEDEN	Hydro Supra	100
UK	Albright & Wilson	160



1990

1980

KEMIRA

FINLAND	Kemira Oy
BELGIUM	ASED
BELGIUM	Battaille
BELGIUM	Carbochim.
BELGIUM	Esso
DENMARK	Superfos
UK	Lindsey and Ketseven
UK	UKF

NORSK HYDRO

NORWAY	Norsk Hydro
FRANCE	Cofaz
GERMANY	Ruhrstickst.
GERMANY	Chem. Werke Hüls
HOLLAND	NSM
HOLLAND	Windmill
SWEDEN	Supra
UK	Fisons

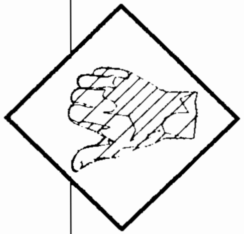
EAST EUROPE 1991

INFLATION ⇧

G D P ⇩

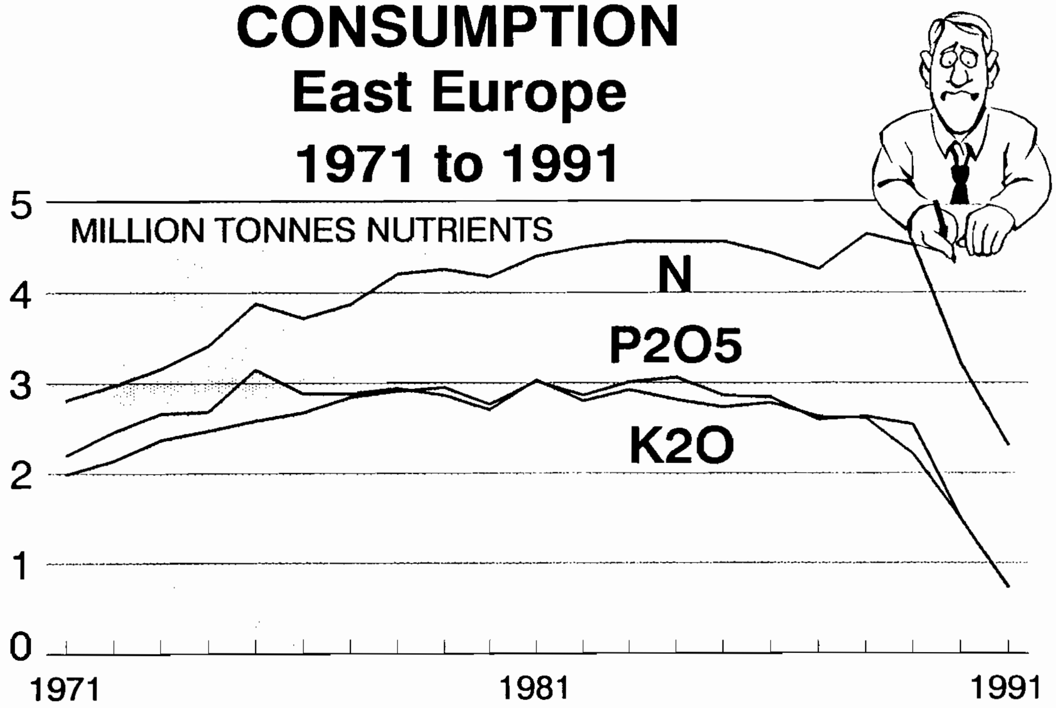
AGRICULTURAL OUTPUT ⇩

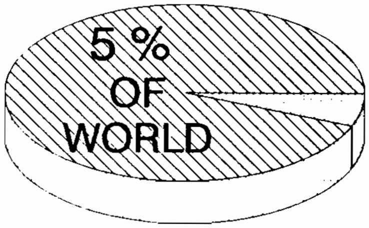
DOMESTIC DEMAND ⇩



AGRICULTURAL EXPORTS ⇧

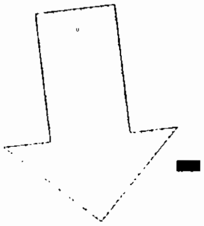
CONSUMPTION
East Europe
1971 to 1991





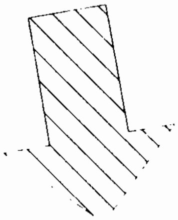
FERTILIZER CONSUMPTION
EAST EUROPE

1990



-33%

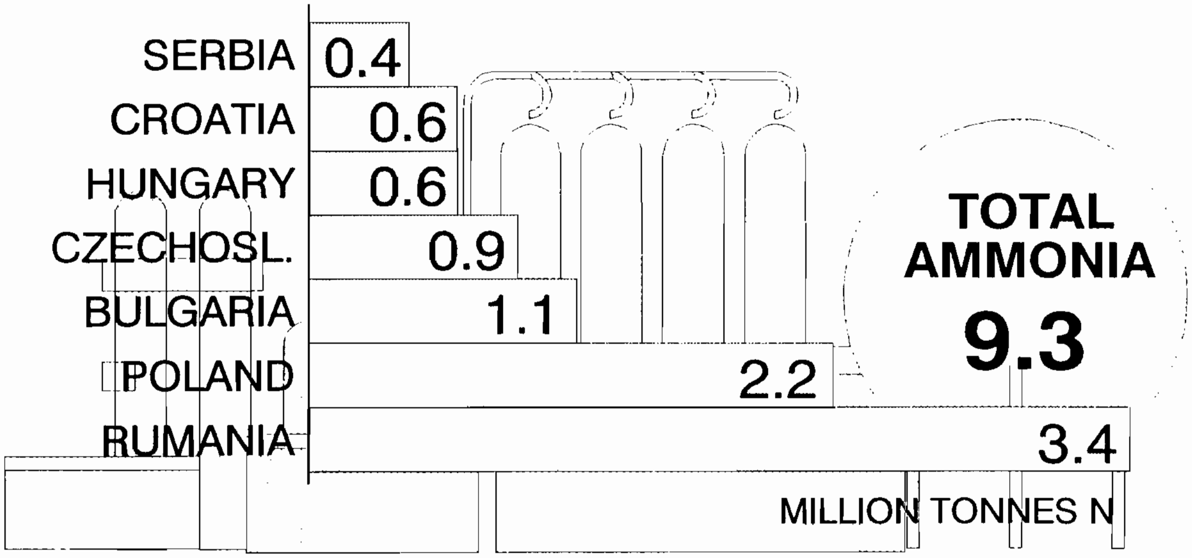
1991



-39%

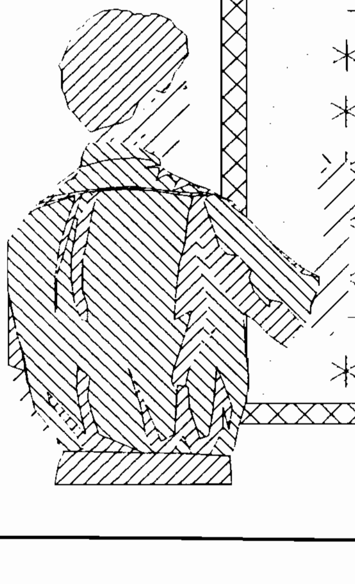
EAST EUROPE

1991 AMMONIA PRODUCTION CAPACITIES



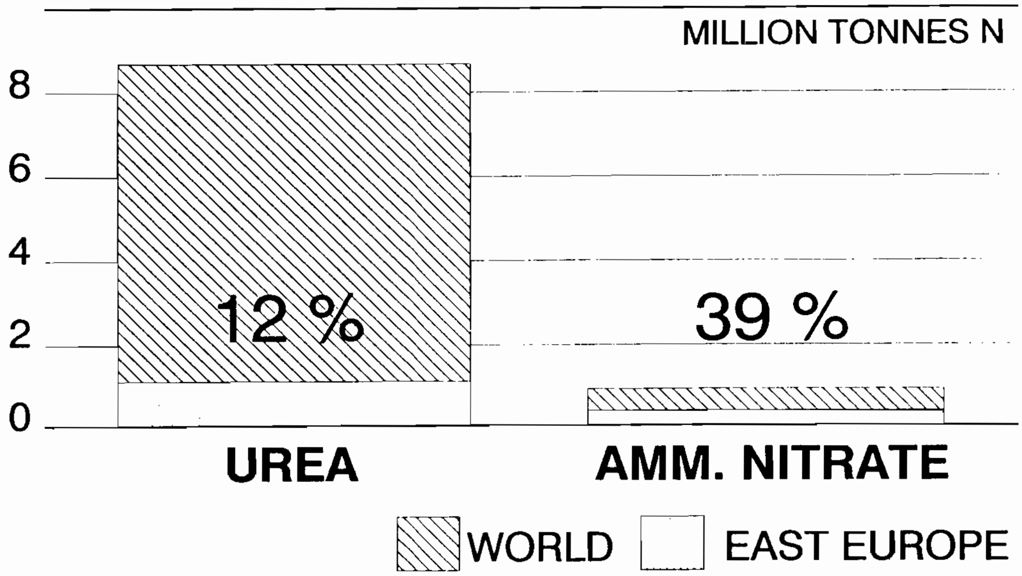
EAST EUROPE

FERTILIZER PRODUCTION, 1990



	MILLION TONNES N	% of WORLD
* AS	0.3	8
* UREA	1.7	5
* AN/CAN	2.1	15
COMPOUNDS	0.7	5
OTHERS	0.2	-
* TOTAL	5.0	6

1990 EXPORTS EAST EUROPE



SOME FACTORS AFFECTING PROFITABILITY IN EAST EUROPE

- GAS PRICE
  - DEPENDENCE ON IMPORTS
  - INCREASED COST
  - PAYABLE IN DOLLARS
- PHOSPHATE ROCK AND POTASH
  - NO SIGNIFICANT RESOURCES
- PLANTS
  - REQUIRE MODERNIZATION

Latin America

Adolfo Sisto
ADIFAL

INTRODUCTION

Latin America is traditionally considered to consist of the Spanish-speaking countries of this hemisphere and Brazil, in other words Mexico, the countries of Central America (except Belize) and those of South America (except for Guyana and Suriname), as well as Cuba, the Dominican Republic and (marginally, owing to its ties with the United States) Puerto Rico.

However, in order to present a more complete overview of the region, this paper includes all the independent countries of the American hemisphere situated to the south of latitude 30 North, including the Antilles.

Their total surface area amounts to approximately 20,000,000 km2 (7,889,000 sq. mi.). Total population is some 430,000,000 inhabitants, giving a population density of 21.6 inhab. per km 2 (56.1 inhab. per sq. mi.).

With the exception of northern Mexico and, in South America, Argentina, Chile, the southern half of Paraguay and all of Uruguay, all these countries are situated between the Tropic of Cancer and the Tropic of Capricorn.

The corresponding data for the United States and Canada show that taken together, the two countries have a total surface area of 18,595,000 km2 (7,177,000 sq.mi.) and a population density of 13.6 inhabitants per sq.km. (35 inhab. per sq.mi.).

In terms of arable land, however, the total land surface mentioned for Latin America drops to 1,763,326 km2 (681,083 sq.mi.), or 176,332,600 hectares (440,831,500 acres)–in other words, just 8.8% of the total surface area –owing to the fact that so much of the territory is taken up by cities, mountain ranges, deserts, swamp land, lakes, forests and jungles, etc.

Fertilizer application in 1990 amounted to a total of 47 kg/ha or 42 lbs per cultivated acre, which is below the world average. This is owed to a number of factors, including the fact that a very large part of the arable land in the region is rainfall dependent.

The following comments are intended to present a very brief overview of the current situation and prospects of the fertilizer industry in Latin America which at the present time produces nitrogen and phosphate materials and on very limited scale, potash-containing products.

As the information that will be given here on production figures will show, the oil resources present in certain countries of the region are more than sufficient for the production of the nitrogen nutrients needed by them, but in the area taken as a whole the balance shows a deficit.As for phosphates, only Brazil, followed by Mexico, has a substantial production capacity, although a number of other countries have phosphate deposits that can be exploited. Potash production is found only in Brazil and Argentina, in relatively small quantities.

The region's foreign debt has held back industrial growth, and since the late seventies, when there was a considerable increase of installed capacity, few projects have been brought to a successful conclusion. A number of previously announced projects are currently stalled due to the lack of funding.

It is important to note that the use of liquid fertilizers, other than that of direct application of anhydrous ammonia, mainly in Mexico and, on a lesser scale, in Venezuela and Colombia, has not been developed in Latin America.

PRODUCTION

Thanks to the hydrocarbon deposits present in many countries of the area the production of ammonia reached important levels, mainly in Brazil, Mexico, Trinidad-Tobago and Venezuela; Cuba has been the only country to obtain ammonia production from other sources.

Brazil is the leader in Latin American production of phosphates, based in the country's low P_20_5 phosphate rock and thanks to its successful development of processing techniques that have made the country practically self-sufficient in the production of this nutrient.

In this area, Brazil is followed by Mexico, which though it has phosphate rock deposits used for production, also needs important amounts of imported rock. Deposits of phosphates also exist in such other countries as Peru and Venezuela, where important exploitation projects have been drawn up, but have not been implemented owing to unfavorable financial conditions.

Sulfur production is also found in the area, depending in some cases on sulfur domes, as in Mexico, and in others on the recuperation of the content found in the natural gas and petroleum of the oil producing countries of the region.

During the period between 1975 and 1990 the fertilizer sector in Latin America registered one of the world's most dynamic growth rates, both in production and in consumption.

PRODUCTION registered an annual growth rate of 5.8%, rising from 2,086,000 MT (2,119,000 short t) to 4,856,000 MT (4,934,000 short t) of nutrients as compared to a total world rate of 3.5%.

In CONSUMPTION, there was an annual MTCA of 3.8%, for a rise from 4,308,000 MT (4,747,000 short t) to 7,534,000 MT (8,302,000 short t) of nutrients as compared to a total world annual growth rate of 3.5%.

The aforementioned growth, however, was not sustained throughout the entire period, owing to the drop in demand between 1981 and 1983 that was principally due to the reduction of farm subsidies in Brazil because of the country's precarious economic situation. This had a serious impact on fertilizer use, which did not recover until 1984.

Reductions in fertilizer use have also been registered during the last three years in other countries in the area such as Brazil, Mexico, Peru and Venezuela, owing to the elimination of government subsidies in some cases and, in others, to the prevailing financial and political situations.

The main consumers of fertilizers in the region are Brazil, Chile, Colombia, Cuba, Mexico and Venezuela, which together account for 87% of total Latin American consumption.

Mexico is the main consumer of N (NPK consumption relationship is 1.0; 0.4; and 0.1) and Brazil of PK (O; 1.5; and 1.5). Several countries are major consumers of K20, which seems logical given the cultivation techniques employed in the tropical and subtropical areas of most of Latin America.

REGIONAL CONSIDERATIONS

NORTH AMERICA (only MEXICO)

The foundations for the development of a sound chemical fertilizer manufacturing industry were established by the federal government, in a decree issued in 1943, which called for the formation of a parastate company to take charge of the exploitation of sea-bird guano deposits found on small islands off the coast of Baja California. The decree was soon expanded to cover the production of chemical fertilizers, an area in which a few small plants had been operating since 1913 but had never exceeded a total annual production of 20,000 MT.

Following a modest beginning, consisting of the construction in different parts of the country of 3 plants, one for the processing of guano, another for the manufacture of bone meal, and a third for the production of superphosphate, in 1951 a new plant was put into operation in Cuauhtitlan (near Mexico City) using natural gas from the State of Veracruz deposits to produce synthetic ammonia, complemented by a sulphuric acid plant and one ammonium sulfate plant.

This ammonia plant was the first of its type in Latin America, with a capacity of 50 MT per day of synthetic ammonia. Its construction for the government company (GUANOS Y FERTILIZANTES DE MEXICO) laid the foundation for the future development of the industry.

Ammonia production from oil (and its derivatives) and natural gas was reserved to the State in November 1958, and assigned to the government oil company, PETROLEOS MEXICANOS, which built plants for ammonia production from natural gas in the states of Chihuahua,Guanajuato and Veracruz. The two original plants, Cuauhtitlan, built, as mentioned previously by GUANOS Y FERTILIZANTES, and the 100 MT Monclova plant, the joint property of private investors and the federal government, which began operations in 1960, have now discontinued operations due to reasons of obsolescence.

Encouraged by the success of GUANOMEX, private sector industrialists acting either alone or in joint investment with the government built now plants, as did the government company itself. By 1965, fertilizer production in the country amounted to 686,000 MT/year of products, which (apart from anhydrous ammonia) included ammonium sulphate, ammonium nitrate, urea, simple superphosphate and NPK granular compounds.

In 1965, the federal government decided that it would be advisable to put the entire fertilizer industry under a single management and to that end began to acquire the privately owned plants, while continuing its own plan for the construction of new plants and changing the government company's name from GUANOS Y FERTILIZANTES DE MEXICO to FERTILIZANTES MEXICANOS, S.A. The process of consolidating the industry under FERTIMEX was completed in 1977.

The privatization of the fertilizer industry forms part of the overall program for the modernization of Mexico embodied in the National Development Plan, a document issued each six years by the incoming administration, which by law must include mention of all the programs to be carried out by the federal government during its term in office.

One of three lines of action established by the current administration within its growth program for the country is the modernization of Mexico's economy, which has as one of its priority objectives the redimensioning of the parastate (that is, government-controlled) industrial sector, reducing its size in order to make it stronger, more manageable and more efficient.

To that end, opportunity is given to other sectors, via the privatization process, to reenter such industrial activities as the manufacture of fertilizers, thus allowing the industry to continue its development within a new framework of open competition in both national and international markets that will promote the increased efficiency of operations as a consequence of the modernization of the industry's production and commercial structure.

In accordance with the foregoing and following a number of preparatory steps, the actual privatization process of FERTILIZANTES MEXICANOS began in 1990 through the sale of the industrial units in operation. At present only two still remain to be sold,the Minatitlan Unit in the State of Veracruz and the major Pacific Coast complex in the city of Lazaro Cardenas in the State of Michoacan. The PEMEX owned ammonia plants are not included at present in the privatization process.

The installed capacity of FERTIMEX at the outset of the privatization process was 4,820,000 MT per year (5,000,000 short t) of inorganic acids (sulphuric, phosphoric -as P205-, and nitric) and 5,487,000 TM (6,000,000 short t) of fertilizer products, equivalent to 2,158,000 MT (2,4900,000 short t) of nutrients and in 1990 the consumption was 1,565,000 TM (1,724,600 short t) of nutrients and the production 1,707,000 TM (1,880,000 short t).

CENTRAL AMERICA AND THE CARIBBEAN

Fertilizer production in this subregion is concentrated in 5 countries: Costa Rica, Cuba, El Salvador, Guatemala and Trinidad and Tobago. To start-up of these operations in most of these installations, (principally those of Central America), took place between 1965 and 1975.

The plants in Costa Rica (Puntarenas) have been operating without interruption and supply fertilizers to other Central America countries.

Operations of the El Salvador (Acajutla) and Guatemala plants (Tecun Uman) were interrupted in 1979 and 1986, respectively, owing in the first case to political instability and in the case of Tecun Uman to the rationalization plans of the Mexican government, which owned the plant. Both these plants have recently been purchased by private investors and are expected to recommence operations soon.

It should be noted that the aforementioned plants do not have a vertical integration, owing to the lack of natural resources for the production of ammonia, phosphoric acid and potash, while Cuba and Trinidad-Tobago do have ammonia-producing capacity.

The Cuban ammonia plants are fed with the naphtha fraction of the crudes imported for refining in Cuba to obtain the oil derivatives needed to cover the different needs of the country. This ammonia is transformed into nitrogen fertilizers and the additional needs as well as other types of products are bought on the open market.

Mixing plants exist in almost all the countries of Central America and in several countries of the Antilles, principally in the Dominican Republic; this country can cover not only its needs but also those of some its neighbors.

Current consumption levels for Central America and the Caribbean stand at 1.5 million MT per year of nutrients and the application doses in Cuba and Costa Rica, amounting to 200 kg/Ha (178 lbs/A) are outstanding; also worth mentioning is the El Salvador consumption of 100 kg/Ha (89.2 lbs/A).

SOUTH AMERICA.

South America produces 2,700,000 MT (2,975,400 short t) a year of nutrients in plants situated in Argentina, Brazil, Chile, Colombia, Ecuador, Peru and Venezuela, although Brazil with its annual production of 2,000,000 MT (2,204,000 short t), accounts for 68% of the total. It is followed in importance by Venezuela, Colombia and Chile.

In Argentina , two major private firms are at present engaged in the production of urea and ammonium nitrate and one of the companies currently has a project for the expansion of its production capacity. Fertilizer dosage in the country is low, owing to its agricultural characteristics.

Brazil is almost the only country in the area to produce enough phosphate products, based on its exploitation of the phosphate rock deposits already mentioned. A paradoxical situation arose this year when, despite this national production, substantial quantities of MAP were imported from the Community of Independent States, causing Brazilian producers to invoke the antidumping laws. The country is also a major importer of other fertilizers.

Chile is best known for its production of the main types of nitrates (sodium and potassium) used in fertilization, thanks to the large deposits existing in the northern part of the country. These are supplemented by imports of urea and phosphates to meet other needs of the country. The nation also pays an important role in the world market through its exports of natural nitrates.

Peru has phosphate deposits in the Bayovar region which, for a variety of reasons, have not as yet been exploited. Fertilizers are imported from outside the region, with imports handled until recently by the government trading company ENCI. At present, a number of private companies are engaged in marketing the fertilizers needed by the country.

Venezuela produces a considerable volume of nitrogen nutrients (urea), supplementing its production through a joint venture with Colombia known as Monomeros Colombo-Venezolanos.

There are also two large deposits of phosphate rock in the country and direct soil application of this material is currently being introduced. Fertilizer consumption in Venezuela is high, standing at 129 kg/H (115 lbs/A).

COMMENTS

Development circumstances in the countries of Latin America over the past 45 years led several of them to opt for a partial or total State centralization of fertilizer production. In many countries, part of the installed capacity is still in government hands, either because the government built the plants or because it acquired them from their original owners.

Today, however, changing conditions throughout the world have affected Latin America as well, bringing about radical changes in economic policies. In the case of the fertilizer industry, those changes are leading to the transfer of responsibility for the manufacture and supply of such inputs to private industry.

It is a process which, as we have seen, began in Mexico in 1990, where it is already well advanced, and is currently under consideration or actually under way in other countries of the hemisphere as well — for example, in Trinidad and Tobago and in Brazil. The same decision will probably be taken by most of the other countries in similar condition.

As mentioned previously, there has been little increase of the industry's installed capacity in recent years, and this may be attributed at least in part to the scarcity of funds resulting from the region's indebtness. It may, therefore, be expected that privatization, together with a greater receptiveness to foreign investment, will generate resources that will make it possible to implement new projects, as well as to reactivate projects that had been suspended in a number of countries, both for the exploitation of raw materials deposits existing in the area or for the construction of new plants.

Where nitrogen is concerned, two new 495,000 MT per year (546,000 short t per year) ammonia projects are known for the moment to exist in Mexico, but both have been indefinitely suspended.

As for phosphorus, there are major projects for the production of phosphate rock, phosphoric acid,and phosphate fertilizers in Venezuela (Tachira deposits) and Peru (Bayovar), all awaiting investment for their implementation.

Chile has announced a project for the construction of a 300,000 MT (330,600 short t) capacity KCI plant, setting 1995 as the probable date for start-up of operations. A similar KC1 project, with a 250,000 MT per year (275,500 short t per year) capacity, is under study in Argentina.

This process of splitting up the industry among different owners will probably lead in Latin America to participation in the industry of a number of smaller concerns organized along the lines of U.S. dealers, each operating within a relatively small area and offering their clients highly efficient services that will include not only the sale of bagged fertilizers but also such supplier functions as the manufacture of blends specially designed and prepared to meet the needs of different clients, application services, farm extension services, the provision of other farming inputs, banking services, etc.

This will mean that companies operating the major plants will have to reconsider their practices with a view to including among the rangeof materials they supply a series of semi-products with new physical and chemical properties, to be used by those dealers as ingredients in the preparation of very high-quality physical mixes that can be efficiently applied and will be profitable for both dealers and farmers.

In the increasingly competitive market that is to be expected, the cost of raw materials, the efficiency of production systems and the quality of products, as well as the transport systems employed, will play a highly important role. Countries lacking in raw materials will, therefore, have to study the situation very carefully in order to avoid finding themselves in very serious problems, unless other very favorable factors exist. Those who are working with obsolete processes and equipment will find themselves forced to replace them, and it will be necessary in every case to review the location of plants from the standpoint of transport of raw materials and products.

Where fertilizers are concerned, it may be expected that international marketing and trade of such products, like so many others, will be increasingly handled on the basis of trading blocs of nations, as in the case of Canada, the United States and Mexico, which are currently in the process of formalizing a North American Free Trade Agreement (NAFTA) Steps are currently being taken as well towards the formation of similar links between Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua and between Colombia, Mexico and Venezuela, in addition to the two agreements already existing in South America, the Andean Pact and the Mercosur.

While this may be expected to simplify trade in production equipment and a wide range of materials, as well as in raw materials and finished products, it will also demand efficiency on the part of all those who take part in any of those activities, as well as their conformance to strict quality standards. Companies that fail to comply will find themselves out of the picture.

Everywhere in the world, and especially today in most Latin American countries, the different branches of public administration and the citizens themselves are registering growing concern over the impact of industry on the environment, particularly as regards the environmental effects of the fertilizer industry and the ecological consequences of fertilizer use.

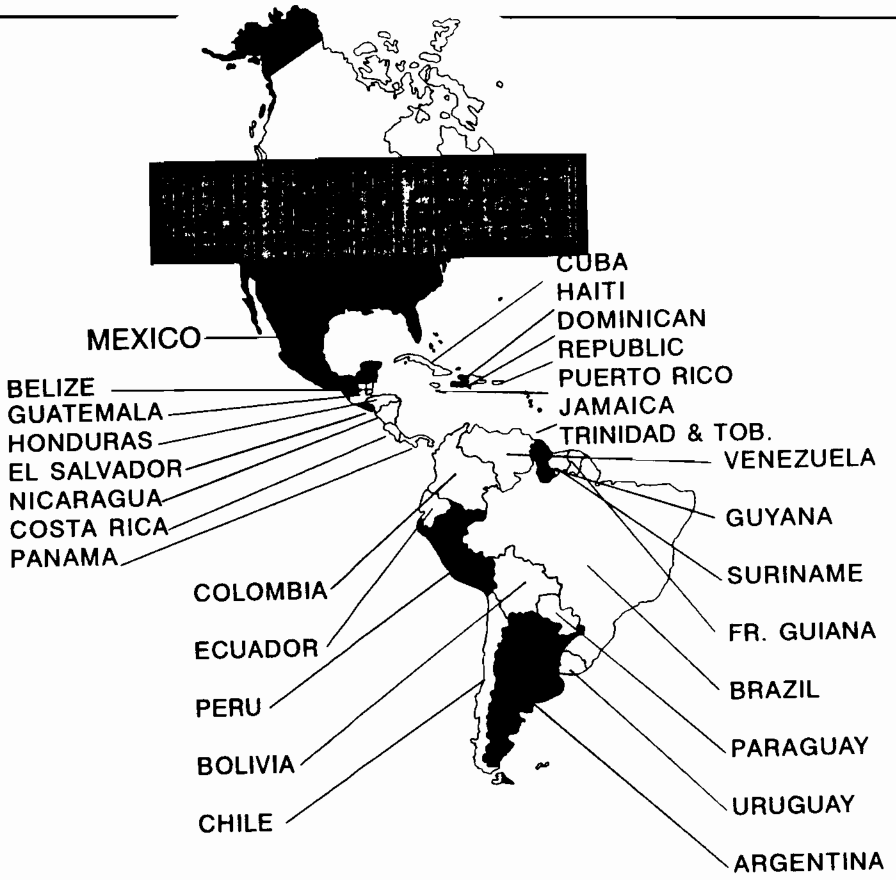
There is a great deal of information available regarding the environmental impact of the industry itself, and solutions have been found that make it possible to adjust installations to the requisite conditions for preventing damage to the environment.

Frequently, however, pollution problems remain unsolved because plant owners and operators have simply not been made aware of the technology that has been developed for the prevention of those problems. Preveyors of such technology should, therefore, be more active in establishing contacts with possible users that would help to promote more effective action in that area, which in some cases might even include the need to replace obsolete installations that no longer justify added investment.

No major use has yet been made in Latin America of fluid fertilizers and micronutrients; consequently, programs should be inplemented for the creation of the necessary infrastructure and promotion of their use.

Finally, it must be remembered that agricultural production in Latin America is of prime importance not only in supplying the continent's food demands, but also in fueling its exports to other regions. Therefore, providing incentives for the improvement of farm yields contributes to social and economic stabilty.

Bolstering agricultural productivity in Latin America by increasing fertilizer supply and supporting effective fertilization techniques may be viewed as a determining factor for gaining that stability, and one that merits integrated planning.



LATIN AMERICA: SOME ECONOMICAL DATA

COUNTRY	POPULATION (millions inhab.)	GROWTH RATE (%)	AREA ('000 Km2)
Mexico	**85.0**	**2.2%**	**1958.2**
Costa Rica	3.0	2.6%	51.4
Cuba	10.5	1.0%	110.9
El Salvador	5.3	1.9%	21.0
Cent. Am. & Car.	**50.4**		**689.7**
Colombia	33.0	2.1%	1141.7
Chile	13.2	1.6%	736.9
Venezuela	19.7	2.6%	916.4
Brazil	150.4	2.1%	8512.0
South America	**297.0**		**17328.9**
LATIN AMERICA	**432.4**		**19976.8**

AMERICA

	AREA		POPULATION		
			TOTAL	DENSITY	
	'000 Km2	'000 sq. miles		per Km2	per sq. mile
	NORTH AMERICA (LESS MEXICO)				
EUA	9,375.052	3,618,770	226,500.000	24.2	62.6
CANADA	9,217.617	3,558,000	26,530.00	2.9	7.5
SUBTOTAL	18,592.670	7,176.770	253,030.0	13.6	35.3
	AMERICA (SOUTH OF LATITUDE 30°N)				
MEXICO	1,958.200	755.865	85,000.0	43.4	112.4
C.AMERICA & CARIB.	689.700	266.224	50,400.0	73.0	189.3
SOUTH AMERICA	17,328.900	6,688.956	297,000.0	17.1	44.4
SUBTOTAL	19,976.800	7,711.045	432,400.5	21.6	56.1
TOTAL	38,569.470	14,887.820	685,430.5	17.7	46.0

LATIN AMERICA: SOME AGRICULTURAL DATA

COUNTRY	AGRIC. AREA ('000 Has.)	AGRIC. SHARE IN GNP	FERT. CONSUMP. (Kg/Ha)
Mexico	20,307.3	9.0%	80.0
Costa Rica	611.2	18.0%	175.1
Cuba	3,316.6	16.0%	199.4
El Salvador	744.9	14.0%	105
Cent. Am. & Carib.	12,694.9		120.3
Colombia	5,937.1	19.0%	101.5
Chile	4,274.0	18.0%	72.8
Venezuela	4,032.4	6.0%	127.8
Brazil	79,161.6	9.0%	40.5
South America	143,330.4		37.1
LATIN AMERICA	176,332.6		47.0

FERTILIZERS AND RAW MATERIALS PRODUCED IN LATIN AMERICA

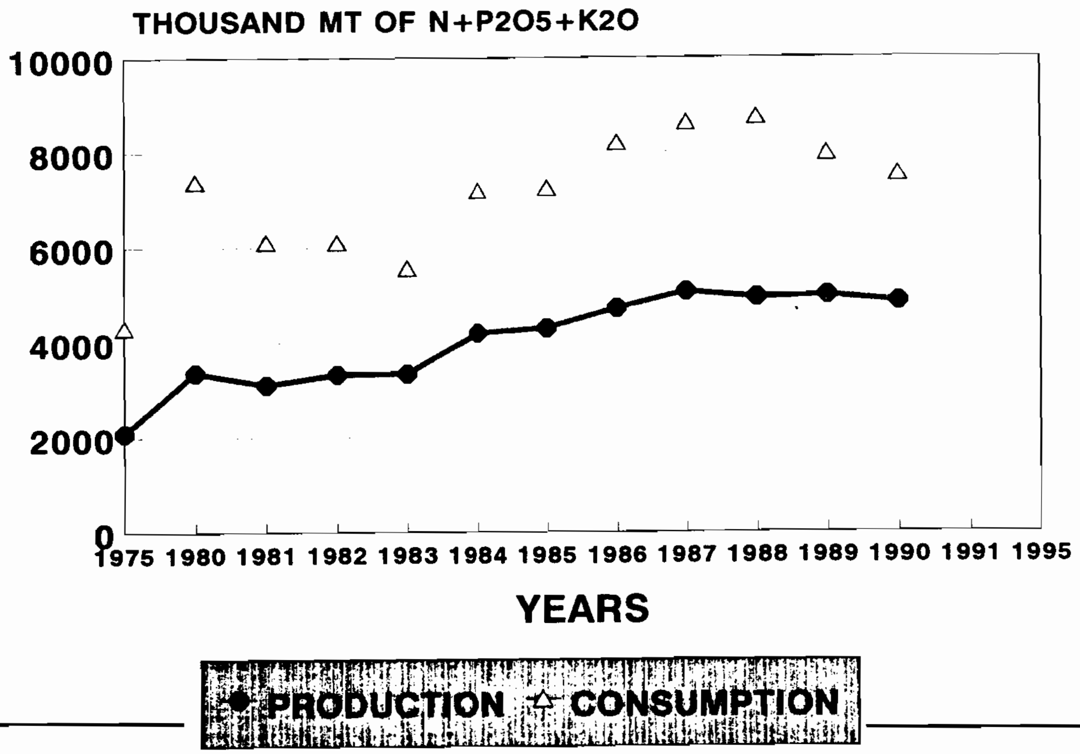
COUNTRY	FERTILIZERS	RAW MATERIALS
MEXICO	UREA, AN, AS, SSF, TSP, DAP, NPK's	AMMONIA, PHOSACID, NITRACID, PHOSROCK, SULFACID, SULPHUR
TRINIDAD & TOBAGO	UREA	AMMONIA
COSTA RICA	AN, AS, NPK's	NITRACID
CUBA	TSP	
GUATEMALA	NPK's	SULFACID.
EL SALVADOR	NPK'S	

FERTILIZERS AND RAW MATERIALS PRODUCED IN LATIN AMERICA (cont)

COUNTRY	FERTILIZERS	RAW MATERIALS
BRAZIL	UREA, AN, AS, SSP, TSP, DAP, MAP, KCL, NPK's	AMMONIA, PHOSACID, PHOSROCK, SULFACID POTASH
VENEZUELA	UREA, AS, DAP, NPK's	AMMONIA, PHOSACID, SULFACID.
COLOMBIA	UREA, AN, AS	AMMONIA, NITRACID
CHILE	SALITRES, K2NO3, SSP	
ARGENTINA	UREA, AS,	AMMONIA.
PERU	UREA, AN, AS, SSP,	PHOSROCK
ECUADOR	TSP, NPK'S	PHOSACID.

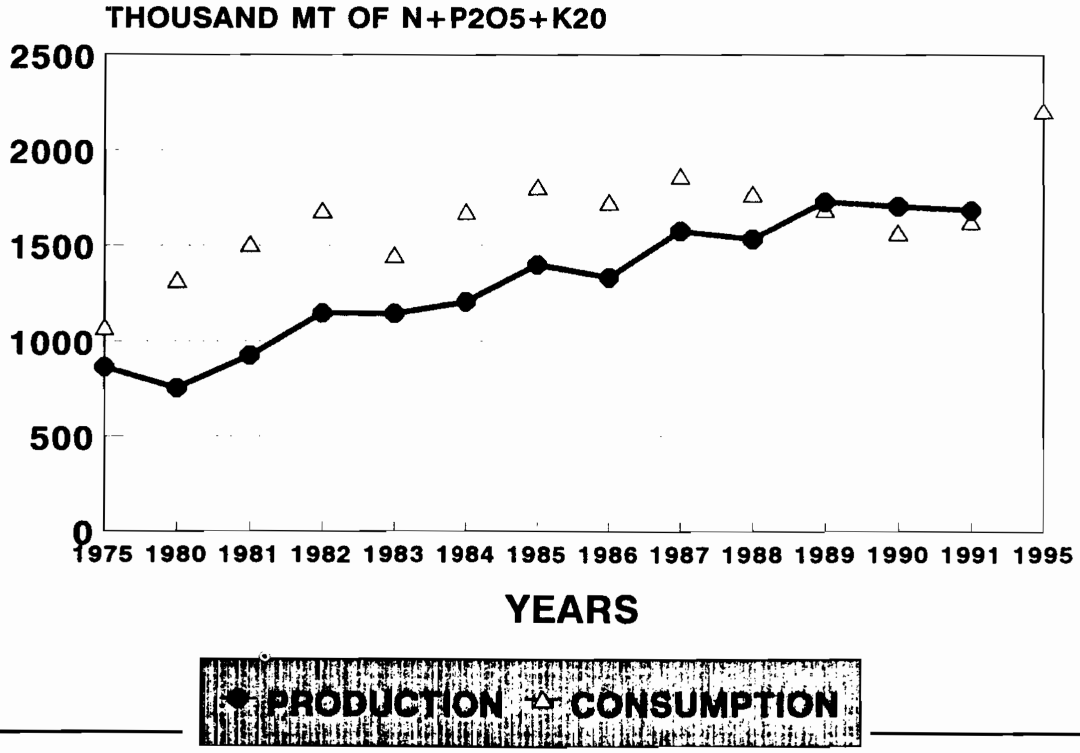
LATIN AMERICA

PRODUCTION AND CONSUMPTION OF FERTILIZERS

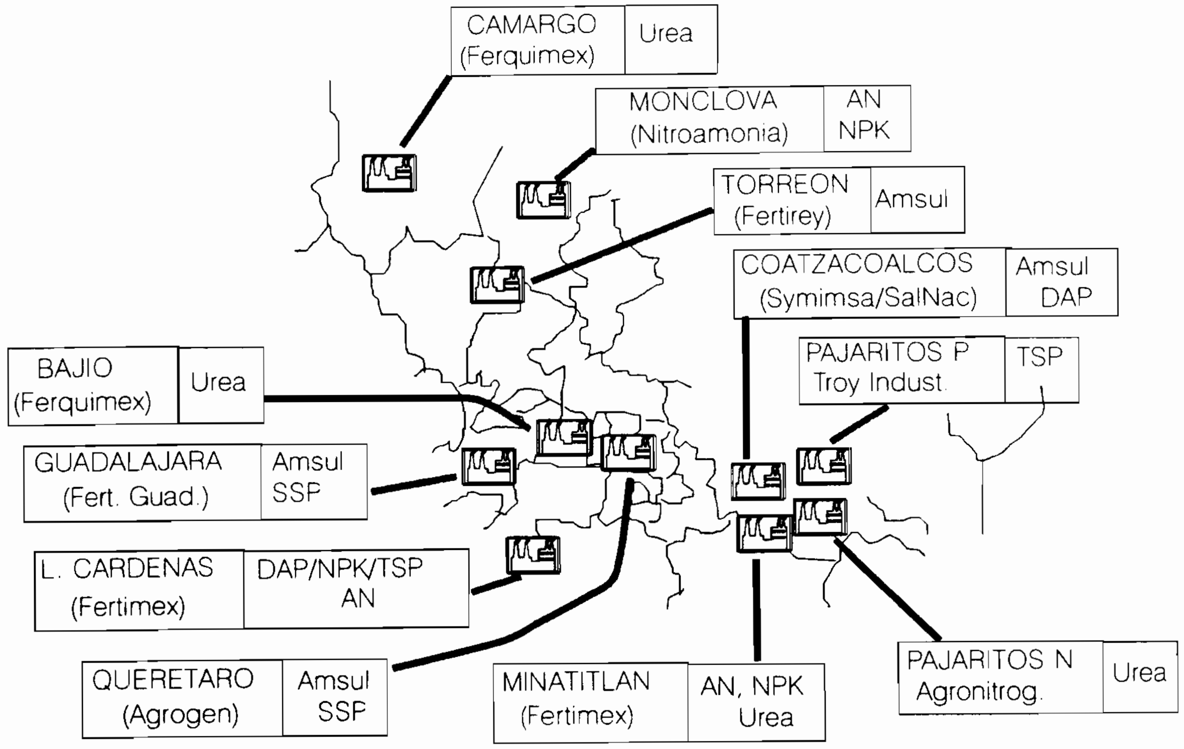


MEXICO

PRODUCTION AND CONSUMPTION OF FERTILIZERS

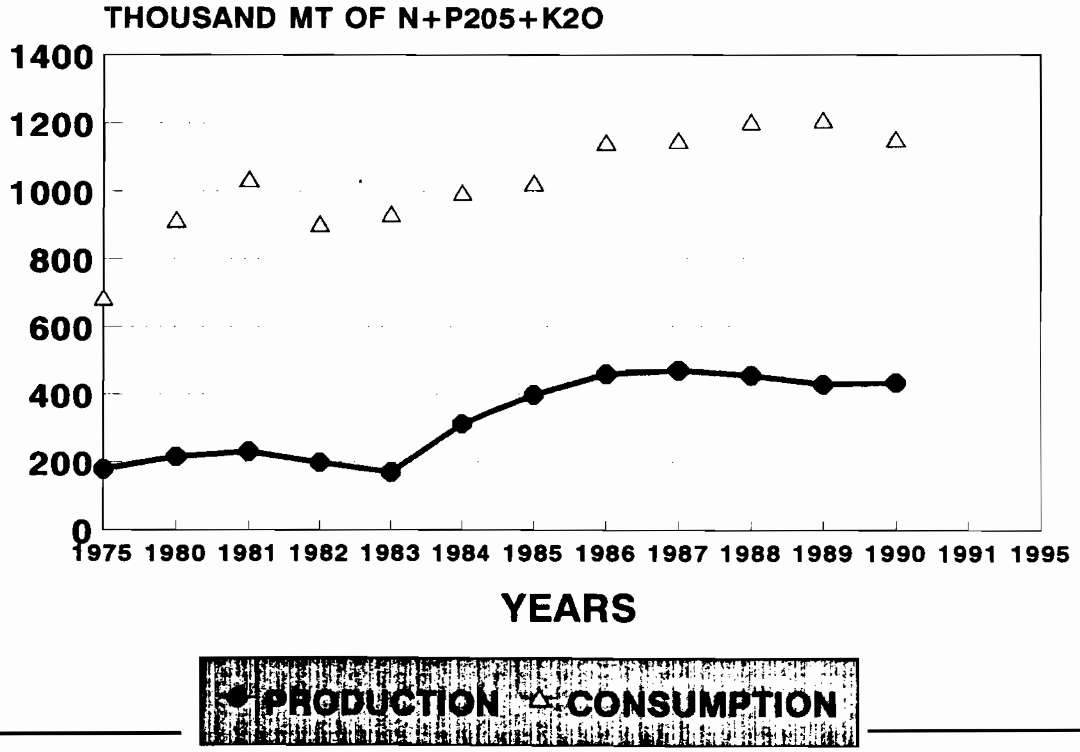


FERTILIZER PLANTS IN MEXICO



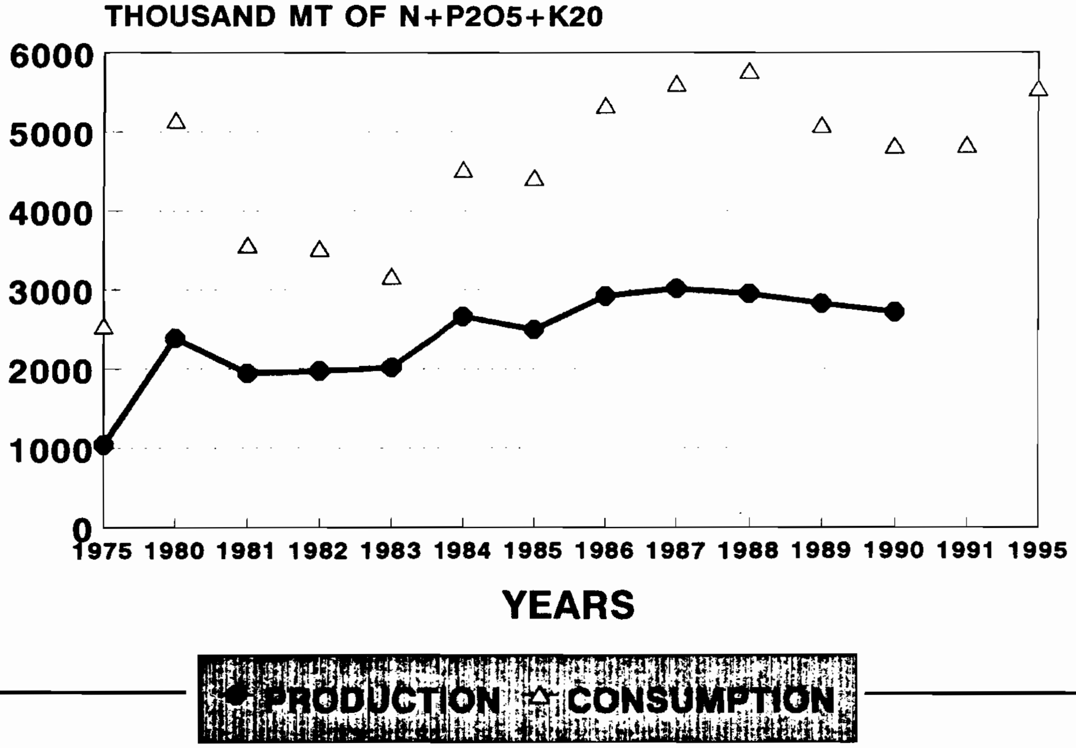
CENTRAL AMERICA

PRODUCTION AND CONSUMPTION OF FERTILIZERS



SOUTH AMERICA

PRODUCTION AND CONSUMPTION OF FERTILIZERS



MAJOR MULTINATIONAL COOPERATION AGREEMENTS IN LATINAMERICA, BY SUBREGIONS

FEATURES	COUNTRIES	YEAR	STATUS
FREE TRADE ZONES	ANDEAN GRP.	1992	IN EXECUTION
	CONASUR	1990	IN PROCESS
	L.A.-U.S.A	2000	IN PROCESS
	MERCOSUR	1995	IN PROCESS
	MEX.-C.A.	1990	IN PROCESS
	NAFTA	1992	AGREEMENTS
	NORTH △	1993	IN PROCESS
	ARG.-VEN.	1995	IN PROCESS
	GUAT.-VEN.	1991	IN PROCESS
	VEN.-CHILE	1992	IN PROCESS
ASSISTANCE AND INTEGRATION PROJECTS	ANDEAN GRP.	1992	IN EXECUTION
	ANDN.G.-JAP.	1991	IN EXECUTION
	CACM-CARICOM	1992	IN PROCESS
	G.3	1991	IN EXECUTION
	HOND.-VEN.	1991	IN EXECUTION
	MERCOSUR-C.E.	1992	IN PROCESS
	MEX.-VEN.	1990	RENEWED


LATIN AMERICA: MAJOR REGIONAL TRADE SUBGROUPS
GROUP OF THREE
CENTRAL AMERICAN COMMON MARKET
ANDEAN GROUP
MERCOSUR

North America
The Views On Yesterday's, Today And Tomorrow's Fertilizer Industry

J.W. Brown
Canadian Fertilizer Institute

Change isn't new to the fertilizer industry. The Canadian and world industries have been continually evolving ever since their inception. The accelerated change of the past decade, both at home and abroad, has placed unprecedented pressures on the industry.Continually adapting to change remains the key to the long term viability of the Canadian, U.S. and world industries.

The world fertilizer industry is currently in a state of flux due to political events in Eastern Europe and the Commonwealth of Independent States.

IFA's most recent projection of world consumption forecasts a decline of 3 percent in 1991/92 following a fall of 4 percent in 1990/91. This drop in consumption is due largely to reduced usage in East Europe and the former U.S.S.R. There is also a significant decline in consumption in West Europe during the past two years due to policies to reduce crop surplus and environmental protection measures and the integration of the former German Democratic Republic (East Germany).

In the short time available, I will attempt to outline some of the significant changes in the Canadian industry both at the basic and retail levels,and attempt to project the more obvious structural changes in the industry in the future.

DECLINE IN PHOSPHATE PRODUCTION AND CONSUMPTION IN CANADA

One of the trends most evident in the Canadian fertilizer market during the past decade is the rapid decline in production and consumption of phosphate fertilizers.

PRODUCTION

Canadian production of wet process phosphoric acid, almost all of which is consumed in the production of ammonium phosphates , peaked in Canada in 1980 at 808 thousand nutrient tons.Since 1980 production has declined almost on annual basis. Production during the 1992 fertilizer year was 408 thousand nutrient tons.The number of phosphate plants has declined from seven in 1980 to three in 1992. Canadian production of phosphate fertilizers is expected to remain flat during the next five years. Ammonium phosphates supply over 90% of the phosphates consumed in Canada and this trend is anticipated to continue in the future.

CONSUMPTION

Phosphate consumption peaked in Canada in 1985 at 724 thousand nutrient tons. Since that time phosphate consumption has continued to decline. A preliminary estimate for domestic phosphate consumption during the 1992 fertilizer year is 580 thousand nutrient tons. During the late sixties and seventies soil tests indicated that phosphate levels were continuing to increase in Canadian soils. During recent years the removal of nutrient phosphates by crops exceeded annual replacement. During the next five years we anticipate a gradual but very slow recovery in phosphate

PRODUCTION AND CONSUMPTION OF NITROGENOUS FERTILIZERS

Production of anhydrous ammonia in Canada increased from 2.55 million tons in 1980 to 3.70 million tons for the 1992 fertilizer year.In the decade of the eighties 1.2 million tons of annual capacity was permanently closed. The closures were the older, smaller less energy efficient plants. During the same period five new world scale plants and three smaller plants came into production with a combined annual capacity of 2.1 million tons.

UREA

Urea production increased from 1.23 million tons in 1980 to 2.49 million tons in 1992.Three older plants, with annual capacity of 210 thousand product tons, were permanently closed. During the same period 1. 1 million tons of new capacity came on stream. With the startup of the Saskferco plant this autumn 600 to 700 thousand tons of additional capacity will be available to the North Americans and World markets. One million tons of urea currently are consumed in the domestic fertilizer market accounting for approximately 40 percent of total fertilizer nitrogen. Urea's share of the total fertilizer market will increase in the future.

AMMONIUM NITRATE

Ammonium nitrate production increased from 873 thousand tons in 1980 to 1.02 million tons in 1992. 382 thousand tons of annual capacity were permanently closed during this period.

AMMONIUM SULPHATE

Production of Ammonium sulphate increased from 222 thousand product tons in 1980 to 355 thousand tons in 1992. one new granular plant came into production during this period.

FERTILIZER NITROGEN CONSUMPTION

Fertilizer nitrogen consumption increased from 831 thousand nutrient tons in 1980 to a peak of 1.25 million tons in 1985.During the later half of the eighties consumption remained flat ranging from 1.14 to 1.16 million nutrient tons.Consumption during the current fertilizer year is estimated to be 1.21 million nutrient tons.

EXPORTS

Exports of nutrient nitrogen mainly anhydrous ammonia and urea increased from 976 thousand nutrient tons in 1980 to 1.7 million tonnea in 1992.

IMPORTS

Imports of nutrient nitrogen mainly urea and ammonium phosphates range from 200 to 230 thousand tons during the later half of the decade.

MURIATE OF POTASH PRODUCTION

Production of potassium chloride in the eighties ranged from 7.3 million nutrient tons in 1980 to 8.3 million nutrient tons in 1988. Production for the 1992 fertilizer year was 7.0 million nutrient tons.In the mid eighties two now mines located in the east coast province of New Brunewick come into production.Combined capacity of these two mines is 1.18 million nutrient tons.Canadian mines are operating at well below designed capacity (60 to 65 percent) As world markets for potash increase again, production from Canadian mines will rise.

CONSUMPTION

Domestic consumption of nutrient potash ranged from 349 thousand tons in 1980 to a high of 404 thousand tons in 1988.Consumption during the 1992 fertilizer year is estimated at 340 thousand nutrient tons.

EXPORTS

Exports of potassium chloride ranged from 6.4 million nutrient tons in 1980 to 7.3 million nutrient tons in 1988.

IMPORTS

Imports of nutrient potash, mainly sulphate of potash and sulphate of potash magnesia, ranged from 13 thousand to 20 thousand nutrient tons.

FEWER BUT LARGER FARMS

The number of farmers in Canada continued its long term downward trend.Canada had 318 thousand census farms in 1981 declining to 280 thousand in 1991.

25% of the census farms produced 68% of the revenue in 1966 whereas in 1991 the top 25% produced 76% of the total output.Likewise in 1981 the top 10% of the farms accounted for 51% of the output. By 1991, the top 10% accounted for 53% of the output.The trend to larger but fewer farms is forecast to continue through the decade of the nineties.

INCREASED INDUSTRY PRODUCTIVITY

In 1984, the Canadian basic fertilizer industry had 8622 permanent employees with total shipments of 17.76 million metric tons.By 1990 total permanent employment in the basic industry was 5816 (a 32.5 % decline) but shipments remained at 17.58 million tons.

CONSOLIDATION OF RETAIL BLENDING PLANTS

Canada has approximately 1300 retail blending plants which mix and distribute 4 million tons of finished fertilizer.Current new environmental regulations require retailers to invest 60 to 80 thousand dollars per plant for fertilizer and pesticide storage and handling facilities.Plants with annual sales of less than five thousand tons cannot afford to commit now capital to supply a flat or in some regions a declining market.Some small plants have already been closed while others have been consolidated into larger retail units.The trend toward fewer but larger retail distribution units is expected to continue during the nineties.The net result will be that fewer but larger companies will be involved in the retail distributions of fertilizers.

INCREASED GOVERNMENT INVOLVMENT IN AGRICULTURE

In the early eighties most of the revenue of grains and oilseed farmers came from the market place.By the end of the decade the majority of the net farms cash income for grains and oilseed farmers ($3.1 billion) came from government safety net programs such as the Gross Revenue Insurance Plan (GRIP).

A successful conclusion to the current round of G.A.T.T. negotiations will create a new order for international trade. Government involvement in agriculture will still be extensive but new trade objectives will apply.

INCREASED GOVERNMENT INVOLVMENT IN THE FERTILIZER INDUSTRY

During the decade of the eighties there was a phlethora of new government regulations involving the fertilizer industry.These regulations included environmental assessment before the construction of new fertilizer plants, new regulations pertaining to the transportation of dangerous goods, " right to-know " legislation concerning the handling, labelling, personel training and storage of dangerous goods in the work place.

Other proposed legislation involves " green house" gases, industry audits of toxic chemical releases from fertilizer plants and a levy for the clean-up of large spills involving the marine shipments of fertilizer materials in Canadian waters.There is a never ending list of new regulations that must be addressed by the industry.The industry will be required to shape this new legislation in the current decade and well into the future.

TRENDS IN DISTRIBUTION OF FERTILIZER MATERIALS

During the decade of the eighties the most significant trend in fertilizer distribution was the swing from single car shipments to unit train or bulk marine cargo shipments to centralized bulk handling terminals. The utilization of these modes of distribution and handling will continue into the future.

SWITCH FROM BAGGED TO BULK SHIPMENTS

In the early sixties, 90% of fertilizer were delivered to farmers as bagged goods. With the advent of bulk blending and the gradual closing of centrally located compound, fertilizer manufacturing plants in the industry gradually moved to bulk distribution of fertilizer mixtures and materials. Currently 85 percent of all fertilizer supplied to farmers is in the bulk form. This switch created a new market for bulk handling, delivery and application equipment. The switch from bags to bulk is almost complete but a further trend to more customs application by the retail dealer is apparent. This change in distribution has greatly increased the efficiency of the industry resulting in the lowering of the delivered cost of plant nutrient to farmers. In the process, much of the back breaking manual labor has been removed from the manufacturing, distribution and application of fertilizers.

THE ROLE OF FERTILIZER IN SUSTAINABLE AGRICULTURE

During recent years the fertilizer industry has come under repeated attacks by environmental groups.There is heightened awareness of the costs that can be associated with improper fertilizer use.Negative impact on water quality is the most frequently cited externality associated with fertilizer use.When improperly applied the nutrients in any fertilizer whether mineral or other sources can run off into surface water or – leak into ground water.The Canadian fertilizer industry recognizes that there are problems which can be intelligently and effectively addressed. More effective fertilizer application results in both improved farm profitability as well as reduced environmental risk.

The Canadian fertilizer industry endorses the concept of sustainable agriculture and is committed to the following initiatives:

1. Field - specific fertilizer recommendations based on soil testing.
2. Communication, education and extension.
3. Research, product and technological development.

In the future, mineral fertilizer use will ensure adequate supplies of food and contribute to economically viable farm operations. An intensified effort by the industry will be devoted to ensuring that fertilizer use is part of a sustainable agricultural system. The key to such efforts will be cooperation and an effective partnership among farmers, the industry, universities and governments.

SUMMARY

The fertilizer industry both in North America and world wide is in a period of accelerated change. Fewer basic producers, consolidation of retail sector, more government involvment in both agriculture and fertilizer industries, fewer but larger customers, increased productivity, are but a few of the many evolving changes in the industry.

The role of the industry in achieving a sustainable agriculture is a current issue that will extend into the future. The industry, in the past, has addressed change expeditiously and efficiently and is likely to do so in the years ahead.

Plant nutrients are an essential input to world food production and with an expanding world population will be put under increased pressure to supply future food requirements. In general, the industry will become more environmentally conscious, more efficient and hopefully more profitable in the decade ahead.

North American The Past, The Present, And An Outlook For The Future

Phillip W. Yelverton
The Fertilizer Institute

INTRODUCTION

I am presenting today on behalf of the North American fertilizer industry. Jim Brown, from the Canadian Fertilizer Institute, contributed a paper on the Canadian industry, and I collected some information on the U.S. industry. Jim will be available for the discussion period.

In this presentation, I have attempted to assess, from a strategic point of view, a period which roughly comprises the last ten years. In addition, I will examine some indications for the next ten years. North America is presented as a single industry in most respects, with some notable exceptions. The recent U.S.Canada trade agreement reinforced the unity between our industries. We expect the NAFTA agreement to bring Mexico fully into this extended commerce zone in the future.

A well-known industry analyst recently published an article in which he identified several significant cycles which the industry has gone through. His conclusion was that the industry is now solidly in a recovery cycle, which began in the late 1980's. I've used a similar frame of reference, using a cycle which began in approximately 1981.

We began the 1981 period in a somewhat enviable position, which some would consider world dominance. Domestic consumption was at an all-time high, grain exports were booming, and we had most of our arable land under production. At the same time, the industry itself had just completed a major round of capacity expansions in North America: ammonia capacity had grown 23 percent, urea 78 percent, and P_20_5 77 percent, as compared to 1970.

Furthermore, many of our current competitors in the world markets had not yet begun to realize their potentials for expanded production and exports. So, we enjoyed an enormous home market, and a great potential to continue expanding our export business, all with relatively little competition.

In the ten or so years since the "good old days", the strategic position of the North American industry has changed significantly, and with it, many business realities.

UNITED STATES CONSUMPTION

U. S. Consumption in 1981 was nearly 54 million gross tons, the all time high. We delivered 12 million tons of nitrogen, 5 and one half million tons of P_2O_5 and over 6 million tons of K2O to farmers in the U.S. Domestic consumption has never again reached that level.

Farm policies instituted in 1983 and 1985 removed acres from production. In effect, farmers were paid not to farm. These ill conceived programs left farmers idle, hurt our industry, and took away our export advantage in world markets for grains.

In the current period, we've regained some of what was lost, but not all. Most people are unsure that we ever will.

This forecast for ten years out shows that, 20 years after our peak, there will be insignificant growth in nitrogen consumption, while in phosphorus and potash, we will not regain the market size we had achieved.

CANADIAN CONSUMPTION

Phosphate and nitrogen consumption in Canada peaked in 1985. Since that time, phosphate consumption has continued to decline, reaching 580 thousand tons from 724 thousand tons. Nitrogen consumption is expected to remain generally flat.

Potash consumption peaked at 404 thousand tons, and is currently at about 340 thousand tons.

WORLD CONSUMPTION

Using the same comparison, in 1981 worldwide consumption was about 60 million tons N, 32 million tons P_2O_5 and 24 million tons K2O. Since 1981, there has been a pattern of frequently slow, sometimes rapid, sometimes steady, and often erratic growth in worldwide consumption.

Fundamentals such as population growth and increased living standards continue to indicate a pattern of slow growth over the next 10 years or so. The potential demand, of course, is much greater than the actual demand is likely to be.

Actual demand is constrained from fully realizing potential by lack of financing, logistical limits, and political problems, among others. Over the past year or two, analysts have begun to pay attention to those limits on worldwide demand. As a result, most forecasts are now much lower than they were two or three years ago.

APPLICATION RATES

Fertilizer application rates in North America did not peak in 1981 when consumption did. In fact, application rates are a difficult indicator, and in North America, have not shown any clear trend since 1981.

Rates, especially in North America and other fully developed agricultural areas such as Western Europe, are affected by many factors, which include:

- Acreage reduction programs
- Production targets
- State and local regulations on nutrient management
- Product cost/benefit ratios; grain prices, fertilizer prices
- Crop hybrids; response rates
- Weather trends, water availability

The trend for worldwide application rates has been on the increase, and most forecasts show potential for more growth, due to factors such as:

- Improved fertility management in developing regions
- Improved product availability
- Need to increase average yield and total output with a static land base.

CROP AREA

Harvested crop area has, of course, followed a pattern very similar to that of fertlizer consumption. Over 140 million hectares were harvested in North America in 1981, about 18 percent of the world total. After 1981, harvested area declined, as a result of aforementioned government policies which resulted in excessive grain inventories.

Harvested area has also declined at the global level, due to a period of worldwide economic recession and oversupply. Mid-decade, however, total worldwide harvested area began a recovery, while U.S. farmers continued to sit idle in response to set-aside programs.

U.S. share of the world total declined throughout the 90's, and forecasts show no reversal of this trend. During the period:

- Europe went from being a major importer to becoming a major exporter
- China actually *exported* minor amounts of grain
- Smaller counties pursued self-sufficiency goals, even under uneconomic conditions.
- Trade barriers proliferated, leading to inefficient trade patterns.

NUTRIENT EXPORTS

In 1981, the U.S. industry was in a somewhat enviable position: domestic consumption was at an all time high, and extensive capacity expansions were offering even greater export capability. Factors such as product availability, favorable dollar export financing programs, and well developed marketing infrastructures placed the U.S. in a dominant export position in 1981.

- From 1971 to 1981 export share of N jumped from 14 percent to 22 percent.
- From 1971 to 1981, export share of phosphate soared to 53 percent, from 28 percent, as new capacities came on line.

After 1981, nitrogen share began to decline. Development shifted to resource-rich less developed countries . At the same time, natural gas deregulation and higher prices left U.S.production less competitive.

After 1981 phosphate share also dropped, primarily due to a worldwide slowdown and recession. This also was the beginning of a period of building for countries with new reserves, Morocco and Jordan being examples.

At present, phosphate share has recovered somewhat, perhaps due to cash shortages and production cutbacks in our competitor countries. Nitrogen share has continued to decline, as expansions in gas-rich countries continue, including regions which base production decisions on the need for currency, or on a lack of other outlets for surplus gas.

Production Costs

Production costs of major products are tracked more closely in the U.S. than in any other country. U.S. competitiveness has been greatly enhanced since 1981, due to improvements in efficiency and cost-cutting actions.

(FIGURE 6)

NH3

Total production cost for ammonia has declined steadily since 1983, from an average of $115 down to below $90. Efficiency and cost containment have been the real success story here:

(FIGURE 7)

Natural gas use: 1983 = 36 mm Btu's
1991 = 34 mm Btu's

This increase in production efficiency has essentially all resulted from upgrades on existing capacity.

(FIGURE 8)

DAP

DAP production cost has also been reduced.
1983 = 149.88
1991 = 136.93

Again, this reduction in production cost can be linked primarily to increased efficiency and cost—containment.

Productivity has also been an issue in Canada, where permanent employment declined 32.5% with essentially constant output between 1984 and 1990.

CONCLUSIONS

The United States enjoyed a position of dominance in 1981, in home shipments, export share and capacity growth. Worldwide changes have modified this strategic position, making it necessary to rethink the realities of operating our businesses.

The North American agriculture industry, and the fertilizer industry in particular, still enjoy many natural and competitive advantages for the future. However, the new business environment indicates a need for new ways of conducting business.

Fierce competition, and the resulting need for cost-cutting measures and lean operations are here to stay. We must find ways to dampen the 'lean to fat' cycle which has crippled our industry in the past.

"Environmental optimization" will become the credo of every business in North America. This concept is analogous to yield optimization or maximum economic yield.

An intensified effort by the industry will be devoted to ensuring that fertilizer use is part of a sustainable agriculture system. The key to such efforts will be cooperation and an effective partnership among farmers, the industry, universities and the government.

Globalization of the industry is upon us; it is no longer a new concept. The only unanswered question is where the pieces will fall and who gets the pie.

Increased government involvement in both agriculture and the fertilizer industry appears inevitable for the future.

TRENDS FOR THE FUTURE

The North American Free Trade Agreement (NAFTA) offers great potential for growth throughout the region.

There will be a decline in phosphate reserves, although the impact on our industry base in unclear. Process regulations, including the ability to dispose of phosphogypsum, may be more of a determinant than ore reserves.

Advocacy in the regulatory arena, such as that provided by TFI, is critical in the short term. However in the long—term, only research can meet the demands of 'environmental optimization'.

Our competitive position in nitrogen for the future is difficult to evaluate. Under present conditions, including gas markets, ROI, and competition, it does not appear favorable for further investment.

At the distribution/farm level of our business, environmental optimization will require more sophistication, greater precision, and continuing agronomic research and product development.

Industry has responded positively and assertively to many problems which have threatened our competitiveness and survival.

At this point, we've identified the challenges:

- Environmental optimization
- Low-cost production
- Aggressive marketing based on clearly defined benefits to the customer
- Establishment of fair competition around the world.

Given that identifying the problem is the greatest part of determining the cure, I think we're well on our way to another 10 years.

Tuesday, October 27, 1992

Session III
Moderator:
Ronald Kirkland

Importance of Water Solubility in Phosphate Fertilizers

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Potash & Phosphate Institute

This paper will be presented from an agronomic prospective since I am an agronomist and not a chemical engineer. To set the stage for a discussion on the importance of water solubility in phosphate fertilizers, as it pertains to their effectiveness for use as fertilizers, there are many factors that influence the effectiveness of P fertilizers in addition to water solubility.

Several environmental factors affect crop response to P fertilizers. These factors are important considerations on the effects of water solubility of the P fertilizers[9].

Environmental Factors Affecting Crop Response to P Fertilization

- Soil pH
- Soil Fe and Al levels
- Soil P levels
- Soil moisture
- Soil level of other nutrients: N, S, K, etc.
- Soil texture
- Soil temperature

There are several crop and crop production factors that can affect the agronomic response of crops to P fertilizers (9).

Factors Affecting Crop Response to P Fertilization

- Type of plant
- Type and extent of root system
- Time required to reach maturity
- Crop management considerations

Phosphorus efficiency is enhanced by any crop management or growth factor that enhances plant growth, yield and profits. A production input, like fertilizer placement or crop rotation, can affect the efficiency of fertilizers as much as 5 to 70 percent. Research results from several locations for one crop (corn) are compiled in the table below. The results indicate the impact that various growth factors can have on increasing yields and P efficiency.

Effects of individual management inputs on corn yield and P efficiency(1).

Management Factor	Yield Increase bu/A	Increased P %	Efficiency bulb	Location
Rotation	15	14	0.30	NC
Population	31	17	0.28	FL
Hybrid	51	69	0.68	FL
Planting date	35	25	0.70	OH
Starter P	24	14	0.69	NE
Irrigation	87	71	0.69	NJ
Compaction	44	36	0.88	IN

A FAO report summarized the importance of using fertilizer in balance with other production inputs. The report said that fertilizer efficiency can be reduced as much as 10 to 50 percent by improper use of cultural practices. Only the whole package of Best Management Practices (BMP's) can insure the highest effectiveness of any P fertilizer in addition to its percent water solubility(5).

Sources of Reduction in Fertilizer Efficiency

	Percent Reduction
Improper fertilizer placement	5-10
Inadequate Irrigation	10-20
Weed infestation	15-50
Insect attack	5-50
Imbalance fertilizer	20-50
Percent seedbed preparation	10-25
Improper seeding	5-20
Delay in seeding	20-40
Inappropriate variety	20-40
Inadequate plant population	10-25

Any consideration given for the effectiveness of a P fertilizer must take into consideration its "available P". Available P can be defined as the water and ammonium citrate soluble P content of the fertilizer material. However, there may be considerable difference in response to the water soluble or the ammonium citrate (AC) soluble portions under different conditions. Short season crops or fast growing crops and those restricted root systems require fertilizers with high proportions of water soluble P.

Phosphorus Compounds Classified on
Basis of Solubility (8)

- P mostly soluble in water
- P not readily soluble in water, but soluble in ammonium citrate (A. C.) solution
- P insoluble in A.C.

For any given crop and set of soil and climatic conditions, the factors associated with a phosphatic fertilizer which determines its effectiveness are (9):

1. Degree of water solubility of contained P.
2. Particle size and distribution.
3. Rate of application.
4. Method of application.

Thus, it is evident that the water solubility of a phosphate fertilizer is an important consideration. Researchers in several states evaluated the degree of water solubility required to be the most effective and efficient.

In Iowa, Webb and Pesek (10) published a series of articles addressing the importance of P water solubility in fertilizers. As water solubility increased, corn yield increased. However, ninety percent of the yield increase was attained with fertilizers having 60 percent of the P in a water soluble form. In the study water solubility ranged from zero to 100 percent.

Ensminger concluded that the importance of water solubility of P depends on several factors. In general, more water soluble P is needed for short season than long season crops. Plants often show a response in favor of water soluble P during early stages of growth, but differences may not be evident in final yields. Importance of water solubility decreases with increasing P rates of application. High water solubility may benefit plants growing under poor weather conditions. Also, differences are more likely to appear when fertilizer is band placed than when broadcast.

Several other studies in the 1950's reached similar conclusions about the effects and need for water solubility of P fertilizers. Most research found that a water solubility of 50 to 60 percent was adequate and achieved 90 percent of the effects of water solubility.

In the 1980's the EEC placed a requirement of 93 percent water solubility for triple superphosphate. Much discussion was expended on the subject, but the fact remained that the data on water solubility requirements for P fertilizers dated back to the 1950's. Dr. Greg Mullins, Auburn University, heard of the controversy and managed to acquire some Moroccan triple superphosphate that had a water solubility of 93 percent. Dr. Mullins conducted several tests comparing the Moroccan TSP with that from different P fertilizer mining and manufacturing areas of the USA.

Mullins(6) obtained six triple superphosphate and one ordinary superphosphate fertilizer sources. Of the six TSP sources, three were from Florida, one was from North Carolina, one was from Idaho and one was from Morocco. The OSP was from Morocco. Each source was tested for several properties including percent water soluble and AC soluble P. A reagent grade monocalcium phosphate (MCP) was purchased from Baker Chemical Co.

The first study that was conducted was a greenhouse study using sorghum-sudangrass hybrid as the test crop. Six rates of P were used with the P sources. Herbage yields and the P concentration in harvested forage were not affected by the source of added P. Herbage yield was increased by increasing P rates.

Mullins and Evans(7) reported on three years of field trials with the acquired P sources. The test crop was a short season crop with a limited root system, Irish potatoes. The test was conducted at two locations, north central Alabama and on the Gulf coast of Alabama. Four rates of P were band applied. Potato yields were increased by added P. Yields were not affected by source of P on either soil. Fertilizer performance was not affected by the level of water soluble P, iron, or aluminum content.

Bartos and Mullins(2) conducted greenhouse studies using wheat as the test crop and grew it at two soil pH's, 5.4 and 6.4. Phosphorus sources were one Florida and one Moroccan TSP. At pH 6.4 maximum yields occurred at a water solubility of 66 percent. At pH 5.4, it was at 39 percent.

Dr. Mullins(7) concluded from his several studies that commercial TSP fertilizers vary in their content of water soluble P and metallic elements. However, his studies show that fertilizer performance was not related to the level of water soluble P or the content of metallic impurities. The results demonstrate that current levels of water-insoluble P in TSP produced from North American rock phosphate sources are not an agronomic problem.

From a domestic viewpoint, it appears that as long as P fertilizers have a P water solubility of 50 to 60 percent, it will satisfactorily produce economic yield responses, as long as best management practices are used.

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Corn Yields as Influenced by Water Solubility of P Fertilizer

Soil	pH	Yield, kg/ha No P	Increase in Grain Yield, kg/ha				
			% Water Soluble P				
			16	34	92	MAP	DAP
Edina SL^1	5.5	4,045	759	853	1,361	1,430	1,336
Floyd SL^1	5.6	3,176	452	527	765	822	784
			% Water Soluble P				
			14	36	43	90	
Clarion SL^2	5.8	5,833	169	307	615	570	
Webster SiCl^2	7.6	6,987	263	339	389	414	

^{1}17 kg/ha P_2O_5; ^{2}25 kg/ha P_2O_5 Webb & Pesek

In Alabama, Ensminger (3) evaluated the response of crops to various P fertilizers. The data show that the degree of response varied with crop. Cotton was very responsive to the different sources.

Relative Efficiency of Phosphate Fertilizers

(Average of 3 locations in Alabama)

Fertilizer	Crop	
	Cotton	Corn
OSP	100	100
Collodial	54	65
RP 2x	66	80
RP	35	52
Ammo-Phos A	16	88

P_2O_5rate = 48 lb/A Auburn, 1950

Ensminger reported later (4) on cotton and wheat responses to water solubility of P fertilizers. Cotton responded to P fertilization, but the response to increased water soluble P varied with soil type.

Effect of Water Solubility of Fertilizer P on Cotton Yields

Soil Type	Seed Cotton Yield, lb/A		
		P_2O_5 Solubility*	
	No P_2O_5	25%	63%
Clay loam	1,208	1,286	1,500
U. fine sandy loam	670	871	863
Loamy sand	962	1,164	1,326
Fine sandy loam	829	1,095	1,217

*48 lb/A P_2O_5

Auburn, 1959

Studies with winter wheat forage yields found that first clipping yields increased with increased water solubility of P, but the effect was less pronounced with the second cutting. Grain yields of the wheat was not affected.

Effect of Water Solubility on P in Ammoniated Super Phosphate on Wheat Yields

% P in Water-Soluble Form	Forage Yield, lb/A	
	1st Cut	2nd Cut
No-P	224	740
14	501	977
30	581	948
52	688	1,168
71	755	1,230
85	805	1,180

Auburn, 1959

The Importance Of Water-Soluble Phosphate In International Agriculture

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It was in 1856 that Elie de Beaumont advocated the addition of finely ground mineral phosphates to supply the Phosphorus (P) needs of growing plants and only one year later that von Liebig reported that phosphate rock could be dissolved with sulfuric acid to increase the efficiency of P uptake by plants (1). Today, phosphate rock is usually only thought of as the raw material from which processed fertilizers such as single (SSP) or triple (TSP) superphosphate and mono (MAP) or diammonium (DAP) phosphate are produced. The apatite (Francolite) commonly found in phosphate rock is not soluble in water and only sparingly soluble in neutral ammonium citrate solution—the accepted measures of plant available P. Acidulation, however, converts the native apatite to monocalcium phosphate (MCP) which is water soluble, and dicalcium phosphate (DCP) which is citrate soluble (table 1). Due to the immediate plant availability of these phosphate forms, products such as TSP, SSP, MAP and DAP continue to be viewed as model phosphate fertilizers.

It is undeniable that fertilizers high in water solubility set the standard for agronomic effectiveness under the widest range of agro-edaphic conditions. They are effective on the majority of soils regardless of pH and with the majority of cropping systems regardless of production intensity. A debate does exist regarding the degree of water solubility required to achieve the most *cost effective* means of overcoming phosphorus deficiencies in today's international agriculture? Rather than focus on the optimum ratios for water-soluble versus citrate-soluble phosphate for conventional fertilizers, however, this paper will draw attention to those situations where water soluble fertilizers may *not* be necessary.

It has been observed in recent years that extensive areas of agricultural land, especially in the tropics, can effectively be fertilized with either unacidulated or partially acidulated phosphate rock. These agronomic observations conflict with the traditional belief that phosphate must be either water- or citrate-soluble to be effectively utilized by crops. How is it possible then that these sparingly-soluble phosphate materials can result in high agronomic effectiveness? The answer to that question will be addressed by describing both those conditions under which water-solubility becomes less of an advantage and the properties required of low-solubility fertilizers to satisfy crop needs.

Fertilizer Properties Influencing Agronomic EffectivenessChemical Solubility of Acidulated P Fertilizer

Phosphorus is absorbed by plants primarily as $H_2PO_4^-$ and $HPO_4^=$ ions present in the soil (table 1). The concentration of these ions in the soil solution and the maintenance of this concentration are of the greatest importance to plant growth. Without the use of a P-containing fertilizer, replenishment of the soil solution with Phosphate ions depends upon the release of P from native forms found in the soil such as the various calcium phosphates (table 1), as iron or aluminum phosphates, or from the clay and organic fractions of the soil. The equilibrium between P in the soil solution and the native forms of soil P can be disrupted by the addition of fertilizer P. The degree to which the concentration of $H_2PO_4^-$ and/or $HPO_4^=$ is altered depends upon the chemical solubility of the fertilizer relative to the chemical solubility of the native P forms. The higher the solubility, the faster these ions will be available for uptake by the crop.

Phosphorus fertilizers are generally classified into three groups with respect to solubility: (1) those in which the P is mostly soluble in water, (2) those not readily soluble in water but mostly soluble in ammonium citrate solution, and (3) those insoluble in ammonium citrate.

Tables 2-4 identify some of the fertilizers in these groupings and some of their characteristics. The sum of the water-soluble and citrate-soluble P fractions, as measured by AOAC procedures, represents the so-called "available" P content of a fertilizer. Chemical solubility relates directly to the quantity of plant-available P which will be released from the fertilizer at any given time following its application to the soil. The P in those fertilizers listed in table 2, therefore, can be expected to enter the soil solution almost immediately following application. For those materials listed in table 3, from 5% to 85% of the P will immediately enter into the soil solution and the remainder will enter over a period of several weeks to several months. In the case of the fertilizers listed in table 4, only a very small quantity will enter the soil solution immediately, but nearly all of the P can be expected to be released through the course of the growing season of the crop. As will be explained later, however, just because the P is released quickly doesn't mean it is all "available" to the crop. Since a large proportion of the soluble P reacts with the soil before the crop's root system develops, it is typical that only 5-15% of the P applied is used by the crop in the growing season immediately following application.

Phosphate Rock Solubility

Unacidulated phosphate rock contains virtually no water-soluble P and only a relatively small amount of citrate-soluble P. The amount of citrate soluble P in a phosphate rock sample, however, does *not* have the same meaning as citrate solubility in an acidulated fertilizer. Citrate solution extracts a specific P compound from superphosphates and ammoniated phosphates. The P solubility (reactivity) of a phosphate rock, however, only provides an *index* related to the rate at which the rock can dissolve in acid soils and, therefore, *how fast* the P becomes plant available in acid soil. The reason for this is described later. [Remember -phosphate rock will only dissolve in acid soil; only soluble phosphate fertilizers should be recommended for soils with high pH].

Typical solubility measurements for some phosphate rocks, including numerous sources from Latin American countries, are presented in table 5. The relationship between rock reactivity and crop response to these rocks has been reported by Leon et al. in a publication which classifies natural phosphates into four groups according to their agronomic effectiveness relative to TSP. Panicum maximum was used as the test crop on an Oxisol from the Colombian Eastern Plains. The natural phosphates were classified as: highly effective (85%-100%), medium effectiveness (70%-84%), low effectiveness (40%-69%), and very low effectiveness (<39%). According to this classification, the only rock indigenous to Latin America qualifying as highly reactive is the Bayovar rock from Peru; the only North American rock in this category is from North Carolina (Note: the term "reactive" is used because the solubility refers to the rate of reaction in the soil rather than the amount "available" to the crop).

Because of these differences in the rate of dissolution, not all phosphate rocks are agronomically effective in their natural form. If they were, the use of ground rock would have flourished since it was first tried in the 1800's. Unfortunately, it happened that the rocks which were used initially exhibited low reactivity and crop response was highly erratic. Based on publications dating back to the early 1900's up through the late 1960's, it is clear that no distinction was made among rock sources relative to apatite composition. The general consensus was that.."a rock is a rock is a rock". Due to this misconception, it was presumed that all rocks could be expected to result in unsatisfactory performance.

It wasn't until the pioneering work of Lehr and McClellan in 1972 (2) at TVA that it was proven that the stability of apatite varied depending on the degree of substitution of phosphate by carbonate within the apatite structure and that reduced stability (high reactivity) due to high substitution was directly related to increased plant availability of P from the apatite. This degree of substitution can be determined by x-ray diffraction techniques, but the reactivity is more commonly estimated using extracting techniques to measure the amount of P solubilized by a given solution. The most typical extracting solutions include 1) neutral ammonium citrate solution, 2) 2% citric acid, and 3) 2% formic acid. Each of these solutions solubilize rock to different degrees, but it is generally agreed that all three are nearly equally effective in ranking different rock samples in order of reactivity (3).

Solubility measurements require careful interpretation. Not only are there great differences in the quantity of soluble P extracted depending on the type of extracting solution used, but there can also be differences related to the laboratory procedure employed for a given solution. For example, results will vary depending on 1) the sample: solution ratio, the solution temperature, the time of extraction, the extraction sequence, and the particle size of the sample. In any comparison among sources, therefore, one must ensure that the data were generated with comparable procedures.

Influence of Phosphate Rock Solubility on Agronomic Effectiveness

Despite the fact some rocks have been classified as "highly reactive" and exhibit "high agronomic effectiveness", only about 22% of the total P_2O_5 is soluble in neutral ammonium citrate solution even in the North Carolina natural phosphate which is the most soluble rock available. Throughout the world, the convention has been adopted that only P determined to be water- or citrate-soluble is "available". Since unacidulated natural phosphate contains no water soluble P and only minimal quantities of citrate soluble P, how could one ever expect unacidulated rock to perform up to the standards of processed fertilizer – even on acid soil? The answer to this question is best addressed by examining the appropriateness of assuming that only water – or citrate-soluble P is available to the plant.

Laboratory studies have shown that water and citrate solutions quantitatively extract specific P compounds (monocalcium and dicalcium phosphate, respectively) from superphosphate and ammoniated phosphates. Neither of these compounds are present, however, in natural phosphate. Since the P-containing component of natural phosphate is a tri-calcium phosphate (Francolite), it is clear that extraction with a citrate solution does not measure a specific *quantity* of a plant-available P form. The P solubility (reactivity) of a natural phosphate only provides a *qualitative index* related to the rate at which the rock dissolves and the P becomes plant available. *The amount of citrate soluble P in a natural phosphate sample, therefore, does not have the same meaning as citrate solubility in a processed fertilizer.*

Due to the difference in what water- or citrate-solubility measurements mean, depending on whether they refer to acidulated or unacidulated fertilizer, it is impossible to make direct comparisons of solubility measurements among these types of fertilizer relative to the expected degree of effectiveness. For example, if a fertilizer such as TSP contained 100% "available" P and it was compared in the field with an unacidulated rock in which only 22% of the P was citrate soluble, one would assume that it would be impossible for the rock to be more than 22% as effective as the TSP. Innumerable examples exist, however, which illustrate that highly reactive rock can be 100% as effective as TSP when used appropriately. This is because citrate solubility measures a quantity of available P in the TSP while it only measures the relative rate of dissolution of the rock. It's possible that all of the P in the rock is actually "available", but over a longer period of time.

One must remember that even if all of the P in a fertilizer like TSP is immediately solubilized, all of it will not be utilized by the plant. Most will react with Iron- or Aluminum-oxides in acid soil to rapidly form compounds not readily available for plant uptake. Generally, only 5-15% of the P applied (even if it is labeled "available P") will actually be used by the crop in the season immediately following application. The only requirement for an unacidulated rock to be equally as effective as the TSP, therefore, is that the rock dissolves fast enough to directly supply a quantity comparable to the 5-15% of the P recovered from the TSP. It is obvious from the greenhouse response curves illustrated in figure 1, North Carolina natural phosphate dissolved fast enough to be as effective as TSP under these conditions while other natural phosphates were less effective.

Particle or Granule Size Effects

The influence of the size of a P fertilizer particle or granule on its agronomic effectiveness must also be viewed in terms of the interaction between size and other factors including source solubility, P-sorption capacity of the soil, and method of application. For water-soluble P sources applied to acid soils, granulation tends to increase the early crop response. Whether such early growth response persists to mature harvest, depends on non-fertilizer factors (4) such as the initial P level in the soil and the P-sorption capacity. The primary reason for these increases can be attributed to a "locality" effect. When granulated, soluble P sources tend to develop points highly concentrated with plant-available P. When close to the seed these pockets can easily supply the quantities required by the young plant despite the limited development of the rooting system. At the same time, the surface area contact between the soluble P and the soil components responsible for P sorption is reduced because of the size of the granule. Granulation does not, however, completely eliminate the problem of P sorption. Even under the best of conditions, no more than 10-15% of any P fertilizer will actually be taken up by the crop planted immediately following fertilizer application.

In the case of P fertilizers low in water solubility, the use of finely ground material or small granules is generally recommended. With these fertilizers, the rate of dissolution and limited diffusion is more likely to be a limiting factor than is the reaction of the P with the soil (5). Maximization of contact with soil and better distribution through the soil are important to increase the probability that plant roots will encounter solubilized P.

Traditionally it was recommended that natural phosphate rock be ground to a very fine powder capable of passing a 200-mesh Tyler screen. This was based on experience with low reactivity rocks. Later, in 1956, Cooke (6) concluded that much of the improvement observed in greenhouse studies by grinding to this size was not reflected in the field and that a standard of 80% passing a 100-mesh Tyler screen (150 um) was sufficient. More recently, studies conducted by IFDC (Chien S. C., Friesen D. K., unpublished) indicate that if the reactivity of the phosphate rock is high (NCNP was used in the IFDC research), even a coarser size is agronomically effective. This is discussed later in more detail, but it has been suggested that the fine fraction of the "as-received" North Carolina reactive rock was sufficient for early P availability while the coarser rock contributed to the residual P pool.

Soil Factors Influencing P Availability

pH

While there are many soil factors which affect the performance of P fertilizer sources, pH is one of the most obvious. As the acidity of a soil increases, the solubility of Iron (Fe) and Aluminum (Al) compounds in the soil increases, thus promoting formation of Fe- and Al-Phosphate compounds through reaction with P supplied to the soil solution by the fertilizer. The process of fertilizer P reacting with Fe and Al compounds in an acid soil is referred to variously as P sorption, P retention or P fixation.

Strong soil acidity, therefore, is usually a detriment to the efficient utilization of highly soluble P fertilizers. Soon after application, P from soluble fertilizer is susceptible to reaction with the soil and subsequent reversion to forms which become plant-available only at a very slow rate. These reactions are enhanced when the P fertilizer itself undergoes an acidic reaction during hydrolysis. Fertilizers which form monocalcium phosphate (TSP, SSP) upon decomposition have been found to lower the pH to 1.5 in the saturated solution surrounding the fertilizer granule. The saturated solution surrounding MAP upon dissolution has been measured at pH 3.5. The acidity associated with dissolution of these fertilizers, therefore, has a tendency to promote additional P sorption by the soil.

The dissolution of natural phosphate rock, on the other hand, *requires* an acid environment. The use of ground phosphate rock is generally recommended only in soils with pH less than 5.5. Phosphate rocks with low chemical reactivity may require an even lower pH to dissolve the rock while those with the highest reactivity may be used on soils with pH up to 6.5. Data from Englestad et. al. (7), for example, shows the effect of soil pH on the effectiveness of various phosphate rocks relative to TSP for flooded rice grown in Thailand and India. While pH had little effect on TSP effectiveness, crop response to P from the phosphate rocks was strongly influenced by the pH. At soil pH 4.6, the rocks performed as predicted by reactivity measurements (i.e. NCNP outperformed rocks of lower reactivity), but when applied to a soil with pH 8.0 all rocks were ineffective at increasing grain yields.

Since the availability of other nutrients can be reduced and Al or Mn toxicities can be promoted at low pHs, liming of the soil is often practiced. When phosphate rock is used in conjunction with lime, it is advisable to use minimum quantities of lime (i.e., to reduce Al saturation rather than to raise pH) and to use acid-tolerant plant species to reduce the negative effect that increased pH and the buildup of Ca in solution can have on the rate of phosphate rock dissolution.

P-Sorption Capacity

Plants can absorb P only from the soil solution, and obviously, the higher the capacity a soil or fertilizer has to maintain high concentrations of P in the soil solution, the greater the degree of utilization by the plant. All soils, however, have varying capacities to revert P from the soil solution to relatively insoluble forms. The capacity of the soil to do this depends primarily on the chemical and/or mineralogical composition of the soil (i.e., amount of Fe, Al, Mn, Ca, clay, O.M., etc.) and the pH of the soil as described above.

All P which enters the soil solution is susceptible to this reversion regardless of the fertilizer source. The difference between sources is only "how soon" the P enters the soil solution and whether or not the source produces acidity which can promote the reactions with Fe and Al in acid soils. In the case of sources which are highly water soluble, all of the P is immediately susceptible. For this reason, the use of reduced solubility sources is often recommended to reduce the rate of P sorption. Partially acidulated phosphate rock is an example of a source found to be effective on acid soils since a portion of the P is water soluble and is readily available for uptake by the young plants while the remainder dissolves at a slower rate.

The effectiveness of finely ground phosphate rock relative to soluble sources has generally been presumed to improve when applied to acid soils with increasing P-sorption capacity since it was assumed that the slow rate of rock dissolution would "protect" the P from reactions in the soil. Recent research at IFDC, however, suggests that this may not be true in all cases. It appears that, in soils with extremely high P-sorption capacity the quantity of P supplied by the phosphate rock alone during the early growth stages of the plant may not be sufficient to develop a strong rooting system. The net result is that the volume of soil explored by the roots is reduced and, as the phosphate rock dissolves, the probability is higher that the solubilized P will react with the soil than it is for the P to be in the absorption zone of the plant root. In order to get maximum benefit from phosphate rock in extremely high P-sorbing soils, especially for fast-growing crops, at least small quantities of water-soluble P should be supplied to promote early plant growth.

When speaking of soils with extremely high P-sorption capacity, however, it is important to specify a reference. In this case, reference is being made to soils which retain 80% or more soluble P when measured by the Fassbender Method (8). One commonly held misconception is that all acid tropical soils are high P-sorbing soils. In actuality, recent surveys indicate that few soils, mostly those derived from volcanic ash, exhibit this degree of P-sorption. Even with volcanic ash soil, it is important to accurately characterize the P-sorption capacity since repeated application of fertilizer P can reduce its capacity. In the Philippines, for example, studies conducted by Harris et. al. (9) as part of the University of Hawaii's Benchmark Soils Project, showed that NCNP was equally as effective as SSP in increasing yields of maize even when grown on a Hydric Dystrandept (i.e. volcanic ash soil).

Field Experiences with Reactive Phosphate Rock

One of the major conclusions that can be drawn from the research completed to date in international trials is that extensive areas in the region exist where NCNP can be effectively used from an agronomic point of view. It has been estimated, for example, that in South America there are over 1 billion ha of acid, infertile Oxisols, Ultisols, and Inceptisols [10]. Areas where these acid soils exist represent areas which could potentially benefit from the use of highly reactive, unacidulated phosphate rock P.

Field trials with NCNP have been conducted on these types of soils in numerous countries throughout Latin America and Asia. The details of these trials will not be presented here, but figures 2 through 6 give examples of typical yield results. Examination of the data collected provide the following observations:

Observation 1

Each of these figures confirm that NCNP continues to be an effective source of P_20_5 even though it has not been ground to a fine powder as is required by lower reactivity phosphate rocks. On these sites, P was obviously deficient and the application of unground NCNP contributed sufficient phosphorus to significantly increase crop yields.

Observation 2

Figures 3, 4 and 5 confirm that NCNP is an effective P_20_5 source for annual crops as well as long-term crops. It is seen to be effective for use with pastures, maize, soybeans, sorghum. Data from the diverse experimentation now in progress with other crops can be drawn upon in the near future to confirm its effectiveness on even a wider range of crops.

Observation 3

Figures 4, 5 and 6 confirm that NCNP is consistently more effective than lower reactivity phosphate rock. The trials in progress generally include locally available phosphate rocks as well as soluble fertilizer and NCNP. The importance of the rate of dissolution as described earlier in this paper is confirmed by comparing NCNP performance to these sources with lower reactivity.

Observation 4

NCNP is suitable for use across a wide range of acid soil conditions and climatic environments. The data being obtained is derived from studies throughout Latin America and Asia on soils ranging from Oxisols to Ultisols to Andepts to Mollisols, and in climates ranging from temperate to tropical.

While the agronomic factors are seen to be appropriate for the use of unacidulated phosphate rock, the exploitation of indigenous deposits in Latin America, for example, has been found to be problematic for a range of reasons including one or more of the following, depending upon the specific deposit:

1. Small size of either reserves or recoverable ore, making it impossible to capitalize on economy of scale or to warrant long-term investment.
2. Remote or unaccessible location requiring major investment in transportation and other infrastructure.
3. Low-grade ores (<22% total P2O5) which increases the cost of local transportation.
4. Medium to low reactivity making them less effective than high reactivity rocks.
5. Igneous origin which results in very low reactivity.
6. Geologic formation requiring costly tunnel mining to access the ore.
7. Location farther from appropriate agricultural zones than are ports through which rock could be imported.

Under these conditions, an alternative approach for capitalizing on the presence of appropriate conditions throughout extensive areas of Latin America for use of a natural, unacidulated P fertilizer is to consider direct application of North Carolina Natural Phosphate (NCNP).

Summary

Some of the important factors influencing the agronomic performance of P-containing fertilizers have been presented above. It is clear that variables including source solubility, particle size, soil acidity, P soil test and P-sorption capacity of the soil, crop type, fertilizer cost, and other factors all influence selection of the most appropriate source and its management. Considering these factors, it is clear that sources containing reactive apatitite such as North Carolina Natural Phosphate exhibit high potential for direct application use on acid soils despite the fact it contains no water-soluble P.

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Table 1 ***Important P-Containing Substances***

Symbol or Formula	Name	Significance
P	Phoshporus	Chemical symbol for phosphrous
P_2O_5	Diphosphorus pentoxide	Does ***not*** occur is soils, plants or fertilizers
H_3PO_4	(Ortho-) phosphoric acid	Acid, salts are orthophosphates
H_2PO_4	Dihydrogen phosphate, monophosphate	Ions in soil solution, forms in which plants absorb P
HPO_4	Hydrogen phosphate, diphosphate	Ions in soil solution, forms in which plants absorb P
$-H_2PO_4$	Phosphoryl group	Radical for linking with organic compounds
$Ca(H_2PO_4)_2.H_2O$	Monocalcium phosphate MCP)	Highly water soluble
$CaHPO_4(2H_2O)$	Dicalcium phosphate	Soluble in ammonium citrate
CaH(PO4)3.3H2O	Octocalcium phosphate	Soluble in ammonium citrate
$Ca_3(PO_4)_2$	(Tri-) calcium phosphate	Occurs usually as apatite
$3Ca_3(PO_4)2.Ca(OH)_2$	Hydroxide apatite	Substituted apatites
$3Ca_3(PO_4)2.CaCO_3$	Carbonate apatite	Substituted apatites
$3Ca_3(PO4)2.CaF_2$	Fluor apatite	Substituted apatites
${}^{Ca}10\text{-}0.42x^{Na}O.3x^{Mg}O.12x^{(PO)}6\text{-}x^{(CO_3)}x^{F}{}_2\text{+}O.4x$	Francolite	Substituted apatites

Table 2 ***Fertilizers in Which P is Highly Soluble***

Fertilizer Name	Major Constituents (%)	Primary Components	Solubility of P Component
Single Superphosphate (SSP)	P (9) S (10-12) Ca (20)	$Ca(H_2PO_4)_2\ H_2O$ $CaSO_42H_2O$	85%-87% soluble in water Remainder soluble in citrate
Triple superphosphate (TSP)	P (20-22) S (1-2) Ca (12-16)	$Ca(H_2PO_4)_2.H_2O$	85%-87% soluble in water Remainder soluble in citrate
Monoammonium phosphate (MAP)	P (21-26) N (10-13)	$NH_4H_2PO_4$	95%-100% soluble in water
Diammonium Phosphate (DAP)	P (20-23) N (16-21)	$(NH_4)_2HPO_4$	95%-100% solublle in water
Ammonium phosphate nitrate (APN)	P (3.4-6.1) N (28-30)	NH_4NO_3 NH_4H2PO_4 $(NH_4)_2HPO_4$	95%-100% soluble in water
Ammonium Phosphate sulfate (APS)	P (9-15) N (13-20) S (7-15)	$NH_4H_2PO_4$ $(NH_4)_2SO_4$	95%-100% soluble in water

Table 3 ***Fertilizers With P Moderately Soluble in Water but Highly Soluble in Ammonium Citrate***

Fertilizer Name	Major Constituents %		Primary Components	Solubility of P Components
Nitric phosphate (NP)	P N	(10-15) (12-17)	$CaHPO_4$ $NH_4H_2PO_4$ $CaSO_4$ NH_4NO_3	5%-85% soluble in water Remainder soluble in citrate
Ammoniated ordinary superphosphate (AOSP)	P N	(6-8) (4)	$CaHPO_4$ $NH_4H_2PO_4$ $CaSO_4.2H_2O$	35%-60% soluble in water Remainder soluble in citrate
Ammoniated concentrated superphosphate (ACSP)	P N	(14-18) (6-8)	$CaHPO_4$ $NH_4H_2PO_4$ $(NH_4)_2HPO_4$	35%-60% soluble in water Remainder soluble in citrate

Table 4 ***Fertilizers in Which P Is Not Readily Soluble in Water but Mostly Soluble in Ammonium Citrate***

Fertilizer Name	Total P Content	Water Solubility (%)	Primary Components
Dicalcium phosphate (DCP)	21-21	3	$CaHPO_4$, $CaHPO_4.2H_20$
Rhenania Phosphate	12-14	<2	CaNa silico-phosphate
Serpentine phosphate	9-10	<2	CaMg silico-phosphates
Basic slag	4-9	<2	Ca silico-carnotite

Table 5 ***SOLUBILITY OF VARIOUS LATIN AMERICAN PHOSPHATE ROCKS***
(Source: Leon et al., 1986)

ROCK SOURCE	COUNTRY	NAC[1]	2% CA[2]	2% FA[3]
		-----------	% of Total	P2O5-----
North Carolina	USA	21.6	50.0	63.4
Bayovar	Peru	17.4	36.2	55.1
Huila	Columbia	16.5	23.1	39.6
Pesca	Columbia	9.3	27.9	25.6
Patos de Minas	Brazil	5.8	23.1	22.1
Sardinata	Columbia	5.1	14.6	19.1
Araxa	Brazil	5.0	25.5	23.4
Lobatera	Venezuela	2.4	36.9	11.9
Catalao	Brazil	1.9	8.4	9.1
Tapira	Brazil	0.6	7.5	8.7

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1. P Extracted by Neutral Ammonium Citrate, 2nd Extraction
2. P Extracted by 2% Citric Acid
3. P Extracted by 2% Formic Acid

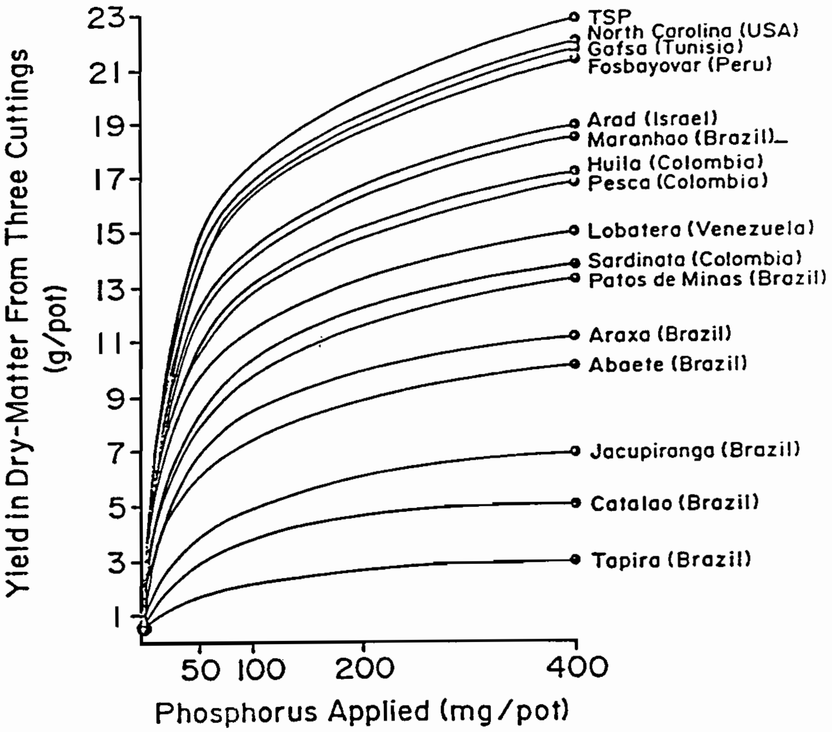

Figure 1 Yield in Dry-Matter of Panicum Maximum Grass, at Various Doses of Phosphorus, From Different Sources.

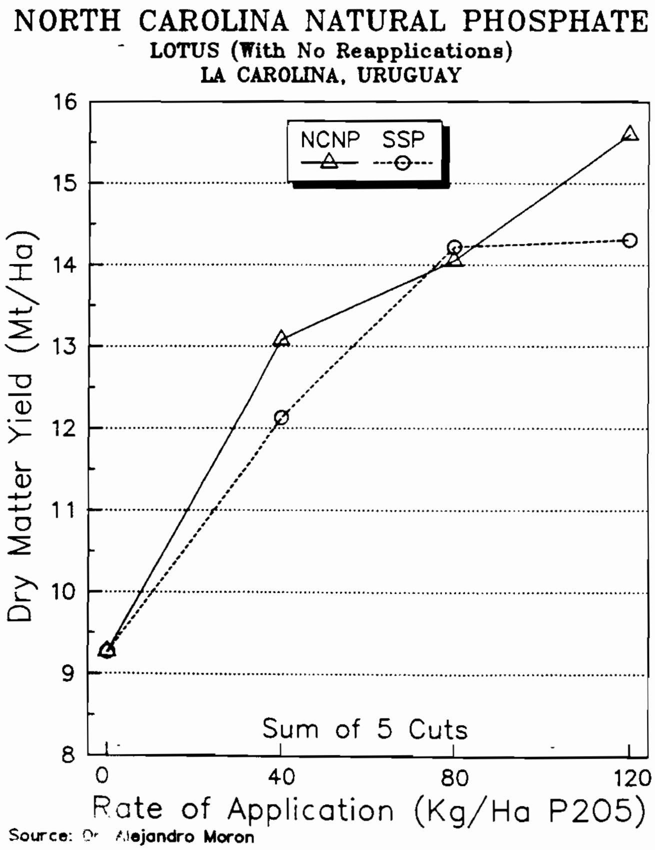

Figure 2

Source: Dr Alejandro Moron

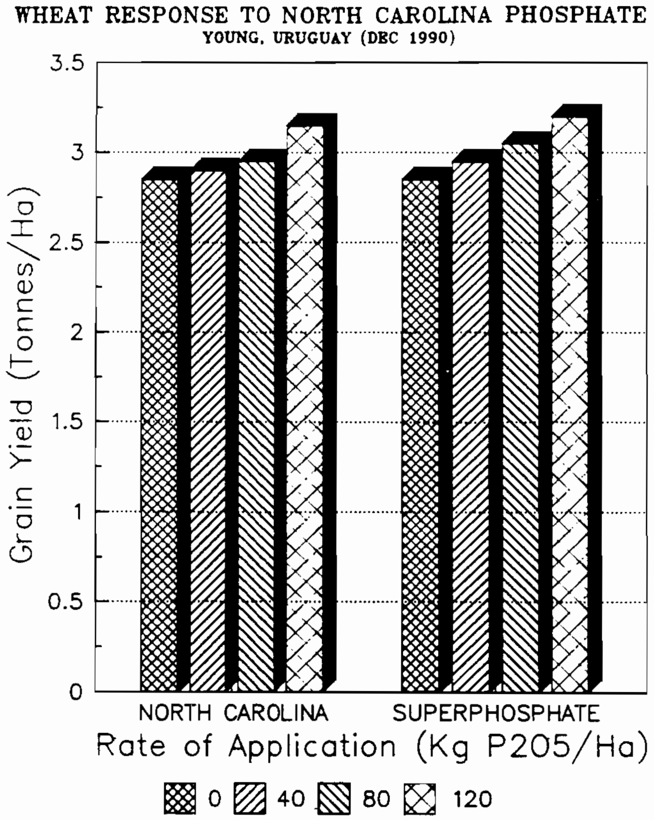

Figure 3 Source: Dr. Alejandro Moron

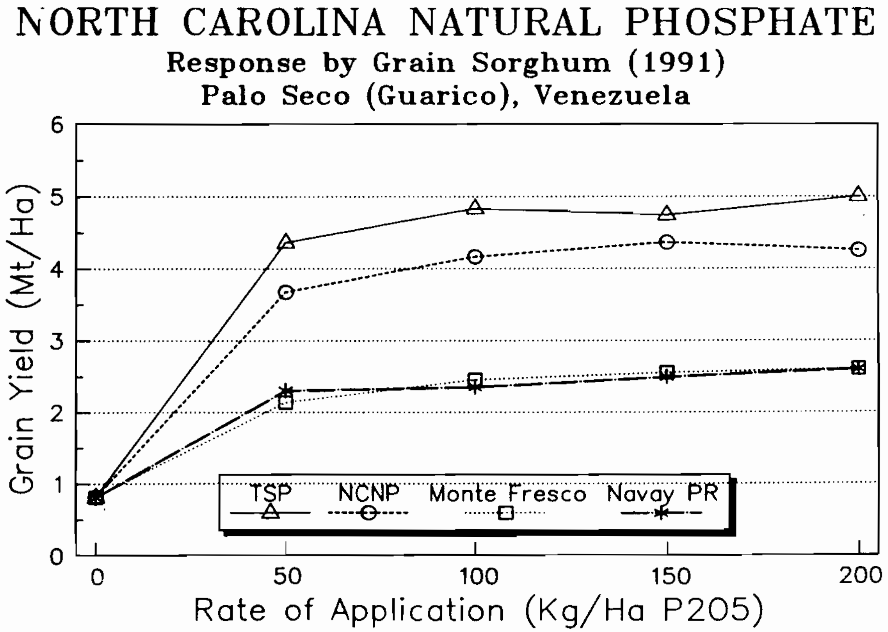

Figure 4 Source: Dr. Eduardo Casanova, UCV

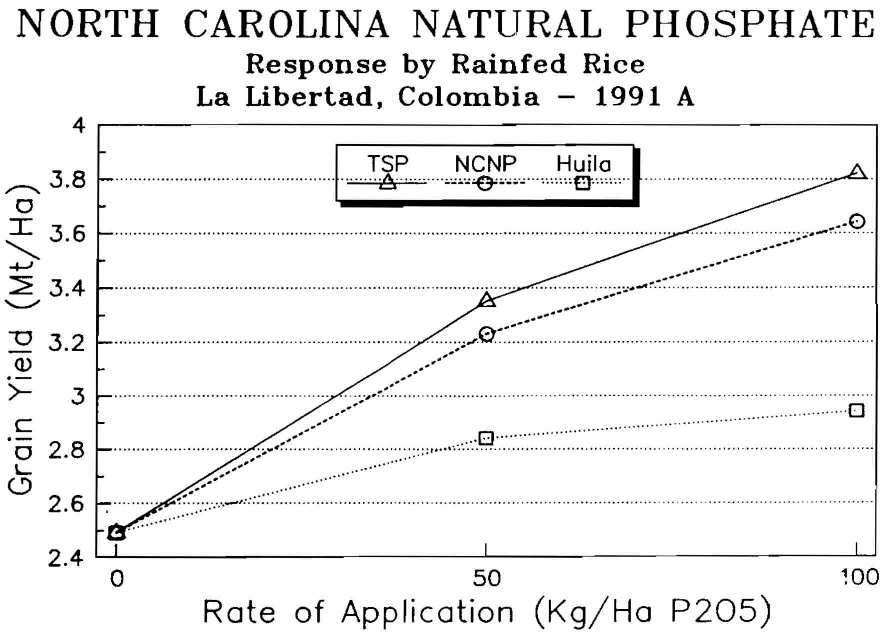
NORTH CAROLINA NATURAL PHOSPHATE
Response by Rainfed Rice
La Libertad, Colombia – 1991 A

Figure 5 Source: ICA, 1991

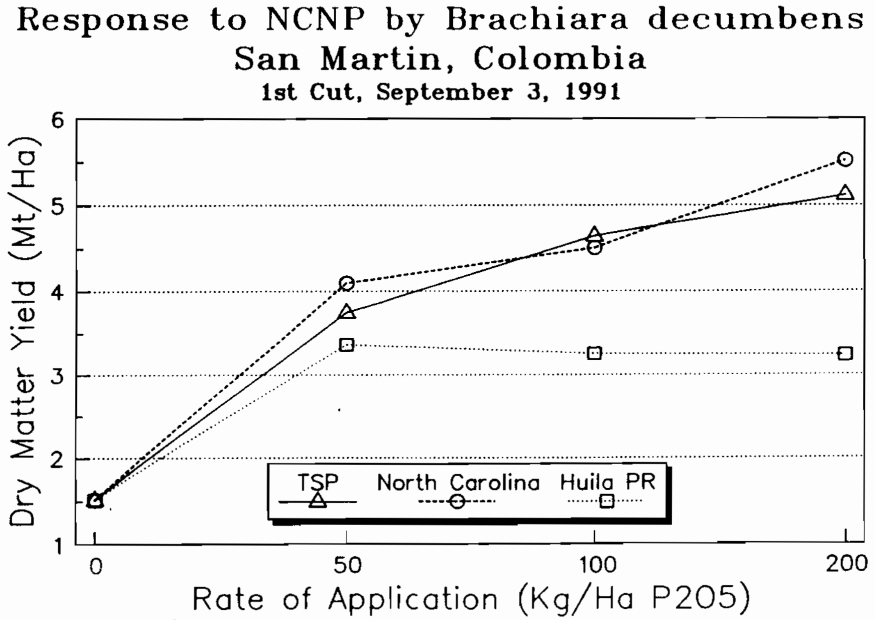
Response to NCNP by Brachiara decumbens
San Martin, Colombia
1st Cut, September 3, 1991

Figure 6 Source, ICA (1991)

Potential For The Inclusion Of Polymers In Controlled Availability Fertilizers

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ABSTRACT

The focus on concomitant conservation of plant nutrients and protection of the environment has fostered some novel approaches in controlled availability fertilizer technology. An example is the use of hydro-philic polymers as a matrix for nitrogen (N) and iron (Fe) fertilizers. This concept was tested in a series of laboratory and greenhouse experiments. Polymers varying in chemical and physical properties were mixed with urea ammonium nitrate (UAN-32% N) to form gels of various viscosities; these gels were applied to soils which then were subjected to extreme leaching conditions for several weeks. A marked reduction in N leaching losses from polymer-UAN mixtures was observed for up to four weeks following gel application. The reduction in N loss was accompanied by increases in forage yields and N uptake by sorghum sudangrass and fescue. Iron sulfate ($FeSO_4$) band-applied to a calcareous, Fe-deficient soil in a hydrophilic polymer matrix was an effective Fe source for grain sorghum. Yields and Fe uptake by the crop were comparable to those obtained using a commercial Fe chelate. The gel matrix apparently provided an environment which limited the contact of applied Fe with soil and maintained Fe in a plant-available form.

INTRODUCTION

Polymers have been used in agricultural systems since the 1930s, when plastic film was introduced for greenhouse covering, fumigation, and mulching (1). All classes of polymers, i.e., plastic, coatings, elastomer, fibers, and water-soluble polymers, currently have agricultural applications, but water soluble or hydrophilic polymers offer the greatest versatility and use. Examples of these are naturally occurring polymers such as polysaccharides, plant gums and seed mucilages; synthetically modified polysaccharides (cellulose and chitin); and synthetics, like polyvinyl alcohols and polyacrylamides. Some water soluble polymers are long chain copolymers that solvate in water to form gels due to numerous polar (ionic or hydrogen bonding) functional groups on the chain backbone. The degree of polymer solvation (or hydration), and thus gel viscosity, is directly proportional to the number of functional groups present in the polymer chain. An ultrahigh molecular weight (10^6 -10^7) polymerized synthetic polymer, such as polyacrylamide (PAM), may absorb up to 1400 times its weight in deionized water (2).

Synthetic hydrophilic polymers may be grouped into four chemical classes according to the charges of the functional groups on the chain: nonionic, anionic polyelectrolytes (negative), cationic polyelectrolytes (positive), and polyampholytes (both charges) (3). Hydration capacities vary within each group according to the composition of the aqueous solvation phase. Solution viscosities decrease with increasing salt content in the order nonionic>anionic=cationic polymers. Polyampholytes, however, are usually more soluble and show higher viscosities in salt than in aqueous solutions (4).

The uses of gel-type polymers in agriculture are diverse (5). Some of the more common uses are: (1) gel "hydroseeding," whereby seeds are mixed with a hydrated polymer matrix before sowing to improve seed germination and stand; the gel provides an intimate water source for the seed that is independent of the moisture in the soil; (2) in porous horticultural potting mixes to improve the water holding capacity of the mix; (3) to improve the aggregate stability of sandy soils and to reduce crusting in clayey soils; and (4) to reduce evaporation losses in arid, sandy soils. Considerable research has also been devoted to the use of polymers as controlled delivery systems for pesticides (6).

Gel polymers may also be useful in controlled availability fertilizers as emphasis on increasing nutrient efficiency and protection of the environment continues. A fertilizer can either be incorporated physically within a gel matrix, or be made an integral part of the polymer itself. In the first case, release of the nutrient occurs either by diffusion or by degradation of the polymer matrix. In the second, cleavage of the chemical bonds between the nutrient and the polymer chain accounts for release.

Mikkelsen et al. (7) indicate that gel-type polymers may be particularly well-suited for controlled availability nitrogen fertilizers. They performed experiments whereby fluid urea ammonium nitrate (UAN, 32% N) was mixed with a variety of polymers to form gels, and applied to a sandy soil which was then subjected to heavy leaching. Nitrogen leaching losses (as NO_3-N) were reduced up to 45% with the polymer/UAN mixtures, compared with UAN alone. In a second experiment, N leaching losses from guar-derived polymer-UAN mixtures were reduced up to 26% compared with UAN alone for the first four weeks after application, and growth and N uptake by fescue was increased up to 40 and 50%, respectively. Additional experiments conducted at TVA are described in this paper.

Gel-type polymers also may have potential for use in iron fertilizers. The polymer does not control availability in the strictest sense, but rather acts as a protective matrix to limit contact of the contained Fe with soil. Presently, there are no effective soil-applied Fe fertilizers that can be used economically on all crops. The Fe in $FeSO_4$, the least costly Fe source, is precipitated as insoluble compounds almost immediately on contact with soil, and is of little benefit to plants. However, this source generally is used as a spot foliar spray to correct Fe deficiencies, although more than one application may be required for severe cases of Fe chlorosis. Commercial Fe chelates are effective Fe sources, but they are also quite expensive; thus, their use is limited to high value crops.

Hydrophilic polymers have been used to effectively increase Fe availability to grain sorghum in greenhouse experiments conducted at TVA. In one experiment (8), dry matter production was highest with banded FeEDDHA or $FeSO_4$ + polyacrylamide polymer treatments; Fe uptake was highest with FeEDDHA, but was similar across all polymer-$FeSO_4$ formulations. Post harvest examination of the fertilizer bands revealed that the two most effective polymer formulations remained intact as a gel in the soil after six weeks' growth. However, the hydrated gels used in the experiment were viscous and difficult to apply to the soil and would require specialized application equipment if used commercially. A second experiment (9) was conducted to determine crop response to granular formulations of $FeSO_4$ + polymers. However, none of these products were effective Fe sources, possibly due to limited gel formation in soil and inadequate protection of the contained Fe from soil reactions. Additional results of experiments conducted at TVA are described in the following section.

METHODS AND RESULTS

Nitrogen (Ref. 5, 7)

Experiment 1

A leaching test was conducted to determine the effectiveness of various gel-forming polymers on reducing N leaching when mixed with UAN solutions. Urea ammonium nitrate solution (32% N) was used to hydrate a variety of gel-type N fertilizers. The treatments (1.3 g N/pot), including UAN alone, were band-applied to soil in plastic pots. All treatment pots were leached weekly for six weeks; the leachate volumes were measured and the concentration of N constituents was determined. There were no significant differences in losses of NO_3, NH_4, or urea, so only total N losses are reported here.

Most of the polymer-UAN gels reduced N leaching compared with UAN alone during the first three to four weeks (Figs. 1-3). After this time, losses were almost equal to N lost from the UAN alone; differences among polymers in effectiveness in reducing N loss were not significant.

Increased viscosity of the gelled N sources generally resulted in reduced N losses (Figs. 4-6). However, the difference in N retention between the two mixtures of the gels was not great. The gels formulated at 15000 cpoise were very viscous; thus, there appeared to be little advantage in using this formulation over the less viscous fertilizers.

Soil sterilization resulted in a 10 to 45% reduction in the amount of N leached compared to UAN alone. This indicated that microbial degradation of the gel matrix, with subsequent reduced effectiveness of the gel, would have to be considered before using some polymers in an unsterile field situation. The N loss could not be attributed to microbial immobilization of N since N losses from UAN were similar in sterile and nonsterile soil.

Experiment 2

The addition of gel-type polymers to fluid UAN fertilizer was tested as a means of increasing plant growth and thus reducing fertilizer N loss. Five gels of different chemical composition were applied to leaching columns and sorghum sudangrass was grown for five weeks. The treatments and gel-type polymers used in the experiment are shown in Table 1. The columns were leached with deionized water adequate for plant needs plus 20%, and the excess water was collected and analyzed for N constituents.

Poor physical properties of the soil in the leaching columns prevented collection of representative leaching fractions by the third week of the experiment; thus, this part of the experiment was terminated.

Plant yields were increased up to 35% at final harvest with polymer additions to the fertilizer solution (Fig. 7). However, large variations in the yield data prevented meaningful statistical comparisons among treatments, and no differences in yield were detected. Nitrogen uptake in the plants treated with gelled N fertilizer was up to 50% greater than with UAN alone, and almost double that of the control with the HPG60-X polymer (Fig. 8).

Experiment 3

Five guar-derived gel fertilizers at three viscosities were band applied to uncropped soil and fescue sod to further study N leaching losses and plant N uptake from gelled N sources. Leachates were collected and analyzed weekly for N constituents; the fescue was harvested at six weeks and analyzed for total N Content.

All of the gelled N treatments reduced N leaching compared with UAN alone (Table 2). Increasing gel viscosity had a slight, but nonsignificant effect, on reducing N losses. Yields and N uptake in fescue were higher with the gelled fertilizers than with UAN applied alone. A treatment of chemically modified guar + UAN resulted in 12 to 40% greater yields than with the other gelled fertilizer treatments.

METHODS AND RESULTS

Iron (Ref. 8, 9)

A series of laboratory and greenhouse experiments was conducted to determine the reactions of polymer-Fe products in soil and their effectiveness as Fe sources for grain sorghum. Four experiments are discussed here. The soil used in these studies was a calcareous, Fe deficient soil from Nebraska with a pH of 7.7. The Fe sources were FeEDDHA, FeSO4, and Fe sulfate + polymer formulations.

Laboratory Experiment 1

Sixteen granular polymer-Fe products were prepared to contain a polymer, Fe source ($FeSO_4$ or $Fe_2(SO_4)_3$), talc, and citric acid or gum acacia. The granules were subjected to a wetting, drying, and wetting cycle in soil for 26 days. Granules and surrounding soil were removed periodically for observation.

Ten of the products hydrated to form gels during the first seven days. An orange "halo," radiating outward from the granules into the soil, was noted around eight products. This indicated that Fe may have been chelated by the citric acid and diffused into the soil. Most of the granules dehydrated when the soil dried; however, rehydration of some products was evident after the soil was rewetted. The products that appeared to have favorable chemical and physical properties were further tested in the greenhouse.

Greenhouse Experiment 4

All granular products containing citric acid effectively prevented chlorosis in grain sorghum during the growth period (Table 3). Forage yields and Fe uptake were significantly higher with the formulations containing citric acid. After harvest, the texture of the fertilizer bands containing citric acid was gelatinous, with one exception, while the bands without citric acid were crumbly. Gelling did not appear to be related to the Fe source. A diffuse orange zone was present around the citric acid-containing bands, as was noted in the laboratory experiment; this may have indicated diffusion of Fe from the gel band into the surrounding soil. The magnitude of Fe diffusion from the bands containing citric acid was much greater than from bands without citric acid.

Libratory Experiment 2

In an effort to simplify the preparation of polymer-Fe products, polymer gels containing only Fe and citric acid were dried and crushed into particles. These particles were band applied to soil in containers and subjected to a wetting/drying/wetting cycle over a three-week period. The soil was periodically removed intact from the containers and sliced to observe gel hydration.

The particles of each product had coalesced into continuous, hydrated gel bands after one week. An orange-colored zone present around the bands indicated diffusion of Fe from the gel band into the surrounding soil. There was no indication of significant band dehydration even though the soil had dried somewhat by the end of the first week. There was essentially no change in band characteristics due to an additional wetting and drying cycle during the second and third week.

These results suggested that dried gel particles may persist in a hydrated state in soil longer than granular products. Thus, these products might offer an advantage over granular products since contained Fe would be isolated from soil reactions longer and possibly maintained in plant available form for a longer period.

Greenhouse Experiment 5

The dried gel particle products used in Lab. Exp. 2 were band applied to the same soil at a rate of 24 mg Fe/pot, and grain sorghum was grown for four weeks. The products resulted in higher yields and greater Fe uptake in grain sorghum than did FeEDDHA (Table 4). Dry matter production and Fe uptake with the gel particles averaged 32% and 34% more than with FeEDDHA. Post harvest examination of the fertilizer bands revealed intact, continuous gelled bands; a diffuse orange zone was present in the soil around the bands, as observed earlier. Root growth was profuse and concentrated in the gel band and in the orange zone around the bands. These results suggest that some granular polymer-$FeSO_4$ products and particles of dried, Fe-containing gels may be effective Fe sources for grain sorghum.

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Table 1. Treatments and gel-type polymers used in Exp. 2.

Treatment	Polymer description
1. No added N	--
2. UAN	--
3. G-50	Guar derivative
4. Hydrosorb®	Potassium polyacrylate
5. Aquastore®	Cross-linked polyacrylamide
6. N-Gel®	Nonionic cellulose ether
7. HPG60-GX	Substituted guar derivative

Table 2. The effect of gel-type fertilizer additions on N leaching from uncropped pots during a six-week period, and yield and N concentrations of fescue (Exp. 3).

Polymer[1]	Viscosity	Weeks after application 1	 2	 3	Yield,[2] g/pot	Tissue N, %
		N Leached (% of applied)				
UAN Alone	---	57.9	61.1	85.5	1.42 b	5.06 bc
Reap 100®	2500	44.8	58.0	85.6	1.61 ab	5.78 a
Reap 100®	5000	41.1	54.7	80.8	1.48 ab	5.37 abc
Reap 100®	7500	46.3	57.5	82.8	1.42 b	5.48 ab
Reap 200A®	2500	44.4	56.8	84.9	1.71 ab	5.31 abc
Reap 200A®	5000	41.7	55.7	83.7	1.39 b	5.48 ab
Reap 200A®	7500	39.0	53.5	80.1	1.51 ab	5.26 bc
Reap 200B®	2500	44.8	58.7	83.7	1.58 ab	4.96 c
Reap 200B®	5000	42.5	57.7	82.6	1.67 ab	5.25 bc
Reap 200B®	7500	40.0	53.9	77.3	1.27 b	5.34 abc
CMG	5000	46.3	59.6	82.3	2.04 a	5.42 abc
CAT	5000	41.6	57.8	81.4	1.78 ab	5.32 abc

[1] Reap 100® is a chemically modified guar (CMG); Reap 200A® and Reap 200B® are stabilized guar; CMG is an anionic form of Reap 100®; CAT is a cationic form of Reap 100®.

[2] Means in a column followed by the same letter are not significantly different ($p = 0.05$).

Table 3. Grain sorghum response to band applications of granular products of iron sulfates and polymers with or without citric acid, and characteristics of the fertilizer bands after harvest (Greenhouse Exp. 4).

				Crop response		Fertilizer band	
Fe Source	Polymer	Citric acid	Plant chlorosis	Yield, g/pot	Fe uptake, mg/pot	Texture[1]	Periphery[2] mm
	-	-	+	0.94	0.03	-	-
$FeSO_4$	Alcosorb®	-	+	1.13	0.08	C	2
$FeSO_4$	Experimental	-	+	1.19	0.06	C	2
$Fe_2(SO_4)_3$	Alcosorb®	-	+	1.37	0.19	C	3
$Fe_2(SO_4)_3$	Experimental	-	+	1.00	0.10	G	2
$FeSO_4$	Alcosorb®	+	-	1.60	0.16	C	20
$FeSO_4$	Experimental	+	-	1.83	0.15	G	20
$Fe_2(SO_4)_3$	Alcosorb®	+	-	1.78	0.15	G	25
$Fe_2(SO_4)_3$	Aquastore®	+	-	1.90	0.18	G	17
LSD (0.05)				0.43	0.05		

[1] C - crumbly; G - gelatinous
[2] Orange color in soil

Table 4. Grain sorghum response to band applications of particles of dried, Fe-containing gels containing citric acid (Greenhouse Exp. 5).

Product[1]	Polymer	Yield,[2] g/pot	Fe uptake,[2] mg/pot
Control	—	1.38 c	0.09 c
FeEDDHA	—	2.80 b	0.19 b
A	Experimental "E"	3.91 a	0.33 a
B	Aquastore®	3.78 a	0.32 a
C	Hydrosorb®	3.77 a	0.29 ab
D	Experimental "J"	3.73 a	0.28 ab
E	Salsorb RD®	3.60 a	0.27 ab
F	Salsorb®	3.48 a	0.23 ab

[1] Product formulation: 10% polymer, 10% citric acid, 1% Fe.
[2] Means in a column followed by the same letter are not significantly different ($p = 0.05$).

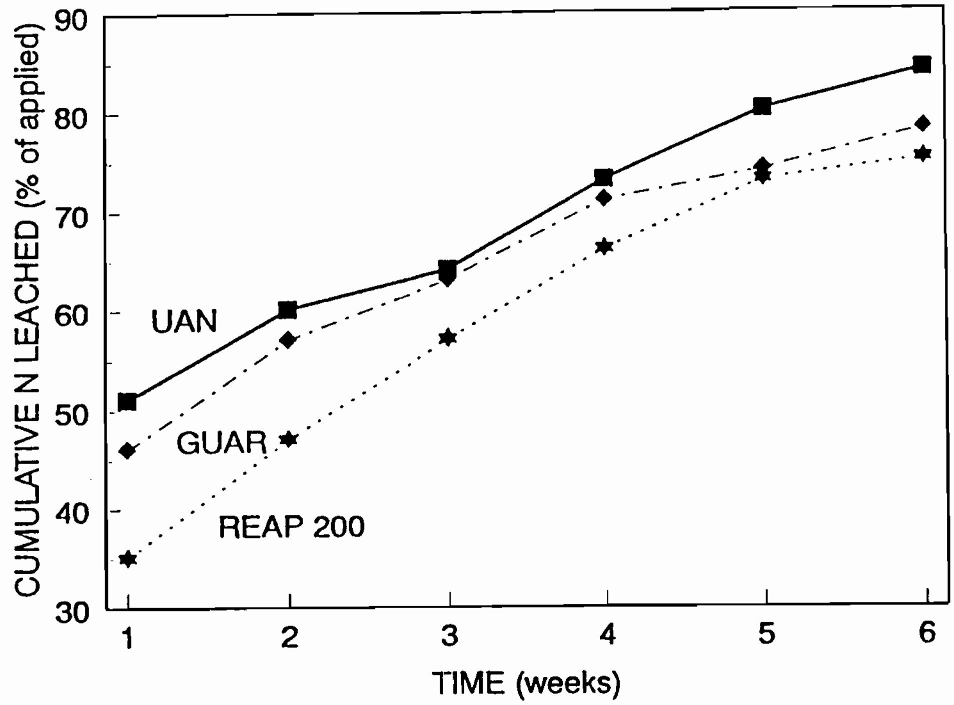

Figure 1. Nitrogen leaching losses from guar-derived gel fertilizers compared with UAN alone during a six-week leaching period.

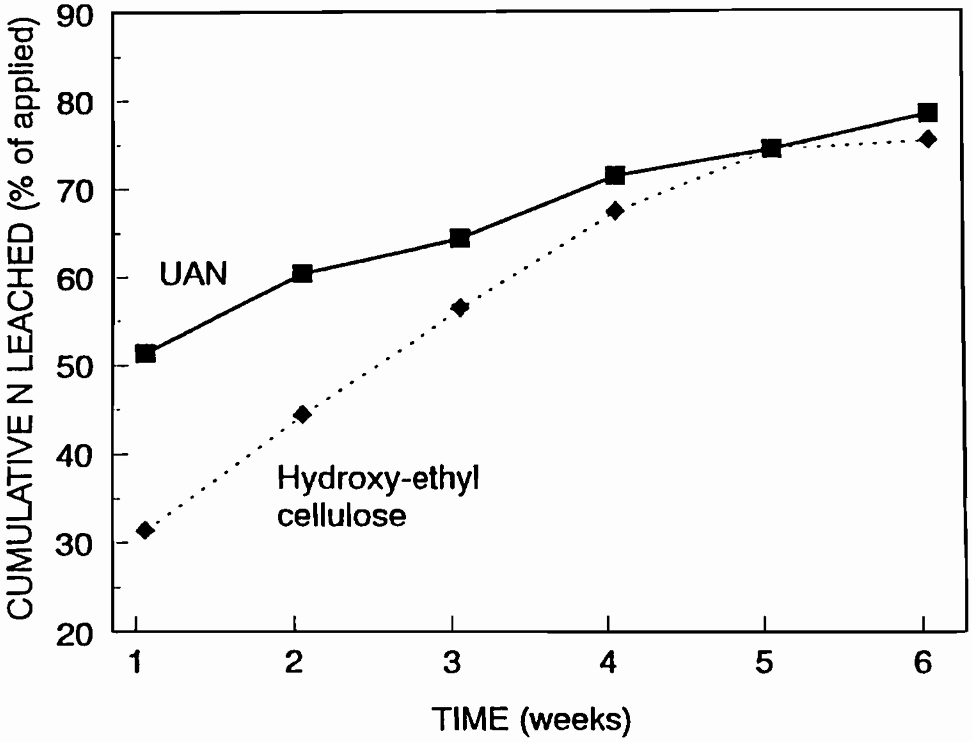

Figure 2. Nitrogen leaching losses from HEC gel fertilizers compared with UAN alone during a six-week leaching period.

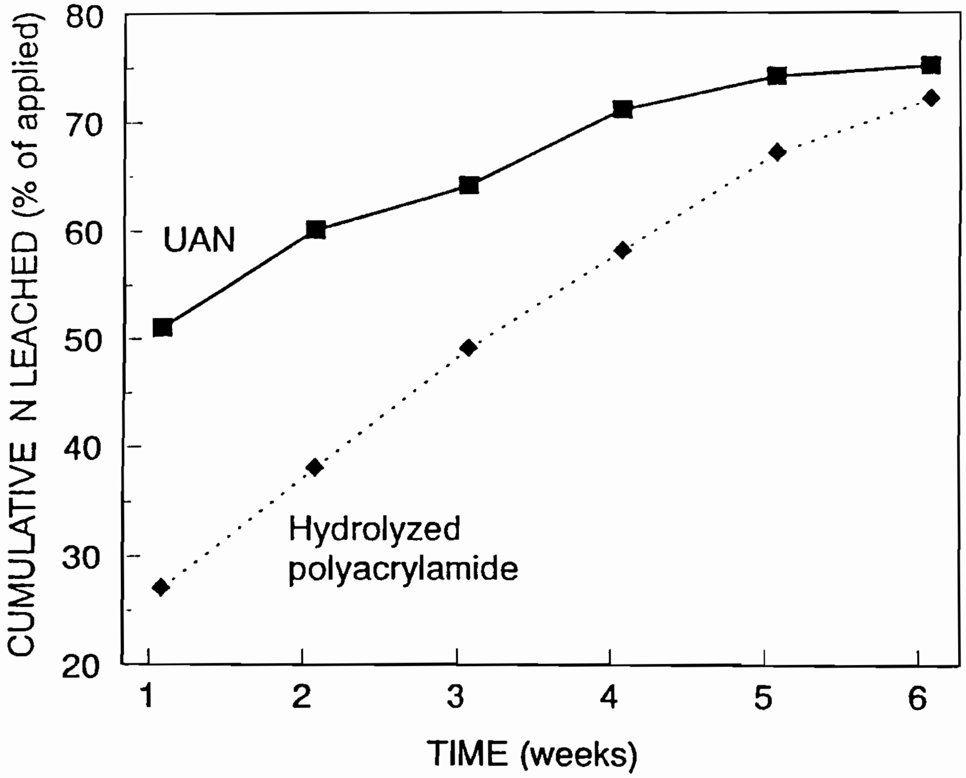

Figure 3. Nitrogen leaching losses from hydrolyzed PAM gel fertilizers compared with UAN alone during a six-week leaching period.

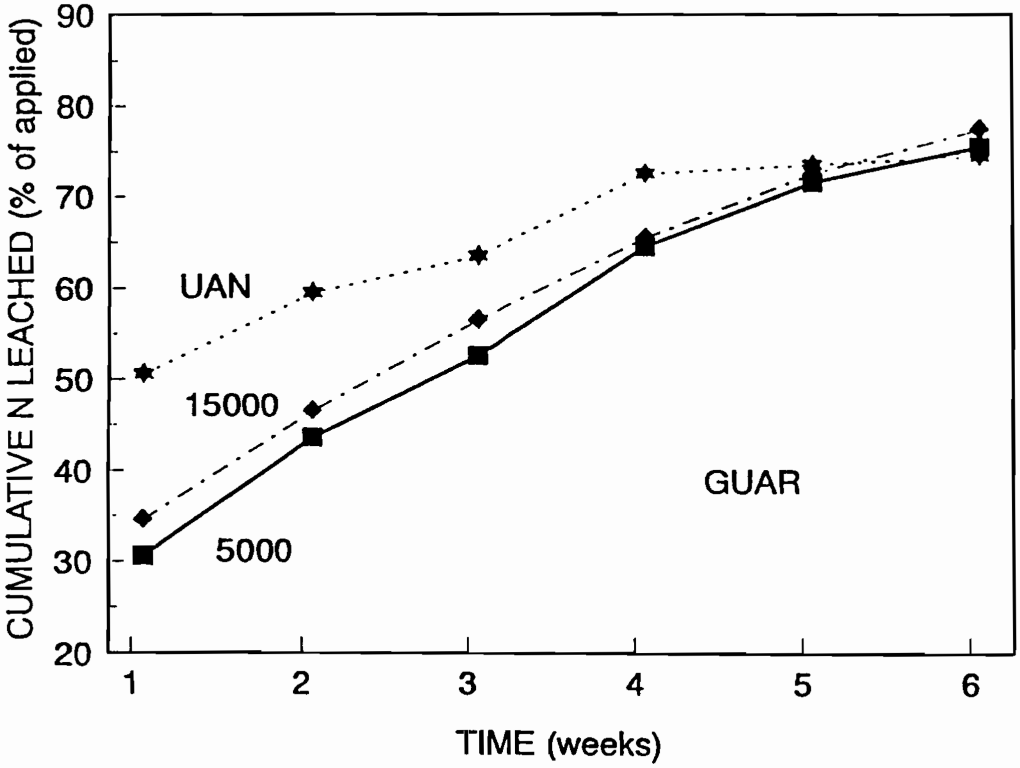

Figure 4. Effect of viscosity on N leaching losses from guar-derived gel fertilizers compared with UAN alone during a six-week leaching period.

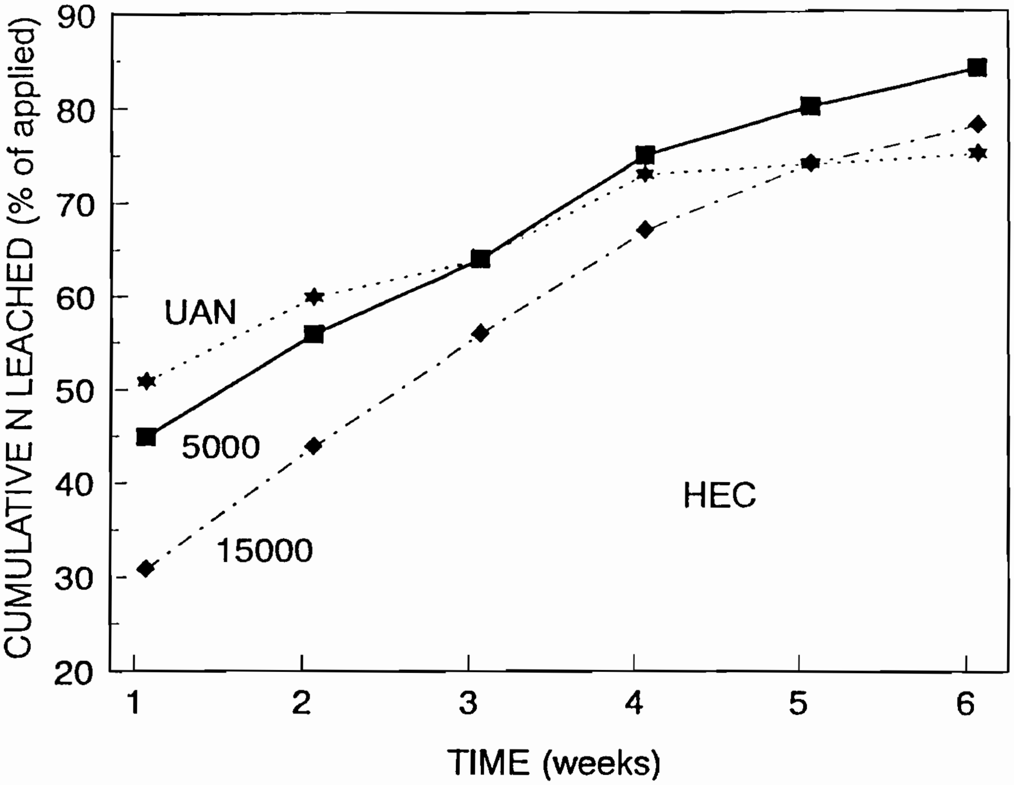

Figure 5. Effect of viscosity on N leaching losses from HEC gel fertilizers compared with UAN alone during a six-week leaching period.

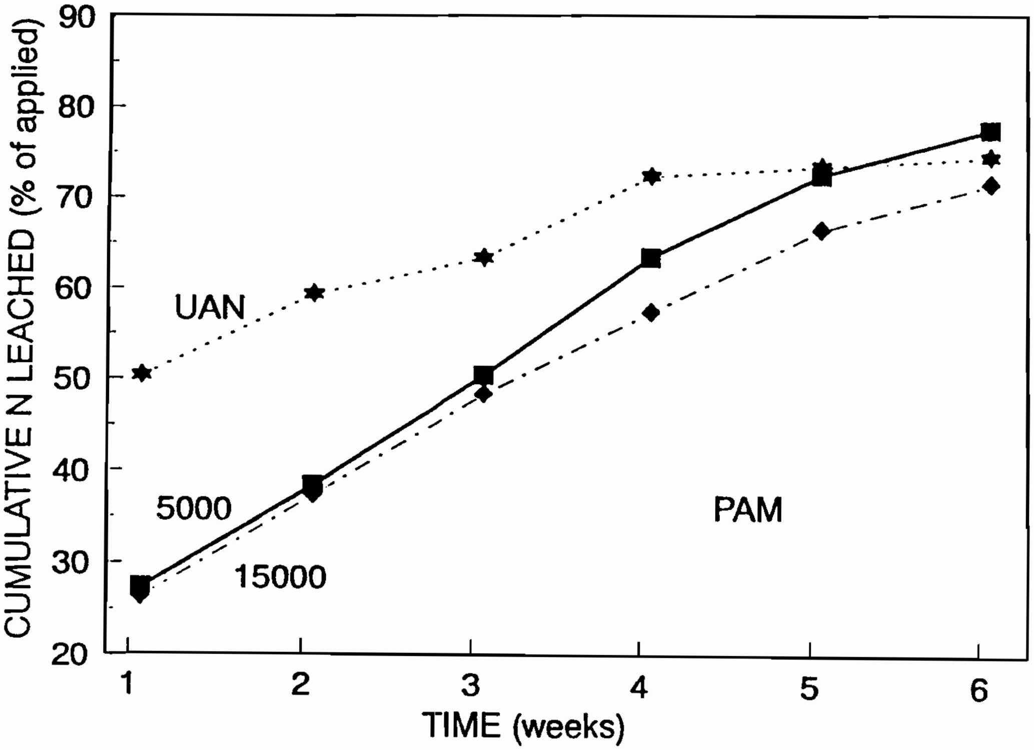

Figure 6. Effect of viscosity on N leaching losses from hydrolyzed PAM gel fertilizers compared with UAN alone during a six-week leaching period.

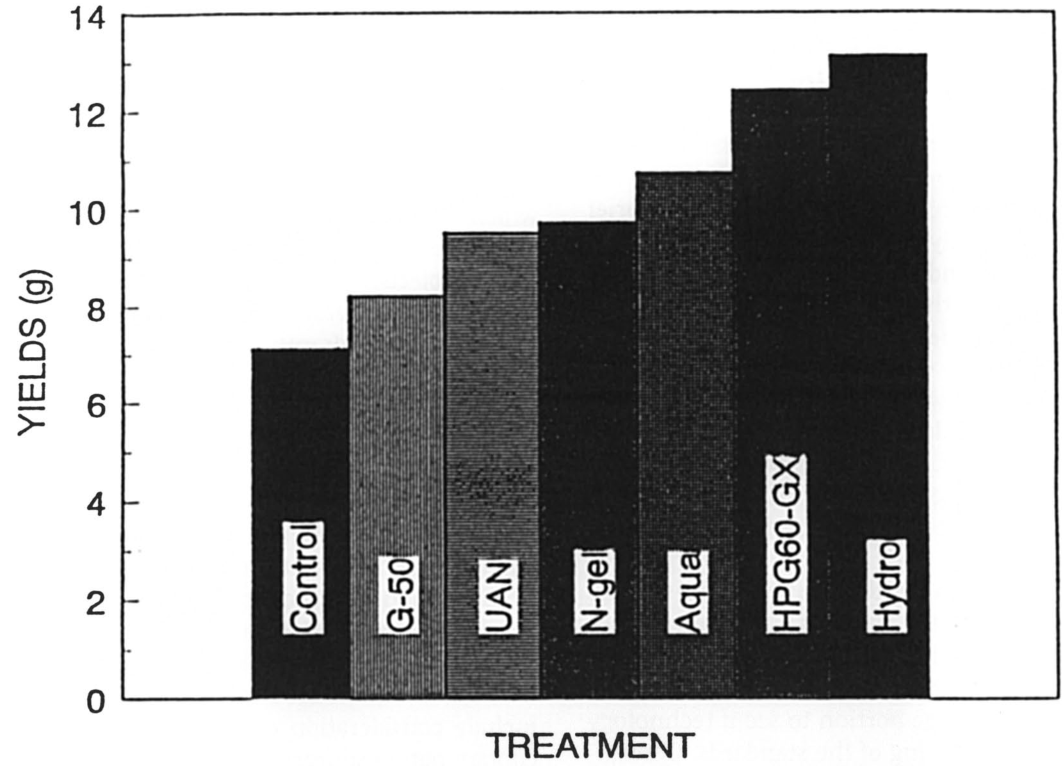

Figure 7. Yield of sorghum sudangrass forage as affected by gel-type polymer fertilizers.

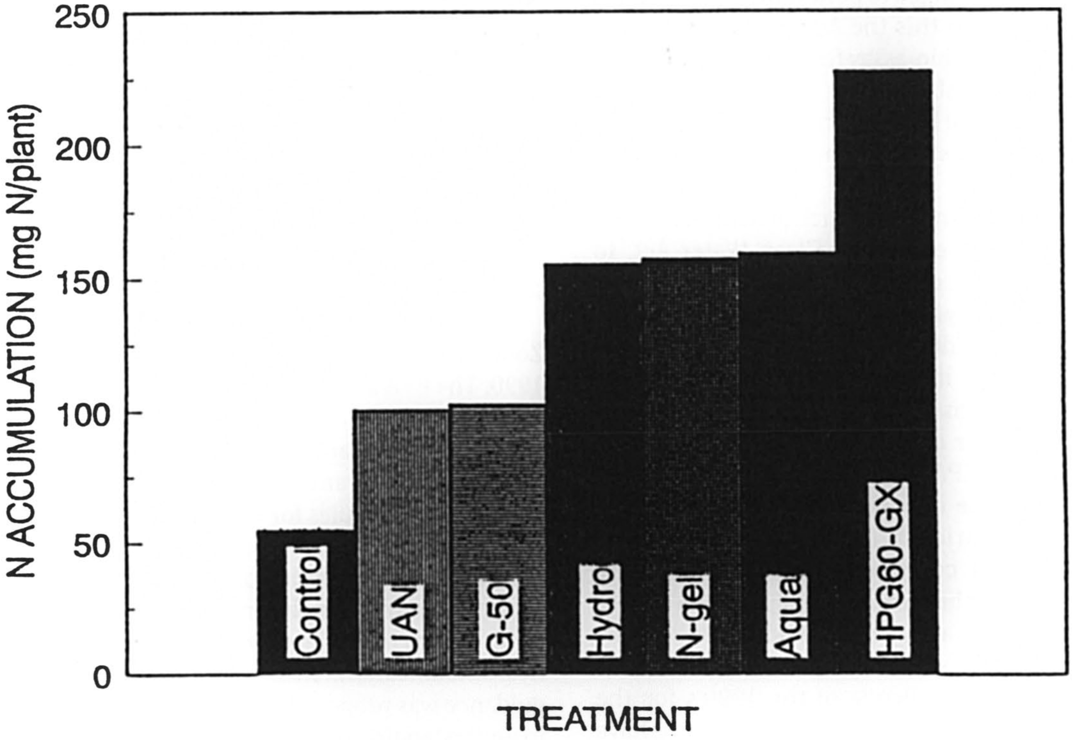

Figure 8. Nitrogen uptake in sorghum sudangrass forage as affected by gel-type polymer fertilizers.

Regulation Update - Clean Water & Phosphogypsum

Karl Johnson
The Fertilizer Institute

I was asked to provide an update on regulatory activities under the Clean Water Act and the latest regulatory status of phosphogypsum. My plan is to cover a brief number of issues hopefully those of particular interest to the fertilizer industry - and spare you of the long laundry list of Clean Water Act activities that could be covered.

1992 marks the twentieth anniversary of the landmark amendments to the Federal Water Pollution Control Act that have come to be known as the Clean Water Act. The Clean Water Act was heralded as a most significant piece of environmental legislation, and it truly was. Clean water goals, such as zero discharge of pollutants, were set and the U.S. Environmental Protection Agency (EPA) given authority to pursue them.

Much has been accomplished. Few, if any, point sources of pollutant discharges to the Nation's waterways are not subject to limitations by this time. The EPA has completed a first round of effluent standards for most industrial sources and revisited a large portion to see if technology advances warrant a tightening of the standards. Conventional pollutants, such as suspended solids, nutrients and pollutants measured by biochemical oxygen demand (BOD) or chemical oxygen demand (COD) were addressed first. The emphasis has now changed to pollutants labeled "toxic pollutants". Coupled with this the Agency has been on a course aimed at requiring bio-assay testing of all industrial effluents. This means that not only must the discharge meet the technology based levels for constituents, but also certain aquatic species must survive in what remains in the effluent.

As you can no doubt imagine, much attention is being given, in this twentieth year of the Clean Water Act, to evaluating progress and looking for the challenges of the future. In recent testimony before the U.S. Senate, LuJuana Wilcher, EPA Assistant Administrator For Water, identified nonpoint pollution, including runoff from agricultural and urban areas as the "single most significant remaining cause of water quality impairment. According to studies assessed by EPA, agricultural activities alone contribute to 60% of the impairments in rivers, 57% in lakes, and 18% in estuaries. Nutrients and siltation are pointed to as the most common pollutants. These are impressive numbers, but bear careful study. I believe there are legitimate questions about how serious the impairments are and how extensive. Perhaps answers to these questions represent the challenge of the 1990's for the agricultural community. But, nonetheless, the claims have been made and the EPA is organized to address them!

Initiatives in the nonpoint arena are not new, of course. The 1972 Clean Water Act set in motion nonpoint source pollution management planning (Under Section 208) efforts by the States. But, as evidence of more recent and greater emphasis on nonpoint source pollution we can cite the 1987 Water Quality Act amendments which have led to the assessment of water quality impairments I mentioned earlier. One doesn't have to look long to find evidence of such assessments and new initiatives on nonpoint source pollution issues. For example, a Rural Clean Water Program Symposium was held in September which featured the results of the 10 year experimental Rural Clean Water Program (RCWP). Findings from 21 RCWP projects, which included the effectiveness of nonpoint source control measures, were presented.

Regional programs, such as the Chesapeake Bay Program, are calling attention to agricultural activities and setting goals for nutrient reduction (e.g. 40% reduction in nitrogen). More are on the way, as evidenced by a symposium celebrating the Year Of The Gulf slated for December in Florida. It will include papers on habitat degradation, coastal and shoreline erosion and public health issues. It is expected that nonpoint source pollution will be discussed in connection with these topics.

Looking a little further ahead, the EPA is working on a Comprehensive State Ground Water Protection Guidance that is expected to be finalized in early 1993. This will include consideration of nonpoint sources as potential contamination sources.

As programs are developed to address nonpoint pollution, one of the issues the fertilizer industry has to address is the tendency of the EPA and environmental groups to point to reduction in fertilizer use as the key element in bringing nutrients under control, whether in surface waters or in groundwater. I believe they view it as the most readily controllable of the many sources of nutrients. Within the fertilizer industry a key resource in addressing these issues is The Fertilizer Institute's (TFI) Agronomy Task Force. The past two years have been particularly busy ones for this group as nonpoint source issues have been considered by the U.S. Congress and in various actions taken by the EPA.

One example I would mention stems from the Coastal Zone Management Act Reauthorization Amendments of 1990. The EPA and the National Oceanic and Atmospheric Administration (NOAA) issued a draft joint guidance for the development and approval of coastal nonpoint pollution control programs. The proposed guidance would provide the ground rules for implementation in coastal areas of technology - based management measures for reducing nonpoint source pollution from major categories of nonpoint sources, including agriculture, forestry, urban areas, marinas and recreational boating, and hydromodification. In a separate document a program guidance was proposed which is aimed at assisting States in understanding how to develop State nonpoint programs in coastal zone areas that conform with EPA's best management practices. In commenting on these documents, TFI expressed the fertilizer industry's continuing support of the adoption of farm level, site specific nutrient management plans which consider all nutrient sources, whether animal wastes, commercial fertilizer, sewage sludge, industrial treatment effluent or legume organic sources. TFI urged EPA not to evaluate the success of farm nutrient management measures or nutrient management plans solely on one criterion, i.e., reduction in the amount of nutrients being applied to land. Many studies demonstrating that fertilizer application was not the key determinant were included to support TFI's position.

The final version of the coastal zone management guidance documents are expected to be released this fall. EPA reports that they are currently under review at the Office of Management and Budget - which is usually the last hurdle to be crossed.

Turning to regulatory developments in the point source area, the recently issued federal stormwater discharge permit program has been in the spotlight. Discharges of contaminated stormwater runoff was recognized as EPA developed standards for process wastewater discharges for many industries during the 1970's and 1980's. But, with few exceptions, stormwater was not addressed. In part, this was due to placing higher priority on the process related sources, and, in part, due to the difficulty in prescribing uniform standards for events so variable. Now, prompted by Congress and litigation bought by environmental groups, EPA has put out nationwide rules requiring stormwater runoff from industrial sites to be subject to permits. Although this program has caused much concern in major industries and small business in general, my assessment is that the fertilizer industry is not acutely affected by the federal program requirements. This is due mostly to the fact that many major plants have already had stormwater considered on a case by case basis as they obtained permits for process related discharges. The industry wide impact is also lessened by the fact that EPA's definition of industrial activity did not encompass fertilizer dealerships. However, my assessment should be tempered with the reality that states may be more inclusive in their implementation of the federal program. Also, dealerships may not be out of the woods in the long run at the federal level either. In September, EPA announced a Phase II effort in which they intend to consider expanding the coverage of the stormwater permit program to include retail and commercial activities.

What's ahead for fertilizer industry with regard to process related point sources? Based on EPA's announced development schedule for new and revised effluent guidelines, it appears things will be status quo for sometime. The most recent plan was published September 8, 1992 (57 Fed Reg 41000) and fertilizer point source categories are not listed.

Fertilizer facilities in some states can expect to see new permit application and issuance fees assessed for permits issued by the federal government. EPA plans to propose the new structure in December. As of early September there are 11 states, including Florida and Louisiana, which are not authorized to issue National Pollutant Discharge Elimination System (NPDES) permits.

Another rule expected within the next year will be of interest to many in the fertilizer industry. It appears that those who have interest in marketing products made using municipal sewage sludge can expect to see the long awaited technical standards. These standards will establish the requirements for sewage sludge that is applied to the land and distributed and marketed for application to the land.

It is reported that in the latest draft of the final rule EPA has raised the pollutant ceiling concentrations significantly for sludge destined for land application. They have dropped organic pollutant limitations. The 50 metric ton per hectare application cap is replaced by an "agronomic rate" test based on nitrogen uptake. Cumulative loading rates for 10 metals remain, but are significantly less stringent than the proposed rule. Also, a category of "super clean sludge" is provided. Sludges meeting the limits for this would be able to marketed without record keeping on loading rates or life of site.

It will be interesting to compare the cumulative loading rates of the new rule with those that would result from typical commercial fertilizer application to see what implications can be drawn. If EPA meets it's last reported schedule, the final internal review process should be underway now. EPA is under court order to issue rules by November 23, 1992.

Before I leave the Clean Water Act portion of my presentation I want to make a comment about the coming legislative session. The Clean Water Act is due for reauthorization. Of course, there is always concern about new program initiatives whenever the Congress revisits existing legislation. But, there is another dimension, in this era of budget deficits. It is the potential for new taxes! One proposal the fertilizer and agricultural chemical industry will be tracking closely is a plan by Congressman Gerry Studds (D, MA) to introduce a bill that would call for taxes to fund a National Clean Water Investment Corporation that would, in turn, fund state and local municipal sewage treatment plant construction and other clean water projects. His plan calls for collecting $3 billion through "polluter pays" taxes: $2 billion per year in assessment on wastewater discharges by industrial facilities, and $1 billion per year in taxes on fertilizer and pesticides, ($500 million each).

Under this scenario the tax on ammonia would be about $27 per ton, urea $16 per ton, DAP $22 per ton and on a 10-10-10 NPK about $7 per ton. In addition to that, the tax on water discharges at fertilizer plants could well exceed $250 million per year. Under this proposal American agriculture would be hit with over $1.25 billion per year to pay for clean up of pollution which is largely unrelated to agriculture.

With that sobering note I will now turn to the other topic I was asked to brief you on - status of EPA regulation of the phosphogypsum by-product of wet process phosphoric acid production. I suspect that most here today are aware that phosphate rock normally contains low levels of uranium. In the phosphoric acid process a portion of the radioactive material present in the rock separates and goes with the by-product phosphogypsum. In time, radon, a gaseous decay product, is formed.

Due to a concern about possible health effects caused by radon emissions from the large stacks of phosphogypsum in storage at phosphate plants, the EPA conducted extensive studies of the emissions and performed risk estimates. They determined that current management practice offered sufficient protection but wanted to protect against chances of increased risk. Therefore they set an emission limit for radon of 20 picocuries per square meter per second. This standard permits the phosphate industry to manage the phosphogypsum at the plant sites in the same manor as they had. However, in doing so, EPA wrote the rule such that the only thing that could be done with phosphogypsum was to stack it or place it in mine cuts. This prohibited it's use in agriculture (as a calcium or sulfur source) and for any other use, including research and development.

TFI, acting on behalf of the phosphate industry petitioned EPA to reconsider this overly stringent ruling. We submitted extensive information and risk estimates demonstrating the low level of risk involved in phosphogypsum use. Two and a half years later, June 3, 1992, EPA published a decision on the petition which provides for agricultural use of certain phosphogypsum, limited R & D uses, and requires a case by case application and review of any other use.

To qualify for agricultural uses the radium concentration in phosphogypsum must not exceed an average of 10 picocuries per gram. Use in R & D must be limited to 700 pounds per activity Testing and certification of the radium content is required along with record keeping.

The phosphate industry has concerns that EPA is still too restrictive, i.e., overly conservative in modeling of risk, and that the requirements will discourage future research of possible beneficial uses of the phosphogypsum resource. Accordingly, on August 3, 1992 TFI petitioned EPA again to reconsider their decision. While we await their response, it is possible to use phosphogypsum in agriculture, provided it meets the radium limitation. I understand the North Florida, North Carolina and possibly certain western sources qualify, but the vast quantities in Central Florida do not.

Fertilizers – Misperceptions And The Need For Public Enlightenment

Harold D. Blenkhorn
Fertilizer Technology Consultant

Since its inception forty-two years ago, The Fertilizer Industry Round Table has served as a forum for the exchange and dissemination of information on various aspects of the manufacture, distribution and end-use of fertilizers. Considering the numerous topics that have been covered in Round Table programs over the years, very seldom has there been a presentation covering the basic "whys and wherefores" of fertilizers and their importance in agriculture. Probably the reason is that the chemical engineers, agronomists, and other participants in our annual programs have always assumed that they were dealing with one of the world's vital commodities.

Simply stated, fertilizers are materials which supply mineral elements for the growing of crops. The importance of fertilizers is easily understood and appreciated by anyone with a basic knowledge of agriculture and natural sciences, but there are a surprising, and indeed, alarming number of people who apparently do not possess such knowledge. There are many, in fact, who question the value and need for fertilizers.

Fertilizers have an image problem that stems from the fact that they are man-made chemical compounds. They are produced in reaction vessels or by purification processes; they usually have clearly defined chemical formulas and are known by such names as diammonium phosphate, potassium chloride, etc. Thus, they are chemicals, and in the minds of a large segment of the general public, like all chemicals used in agriculture, they are an abomination or, at least, to be regarded with suspicion.

Why is then such a wide-spread skepticism and often outright fear of the chemicals used in modern agriculture? A colorful American personality and homespun philosopher of the past, Will Rogers, once said, "All I know is what I read in the newspapers." On the surface this doesn't sound like a very profound statement, but I think we can be assured that old Will had something in mind. Perhaps he was telling us that shallow reading habits are likely to leave us ill-informed.

Common Perceptions of Fertilizers

The prevailing negative attitude toward fertilizers is constantly reinforced by antichemical articles which regularly appear in the popular press. Specific examples are not difficult to find. *Figure 1.* shows a selection of titles of newspaper and magazine articles which I have spotted during the past few months.

What sort of comments on fertilizers would one expect from a feature under the title of *"The Dangers of Chemical Fertilizers"*, or *"Fertilizer Folly"*. From articles such as these and others which I have collected over the past several years, I have gleaned the following:

- Chemical fertilizers are bad because their residues get into the food chain.
- Plant growth from chemical fertilizers is unnatural.
- Chemical fertilizers kill soil bacteria and earth worms.
- Intensive chemical fertilizing hardens the soil so that increasingly powerful machines are required for cultivation.
- Chemical nitrogen fertilizers are turning the prairies into a desert.
- Plants growing in highly chemicalized soil do not have natural resistance to disease.
- Crops grown organically have better flavor, better nutritional value, and longer shelf-life than those which are grown chemically.
- Artificial fertilizer introduces to the soil various unnecessary and even poisonous elements that are added to make them soluble.
- Ultimately, it becomes apparent that synthetic fertilizers are not only damaging, they are also unnecessary.

These pronouncements are, in some cases, opinions and observations of people who write letters to the editors of newspapers and magazines for the purpose of making public statements about the evils of chemical fertilizers and the greedy corporations that sell them. In other instances, they were taken from "authoritative" books and articles on "organic" and "ecological" agriculture. Some of these statements might be somewhat debatable, but for the most part they are simply preposterous. At best, they are examples of an almost pathetic ignorance of what fertilizers are, and how and why they are used. But at worst, they serve to spread and perpetuate misinformation and gross inaccuracies about fertilizers.

Where did all these strange notions come from? Where, for example, did any one ever get the idea that fertilizers kill earthworms? I am inclined to attribute many of the persistent myths surrounding fertilizers to two books which were published about fifty years ago.

In 1940, Sir Albert Howard, a British Colonial Service Agriculturist and avid follower of what was then known as the "humus school", published a book under the title *"An Agricultural Testament"*. This was a lengthy piece of work in which the author set forth his opinions as to why all chemicals – artificial fertilizers, insecticides, fungicides, etc., – should be entirely rejected and why crops should be grown exclusively with composted plant residues and animal manures.

Another member of the humus school was Lady Eve Balfour who published *"The Living Soil"* in 1943. This book dealt largely with the adverse effects of chemicals on the microflora and fauna of the soil. One of her pet theories was that chemical fertilizers hastened the decomposition of organic matter, thereby depleting the natural supply of nitrogen in the soil.

These two books, particularly Howard's *"Agricultural Testament"*, caused a sensation in agricultural circles. Then, as now, there were those who believed that "raw chemicals" were unnatural and harmful. They welcomed Howard's book with an, "I told you so" attitude. As might be expected, there was also a considerable reaction from the scientific community. Howard had stated that an example of the evils of chemicals was the American Dust Bowl of the 1930's – the cause of the Dust Bowl was the use of chemical NPKs which had "disrupted the natural life cycles of the soil". Upon receiving this remarkable piece of information, a scientist at the Rothamsted Experimental Station, looked up the statistics on American fertilizer consumption and found that the average for the States of Kansas, Colorado and Oklahoma was 50 pounds of ammonium sulphate, 1500 pounds of superphosphate and 40 pounds of muriate of potash per 1000 ACRES. In those days, the phrases of Winston Churchill were ringing in everyone's ears – the scientist was easily inspired to observe that, " never was so much attributed to so little".

One notable reaction to the Howard/Balfour pro-humus argument was an excellent book published in 1944 under the title *"Chemicals, Humus and the Soil"* by an obviously competent scientist, Donald P. Hopkins. This book was, as the sub-title states, "a sample presentation of contemporary knowledge and opinions about fertilizers, manures and soil fertility".

Hopkins reviewed and discussed the writings of Howard and Balfour at considerable length. One of the direct quotations from Howard's book serves to illustrate his amazingly vehement attitude towards chemical fertilizers.

"The slow poisoning of the life of the soil by artificial manures is one of the greatest calamities which has befallen agriculture and mankind. The responsibility for this disaster must be shared equally by the disciples of Liebig and by the economic system under which we are living. The experiments of the Broadbalk field showed that increased crops could be obtained by skillful use of chemicals. Industry at once manufactured these manures and organized their sale.

It is quite apparent that Sir Albert had no use for chemical fertilizers, nor for those who are engaged in their manufacture and distribution. His reference to "Liebig" refers to the German chemist who first recognized that plants are nourished from dissolved mineral elements. "Broadbalk field" refers to the Rothamsted Experimental Station. Both will be discussed later in this presentation.

The thesis of the humus school as presented in Howard's *"Agricultural. Testament"* is summarized by Hopkins as follows:

1. Nature is the supreme farmer. Nature has never needed artificial fertilizers. We should, therefore, follow suit and leave fertility maintenance to the plan of Nature simply insuring the return to the soil of organic wastes for regeneration by bacteria, worms, etc.

2. All crop yield increases from chemicals are short-term benefits. Plants raised by these means are much more liable to pest and disease attacks, the natural laws of growth having been violated and disturbed. Plant disease will cure itself when plants are raised in humus manures; but plants raised by chemical help are in ever-increasing need of insecticides and further chemical treatments.

3. Comparisons of crops grown on chemicals and on humus manures always favour the latter. The nutritional value of compost-raised crops is higher than that of chemical-raised crops.

There is an unmistakable similarity between the preachings of the humus school of fifty years ago and the perceptions of the organic people of today. Although Sir Albert Howard is now largely forgotten and his "Testament" long out of print, the tarnished reputation of chemicals has been kept alive by more recent organic enthusiasts. J. I. Rodale, founder of the Rodale Press which publishes *"Organic Gardening"* magazine, was an admirer of Howard. One of Rodale's early books – *"Pay Dirt Farming and Gardening with Compost"* (1946), contains an introduction written by Howard. Throughout the text of "Pay Dirt" there are frequent references to Howard, Balfour, and others of the Humus school of their time. Through Rodale, and a succession of more recent books and articles on organic and ecological farming, the misinformation originated by Howard and Balfour has been recycled to the receptive minds of the present generation.

The writings of Belfour and Howard – confirmed, repeated, and embellished in present day anti-fertilizer propaganda – have served to build up a case against fertilizers. This case, however, is based on supposition and preconceived notions rather than on scientific evidence. In many instances, the arguement is completely lacking even in common sense or logic. By a lengthy explanation and presentation of scientific data, each of the previously-noted statements relating to the adverse effects of fertilizers could be conclusively proven to be erroneous, if not ridiculous. To do this, however, would be a time consuming task which is beyond the intended scope of this presentation.

Mistaken ideas are based ignorance, and ignorance is a state of not knowing. Or, as Mark Twain used to say, "The worst kind of ignorance is what you know for sure that just ain't so". It occurred to me that the best approach to clearing up some of the aforementioned misconceptions is to review some widely unknown facts about the history of fertilizers, and what they are and why we use them.

Historical Events

Agriculture, the systematic planting of food crops and domestication of animals, is believed to have had its beginnings about 10,000 years ago. It can be visualized that early man became aware that plant growth could be stimulated by certain substances and that crops grew better in certain locations. Animal excreta and decayed plant and animal matter were known to stimulate plant growth. It was discovered that crops grew well on river deltas, that crops became progressively poorer when grown on the same field for a few years in succession, but would improve after shifting to a new location.

The material most commonly added to the soil to improve the growth of crops was bones, which were known to be used more than 2000 years ago. An interesting historical note on the use of bones as a fertilizer is to be found in the USDA-TVA monograph *"Superphosphate, Its History, Chemistry, and Manufacture"*. Editor K. D. Jacob cites a Welsh manuscript which contains records of events dating back to the first century A.D. It tells of a battle between native Welshmen and invading Romans, in which the Romans were "slaughtered most terribly". After the bones of the vanquished has been picked clean by the wolves and ravens, they were gathered up **and** used as building material for the construction of a prison. The bones ultimately decayed and were reduced to dust -" ... then they carried the remains and put it on the surface of the ploughed land, and from that time they had astonishing crops of wheat, barley and every other grain for many years".

What these ancient people had discovered was that the fertilizing effect of bones was improved when they were reduced to fine particles. This was somewhat of a technological break through but apparently remained unknown to the rest of the world. It presumably did not become common practise because of the means by which the bones were procured and the long-term process of getting them into a pulverized state.

The advantage of grinding bones was rediscovered in the latter part of the 18th century. It was noticed that waste bone dust from the manufacture of knife handles in the cutlery factories of Yorkshire had a stimulating effect on the growth of grass on the fields where it was discarded. This led to the introduction of mills which were designed for the specific purpose of grinding bones for use as a fertilizer. During the early part of the 19th century, "bone manure" was widely used by the farmers of England, to the extent that domestic sources became scarce and imports were required. During the period 1800 to about 1840, it is reported that as much as 100,000 tons of bones were imported into England from Continental Europe. British soil scientists believe that to this day, a portion of the phosphorous contained in the soils of certain farming areas of England can be attributed to the residues of bones which were applied two centuries ago.

The use of bones brought about marginal increases in crop yield, but agricultural productivity at the turn of the 19th century was essentially static. The economist and pioneer demographer, Thomas Robert Malthus, apparently did not hold out much hope for any improvement in the immediate future. In his *"Essay on Population"* in 1798, Malthus made this now famous statement:

> *"The power of population is indefinitely greater than the power in the earth to produce subsistence for man."*

Malthus based his quiet correct conclusions on the agriculture that existed in his time. His lack of confidende in the "power in the earth" was probably due to his having seen the stunted crops that grew in the nutrient-starved soil. The problem was that they didn't know about nutrients. They could do nothing about the power in the earth because they didn't know what it was.

As far as most people were concerned, the question of what made plants grow had been settled about 2000 years earlier by Aristotle, who believed that the nourishment and development of plants was due to the direct assimilation of decayed plant and animal matter. This theory persisted into the 18th century - the usual understanding of why the fertilizing value of bones was improved by grinding was that the fine particles could be more easily ingested by the plant.

Although it wasn't reflected in agricultural productivity, knowledge which would lead to a better understanding of plant growth was gradually coming to light during the early 1800's. Advances in the sciences of chemistry and biology made it possible to uncover many of the clues to the mystery of what made plants grow. Scientists were able to determine the chemical composition of plants and found that live tissue was largely composed of nitrogen, carbon, hydrogen and oxygen. Plant ash consistently contained phosphorous, potassium, calcium, and other mineral elements, indicating that they were somehow involved in plant growth.

The various discoveries leading to an accurate understanding of plant nutrition have been reviewed in detail by Sir John Russel, a distinguished British scientist who wrote extensively on the subject of soils and fertilizers, and served as director of the Rothamsted Experimental Station from the 1920's to the 1940's. During the period of the 1830's the conclusions that could be drawn from the published results of many years of investigation by European scientists are summarized by Russel as follows:

1. The main part of the crop is composed of carbon, oxygen and hydrogen, most, if not all of which comes from the air and from water, and not from the organic matter of the soil.

2. The nitrogen of the crop comes largely, if not entirely, from the soil or from manure.

3. Mineral matter is an essential part of the crop and it comes from the soil or from manure. (Manure in this sense meaning any material applied as a plant nutrient.)

Today, we can recognize that these were highly advanced discoveries, but at that time they caused no particular excitement. The various facts that scientists had learned about plant growth were regarded as rather deep and obscure science with little or no practical value.

Actually, they were well on the way to an understanding of the elusive "power in the earth", but no one knew it.

In the development of scientific knowledge over the centuries, there have fortunately been a few individuals who (as was said of Charles Darwin), "... saw what everyone else had seen, but thought what no one else had thought". In 1840, a German chemistry professor by the name of Justus von Liebig came forward with a unique idea. On the basis of known scientific discoveries, plus his own considerable knowledge, Liebig suggested that crops could be fertilized by the direct application of soluble chemical compounds containing definite amounts of specific mineral elements which by that time were known to be essential for plant growth. It is natural to ask, "Why didn't someone think of this before?". To this question, Sir John Russel's answer was, "This seems simple and obvious now, but to men of Liebig's day it was not: indeed only a genius could have thought of it.

Liebig is generally referred to as the "Father of the Fertilizer Industry". If people of organic inclination wish to hold someone responsible for originating the practise of using chemical compounds as fertilizers, Liebig would be the culprit. There is, however, another individual who runs a very close second to Liebig – that person being the Englishman John Bennet Lawes, who was a pioneer in the manufacture of fertilizers.

Lawes was an Oxford-educated, country squire, who owned a large estate at Rothamsted near London. Like Liebig, Lawes was well informed on current developments in chemistry and plant science, and had a keen interest in seeking improved products for crop fertilization. At that time (Mid-1830's) it was well known that the mineral content (and plant growth agent) of bones was tricalcium phosphate – an insoluble substance which was sparingly available to plants. It was also known that the treatment of bones with a strong acid such as sulphuric would bring about a conversion to water soluble monocalcium phosphate in accordance with the following simplified equation:

$\mathrm{Ca3, (PO4)2, + H2SO, \rightarrow 2CaHP04, + CaSO4}$

The monocalcium phosphate - calcium-sulphate reaction product was called "superphosphate of lime". Lawes prepared small batches of acid-treated bones and demonstrated their superior fertilizing value by field experiments. Since bones were becoming scarce and expensive, Lawes conducted acidulation trials with mineral sources of phosphate (apatite rock) and found that it was solubilized in the same manner as bones. Since deposits of natural phosphates were known to exist in England and elsewhere, Lawes could foresee the economic potential of manufacturing superphosphate. In 1842, he took out a patent for the acidulation of "bones and other phosphoritic substances", and set up a factory for the manufacture of "artificial fertilizers".

An appreciation of the inadequate fertilizing value of bones and other natural phosphates, and the need for improved fertilizers, can be gained from Lawes' patent application which states in part.

"Whereas bones, bone ash, and bone dust and other phosphoritic substances have been heretofore employed as manures, but always, to the best of my knowledge, in a chemically undecomposed state, whereby their action on the soils to which they have been applied has been tardy and imperfect. And whereas it is in particular well known that in the case of a large proportion of the soils of this country, the application of bone dust is of no utility in producing crops of turnips on account of the slow decomposition of the bone dust in the soil, and the consequent exposure of the young plant for a long period to the ravages of the turnip fly .... "

At the time that Lawes applied for his patent he was able to draw on the results of several years of field tests on his experimental phosphatic fertilizers. (His estate would later become the renowned Rothamsted Experimental Station.) His reference to the action of natural phosphates being "tardy and imperfect" are probably based on data from the Rothamsted archives which date back to the early 1840's. Results of a fertilizer comparison on turnips were:

	Tons per Acre
No phosphate	2.2
Mineral phosphate	3.05
Mineral phosphate + sulphuric acid	6.8

As these figures demonstrate, the soluble form of phosphorous produced a striking increase in yield. From subsequent experiments, it would be learned that readily available phosphates promote root development during early stages of growth, producing large vigorous plants with a yield potential much higher than previously realized. This was a major advance in crop fertilization, and a prime example of what could be accomplished by the practical application of scientific discoveries.

By the mid-19th century, the clues to the puzzle of what made plants grow were beginning to fall into place. The major plant food elements had been identified, and it was established that the ones needed the most were nitrogen, phosphorous, and potassium.

The Essential Elements.

The essential plant food elements as we now know them are shown in *Table 1*. These same elements (Table 2.) are also, with a few exceptions, essential for the animal world. The major (macro) mineral elements N, P, K, Ca, S, Mg, and the micronutrient iron (Fe) were known during the time of Liebig. The remaining micronutrients were not identified until the present century, the most recent to be added to the list is chlorine, which was determined to be essential in 1954.

It is an immutable scientific fact that plant nutrients are absorbed in the form of simple ions (shown in Table 1.) through the root system. Also, to a limited extent, they can be absorbed into leaf tissue from foliar sprays. Nutrients contained in organic residues (see Figure 2.) are absorbed in the same manner as inorganic sources, but must first undergo complete decomposition.

It is intersting to note that as recently as twenty years ago, and no doubt still today, there are those who will not accept what has been scientifically proven. Recently, I was surprised to discover that Lady Eve Balfour (who must have lived to a ripe old age) revised and reissued her book, *"The Living Soil"*, in 1975, the original having been released in 1943. In the introductory chapter, Lady Balfour reviews significant discoveries that occurred during the intervening years. She states the following:

> *"It is now known that plants are able to absorb through their roots unbroken molecules of quite complicated organic compounds whether man-made or poisonous, like DDT, or beneficial products of microbiological life. This discovery has swept away for ever the dogma that all plant food must be reduced to a solution of simple salt before it can be utilized by plants. Thus the bottom has dropped out of the argument that there is no difference between a plant nutrient contained in organic materials and the same nutrient in chemical form."*

As she had done many times before, Lady Balfour stated her viewpoint with great conviction, but the sincerely of her beliefs didn't alter the fact that she was wrong. The subject of plant uptake of organic compounds was discussed at a nitrogen symposium held at TVA In 1982. Dr. J. E. Harper (University of Illinois) expressed a more conventional interpretation:

"Although mechanisms apparently exist for uptake of various organic N compounds, the contribution of these organic N compounds to overall N requirements of plants in field experiments is not well defined, but would appear to be of minimal consequence."

There are still some mysteries as to the exact role of some of the plant nutrients in the process of plant growth, but there is extensive knowledge about what happens to crops when essential elements are deficient. The time-honoured method of studying the absolute effects of nutrients on plant growth is to grow plants in an inert media and fertilize with a series of pure chemical formulations in which selected elements are omitted. The results of sand culture studies on sugar cane and potatoes are shown in Figures 3 and 4. This type of experiment illustrates what Liebig called "the law of the minimum" which states that if one element is lacking, plant growth will be restricted even when all other elements are abundant. Note that in the case of sugar cane, the omission of either nitrogen or phosphorus results in a yield reduction of more than 80%. It is also interesting to note that the omission of any one of the three micronutrients - iron, manganese or boron results in a yield reduction of about 25%, even though they are required in very small amounts for normal growth. A striking feature of the potato study is that the absence of calcium, an element usually taken for granted because its content in most soils is adequate, results in almost a complete crop failure.

Materials that Supply Plant Nutrients

Table 3. lists the major inorganic materials which now essentially supply the world with plant nutrients. Organic materials are listed in Table 4. - these include slaughterhouse wastes, animal manures, and various plant residues. Except for manures and crop residues which are returned to the soil as part of routine farming practices (and they do contribute significant amounts of nutrients), organics, because of limited supply and high cost relative to inorganics, have little or no place in commercial agriculture today. In the U.S.A. a century ago, practically all plant-nutrient nitrogen was from organic sources. One widely used source was Peruvian guano, another was a product known as "poudrette". L. B. Nelson, in his *History of the U.S. Fertilizer Industry* reports that 70,000 tons of this product was marketed in 1880. What, exactly, was poudrette? Suffice it to say that it was generated domestically in great quantities, but ceased to become available after modern plumbing came into fashion.

At the turn of the century, sodium nitrate from natural deposits in Chile and ammonium sulphate, an industrial by-product, began to displace organics. A process for manufacturing ammonia from atmospheric nitrogen was invented by the German scientists Haber and Bosch in 1911, but did not have a significant impact until the end of the second world war when nitrate plants, originally built for production of explosives, were diverted to the manufacture of ammonium nitrate. Today, anhydrous ammonia and its derivatives ammonium nitrate, ammonium phosphates and urea, account for about 95% of the fertilizer nitrogen used in the U.S.A.

The crops that feed the world are well served by inorganic sources of plant nutrients. The selection of materials listed in Table 3. enable us to combine essential mineral elements in an infinite number of ways for an infinite number of crops and soil conditions. We can use these materials to fertilize a crop with one element, two elements or five or six, depending upon the need we can apply nitrogen to a cereal crop; we can apply potash to alfalfa; we can formulate a high phosphorous grade with a NPK ratio of 1:4:1 to use as a banded starter for the germinating seedlings in row crops. If micronutrients are needed, we can incorporate them into regular fertilizers to supply 5 Ib./acre of boron, 2 Ib./acre of copper, or 1/2 Ib./acre of molybdenum. The fertilizers and application equipment available to modern agriculture allow us to fertilize our crops with optimum amounts of selected plant nutrients. There is no such flexibility with organic materials, nor within the organic approach to farming.

Organic and Natural

The mistaken ideas that people have about fertilizers reflects ignorance of the technical aspects as to their composition, methods and rates of application, etc. But there is also an underlying ignorance about the basics of agriculture. The person who says, "Chemical fertilizers are unnecessary", probably assumes that the alternative is to farm organically. This is thought to be a neat system in which soil fertility is maintained by the addition of crop residues, animal manures,and other "naturally occurring substances" such as untreated phosphate rock and pulverized granite, which are regarded as "non-chemical". What organic proponents forget is that the objective of farming is to produce something to sell. What farmers sell is food, and food contains nutrients - the meat, milk, eggs, cereals, fruits and vegetables that we eat, and even the cotton and woollen fibres that we wear on our backs all came, directly or indirectly, from plants which depended on mineral elements from the soil for their growth and development. When these products go through the farm gate, their nutrient content goes with them, resulting in a net loss of soil nutrients which are not replaced in an organic system. This is why we must use fertilizers.

The realities of organic farming were recently reviewed by a scientist from Rothamsted, who participated in a Rockefeller Foundation-sponsored seminar on world agriculture, held at Annapolis, Maryland, April 1992. The following is a summary of remarks by A. E. Johnson, Lawes Trust Senior Fellow at the Rothamsted Experimental Station.

'Analysis of British agricultural. data going back almost 150 years shows there is "no free lunch" for organic farmers. They are wrong if they believe that they can keep yields up without adding mineral fertilizers to their soils. What they are doing is mining reserves that have been built up in the past, and they are kidding themselves. Yields can only be maintained if farmers maintain the levels of phosphorous and potassium in their soils.

It is an illusion to think that non-fertilized fields are also non-polluting. British studies indicate that fall nitrate run-off levels from unfertilized farms can be eight times that of levels permitted by the European community. "I don't want people to tell me that organic farming is benign in that way. There are huge losses, mainly of nitrate, in organic farming".

"Organic farming is often an attitude of mind that is not based in reality."

This is not the first time that Rothamsted scientists have expressed their views on organic farming. The comments of Sir John Russel as quoted by D. P. Hopkins are:

"We have searched diligently for evidence that organic manure gives crops of better quality than inorganic fertilizers, and so far our experiments, made jointly with Dunn Nutritional Laboratories at Cambridge, have all given negative results. No difference has been found. (1939)

From time to time there has been much discussion on the question whether organic or inorganic sources of plant nutrients are best. It seems strange that in this twentieth century there should still be people who think that ammonia derived from organic matter differs in some subtle way from ammonia derived from gas liquor, or produced synthetically. I know of no evidence that organic manures produce healthier or more nutritive crops than inorganic fertilizers. (1943)

Another example of a lack of knowledge and understanding of agriculture is the idea that the use of fertilizers and other crop chemicals is "unnatural" and that we should go back to more "natural" ways of farming. The truth of the matter is, that agriculture is not and never was natural. In the strict sense of the word, anything contrived or altered by man cannot be said to be natural. Agriculture was contrived by man in an effort to provide himself with a dependable supply of food. He was forced into it because of the unreliable bounty of nature.

To define the true meaning of agriculture as it relates to scientific progress and the survival of man, I can do no better than draw on the wisdom of the noted British Plant Scientist, E. C. Large. His comments on the natural or unnatural characteristics of agriculture (probably directed to Sir Albert Howard and his followers) are quoted from his book, *"The Advance of Fungi"* (1940).

All agriculture is artificial. There is nothing more artificial than a field of cultivated potatoes. For what is agriculture, after all, but an attempt to strip the earth's surface of its wild mixed flora and fauna, and to reserve such areas exclusively for the growth of plant prodigies, most of them brought from foreign lands, and all of them chosen for abnormalities of special utility to man?

Agriculture, the exclusive tending of vegetable freaks and monsters is necessary if the human species is to survive. But as it is necessary, so there is no point at which it is philosophically possible to draw a line, and reasonably say that up to such and such a level in its historical development, agriculture was "natural" and right, while all beyond is "unnatural" and wrong.

No one can say, for example, that it was natural and right and proper to put lime on sour land, as their great-great grandfathers had done, but wrong to stimulate the growth of plants with synthetic sulphate of ammonia. Both lime and sulphate of ammonia are products of the chemical industry; both are ultimately derived from the waters and rocks of the earth and the constituents of the atmosphere.

The best that man can do at any time to defend the health of the hypertrophic crop plants that in his cunning he has sought out and made, is to apply to the work of rearing them the whole of his science.

Fertilizers Feed the World

On a year to year basis, the food that may be directly attributed to applied inorganic plant nutrients amounts to about 30% of the world's annual production. A significant additional portion of our annual harvest is accounted for by the reserves of nutrients which have been built up in the soil over the years from previous fertilizer applications. For the benefit of organic persons who are concerned about the residues which fertilizers leave in the soil, these residues are plant nutrients, and fortunately for the hungry people of the world, they do, indeed, enter the food chain.

World population is growing at a rate of 80 to 90 million people per year. As E. C. Large pointed out fifty years ago, we have an obligation to use all of the scientific resources that we have at our disposal and develop new ones if we hope to feed ourselves. It is only through constant improvements in food productivity that we have been able to hang on to a "stay of execution" from the sentence handed down by Thomas Malthus 200 years ago.

Education is needed

To echo the sentiments expressed by Sir John Russel, it is strange that in this closing decade of the twentieth century, there are still people who believe that fertilizers are harmful chemicals and that their use is unnatural and unnecessary. All of us, from all walks of life, including self-declared ecologists and environmentalists, are dependent on plants for our food, and plants are dependent upon mineral elements. There is no substitute for these essential mineral elements, but there are those who believe otherwise because of what they read in the newspapers.

How do we overcome and counteract public ignorance of the realities of agriculture when such ignorance is aided and abetted by the media? This is a challenge which will demand the best efforts of the fertilizer industry and the scientific community.

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WHAT'S WRONG WITH SYNTHETIC FERTILIZERS?

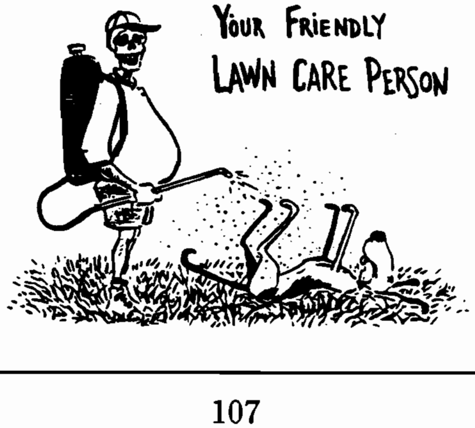
Lawn owner, spare that herbicide

The dangers of chemical fertilizers
They can be as harmful as pesticides

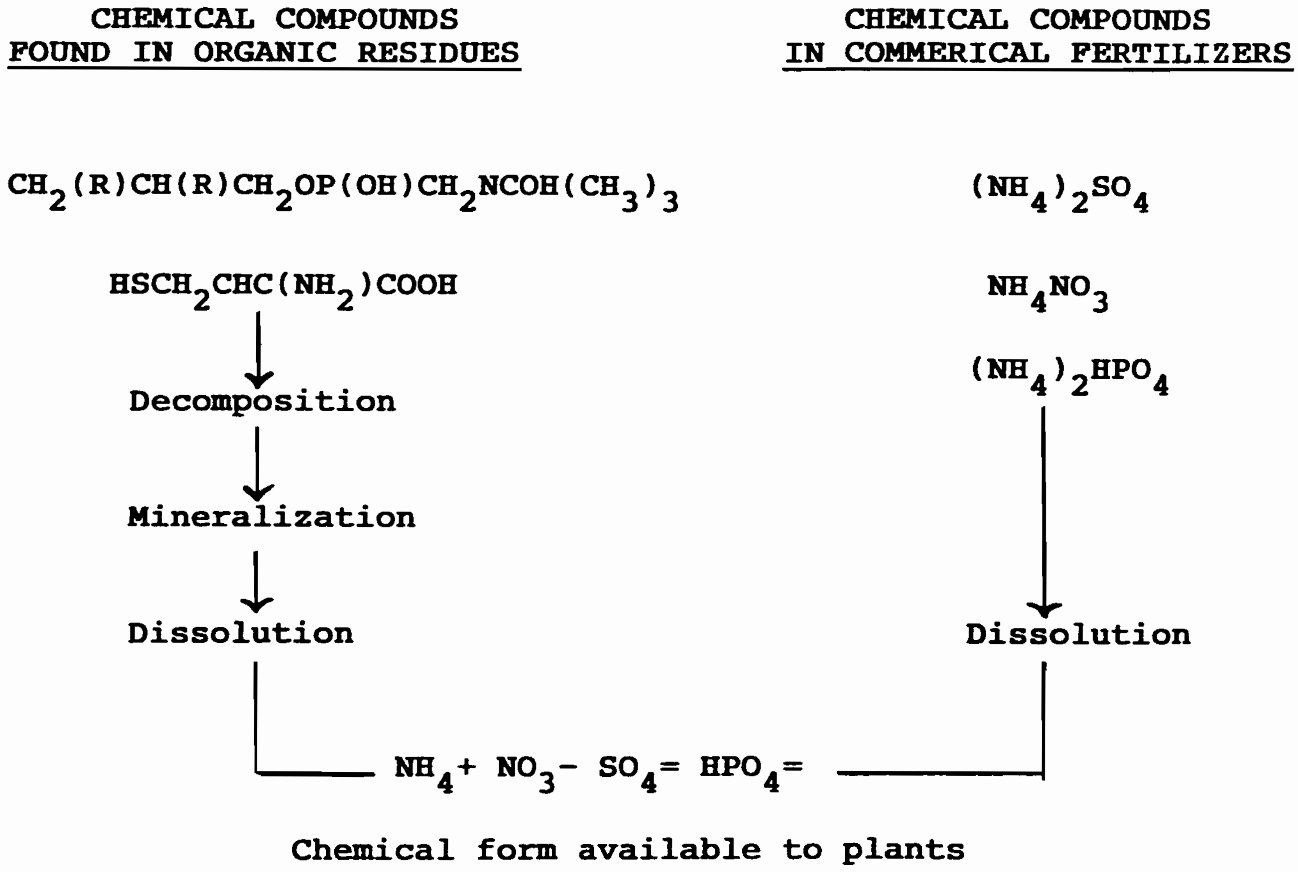
Beware those killer chemicals in your lawn

FERTILIZER FOLLY

Pesticides: are they silent killers?



ORGANIC AND INORGANIC SOURCES OF PLANT NUTRIENTS



CHEMICAL COMPOUNDS FOUND IN ORGANIC RESIDUES

$CH_2(R)CH(R)CH_2OP(OH)CH_2NCOH(CH_3)_3$

$HSCH_2CHC(NH_2)COOH$

Decomposition

Mineralization

Dissolution

CHEMICAL COMPOUNDS IN COMMERICAL FERTILIZERS

$(NH_4)_2SO_4$

NH_4NO_3

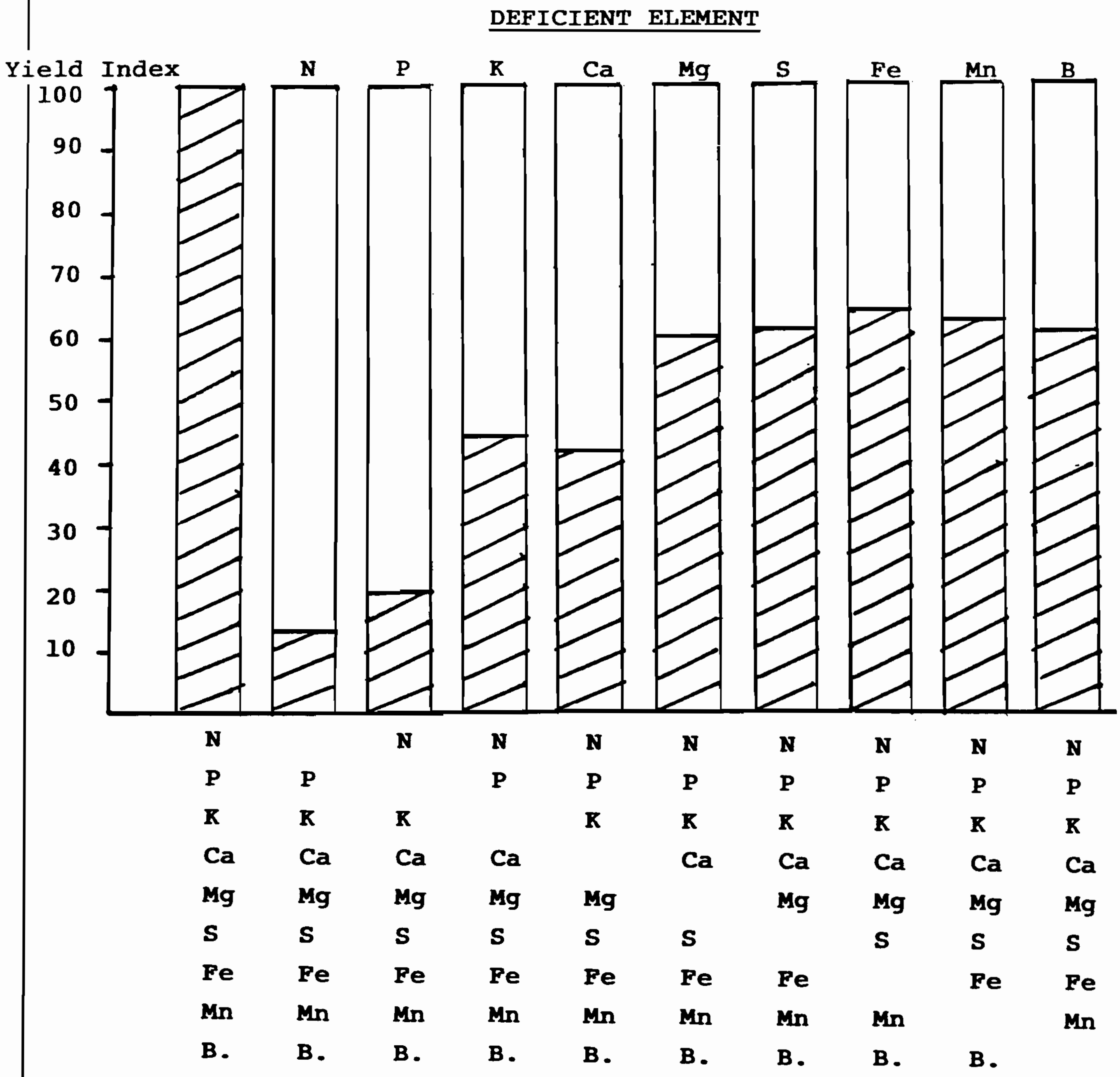
$(NH_4)_2HPO_4$

Dissolution

NH_4+ NO_3- $SO_4=$ $HPO_4=$

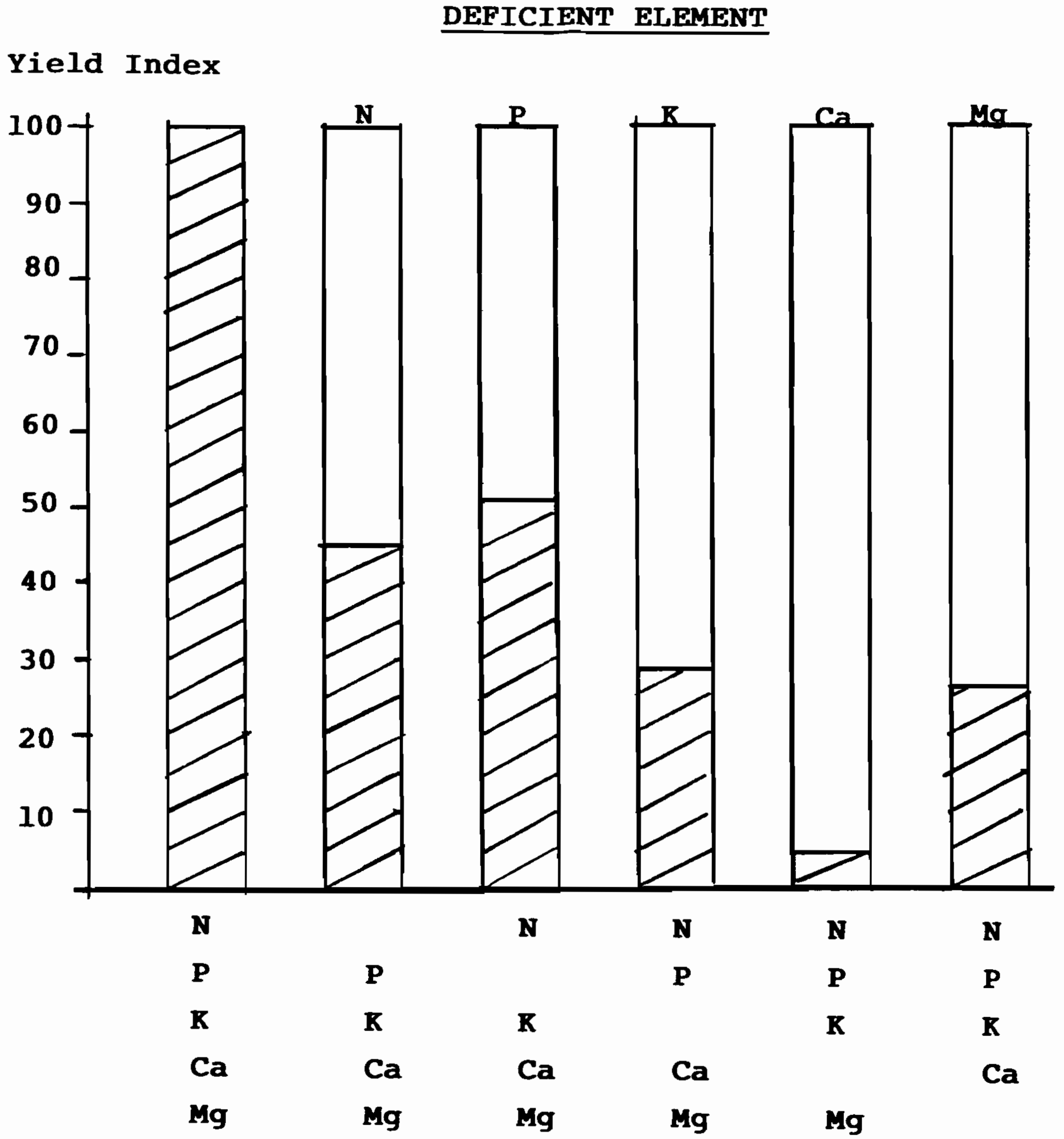
Chemical form available to plants

EFFECT OF MINERAL DEFICIENCIES ON YIELD OF SUGAR CANE -SAND CULTURE, UNIVERSITY OF PUERTO RICO, 1963



SAND CULTURE STUDY OF MINERAL DEFICIENCIES ON POTATOES

ENGLAND, 1938



ESSENTIAL PLANT FOOD ELEMENTS

MACRO NUTRIENTS
(Needed in relatively large amounts)

Mainly from water and air through photosynthesis	Carbon	C
	Hydrogen	H
	Oxygen	O

		Chemical Form Taken up By Plants	
Nitrogen	N	NH_4^+	NO_3^-
Phosphorous	P	$HPO_4^=$	$H_2PO_4^-$
Potassium	K	K^+	
Calcium	Ca	Ca^{++}	
Magnesium	Mg	Mg^{++}	
Sulphur	S	$SO_4^=$	

MICRO NUTRIENTS
(Needed in relatively small amounts)

Mineral nutrients mainly from soil through absorption by root system	Iron	Fe	Fe^{++}	Fe^{+++}
	Zinc	Zn	Zn^{++}	
	Manganese	Mn	Mn^{++}	
	Copper	Cu	Cu^+	Cu^{++}
	Borax	B	$BO_3^=$	
	Molybdenum	Mo	$MoO_4^=$	
	Chlorine	Cl	Cl^-	

Other mineral elements found to be beneficial for certain plant species:

Cobalt	Co
Silica	Si
Sodium	Na
Vanadium	V

ESSENTIAL CHEMICAL ELEMENTS

ELEMENT	PLANT WORLD	ANIMAL WORLD
N	*	*
P	*	*
K	*	*
Ca	*	*
Mg	*	*
S	*	*
Fe	*	*
Zn	*	*
Cu	*	*
B	*	?
Mo	*	*
Cl	*	*
F	0	*
I	0	*
Na	**	*
Si	?	*
Se	0	*
V	?	*
Ni	?	*
Co	?	*

*	Established as essential
?	Some evidence of essentiality
**	Beneficial for some plant species
0	Not known to be essential

INORGANIC FERTILIZER MATERIALS

	% Plant Nutrient Content					
Macronutrients	**N**	**P205**	**K20**	**Ca**	**Mg**	**S**
Ammonium Nitrate	34					
Urea	46					
Calcium Nitrate	15					
Sodium Nitrate	16					
Ammonium Sulphate	21					24
Monoammonium Phosphate	12	50				
Diammonium Phosphate	18	46				
Single Superphosphate	20			20		12
Triple Superphosphate	45			12		
Muriate of Potash			60			
Sulphate of Potash			50			
Potassium Nitrate	14		44			
Potassium Magnesium Sulphate			21		11	12

Micronutrients*	Fe	Zn	Mn	B	Cu	Mo
Ferrous Sulphate	20					
Zinc Sulphate		36				
Manganese Sulphate			27			
Sodium Borate				11		
Copper Sulphate					25	
Ammonium Molybdate						54

* Other compounds may be used

ORGANIC MATERIALS

	% Total Nutrient Content					
	N	P205	K20	Ca	Mg	S
Animal By-Products						
Dried Blood	13.0	2.0	1.0	-	-	-
Steamed Bonemeal	2.5	25.0	-	23.0	.6	.4
Fish Scrap	9.5	7.0	-	6.0	.6	.4
Dried Locusts	10.0	1.5	.5	.3	-	.7
Wool Waste	3.5	.5	2.0	.3	-	.2
Excreta						
Peruvian Guano	13.0	12.0	2.5	7.7	.3	1.4
Dried Cattle Manure	2.0	1.5	2.0	2.8	.6	.2
Dried Horse Manure	2.0	1.5	1.5	.7	.3	-
Dried Poultry Manure	5.0	3.0	1.5	2.8	.6	.8
Dried Sewage Sludge	2.0	2.0	-	1.8	.3	.2
Activated Sewage Sludge	6.0	3.0	.5	1.8	.9	.4
Plant Residues						
Wood Ashes	-	2.0	5.0	23.0	2.0	-
Soot	1.5	.5	.5	2.0	.4	2.4
Seaweed	1.5	.5	2.0	2.0	.4	1.4
Grain Straw	.6	.2	1.1	-	-	-
Alfalfa Hay	2.5	.5	2.1	-	-	-

Tuesday, October 27, 1992

Session IV

Moderator:

F. Zane Blevins

Utilization Of By-Product Materials By Agriculture

Frank P. Achorn
SE-ME, Inc.

History shows that the origin of the fertilizer industry in the U.S. and other countries was to utilize by-products such as seed meals, fish, scrap, and other waste materials. Recycling waste in the U.S. has again become necessary as well as popular and sometimes very profitable for many industries. TVA and some industrial firms have an active waste minimization and utilization program.It has three main parts, and they are:

1. Elimination of waste at its source.
2. Recycling by-products or waste into useful products.
3. Treatment and safe disposal.

The fertilizer industry has been engaged in all three of these phases of waste utilization. It has been stated that "one company's waste is another company's treasure" and in the past, the fertilizer industry has practiced recycling as a way to prevent pollution at its' source. If possible, all waste problems should be solved at their source.

The fertilizer industry has gradually changed in the past 50 years from an industry that primarily consumed waste to one that generates a significant amount of waste. This industry became a more sophisticated chemical industry that generates more waste than we consume. This was necessary to increase the plant nutrient concentration of N, P, and K so that these nutrients could be delivered to the farmer at a lower cost which in turn allowed food prices to be kept relatively inexpensive. It allowed the U.S. food and fiber production to be competitive in the world markets so that we now export 20% of the corn, 64% of the wheat, 34% of the soybeans, and 38% of cotton we produce (1). These exports contribute very positively to the U.S. balance of trade and we need to continue or increase our food exports. However, we should strive to do this in an environmentally responsible way. Perhaps increased efforts to recycle by–products into fertilizers will help us reach this objective. Some suggested by-products that offer potential for recycling are:

1. By-product ammonium sulfate from steel mills and fiber industry.
2. By-products from the fertilizer industry—for example, phosphogypsum from the production of ammonium phosphate, fluosilicic acid, sulfur, etc.
3. Dust from cement kilns and limestone crushing operations.
4. Spent acids (H_2SO_4, H_3PO_4, HCl, etc.) include alkylation, battery reclamation, and metal treatment acids.
5. Dust from metallurgical processes.
6. Slag and ashes from fossil fuel electric generating plants.
7. Sewage sludge and compost.
8. Animal manure from feedlots, chicken and egg producers, hog producers, etc.
9. Food processing waste.
10. Calcium phosphate sludges from sewage treatment plants.
11. By-products from munition manufacture.
12. Ammonium chloride from the pesticide industry.
13. Ammonium bisulfite.
14. Granular woodash.

By-Product Ammonium Sulfate

The fertilizer industry has long been involved in the utilization of by-product ammonium sulfate from steel mills and synthetic fiber industries. The potential for the production of crystalline ammonium sulfate from electric generating plants that use high sulfur coals is also present. Ammonium sulfate is an excellent source of N and S in the conventional ammoniation granulation plants. Figure 1 shows a sketch of a typical plant of this type. A decade ago, there were over 100 of them in the U.S.; the current count shows that there are only about 30 plants left. This should be discouraging to the chemical industries because they are losing one of their ways to recycle by-products. Their alternative is "waste disposal" which is quite expensive and under watchful eyes of pollution control officials. Some of the steel mills and synthetic fiber industry can alter their processes so that they produce a more usable by-product such as granular ammonium sulfate or so they don't produce this by-product at all. However, if the current recycling through granulation plants is to continue, then the by-product must be economically feasible for the granulation plants to use. Currently TVA is developing a low-cost conditioning agent for the fine size ammonium sulfate crystals. They are also developing several new processes for the granulation of ammonium sulfate fines.

By-product ammonium sulfate solution (8% N and 9% S) has been and can be used as a source of N and S for fluids. Because of its low plant nutrient content, it should be used in combination with solid materials that are used in suspensions (MAP , potash, etc.). It is used to replace water normally used in preparing suspensions.

Ammonium Sulfite Solution

Some companies that reclaim or recycle lead from batteries do so by re-melting the lead to purify it. During this process, sulfur dioxide (S02) is evolved and is absorbed in water to form sulfurous acid. This acid is neutralized to form ammonium bisulfite solution. This near-neutral solution has a grade that ranges from 8-0-0-12S to 9-0-0-13. The solutions are sold to fluid fertilizer dealers who use them as a source of S. It is usually mixed with urea ammonium nitrate solution (32-0-0) to produce a KS liquid. Some companies are considering converting it to ammonium thiosulfate solution (12-0-0-26) by reacting it with additional sulfur.

By-Products From Fertilizer Manufacture

Phosphogypsum

Probably the most plentiful by-product from our industry is phosphogypsum–a by-product from the manufacture of phosphoric acid and ammonium phosphates. As the fertilizer industry has matured, there has been a tendency to remove what we have considered to be impurities, so higher and higher analysis grades could be produced. For example, in our phosphate industry, we have progressed from normal superphosphate which is made by simply reacting phosphate rock with sulfuric acid to the production of high-analysis ammonium phosphates which usually contain about 64 units of plant food (11-52-0 and 18-46-0). Although the normal superphosphate contained only 18 to 20% P_20_5, it also contained 11% S and 19% Ca. Farmers throughout the U.S. are beginning to report sulfur deficiencies and some regions are reporting positive responses to calcium. Although the ammonium phosphates do contain small amounts of S and Ca, their contents of these nutrients are usually not enough to supply sufficient Ca and S for efficient food production. It has been proved that both Ca and S are required for plant growth and they are designated as secondary nutrients next in importance to N, P, and K.

Perhaps in our zeal to lower plant nutrient cost, we may have created other problems. We have removed the calcium and sulfur from normal superphophate and now we pile these nutrients as gypsum in large piles close to ammonium phosphate production and away from the use area. We have regressed from the production of 7.8 million tons of superphosphate in 1959 (equivalent to about 1.5 million tons of P2O5) to about 400,000 tons in 1991 (2). We now produce 16 million tons of ammonium phosphates (equivalent to 7.7 million tons of P2O5) (3). These statistics do not show that we also produce about 39 million tons of phosphogypsum each year which is currently piled in large piles (4). Eventually, we need to find a use for this type of by-product gypsum.

There have been some complaints concerning groundwater contamination in areas close to these piles. These complaints have been increasing in numbers during recent years. Regulations for new piles require that the pile and its associated pond must have liners. The total cost of establishing, maintaining, and monitoring piles has increased dramatically, and now it is a significant part of the total cost of manufacturing ammonium phosphate. This cost is expected to continue to increase unless we find a way to recycle at least some of the gypsum. Tests by TVA and others have shown that phosphogypsum can be granulated and used as a source of sulfur and calcium in bulk blends (5). Several producers of granular homogenous N:P:K mixtures have also used it to produce mixtures of higher S content and as a filler to reduce overgrading.

TVA's process for the granulation of gypsum uses a rotary granulator. A combination of limestone and lignosulfonate is used as granulation promoters. At least two commercial plants produce granular gypsum by adding 200 pounds of calcictic limestone, 125 pounds of sulfuric acid (77.7% H_2SO_4), and a small quantity of ammonia to neutralize excess sulfuric acid. Most of this granular gypsum is sold to peanut growers. The plants now use natural gypsum; they formerly used phosphogypsum from Florida. However, the EPA has this last summer ruled that this gypsum could be shipped only if its radium content is less than 10 pico Curies which means that almost all of Florida's phosphogypsum cannot be shipped. It must be processed "onsite."

The Florida Institute of Phosphate Research (FIPR) has developed, in cooperation with the Davey McKee Company (Division of John Brown E&C Ltd.), a process for the conversion of phosphogypsum to sulfuric acid and a slag that would be used as a road aggregate. The aggregate has significantly less radon emission than the gypsum from which it is made (6).

At the 1968 Fertilizer Industry Round Table, D. S. Ashburnet described the "Marchon Process" for the production of cement and sulfuric acid (7). A flow diagram of the process is shown in Figure 2. Obviously, it is a complex plant; however, this process had some interest when there was a worldwide sulfur shortage. In 1968 the investment cost of 300,000 tons/year of H_2S0_4 plant was quoted to be $19 million. Using the Chemical Engineering plant economic indexes for 1968 and 1992, the estimated 1992 cost would be at least $60 million. It is believed this capital cost is probably low because of environmental regulations which have been instituted since 1968. Also, these investments were for plants that used natural gypsum and they probably would be higher if phosphogypsum were used. The paper shows that the P_2O_5 in gypsum is no problem for the quality of the cement that would be produced. These investment costs would be hard to justify at this time because of the depressed market conditions for phosphates.

Perhaps we should consider a limited re-entry of superphosphates into the phosphate manufacturing and marketing system. In the production of triple superphosphate, at least part of the calcium is shipped with the product. Perhaps when the cost of disposing of spent sulfuric acid becomes exorbitant and the cost for maintaining and establishing phosphogypsum piles becomes even higher, then we will again consider the production of normal superphosphates. In the past, normal superphosphate plants have been notorious polluters. Figure 3 shows a sketch of a modern-day normal superphosphate plant. It uses a cone mixer, a continuous din and highly efficient Venturi scrubbers. The scrubbers are used to produce fluosilicic acid (23% SiF6) most of which is shipped to municipalities for water treatment. It also could be used to produce aluminum fluoride, fluocarbons, synthetic cryolite, and many other materials.

Use of By-Product Acids

Sulfuric Acid

There are many sources of spent sulfuric acid. Many of the steel manufacturers convert the sulfur in their iron ores to sulfuric acid and ammoniate the acid to produce ammonium sulfate. Others sell the acid without further processing and still others use it to produce phosphoric acid.

Sulfuric acid is frequently used as a drying agent by the chemical industry, and this acid is available for the fertilizer industry provided the equipment is available to convert it to fertilizers. Regional granulation plants such as the one shown in Figure 1 are good for this purpose. If large quantities of the acid are to be used, then the plant needs to be equipped with a pre-reactor so that over-granulation will not occur. The plant in Figure 1 has a TVA-type pipe-cross reactor; however, a tank-type pre-reactor will work just as well.

Other sources of by-product sulfuric acid are available and are very difficult to dispose of them because of their low concentration. One such acid of this type is by-product acid from metal treating processes. The galvanizing industry has a by-product acid that contains only about 10% H_2SO_4); however, it also contains 6-10% Fe and about 3% Zn. The costs of disposing of this acid was about $1.25/gallon. The disposal process was to ship it to Oklahoma or Texas and pump it into deep wells. This is an expensive and unwise process. With guidance from TVA, galvanizers developed a program in which the acid could be utilized by fluid fertilizer dealers. The acid was first partially ammoniated to a pH of 2 by the by-product producer, and then it was shipped to the fertilizer dealer who ammoniated it further and added other ingredients as well as a suspending clay to suspend the solids and impurities in the acid. Typical grades that were produced by the dealer were:

17 .4-4.6-0-1. 1S-0.5Zn-1Fe
12.6-0-0-3. 3S-1.2Zn-3.3Fe
26-0-0-1. 0-1Zn-4Fe

A process has also been developed in which the acid is concentrated and the zinc and iron are allowed to crystalize in the acid. The sulfuric acid is recycled and zinc and iron are sold as micronutrients.

Spent Phosphoric Acid

Spent phosphoric acids are also available as by-products from metal treating processes. Most of this acid has been successfully used to produce solution-type fertilizers such as the starter-type fertilizer grade 7-21-7. Figure 4 shows a sketch of a typical plant that uses this acid. This acid is rather high in aluminum content (about 6% A1203) and when it is ammoniated, it forms an ammonium aluminum precipitate which settles and causes problems with storage and application. TVA developed procedures in which ammonium polyphosphate solution (10-34-0) is used to sequester (dissolve) the impurities so that the product will be a clear liquid. Usually about 25% of the products must be supplied by the 10-34-0. Some regional granulation plants have used this acid to produce granular homogenous mixtures and have encountered problems because of the by-product's low P_2O_5 content of 22% and its high water content of 65%. This high water content causes problems with excessive liquid phase in the granulator. This problem can be solved by using a pre-reactor such as a pipe-cross reactor or a tank-type reactor. If sufficient sulfuric acid (77 to 93% H_2SO_4) is also included in the formula, the chemical heat of reaction will ensure that the water in the acids will be evaporated. If one of the pre-reactors is used, most of the heat and water in the acids will not enter the bed of material in the granulator, thus eliminating some of the problems formerly encountered with excessive liquid phase in the granulator. For each 20 pounds of P_2O_5 supplied by the spent phosphoric acid, 4.8 pounds of ammonia is required to produce monoammonium phosphate (MAP) in the N:P:K mixtures. This 4.8 pounds of ammonia, when reacted with the by-product phosphoric acid, will evaporate 12 pounds of water if no heat loss is considered. If spent sulfuric acid that contains 93% H_2SO_4 is used, then for each pound of acid used, 0.323 pound of ammonia is required to neutralize the acid. Heat from this neutralization can also be used to evaporate water from both acids. For example, the heat of neutralization for 100 pounds of 93% sulfuric acid is enough to evaporate about 87 pounds of water if liquid ammonia is used and no heat loss is considered. These data show that it is possible to recycle these acids by producing both fluid and granular fertilizer.

Fluosilicic Acid

It was mentioned earlier that fluosilicic acid recovered from normal superphosphate plants is sold to municipalities for water treatment. However, these plants produce only a small percentage of the total fluosilicic acid produced by the fertilizer industry. Most of this by-product acid is produced during the manufacture of phosphoric acid. Currently it is stored in ponds and some of it is recirculated to the scrubbers of the diammonium phosphate (DAP) production units and then ends up in the product. However, not all of the fluosilicic acid returns to the DAP because the acid is mostly water–thus the name pond water. Consequently, not all of the fluosilicic acid is consumed in the manufacture of DAP. It collects in the ponds and may eventually have to be recovered from these ponds. Some companies have installed Venturi scrubbers quite similar to the Venturi scrubbers used by the normal superphosphate plant so that at least part of their exit gas from the phosphoric acid plant is converted to a more concentrated acid and sold to chemical companies as a source of fluorine. Studies have shown that if all of the fluosilicic acid generated by the phosphoric acid plants were converted to concentrated fluosilicic acid, the market for fluorine would soon become saturated and would not be a profitable venture. Probably the fluorine content will increase to such an extent that increased recycling of the acid becomes a necessity.

Perhaps the concentrated acid could be used as a partial replacement of sulfuric acid to acidulate phosphate rock in the manufacture of phosphate acid. Perhaps it could be ammoniated to form ammonium fluoride solution and silica. The ammonium fluoride would be used as an alternate source of nitrogen in the DAP plant and silica would be returned to the gypsum pile. Currently some DAP producers use urea or ammonium nitrate as supplemental sources of nitrogen so they can make the 18% nitrogen. Probably it would be more profitable to use ammonium fluoride for this purpose.

Sewage Sludge

Several companies have recycled sludge into granular fertilizers. Plant tests with a dry sanitized sludge that was supplied by the City of Houston show with formulation containing as much as 1,500 pounds of dry sludge per ton of product, it is possible to obtain reasonably good granulation in a conventional granulation plant that has a TVA rotary ammoniator, dryer, and cooler. Superphosphate, dolomitic limestone, lignosulfonate, acids, and ammonia are usually added to promote granulation of the sludge. When more than 1500 pounds of sludge per ton of product is used, granulation becomes difficult and usually there are too many fines in the product. When acids are used to promote granulation, care must be taken to ensure that the acids are neutralized. Some companies have experienced problems with spontaneous combustion of their product. This usually occurs when the pH of the product is less than 3.0 and the product is stored in bulk and at temperatures greater than 1000F.

Some dealers throughout the country have started a program in which they inject fluid sewage sludge on farms close to the community (8). The community pays the dealer for this service. The dealer supplements these applications with suitable applications of chemical fertilizers. Applications are strictly scrutinized by state officials and the company. Most experts report "Sludge from municipal sources is generally safe if it is handled correctly." The program required good agricultural management practices which need to be carried out anyway if maximum economic yields are to be realized. TVA agronomists have worked extensively in these programs and report they are safe and an economical alternative for sewage sludge disposal (9).

By-product limestone dust has been successfully converted into "fluid lime" (suspensions) for direct application and quick soil pH adjustment because of the very small size of the particles in the "fluid lime."

Recently it has been found that the pesticide manufacturers sometimes have ammonium chloride solution which must be disposed. This is an excellent solution for fluid fertilizers. Currently some of these companies are experiencing exorbitant disposal costs for this by-product.

Animal Manures

It has been reported that one of the major sources of nitrate nitrogen in drinking water is from feedlots and other locations where animal manure has been allowed to accumulate in large quantities. This agricultural waste also needs to be safely utilized. In the past, feedlot managers have been able to sell some of this waste; however, it has been increasingly difficult to dispose of it. Some managers now pay a fee to those who will utilize the material. It does contain a small quantity of plant nutrients. Information from the July issue of *Fertilizer-International* was used to calculate the following percentages of N, P_2O_5, and K_2O in three typical manures:

% Nutrient Content

Farmyard Manure	N	P_2O_5	K_2O	Total
Cattle	0.6	0.3	0.7	1.6
Pigs	0.6	0.6	0.4	1.6
Poultry	4.2	2.8	1.9	8.9

With the exception of poultry, the plant nutrient content is too low to be of much value. However, if the fee for utilizing the manures is high enough, it can be granulated using the procedure normally used for granulating dry sewage sludge.

Other data has shown that heat-treated and granulated poultry manure is a satisfactory feed supplement for cattle (10).

By-Products From Defense Industry

Sometimes the Defense Department has by-product nitrate products from the manufacture of munitions. One such product has been sodium nitrate (16% N). It is usually in the crystalline form and is used primarily in the production of granular N:P:K mixtures. Care must be taken during granulation to avoid fires in the granulator when the pH of the N:P:K mixture is too low and the temperature in the granulator is too high. This is one of the reasons the TVA pipe-cross reactor (PCR) was invented. The acids required in the formulation are first neutralized in the PCR and the melt from the PCR is used to promote granulation of the sodium nitrate, potash, and other materials used in the formulation. The pre-reaction of the acid helps avoid fires in the granulator.

Finding Waste Treasures

Frequently the question asked is where can a company find these useful wastes?. One source of information is publications from regional waste exchangers. For example, there is a Southeast Waste Exchange (SWE) that is part of the Urban Institute of The University of North Carolina, Charlotte, North Carolina.SWE publishes a bimonthly journal *(Waste Watcher)* that lists various wastes that are available for use by the fertilizer industry. They emphasize safe recycling of industrial wastes. They also list a bulletin board of services and markets. Companies list the wastes they have available and others list the type of wastes they want.

Other sources of information concerning availability of usable waste might be local organizations that are interested in safe disposal of waste. In Alabama, a group of this type is the Waste Reduction and Technology Transfer group (WRATT). This is a group of retirees scattered over the state who visit various industries to make waste reduction assessments. They are invited by individual companies, and the contents of their reports are confidential. However, with company approval, they can release information concerning supply of useful waste by the company that was assessed. In Alabama there are three main sponsors of the WRATT Program.They are:

Alabama Business Council
Tennessee Valley Authority (TVA)
Alabama Department of Environmental
Management (ADEM)

It is a program in which government agencies and commercial firms cooperate in eliminating or reducing waste streams by recycling onsite or offsite or by process or material substitution. Similar type organizations have been organized in other states.

We encourage the agriculture industry to look at waste as a resource. Some of it has value to the fertilizer industry. Remember:"Someone's waste may be another's treasure."

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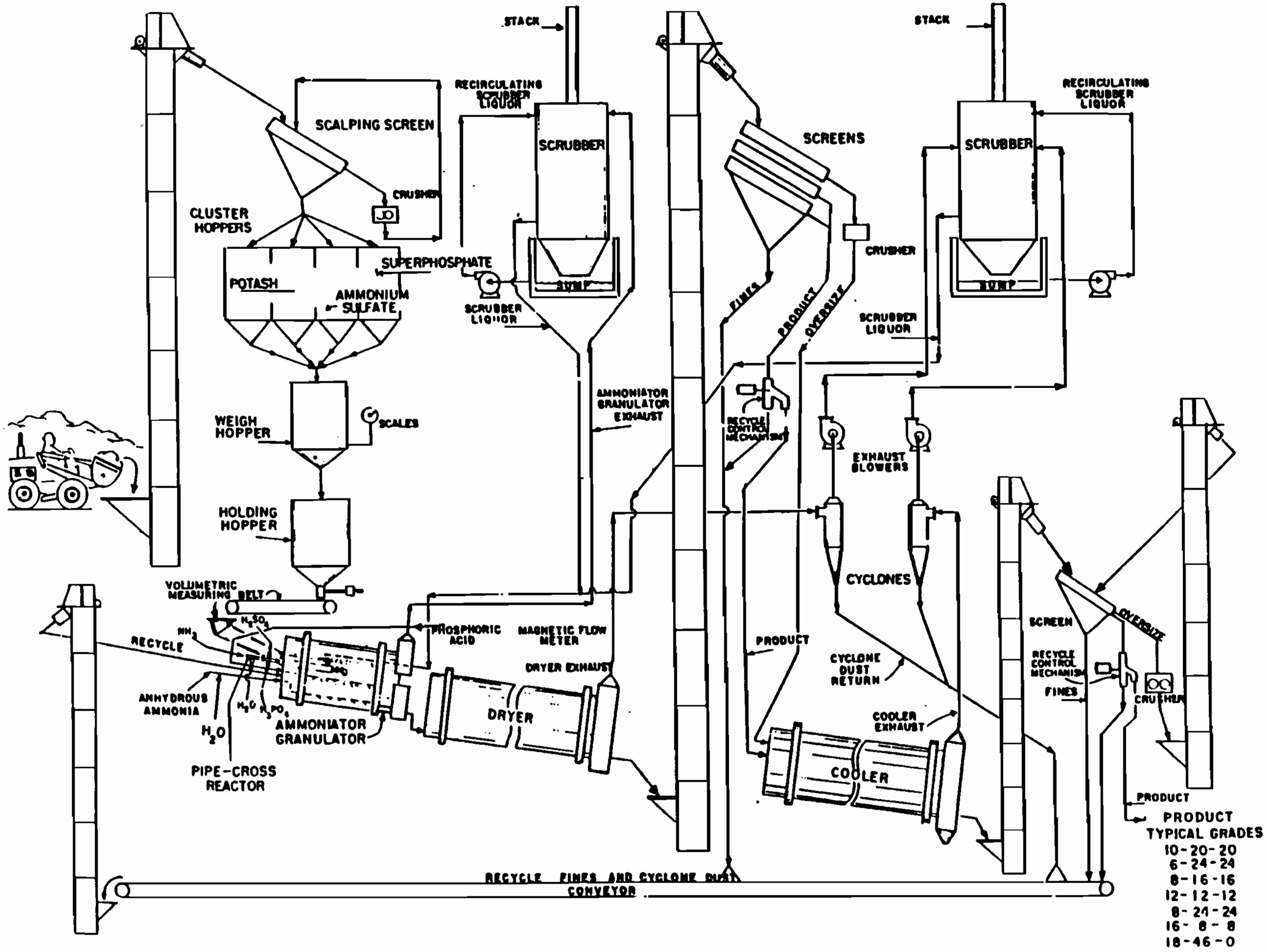

Figure 1
AMMONIATION – GRANULATION PLANT

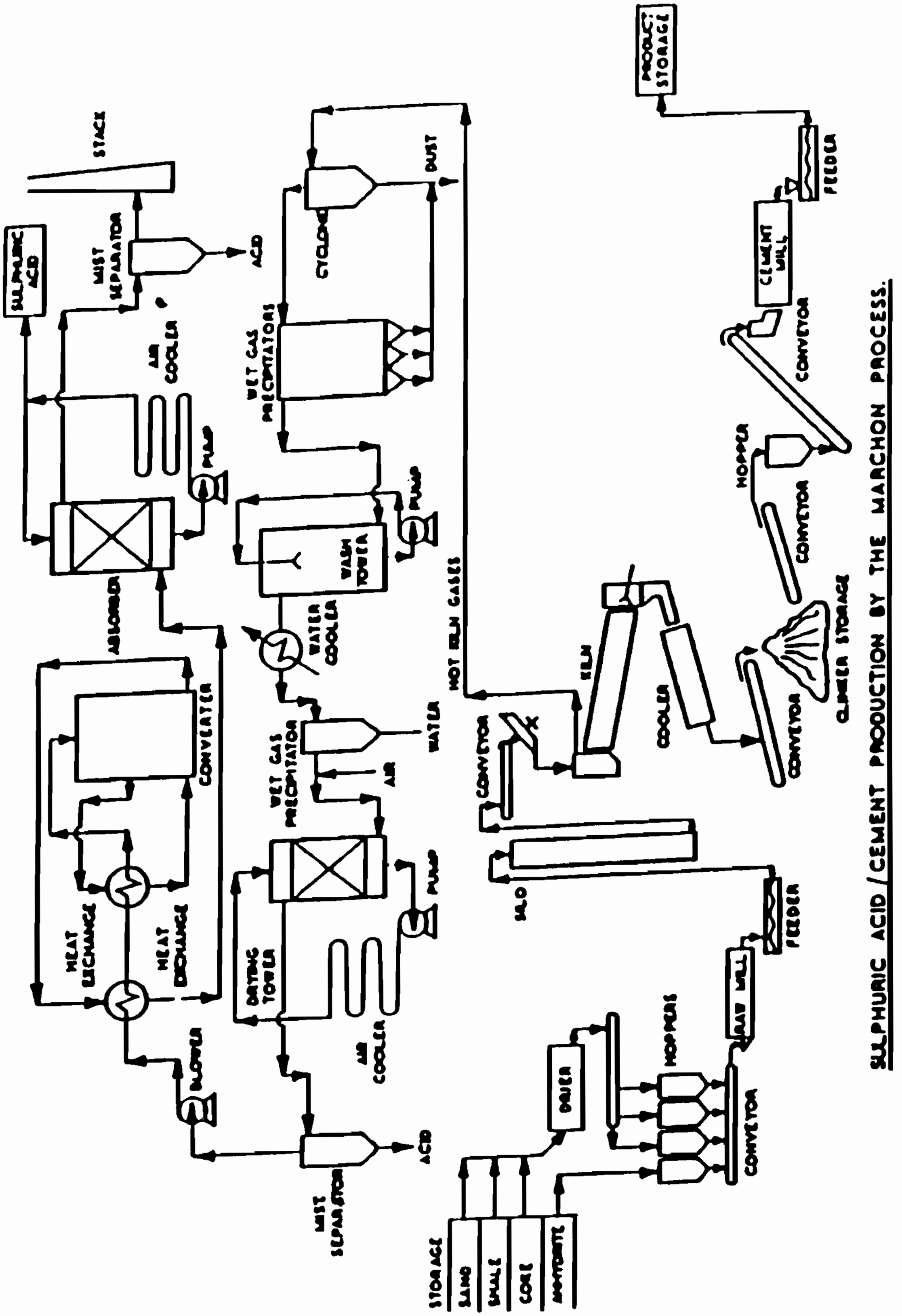

Figure 2
SULPHURIC ACID/CEMENT PRODUCTION BY THE MARCHON PROCESS

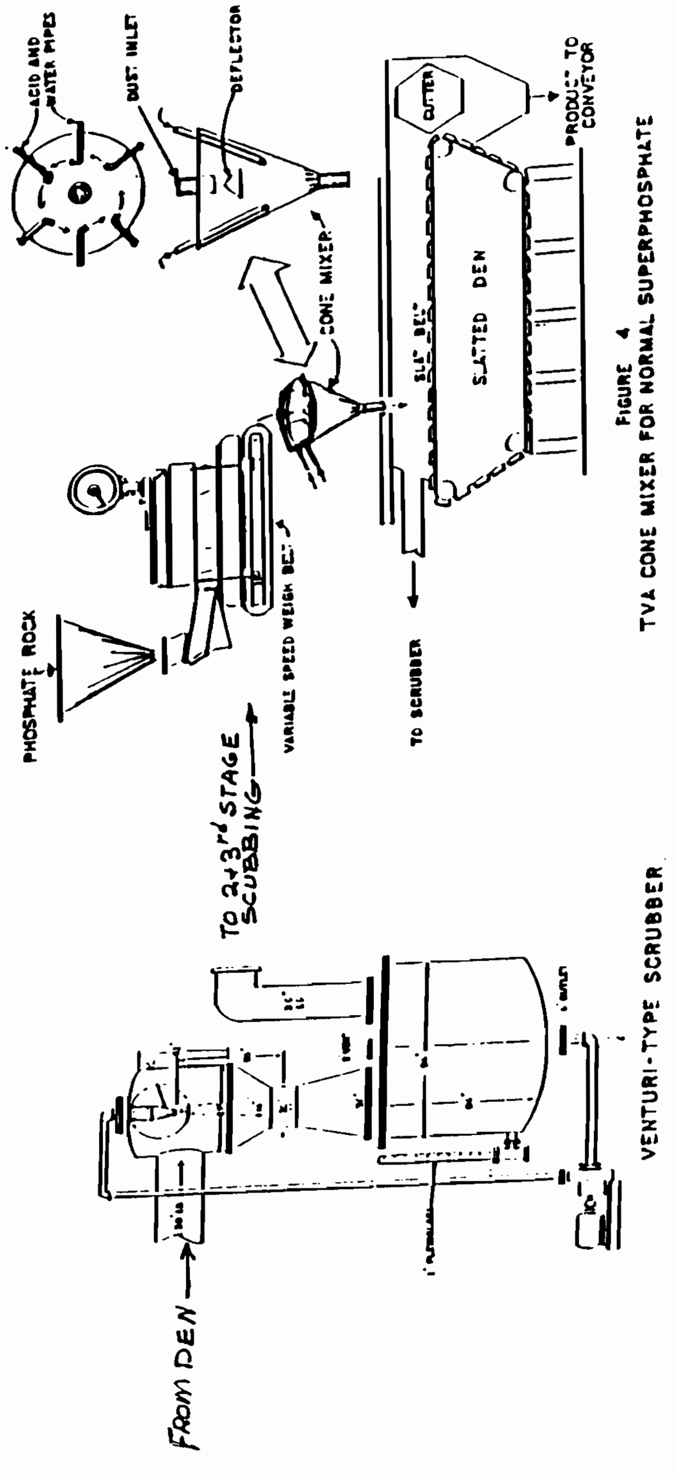

Figure 3
NORMAL SUPERPHOSPHATE PLANT

Utilization Of By-Product Ammonium Sulfate

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Background

Sulfur is generally referred to as a secondary plant nutrient, but it actually ranks in importance with nitrogen and phosphorous in protein synthesis. It is also an integral part of vitamins and enzymes essential to life. Soils in many areas of the world today are deficient in sulfur and soil sulfur reserves are being rapidly depleted. To address growing agronomic needs for sulfur, TVA's National Fertilizer and Environmental Research Center (NFERC) has been committed to development of technologies to produce low-cost sulfur-containing fertilizers since the mid 1970's. In the late 1970's and early 1980's, NFERC developed and demonstrated a 29-0-0-5S urea-ammonium sulfate (UAS) suspension. In 1984, NFERC developed and later patented a new family of nitrogen-sulfur (NS) suspensions to replace the earlier UAS suspension with more versatile, better quality products made by a simpler, more economical process. These new NS fluids were the subjects of papers presented by NFERC at the 1987 and 1990 Summer ACS meetings and in publications in Solutions (September-October 1988) and *Fertilizer Research* (August 1991). NFERC's current endeavors involve development of technologies for successful utilization of low-quality, by-product ammonium sulfate (AS) in the fertilizer industry, which is the subject of this paper. NFERC's current focus on utilization of by-product AS centers around the economic and environmental aspects of these technologies as the primary rationale for development, since the needs for sulfur in soils is now generally well known and sulfur application is common and now charged for in many areas.

Rationale

AS is an important nitrogen and NS fertilizer in United States and world agriculture. It is produced as a by-product of coke and caprolactam production as well as by ammoniation of spent sulfuric acid. By-product AS production in the United States has remained relatively constant over the past several years at about 2,000,000 tons per year.

AS contains N and S in readily available forms, and it is more economical than other sources of N and S. However, much of the crystalline by-product AS on the market today is not suitable for storage and use in solid form because the crystals are too small and/or contain too much moisture. This results in severe caking during shipment and storage, which soon renders the AS difficult or impossible to handle, mix, or apply as a solid. AS is preferably produced, shipped, stored, and used in the form of large crystals or granules to overcome the problems with small, wet crystals. In addition to better shipping, storage, and handling properties, the larger AS crystals or granules are more suitable for bulk blending and application as a solid because they better match the size of other common fertilizer solids. The small crystals are unsuitable for this purpose. On the other hand, the low-quality small crystals or fines are generally substantially less expensive than the larger crystals and granules. NFERC's objective is to develop methods to satisfactorily ship, store, and use such low-quality. AS fines in normal fertilizer operations to allow industry to take advantage of the favorable economics and to facilitate use of an often unwanted, unusable by-product.

Current Work

There are at least three options for utilization of low-quality AS fines. The AS can be stored as is, but this results in severe caking during storage, soon rendering the material unsatisfactory for use. Two viable methods also are available. NFERC has developed and begun marketing one method and is currently developing a second method for successful storage and use of low-quality AS fines. The method currently being introduced involves production and storage of AS suspension intermediates for later use in production of suspension and solution fertilizers. There are distinct advantages in producing, storing, and using low-quality AS fines in suspension form. Although AS fines are often unsuitable for shipping, storage, handling, blending, or application in solid form, they are ideal for use in suspension fertilizers because they are easier to suspend, require less clay, and allow production of higher grades. Larger crystals or granules are more difficult to suspend, require the addition of extra clay which reduces grade, and can plug screens and application equipment. Simply put, ammonium sulfate which is of the lowest quality for use as a solid can often be of the highest quality for use in suspensions. Production of AS suspensions provides a good means for stable storage of small and/or wet by-product AS crystals, providing the dealer with a good, inexpensive fluid sulfur source ready immediately when needed for application or blending with other fertilizer fluids and solids. Furthermore, a by-product AS producer would not have to dry or even centrifuge the AS crystals and could simply blend wet crystals or slurry with clay and water, lowering production costs and at the same time upgrading a low quality AS into a more usable form. In addition, efforts to obtain large crystals with long retention times in crystallizers would be unnecessary and even detrimental if the AS is intended for fluid fertilizer use. Small crystals are easier to produce with shorter crystallizer retention times and less elaborate, less expensive equipment. Disadvantages to production and storage of AS suspension intermediates are (1) the suspensions are more dilute than the AS solid (2/3 to 3/4 the concentration of the solid), (2) storage for fluids is generally more expensive than storage for solids, and (3) the AS suspension intermediates obviously must be restricted to fluid fertilizer programs.

Another method under investigation at NFERC involves treating the AS fines to improve their storage properties in solid form and to allow their use in both solid and fluid fertilizer programs. This approach has proved to be far more complex than producing AS suspensions or improving dry storage properties of other common fertilizer products because of the variability in crystal size, moisture content, and free acid content and the effects of these variables on the performance of the various treatments. In addition, when the treated AS is to be used for production of fluids, the process becomes even more complicated in that the various treatments have widely varying effects on the properties of the finished fluid fertilizer products. So far, NFERC has developed simple and economical methods for treating relatively dry AS fines to allow satisfactory long-term dry storage followed by use in either fluid or solid fertilizer programs; however, much remains to be developed for treating the wetter and more acidic AS fines. Advantages of treating the AS fines and storage in solid form are (1) the material can be used in either fluid or solid fertilizer programs and (2) storage for solids is generally less expensive than for fluids. One disadvantage encountered so far is that the treated AS fines are more restricted in their potential uses for fluid fertilizers due to the effects that some treatments have on the properties of the fluid fertilizer end products.

Economic Advantage With AS Fines

Whether in fluid or solid form, by-product AS fines generally have a distinct economic advantage over other common fertilizer sources of N and S, especially those used in fluid fertilizers. By-product AS can be used to replace ammonium thiosulfate (ATS) solution or elemental sulfur in production of fluid fertilizers with substantial savings in raw materials costs. When by-product AS is used to replace either elemental sulfur or ATS, less urea-ammonium nitrate solution (UAN) is required to produce the same grade of fluid fertilizer. This adds to the raw material cost savings when using by-product AS. Figure 1 illustrates calculation of the quantities of ATS and UAN (32% N) required to replace the same total N and S supplied in 1 ton of AS. Equating the nutrient content of AS with ATS and UAN and solving the equations first for S and then for N shows that 0.923 ton of ATS and 0.31 ton of UAN are required to supply the 21 units of N and 24 units of S available in one ton of AS. Figure 2 shows that 47% less UAN is required when by-product AS replaces the same quantity of N and S provided by ATS and UAN. When ATS is used in solution and suspension fertilizers, supplemental M is generally supplied by UAN, and when ATS is replaced by AS, 47% less UAN is required to supply the same total units of N and S. When elemental sulfur is used in production of fluid fertilizer blends, elemental sulfur supplies no N at all, and all of the supplemental N is generally supplied as UAN. Therefore, 100% less UAN is required to supply the same total units of N and S. Equating the nutrient content of AS with elemental sulfur and UAN and solving equations similar to those shown in Figure 1 shows that 0.253 ton of elemental sulfur and 0.656 ton of UAN are required to replace the 21 units of N and 24 units of S available in one ton of AS. The lower UAN requirement with AS is one of the reasons by-product AS has such a dramatic economic advantage compared with use of ATS and elemental sulfur in fluid fertilizers. Since the extra N in AS replaces UAN in fluid fertilizers, it can be credited and charged for at UAN prices. However, since the N in AS is so much less expensive than the N in UAN, the result is substantial savings in raw material costs and hence substantial increases in profits for dealers. Figures 3 and 4 illustrate examples of calculating cost savings with by-product AS replacing ATS or elemental sulfur, respectively. For raw material costs of \$60/ton for AS, \$115/ton for ATS, \$200/ton for elemental sulfur, and \$100/ton for UAN, the savings in raw material costs are \$83/ton of ATS and \$221/ton of elemental sulfur replaced with AS. Using the equations shown in Figures 3 and 4 to equate the nutrient content of AS with either ATS or elemental sulfur, several cost savings equations were developed to enable dealers to determine the savings that can be achieved with by-product AS as functions of raw material costs and usage rates. Equations 1 and 2 determine the savings achieved when ATS or 95% S, respectively, are replaced with by-product AS in production of fluid fertilizers, expressed in terms of dollars saved per ton of ATS or 95% S replaced. Equations 3 and 4 determine the savings achieved when ATS or 95: S, respectively, are replaced with AS suspension intermediates, expressed in terms of dollars saved per ton of ATS or 95% S replaced. Equations 3 and 4 differ from equations 1 and 2 only in that they take into account the cost of the clay to produce the AS suspension intermediates. Equations 5-8 are simplified versions of equations 1-4, respectively, and give very close approximations of savings. For any equation, the calculated savings per ton of ATS or 95% S replaced can be multiplied by the annual usage rate of ATS or 95% S, respectively, to determine the annual savings on either raw material. The annual savings on each raw material (ATS and 95% S) can then be added to determine the total annual savings by replacing all ATS and 95% S with AS.

Use of AS With No Extra Clay

$$Sa = ATS + 0.336U - 1.08AS \tag{1}$$

$$Ss = S + 2.6U — 3.96AS \tag{2}$$

where Sa = savings on ATS, \$/ton ATS replaced with AS
Ss = savings on 95% S, \$/ton 95% S replaced with AS
ATS = price of ATS, \$/ton
U = price of UAN-32, \$/ton
AS = price of AS, \$/ton
S = Price of 95% S, \$/ton

Production of AS Suspension Intermediates for Later Use

$$Sa = ATS + 0.336U — 1.08AS — 3.5 \tag{3}$$

$$SS = S + 2.6U — 3.96AS — 13 \tag{4}$$

For Close Estimates, Equations 1-4
Can Be Simplified to:

$$Sa = ATS + 0.34U - 1.1AS \tag{5}$$
$$Ss = S + 2.6U - 4AS \tag{6}$$
$$Sa = ATS + 0.34U - 1.1AS - 3 \tag{7}$$
$$Ss = S + 2.6U - 4AS - 13 \tag{8}$$

EXAMPLE

A dealer uses 650 tons per year of ATS and 185 tons per year of 95% S. How much can be saved by supplying these sulfur needs with by-product AS? Raw material costs are \$115/ton of ATS, \$270/ton of 95% S, \$100/ton of UAN-32, and, \$60/ton of AS. Then from equation l:

$Sa = ATS + 0.336U - 1.08AS$
$Sa = \$115 + 0.336 \times \$100 - 1.08 \times \$60$
$Sa = \$83.80$ saved per ton ATS replaced with AS

From equation 2:

$Ss = S + 2.6U - 3.96AS$
$Ss = \$270 + 2.6 \times \$100 - 3.96 \times \$60$
$Ss = \$292.40$ saved per ton 95% S replaced with AS

The annual savings by replacing 650 tons per year of ATS and 185 tons per year of 95% S with by-product AS would be:

\$ 83.80/ton x 650 tons/year =	\$54,470/year
\$292.40/ton x 650 tons/year =	\$54.094/vear
Total=	\$108,564/year

Equation 1 was used to generate the information in Figures 5 through 7, which illustrate the savings achieved by replacing ATS with by-product AS as functions of UAN, ATS, and AS costs. Surprisingly, with UAN-32 at \$100/ton and by-product AS at \$40/ton, the cost of ATS solution must fall below \$10/ton for by-product AS to loose its economic advantage over ATS. Shown below are some example scenarios for savings with by-product AS calculated from equations l and 2:

Raw Material Costs. $/ton				Savings. $/ton replaced	
AS	ATS	ES	UAN	ATS	ES
60	80	—	80	42	—
40	80	—	80	64	—
60	115	—	100	83	—
60	125	—	120	101	—
60	—	200	80	—	170
60	—	200	96	—	212
60	—	270	120	—	344

In the vast majority of the cases with application of sulfur in fluid fertilizer form, nitrogen is applied in quantities greater than the amount of sulfur, so the assumption to credit the UAN value of nitrogen in AS is almost always valid and the above equations and cost savings apply in most cases. Obviously, savings would be lower for finished grades with N:S ratios substantially less than 1, since the extra N in AS for such grades would not be required.

Ammonium Sulfate Suspension Intermediates

Production of AS suspension intermediates from AS fines and storage for later use in fluid fertilizer blends is a dramatically better alternative to the severe caking encountered when low-quality AS fines are shipped and stored as produced. Furthermore, the solubility characteristics of AS lend it to production of high-quality long-storing suspensions. As shown in Figure 7, the solubility of AS does not vary appreciably with temperature. This is a distinct advantage for the solid phase(s) present in a suspension. In some suspensions, temperature fluctuations during storage result in appreciable dissolution of small crystals and then precipitation on existing crystals, which results in substantial crystal growth over time. With AS, temperature fluctuations normally encountered in storage dissolve and precipitate only very small amounts of AS, so crystal size remains relatively constant over long periods of time. Another advantage associated with ammonium sulfate's temperature-insensitive solubility is the viscosity of AS suspensions remains practically constant over the entire range of temperatures normally encountered in field storage (0-100 °F). This is because the solids content of the AS suspensions changes only very little over this temperature range. AS suspensions, such as 14-0-0-16S and 16-0-0-18S, can be produced with up to twice the nutrient content and with as little as 38% of the water contained in 8-0-0-9S AS solution (Figure 8). As shown in Figure 9, AS solutions must be limited to about 8-0-0-9S grade; above about 9.5% S, the salt-out temperature of AS solutions increases very rapidly with increase in concentration, and care must be taken to avoid crystallization and settling out in storage tanks. With 8-0-0-9S, which contains 63% water, many blends cannot be formulated to contain the desired sulfur content. With the AS suspensions, containing 30 to 34% plant food and only 24 to 32% water, storage volume requirements are lower, shipping costs are lower, and much more flexibility is available in formulating fluid blends than with AS solutions. Furthermore, the AS suspensions can be blended with UAN solution and water with only mild mixing to produce true NS solutions, such as 20-0-0-5S, 22-0-0-4S, and 25-0-0-3S, as illustrated in the solubility diagram in Figure 10. The resulting solutions are slightly cloudy due to the clay in the AS suspensions, but the clay content is less than 1%. The clay particles, which are only 1/1000 mm in size, resist settling, but yet do not impart any thickness to the solutions as might be expected. The clay apparently resists settling because of first being gelled in the AS suspension intermediate. The resulting solutions have viscosities and flow properties that are typical of solution fertilizers. A 22-0-0-4S solution made from AS suspension and UAN , for example, has the same N-to-S ratio as 28-0-0-5S solution made from ATS and UAN and it handles and applies as a true solution, but the cost of raw materials is substantially lower than that for 28-0-0-5S made from ATS. Physical properties of AS suspensions are shown in the following tabulation:

	14–0–0–16S	15–0–0–17S	16–0–0–18S
Clay, wt %	2.8	2.3	1.8
Viscosity, cP			
at 100 °F	1150	1140	1130
at 80 °F	1160	1160	1170
at 45 °F	1190	1190	1190
at 32 °F	1200	1240	1270
at 15 °F	1210	1260	1320
at 0 °F	1120	1280	1340
Preferred crystal size range, Tyler mesh	99% -10	99%: -10	99% -10
	95% -20	95% -20	95% -20
	85% -28	85% -28	85% -28
Solidification temperature, °F	-2	-2	-2
Specific gravity, 1b/gal	11.6	12.0	12.3

AS suspension could well be considered the "sulfur version" of a high-potash suspension such as 4-10-30, or a sulfur base suspension analogous to a phosphate base suspension such as 10-30-0 from MAP.

Production of AS Suspensions

AS suspensions are very easy to produce in common batch suspension fertilizer equipment (Figure 11). The procedure consists of simply adding the water of formulation to the mix tank, starting agitation and recirculation, and then adding the dry clay with continued recirculation and agitation for a few minutes. Next, the AS fines are fed into the mix tank with continued recirculation and agitation. When addition of the AS is complete, the mixture is further recirculated and agitated for a few minutes if desired to ensure a homogeneous mixture. The suspension is then ready for direct application, production of fluid blends, or storage for later use. The higher-grade, lower-clay-content suspensions such as the 16-0-0-18S grade are most suitable for short term storage (up to 1 month), and grades such as 14-0-0-16S with 3% clay are suitable for long-term storage (up to 6 months or longer). The AS suspensions should be agitated by air sparging and/or recirculating with a pump (preferably both) during storage to maintain optimum condition and homogeneity of the suspensions. The 16-0-0-18S grade should be agitated more frequently for shorter periods of time, such as for 2 or 3 minutes three to five times per week, whereas the 14-0-0-16S grade only needs agitation two to three times per month. Agitation time depends on the intensity of the agitation (air pressure and volume or recirculation rate in relation to tank volume).

An important consideration in the production and storage of AS suspensions is the size of the ammonium sulfate crystals. AS referred to as "fines" can vary dramatically in size, as shown in Figures 12 and 13. As shown in Figure 13, the smaller crystals are more suitable for production of AS suspensions because they (1) allow production of higher grades, (2) require less clay, (3) result in less settling, and (4) result in less clogging of screens and application equipment. However, the smaller AS crystals do not store as well in solid form, so they must be converted to suspensions as soon as possible after shipment. If possible, it is desirable to use AS crystals with a size range similar to that of solution-grade potassium chloride, such as the ammonium sulfate "AS–1" in Figure 13; solution-grade potassium chloride is already commonly used in production of suspension fertilizers and the specific gravity of potassium chloride crystals is even greater than that of AS (2.0 versus 1.8). If larger crystal AS fines are used, it is usually necessary to reduce the grade and increase the clay content to prevent settling in the suspension. Also, the larger AS crystals take longer to dissolve when making solution fertilizers from the AS suspensions. However, the larger AS crystals generally have better storage properties in solid form.

AS suspensions can also be produced from by-product sulfuric acid and ammonia by the hot mix process for AS suspensions. The hot mix process is more suitable for continuous operation for corrosion reasons. In the continuous hot mix process, sulfuric acid and ammonia replace ammonium sulfate and are fed simultaneously to a reactor at rates required for maintaining the pH in the neutral range to lessen tendency for corrosion. Reaction of sulfuric acid with ammonia produces a hot slurry containing ammonium sulfate crystals. This hot slurry is cooled to about 100 °F in a spray-type evaporative cooler with addition of suspending clay in the cooler or after cooling in a separate mixer.

The hot mix process would be applicable to industries which are currently generating waste/by-product sulfuric acid or otherwise generating hot ammonium sulfate slurry as a by-product stream, such as in production of coke. Conversion of the hot AS slurry directly into AS suspension would eliminate the need for elaborate equipment for producing large crystals and eliminate centrifuging and drying steps in production of crystalline AS. To accomplish this, a common batch suspension fertilizer plant could be installed at the AS producer site to intercept the AS slurry before centrifuging and drying and convert the AS slurry directly into AS suspension by cooling and adding clay.

Treating AS to Improve Dry Storage Properties

NFERC is currently developing methods for treating AS fines to improve dry storage and flow properties for direct use in both solid and fluid fertilizer programs and for use in granulation. So far, simple and economical methods have been developed for treatment of relatively dry (<0.5% moisture) AS fines which provide for satisfactory storage for at least 6 months and excellent after-storage flowability for direct application of the fines, for use in solid and fluid fertilizer programs, and for use in granulation. These methods have so far been proven with 50-pound quantities of AS, stored under roof but exposed to atmospheric humidity. Currently, NFERC is testing these methods in 5-ton quantities in bays also exposed to outdoor conditions. If AS fines are relatively dry as produced or can be dried after production, methods for treating the fines to obtain good long-term storage properties are simple and inexpensive. However, methods for treating AS fines which are relatively wet (>1% moisture) and/or have relatively high free acid contents has been up to this point complicated and unpredictable. Performance of various treatments appears to be affected, often unpredictably, by moisture and free acid contents, crystal size, and possibly other variables, such as perhaps the variation in organic residue present on the AS fines. Further complicating matters, performance of the treated AS fines in fluid fertilizers varies dramatically with the type of treatment and acidity of the AS fines.

Figure 14 illustrates the relative flowability of untreated AS fines as a function of moisture content. The relative flowability of the AS fines is represented by the angle of repose, which has proved to be a useful and predictable measure of flowability of the AS fines. The angle of repose, however, indicates only flowability and yields no information on the caking tendency of the fines, for which measurements in addition to actual storage have been used. Generally, AS fines with angles of repose less than about 40 degrees have demonstrated good flowability, whereas AS fines with angles of repose much in excess of 40 degrees have poor flow properties. Figure 14 shows that, even when considering AS fines from two different sources with significantly different crystal size distributions, the relationship between flowability and moisture content is practically the same. With moisture contents much in excess of 0.1 to 0.2%, the flow properties of AS fines are generally poor. However, several treatment methods for a relatively dry AS (0.2% moisture), Figure 15, have been successful in reducing the angle of repose to satisfactory flowability levels. Furthermore, these treatments have resulted in good storage and after-storage flow properties in 6-month storage tests of 50-pound quantities, as illustrated in Figure 16. The 50-pound sample of untreated AS, as well as a 25-ton pile of the same untreated AS, exhibited severe caking throughout during the 6 months of storage, even though the moisture content remained relatively constant at about 0.2%. Surprisingly, some of the AS samples which had undergone treatment before storage actually had substantially higher moisture contents than the untreated AS fines after storage, but yet did not exhibit caking and had excellent flow properties after storage. The untreated AS fines exhibited caking throughout the volume of the material, but the treated AS fines generally formed 1/2- to 1-inch crusts on top of the material, with the material underneath being as free flowing as dry sand. The hardness of the thin crust on the treated AS fines varied from very soft and crumbly to hard depending on the method of treatment. The successful treatment methods shown in Figures 15 and 16 are currently being tested in 5-ton quantities at NFERC. In addition, accelerated caking and critical relative humidity (CRH) tests have been conducted to further characterize and predict the performance of the various treatment methods successful in the 50-pound tests. In CRH tests, most of the treatment methods increased the CRH by about 5 percentage points, from about 73% to about 78%; this is not a dramatic difference but could be a factor in a humid climate.

Development of successful treatment methods for wet and/or high acidity AS fines is another matter altogether. So far, results are inconclusive, and often even excessive treatments have been unsuccessful in obtaining satisfactory initial flowabilities. When excessive treatments are used to obtain satisfactory initial flowabilities, the result can be a decrease in flowability and an increase in caking tendency as shown in Figures 17 and 18.

Finally, successful treatment of AS fines can be complicated when the fines are to be used in production of fluid fertilizers. For example, various AS fines treatment methods can result in suspension viscosities which are either too low, resulting in settling of crystals, or too high, preventing pumping and successful handling in general, as illustrated in Figure 19. Much remains to investigate on methods to utilize the successfully treated AS fines satisfactorily in fluid fertilizers, due to both property and appearance effects in the finished fluid fertilizers. Having to lower the suspension grade substantially by varying degrees depending on treatment type/level, which depends on AS moisture, acidity, and source, would be a distinct disadvantage and limitation to using the treated AS fines in fluid fertilizer programs. Currently, NFERC is investigating treatment methods for AS fines to meet both objectives—improving dry storage properties for use as is and suitability for use in fluid fertilizer programs.

In summary, utilization of by-product AS fines, whether in solid or fluid form, can provide substantial economic savings and increase in profits over elemental sulfur, ATS, or even urea and UAN solutions when considering nitrogen alone. Also, production of AS suspensions or treated dry AS from by-product AS fines transforms one of the lowest quality, least expensive, and often unwanted forms of by-product AS into products with good storage, handling and application properties.

COST SAVINGS WITH B-P AS

UNITS OF N AND S IN 1 TON OF AS, ATS, AND UAN-32

AS: 21N + 24S

ATS: 12N + 26S

UAN: 32N

HOW MUCH ATS AND UAN PROVIDE 21N + 24S ?

1 TON AS = (?) TON ATS + (?) TON UAN-32

21N + 24S = (?)(12N) + (?)(26N) + (?)(32N)

21N + 24S = 0.923(12N) + (0.923)(26S) + (0.31)(32N)

1 TON AS = 0.923 TON ATS + 0.31 TON UAN-32

FIGURE 1

47% LESS UAN-32 REQUIRED WITH AS

1 TON AS/0.923 TON ATS = 1.08 TONS AS/TON ATS

1.08 TONS AS SUPPLIES 22.7 UNITS N

1 TON ATS SUPPLIES 12 UNITS N

1 TON ATS SUPPLIES 10.7 LESS UNITS N

10.7 UNITS N/0.32 = 0.334 TONS UAN-32

10.7/22.7 = 47% LESS UAN-32 REQUIRED WITH AS

FIGURE 2

COST SAVINGS WITH B-P AS

1 TON AS = 0.923 TON ATS + 0.31 TON UAN-32

EXAMPLE

AS = \$60/TON
ATS = \$115/TON
UAN = \$100/TON

\$60 = 0.923(\$115) + 0.31(\$100)

\$60 ≠ \$137

SAVINGS = \$77/TON AS USED

SAVINGS = \$83/TON ATS REPLACED WITH AS

FIGURE 3

COST SAVINGS WITH B-P AS

HOW MUCH 95% S AND UAN-32 PROVIDE 21N + 24S ?

1 TON AS = 0.253 TON 95% S + 0.656 TON UAN-32

EXAMPLE

AS = \$60/TON
95% S = \$200/TON
UAN-32 = \$100/TON

\$60 = 0.253(\$200) + 0.656(\$100)

\$60 ≠ \$116

SAVINGS = \$56/TON AS USED

SAVINGS = \$221/TON 95% S REPLACED

FIGURE 4

COST SAVINGS WITH BY-PRODUCT AMMONIUM SULFATE AS VERSUS ATS SOLUTION UAN-32 = $120/TON

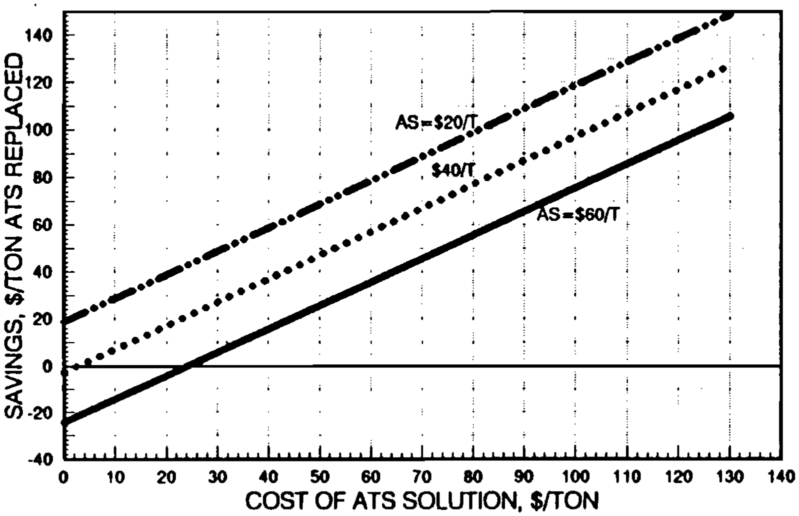

FIGURE 5

COST SAVINGS WITH BY-PRODUCT AMMONIUM SULFATE AS VERSUS ATS SOLUTION UAN-32 = $100/TON

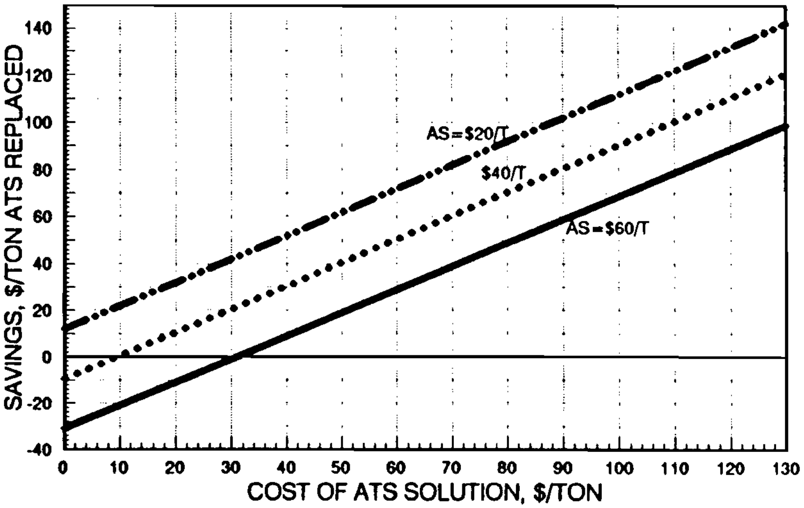

FIGURE 6

COST SAVINGS WITH BY-PRODUCT AMMONIUM SULFATE AS VERSUS ATS SOLUTION UAN-32 = $80/TON

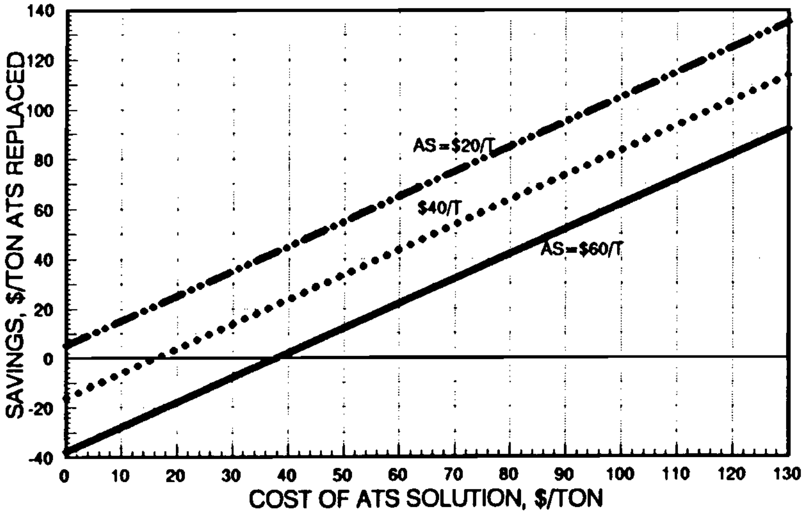

FIGURE 7

SOLUBILITY OF AMMONIUM SULFATE IN WATER

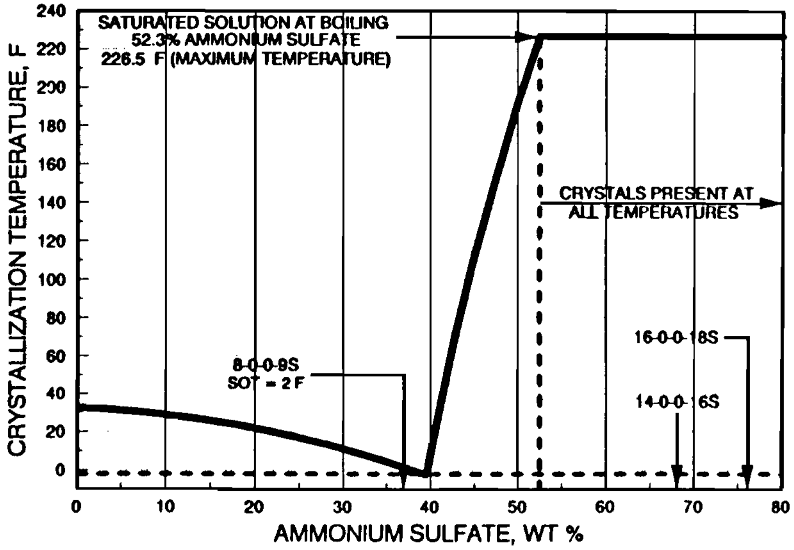

FIGURE 8

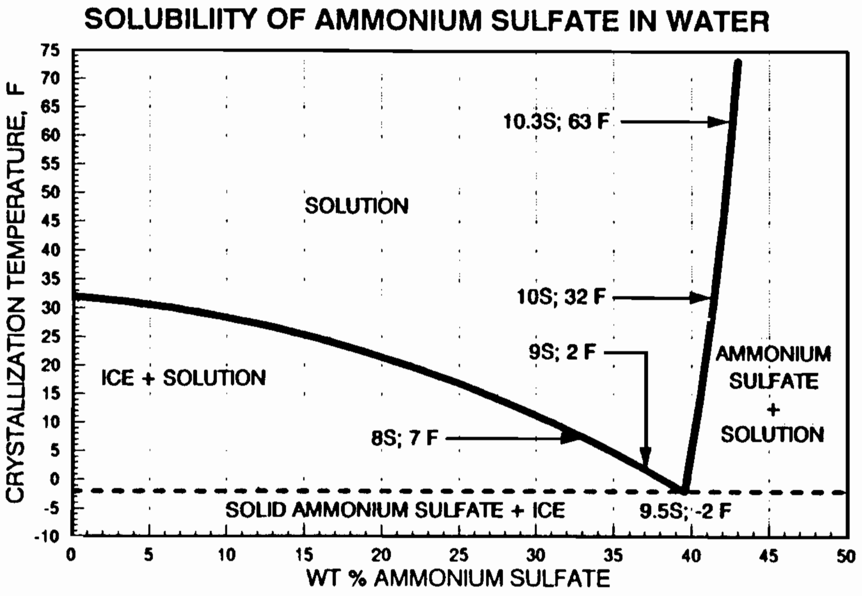
SOLUBILIITY OF AMMONIUM SULFATE IN WATER

FIGURE 9

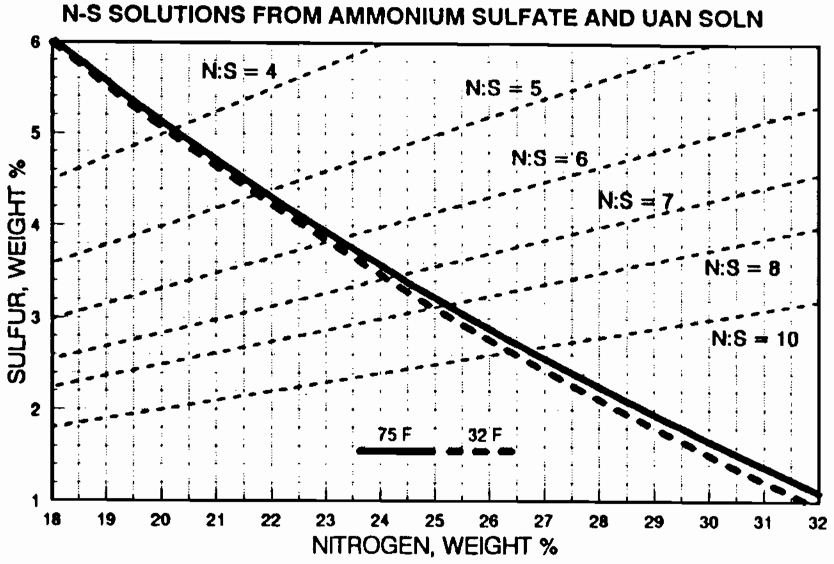
N-S SOLUTIONS FROM AMMONIUM SULFATE AND UAN SOLN

FIGURE 10

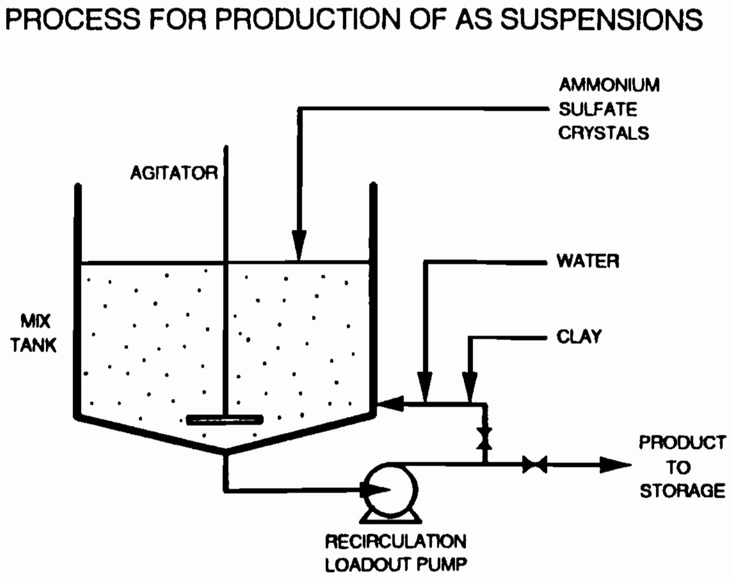
PROCESS FOR PRODUCTION OF AS SUSPENSIONS

FIGURE 11

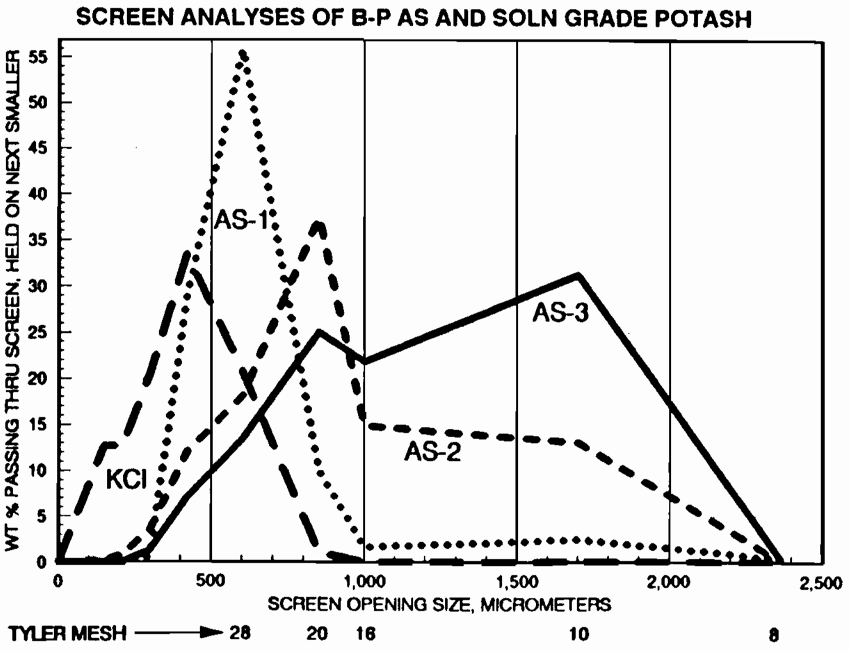
SCREEN ANALYSES OF B-P AS AND SOLN GRADE POTASH

FIGURE 12

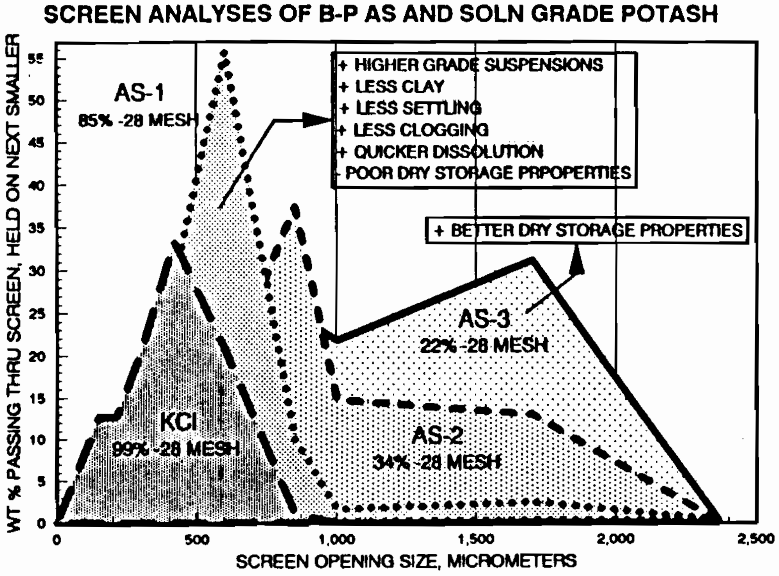
SCREEN ANALYSES OF B-P AS AND SOLN GRADE POTASH

FIGURE 13

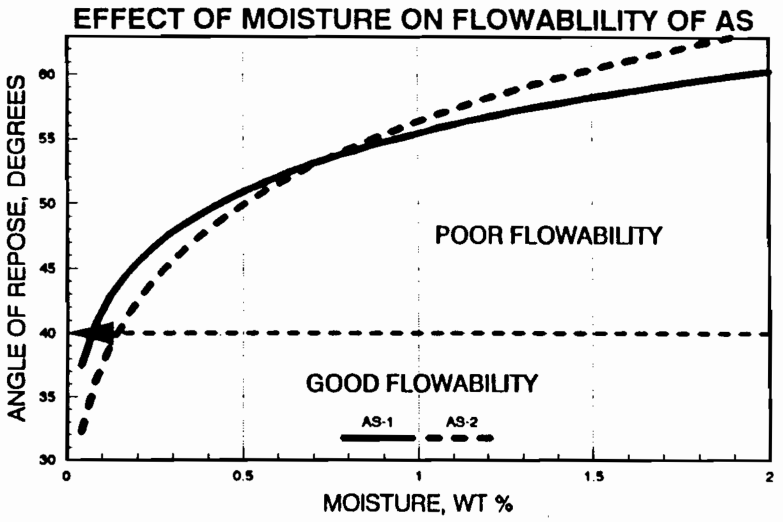
EFFECT OF MOISTURE ON FLOWABLILITY OF AS

FIGURE 14

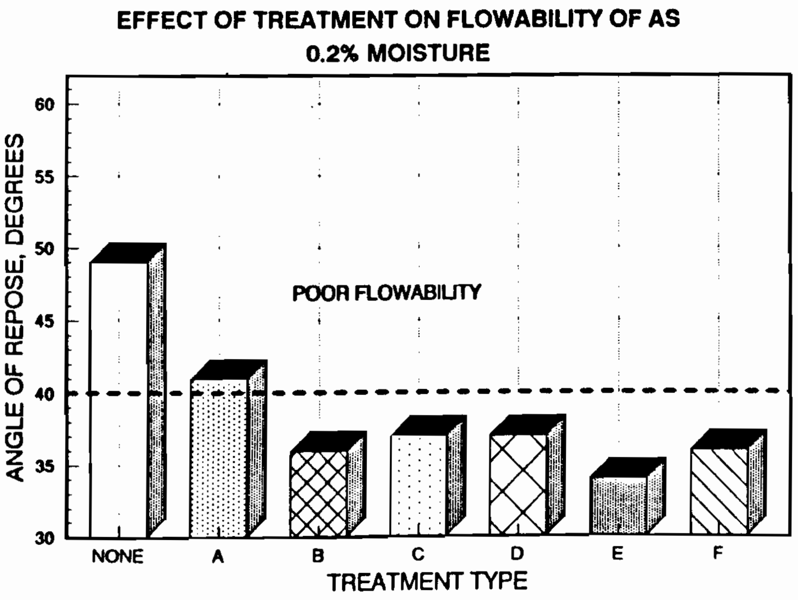
EFFECT OF TREATMENT ON FLOWABILITY OF AS
0.2% MOISTURE

FIGURE 15

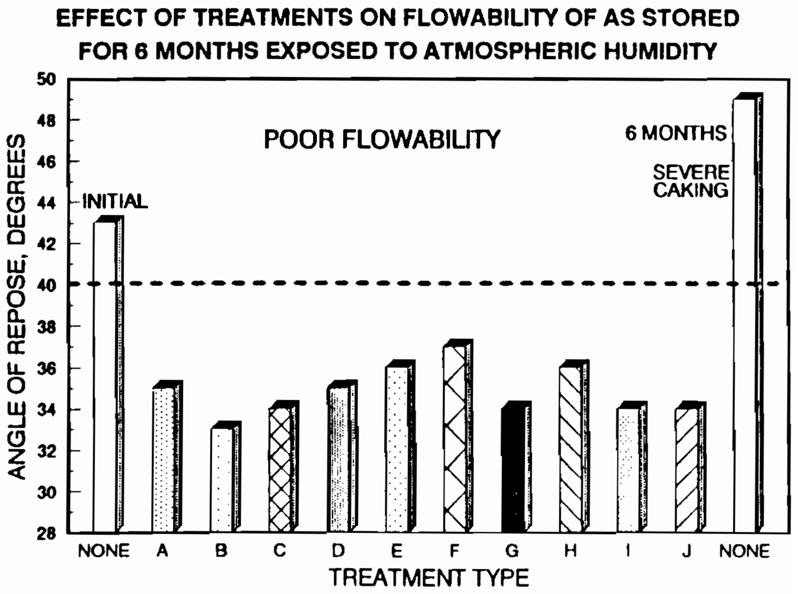
EFFECT OF TREATMENTS ON FLOWABILITY OF AS STORED FOR 6 MONTHS EXPOSED TO ATMOSPHERIC HUMIDITY

FIGURE 16

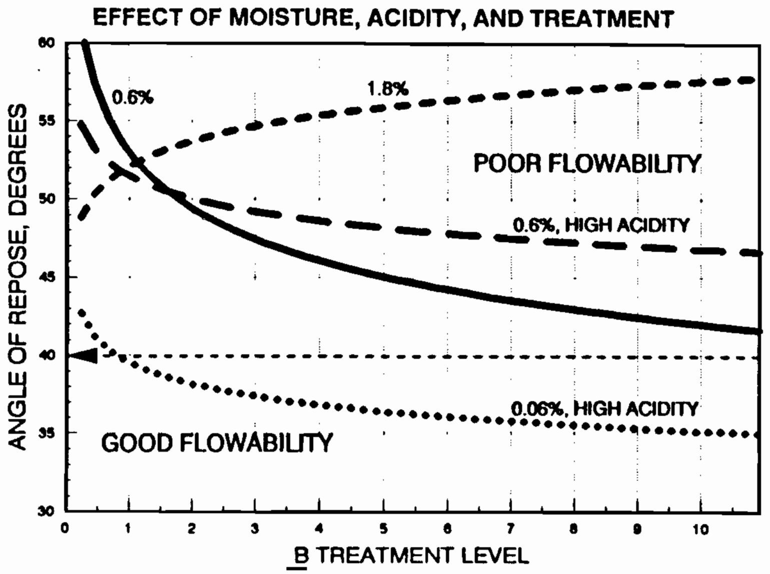

FIGURE 17

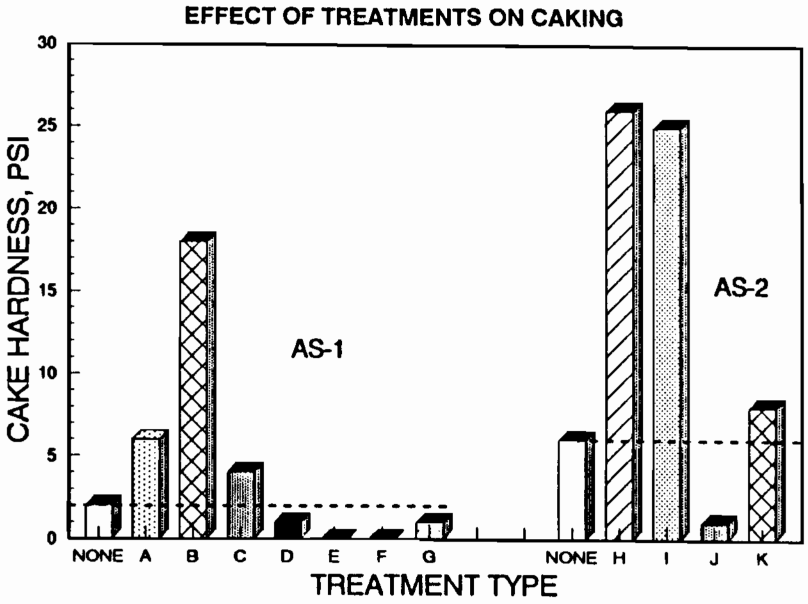

FIGURE 18

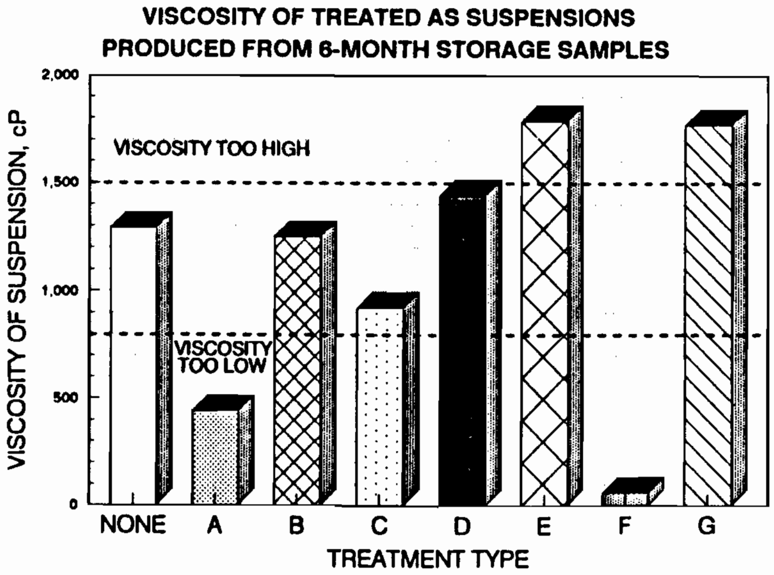

FIGURE 19

Use Of By-Product Phophogypsum To Correct Sulfur Deficiencies In Forage

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Importace of Sulfur

Sulfur deficiencies for plant growth have been reported in over 35 states including Florida. Though sulfur is usually termed a secondary plant nutrient, sulfur should be considered one of the major nutrients essential for crop growth along with nitrogen, phosphorus and potassium. Sulfur is required by plants for the synthesis of certain amino acids which are required for protein production. Thus, if sulfur is limiting, forage quality, as well as quantity, will be reduced. In fact sulfur deficiencies are often confused with nitrogen deficiency. In less severe cases of sulfur deficiency, visual symptoms may not always show up, but crop yield and quality will still be affected.

Until recently, little attention has been focused on the need for sulfur fertilization in Florida and other parts of the country. This is understandable since in the past low analysis fertilizers contained sulfur and therefore ranchers did not need to be concerned with sulfur fertilization. However, today fertilizer manufacturing technology has become highly advanced and as a consequence high analysis fertilizers such as triple superphosphate and diammonium phosphate are free of sulfur impurities. As a result, sulfur deficiencies are becoming more pronounced and widespread throughout the world. Coarse textured soils such as those commonly found in Florida often exhibit sulfur deficiencies since they have a very low nutrient holding capacity.

It is important to note that sulfur fertilization will only increase yields and quality of crops if the plants are deficient in sulfur to begin with. The sulfur status of a crop is best determined by having a plant tissue sample analyzed for sulfur by a reputable laboratory. In fact, a tissue analysis for sulfur is more reliable than a soil test for determining sulfur deficiencies. For grasses, the level of sulfur in the plant tissue should range from 0.2-0.5 percent. If the level of sulfur is less than 0.2 percent, the grass should respond to sulfur fertilization.

Over the years, we have demonstrated that addition of sulfur can increase production of harvested forages such as bahiagrass (*Paspalum notatum* L.) by as much as 25 percent and protein content by 1.2 percent. In these studies, the sources of sulfur were ammonium sulfate and sulfate of potash. Bahiagrass is an important forage crop grown in Florida, with nearly 2.5 million acres grown annually. In fact bahiagrass is found on more acres than all other improved grasses combined. However, there is a need to find alternative economic sources of sulfur which growers may use such as by-product phosphogypsum.

Phosphogypsum

Phosphogypsum ($CaSO_4$), a by-product of the wet-acid production of phosphoric acid from rock phosphate process, is believed to be a potential low cost source of sulfur and calcium for forages. For a detailed review of the various uses of phosphogypum in agriculture please see the review by Alcordo and Rechcigl (1993).

In Florida alone, there are over 600 million tons of by-product phosphogypum in waste stacks with an additional 30 million tons accumulating annually. Over all there are over 9 billion tons of phosphogypsum stacked in the United States! Unfortunately, phosphogypsum has generally been considered a waste product without much economical use. One reason for this is that phosphogypsum contains low levels of radium (20-30 pCi Ra-226 g^{-1}) creating concern over what effects it has on the environment.

Phosphogypsum Field Study

Methods

Over the past 3 years, we have been evaluating both the agricultural as well as the environmental impact of phosphogypsum use on forages grown in Florida. 1 would like to present the findings of part of that study, specifically dealing with the effects of phosphogypsum on bahiagrass and the environment.

The study was conducted at the Ona Agricultural Research and Education Center which is a part of the University of Florida. Four rates (0, 0.2 (applied annually), 1.0 and 2.0 tons/acre (applied once)) of phosphogypsum were applied to established bahiagrass plots located on a Myakka fine sand (Aeric Haplaquod). Bahiagrass forage was harvested monthly from March until December in order to access the influence of phosphogypsum on forage production. Subsamples of the forage were also collected for elemental analysis. Soil samples were collected annually to a depth of 3 feet and dried and sieved prior to chemical analysis. Water samples were collected monthly and filtered and frozen prior to chemical analysis.

Results

Yield

Regardless of rate or time of application, phosphogypsum addition increased bahiagrass yields by approximately 15 percent (Figure 1). This increase in yield is a result of the phosphogysum supplying sulfur and/or calcium to the forage. Numerous other studies have also shown addition of sulfur to increase the yields of forages when sulfur was deficient.

Forage Quality

Phosphogypsum also increased the bahiagrass protein content by 1 percentage unit and the digestibility by as much as 8 percentage units (Figures 2 and 3). It has been well established in the literature that addition of sulfur will increase the quality (protein and digestibility) of forages.

However it should be recognized the these increases in forage production and quality will only be obtained if the soil is deficient in sulfur to begin with.

As expected, the addition of phosphogysum increased both the calcium and the sulfur content of the bahiagrass tissue (Figures 4 and 5). The calcium content ranged from 0.42-0.60 percent while the sulfur content ranged from 0.18 to 0.40 percent for the 0 and 2.0 tons phosphogypsum/acre treatments, respectively.

Phosphogypsum addition did slightly increase the fluoride content of the bahiagrass tissue, though it is well below the 30 ppm maximum acceptable level for livestock intake (Figure 6). The low levels of tissue fluoride found in this study are of great significance since high levels of fluoride can cause the teeth in cattle to fall out.

Tissue Ra-226 ranged from 0.01 to 0.03 pCi/g for the 0 and 2.0 tons/acre phosphogypsum plots, respectively (Figure 7). Though the level of Ra-226 did increase with increasing rates of phosphogypsum, the increases in Ra-226 were very low and not significant. Currently there is not a maximum level set for Ra-226 in forage tissue.

Soil Data

Addition of phosphogypsum did not increase the Ra-226 levels in the soil down to a depth of 3 feet into the soil profile (Figure 8). The levels of Ra-226 averaged 0.5 pCi/g, well below the maximum level of 5.0 pCi/g. As expected both calcium and sulfur levels were increased in the soil with the addition of phosphogypsum (data not shown).

Water Data

Phosphogypsum increased the electrical conductivity of water samples to a depth of 4.0 feet (Figure 9). The electrical conductivity levels ranged from 450 to 800 umho/cm which is well below the 1500 umho/cm level set for acceptable irrigation water.

There were no significant increases in Ra-226 levels in the water samples taken with levels of Ra-226 averaging less than 1 pCi/L (Figure 10). The maximum acceptable level for Ra-226 in water is currently 20 pCi/L, showing that the addition of phosphogypsum (up to 2.0 tons/acre) did not present any water quality problems.

The addition of up to 2.0 tons/acre of phosphogypsum did double the fluoride levels in the water (Figure 11). Fluoride levels averaged 0.1 and 0.4 ppm for the 0 and 2.0 tons/acre phosphogypsum treatments at the 2.0 foot depth, respectively. This is below the 1.0 ppm fluoride level set for drinking water to prevent dental decays.

Radon Flux and Ambient Radon

One of the major concerns by environmental groups and E.P.A regarding the agricultural use of phosphogypsum centers around radon. There is concern that application of phosphogypsum to farmland will result in an increase in ambient radon as well as radon flux levels which ultimately could be hazardous to humans. It has indeed been established that phosphogypsum does contain low levels of Ra-226 which ultimately does decay to radon gas. In this study we did evaluate the effects of agriculturally applied phosphogypsum on radon flux and ambient radon levels. It was shown that there were no increases in radon flux levels with the addition of up to 2.0 tons/acre of phosphogypsum (Figure 12). Radon flux levels averaged 0.05 pCi/sq m/s which is substantially below the U.S. average radon flux level of 0.45 pCi/sq m/s as established by the N.C.R.P.

The addition of phosphogypsum also did not affect the ambient atmospheric radon levels, averaging 0.20 pCi/L (Figure 13). The average level for ambient radon in the U. S. as established by E.P.A is 0.40 pCi/L.

Conclusions

Based on the results of this study, the addition of phosphogypsum can increase both the yield and quality of harvested bahiagrass. However these increases can only be expected if the bahiagrass tissue is grown on sulfur and/or calcium deficient soils as are found in over 35 states in the U.S. The best way to determine a sulfur deficiency is through a tissue test. In the case of bahiagrass, if the tissue sulfur content is below 0.20 percent then the plant is deficient in sulfur and sulfur should be applied. There also does not appear to be any environmental problems to occur from agricultural application of up to 2 tons of phosphogysum per acre. Thus, phosphogypsum appears to be a safe, viable and economical source of sulfur for forage production.

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1. Alcordo, I.S. and J. E. Rechcigl. 1993. "Phosphogypsum use in agriculture: A review." *Advances in Agronomy*. Academic Press Vol. 49. (in press).
2. Rechcigl, I. E., 1. S. Alcordo, C. E. Roessler, and R. C. Littell. 1992. "Influence of phosphogypsum on forage yield and quality, and on the environment in a typical Florida spodosol soil." Florida Institute of Phosphate Research Progress Report. Bartow, FL.

Figure 1.
Influence of phosphogypsum on bahiagrass yields.

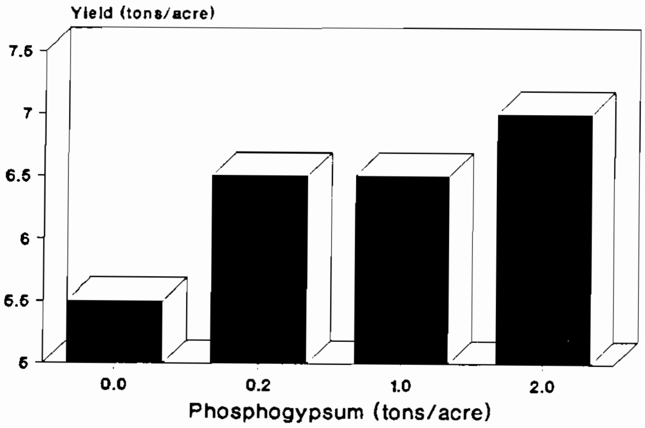


Figure 2.
Influence of phosphogypsum on bahiagrass protein content.

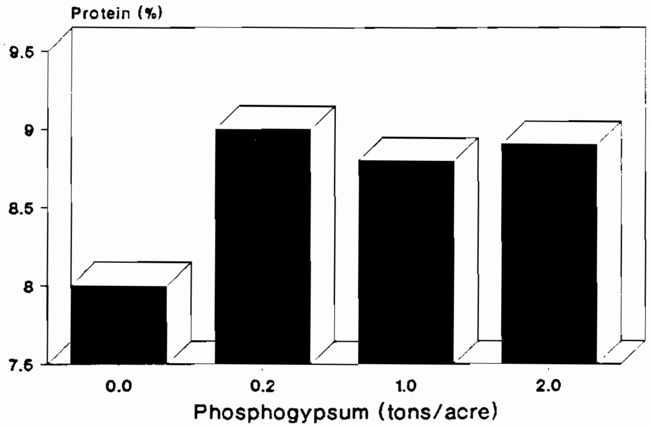


Figure 3.
Influence of phosphogypsum on bahiagrass digestibility.

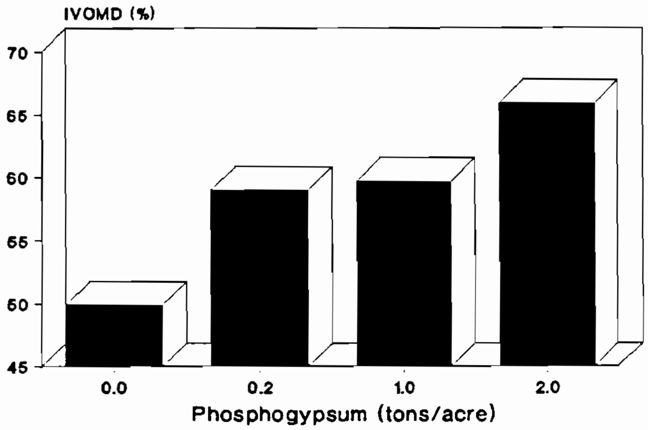


Figure 4.
Influence of phosphogypsum on bahiagrass tissue sulfur content.

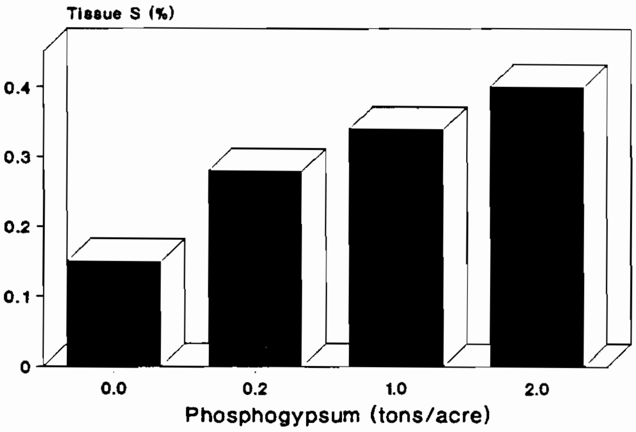


Figure 5.
Influence of phosphogypsum on bahiagrass tissue calcium content.

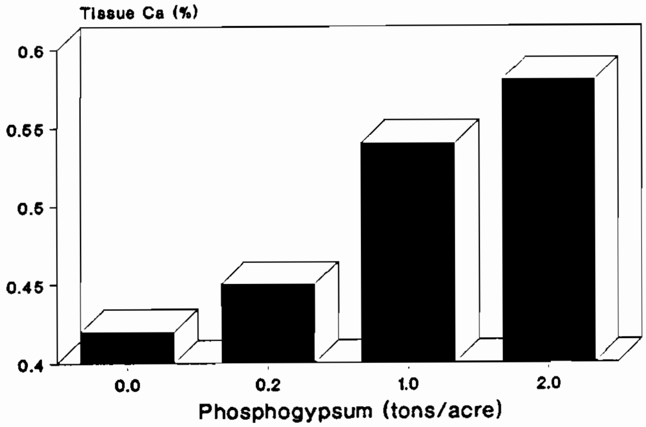


Figure 6.
Influence of phosphogypsum on bahiagrass tissue fluoride content.

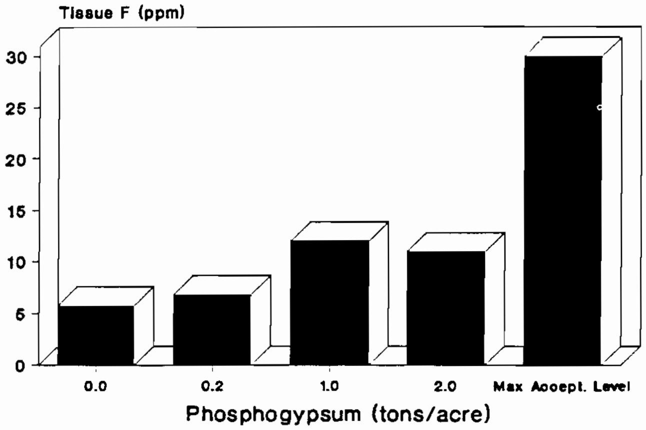


Figure 7.
Influence of phosphogypsum on bahiagrass tissue Ra-226 content.

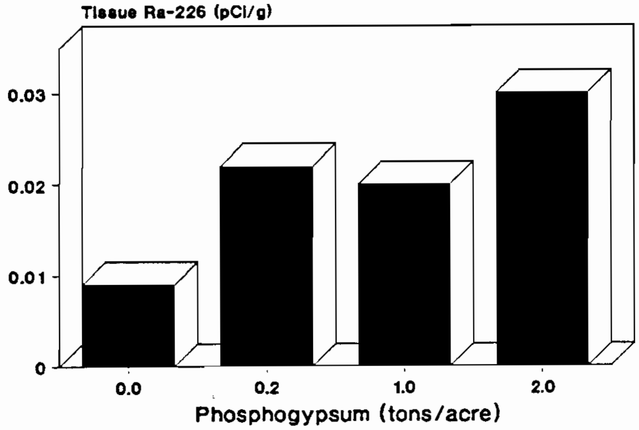


Figure 8.
Influence of phosphogypsum on on soil Ra-226 content.

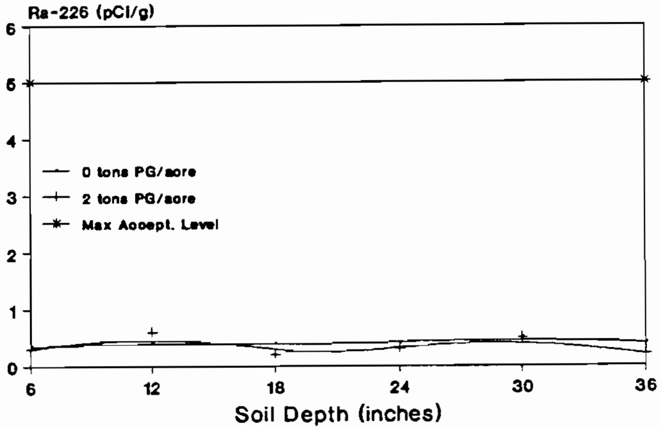


Figure 9.
Influence of phosphogypsum on electrical conductivity of surfave and ground water.

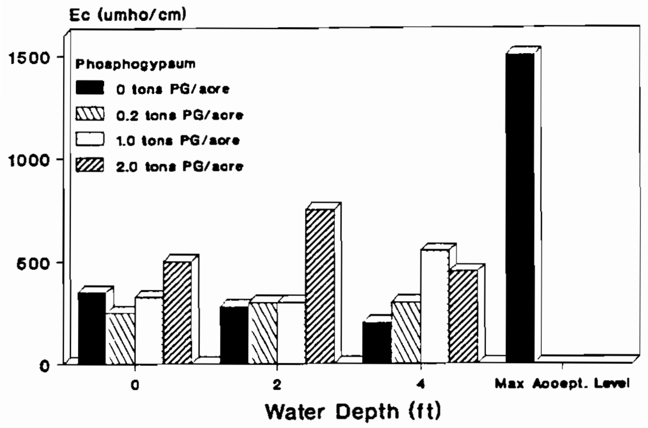


Figure 10.
Influence of phosphogypsum on Ra-226 content of surface and ground water.

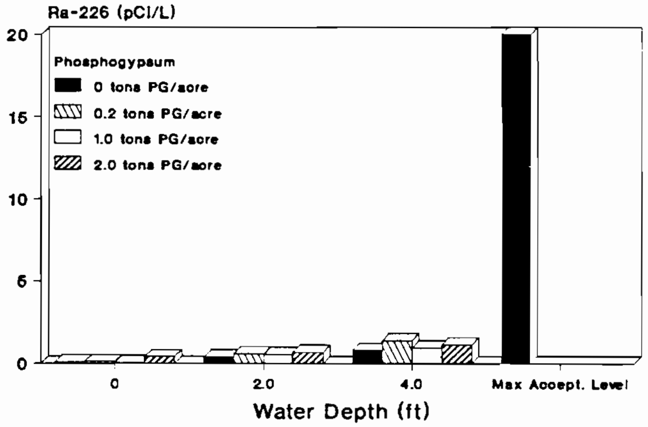


Figure 11.
Influence of phosphogypsum on fluoride content of surface and ground water.

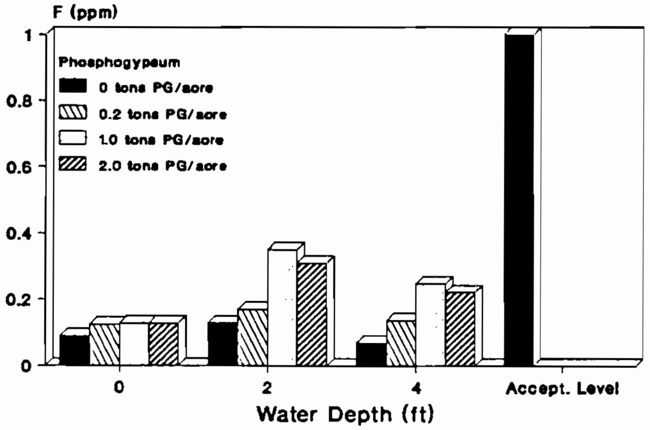


Figure 12.
Influence of phosphogypsum on radon flux.

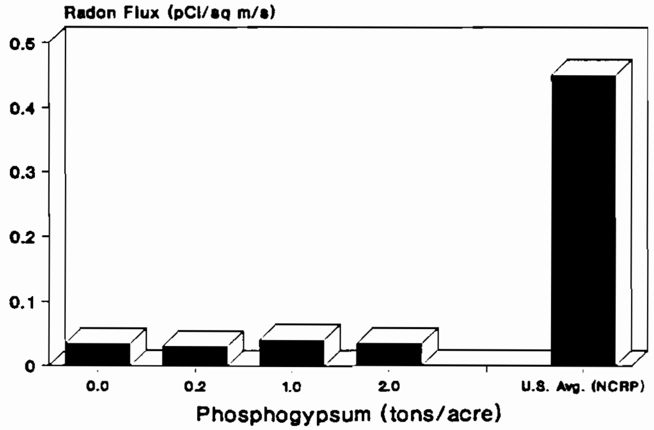
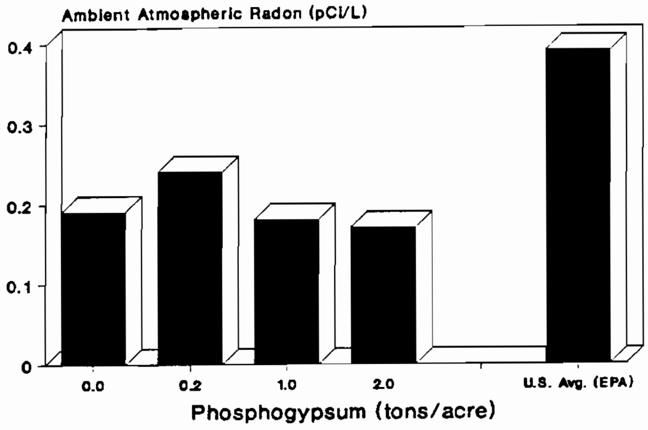


Figure 13.
Influence of phosphogypsum on ambient atmospheric radon



Processing Sludges For Acceptance In The Fertilizer Industry

Lee D. Hoffmann
FEECO International, Inc.

1. ***Introduction*** - In 1982 John Naisbitt published a book called "Megatrends".

This book was a based on a collection of news stories which were summarized into the (10) major cultural shifts. Below are the trends as described in this book:

a. Industrial Society to an Information Society.
b. Forced Technology to a High Tech/High Touch Society.
c. National Economy to a World Economy.
d. Short Term Oriented to Long Term Oriented.
e. Centralization to Decentralization.
f. Institutional Help to Self Help.
g. Representative Democracy to Participatory Democracy.
h. Hierarchies to Networking.
i. North to South.
j. Either/Or to Multiple Option.

In particular I would like to focus your attention on item "J". Personal choices for Americans remained rather narrow and limited from the postwar period through much of the 60's.

I am sure you can all remember all telephones were black, bathroom fixtures were white, checks only came in green, there were only (3) television stations, and soft drinks came in (3) flavors. (Coke, Pepsi, and 7-Up). In contrast, telephones, bathroom fixtures and checks, are now available multi-colors and styles. Cable TV offers over (30) stations and there are at least (8) variations of Coke. Today there is Coke, Diet Coke, Caffeine Free Coke, Caffeine Free Diet Coke, Cherry Coke, Diet Cherry Coke, Caffeine Free Cherry Coke, and Caffeine Free Diet Cherry Coke. Let alone the multitude of Flavored Mineral Waters.

Well I propose that Sewage Sludge is the Diet Coke of the Fertilizer Industry.

You may wonder why I would open with something so seemingly extraneous to the Fertilizer Industry. Well, believe it or not, the same people that support the above alternatives are the same people that are fertilizing their lawns and nourishing their gardens, and maintaining our golf courses and probably most important of all, the same people that are feeding the world.

A study of our marketing statistics indicates that, never before, have we received more inquiries on equipment needed to process alternative items such as Bat, Chicken, Cattle and Turkey manure, as well as Industrial Sludges and most of all Municipal Wastewater Sludges.

Since we have seen the most activity in Sewage Sludge and it is such an abundant material the balance of this paper will concentrate on its beneficial use.

We are presently working with entrepreneurs who are contracting for the output of these facilities. In most cases they are being paid to take this output and in addition then convert it to fertilizer. Much of the equipment to do so, is very similar to traditional fertilizer manufacturing equipment; however process technology and controls are more refined.

2. Government's Present and Proposed Position on Agricultural Sewage

Sludge Use:

a. **Sewage Sludge Survey** - In November of 1990 the EPA published a report called the National Sewage Sludge Survey. This survey consisted of data collection and an informational questionnaire to obtain data on sewage sludge quality and management. The data in this report was based on 1988 disposal methods.

The results of the survey have provided the EPA with current data and information essential to establishing numerical pollutant limits in the final part of the 503 rule that will encourage the beneficial reuse of sewage sludge and provide a greater degree of public health and environmental protection.

b. Because of its origin, wastewater products used in agriculture are subject to regulations which are not imposed on chemical fertilizers. No other material used in agricultural has been subjected to a more rigorous and comprehensive risk analysis.

c. The biggest negative associated with the agricultural use of sewage sludge presently is the perception around heavy metals. The attached graphs will assist in our discussion of the heavy metals issue:

Allowable Metals/Average Metals Graph - Along the bottom of the graph you will notice (10) metals the EPA seems most concerned with.

(1)The first bar indicates what the EPA has defined as **"Cumulative Pollutant Loading Rates"** in kilograms per hectare (2.471 acres). These figures were published in February of 1989 and are about to be revised. The new numbers will be issued later next month. The EPA would not give any indication on which way any of the allowances were going.

(2)In order to contrast these numbers I needed to assume an application rate. For this I assumed the load would be if the entire EPA allowable, 50 dry metric ton per hectare, sludge load was applied. The metals content is the average derived from the National Sewage Sludge Survey.

You will note that in most cases, with the exception of Copper, the metals loading is insignificant. I would also like to point out that a present land application operation, in the Rockford, IL area, is currently applying at a rate that is only 6% of the currently allowable 50 metric ton limit. This would make these insignificant numbers even less significant.

I should also point out that the EPA has several calculations that must be performed to determine the maximum sludge that can be applied per hectare. Generally these calculations will reduce the amount of allowable sludge. However in no event may it exceed the 50 metric ton limit.

Average Metals Mg/Kg Graph - Along the bottom of the graph you will again notice the same list of metals. However, on this graph we compare the average metals contents, again from the National Sewage Sludge Survey, against various products you are familiar with. As you can see, according to current EPA publications, metals in sewage sludge do not appear to be that big of an issue. This certainly will need to be re-addressed once the new regulations are published.

3. **Present Disposal Statistics** - At the time of the National Sewage Sludge Survey (August 1988 - September 1989) there were 11,407 publicly owned sewage treatment facilities in the United States and Puerto Rico. The survey summarized the sludge disposal methods into these following categories:

a. **Land Application** - The application of liquid, dewatered, dried, or composted sewage sludge to the land by surface spraying, surface spreading, or subsurface injection.

b. **Distribution and Marketing** - The give-away, transfer, or sale of sewage sludge or sewage sludge product in either bagged or bulk form.(Milorganite, Composting)

c. **Sewage Sludge Incineration** - The treatment of sewage sludge exclusively in an enclosed device using controlled flame combustion.

d. **Monofill** - A controlled area of land that contains one or more sewage sludge units. A sewage sludge unit is defined as a controlled area of land where only sewage sludge is placed. The sludge is covered with a cover material at the end of each operating day or at more frequent intervals.

e. **Co-Disposal Landfill** - An area of land or an excavation that is used for the permanent disposal of solid waste residuals, and sewage sludges.

f. **Ocean Disposal** - Dumping or controlled release of sewage sludge form a barge or other vessel into marine water.

g. **Co-incineration** - The combined treatment of sewage sludge and other combustible waste materials in an enclosed device using controlled flame combustion.

h. **Surface Disposal** - A controlled area of land where only sewage sludge is placed for a period of one year or longer. Sludge placed in this area is not provided with a daily or final cover.

As you can see from the graph there were approximately 5.6 million dry metric tons of sewage sludge disposed of in 1988.

In our opinion the Distribution and Marketing sector holds much potential for growth. Potential uses for dried sludge are as follows:

i. Dry granular sewage sludge is very similar in appearance and handling to Commercial Fertilizers and can be applied with the same equipment.

ii. A component in commercial fertilizer granulation.

iii. A granular ingredient in bulk blends.

iv. It can still be landfilled without the cost of transporting the liquid (80%) component. In addition there is less concern about the liquids leeching.

v. Alternative fuel- the average heat value of dried sludge is approximately 4,000 btu's/pound. This approaches the values associated with low grade coals.

Other Advantages

1) Indefinite shelf life.
2) Better odor control.
3) Less expensive and more convenient storage.
4) Generally more aesthetic.

4. **Agricultural Value of Sewage Sludge -**

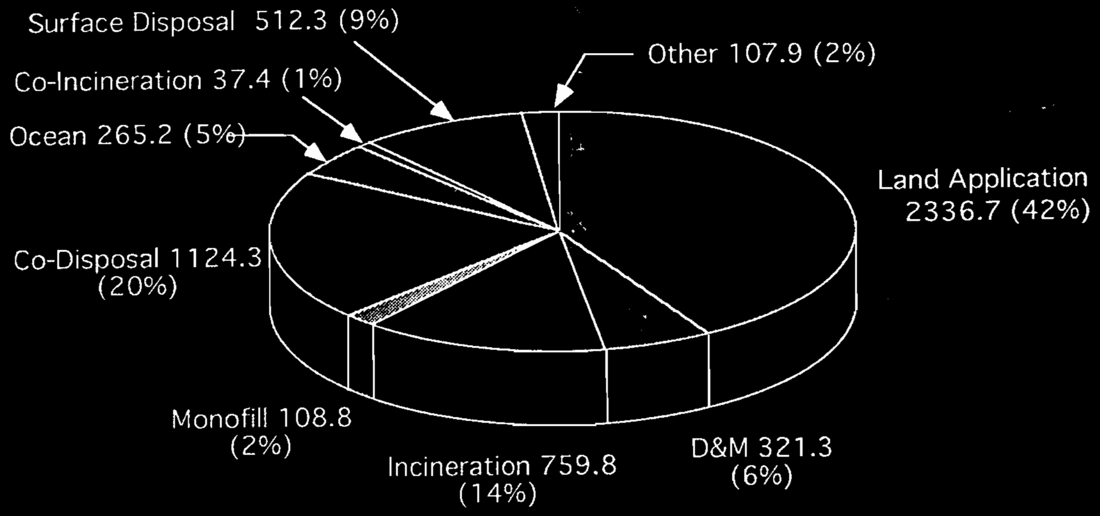
a. **Soil Conditioner** - The organic components of sewage sludge improves the soils bulk density, porosity, and water retention properties. Many studies have indicated that decreased bulk density and increased soil aggregate stability, result in better cultivation and less erosion potential. Reduced runoff and sediment losses have also been noted from using sewage sludge. Water retention increases with sludge addition, helping to provide necessary water for plant, particularly during periods of drought or water stress.

b. **Nutrient Value** - Most programs for beneficial use involve little or no charge for the farmer and, therefore, can represent a significant cost savings to him. The value of 10 dry tons of sludge applied to (1) acre of land, can amount to approximately $90.00 in nutrient value. Sludges vary slightly from facility to facility, but for reference, the Milorganite product manufactured in Milwaukee has an analysis of 6-2-0. Also, Milorganite is currently retailing for around $240.00 per ton, and wholesaling for around $140.00 per ton.

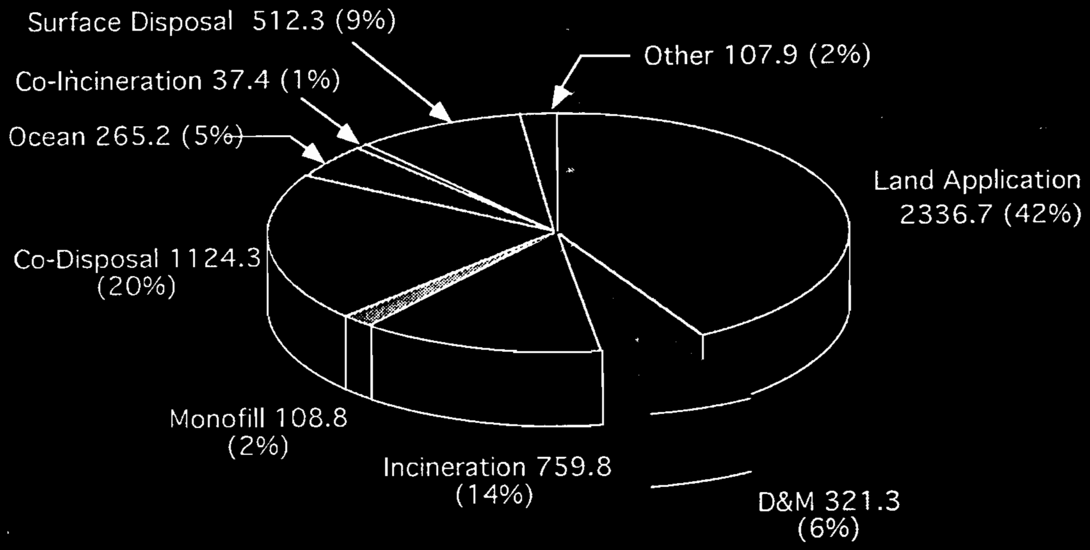
5. **Typical DryingProcess** - Attached is a very simplified flow diagram for several plants we are presently working on. I would also like to point out that we have similar capabilities available for pilot testing.

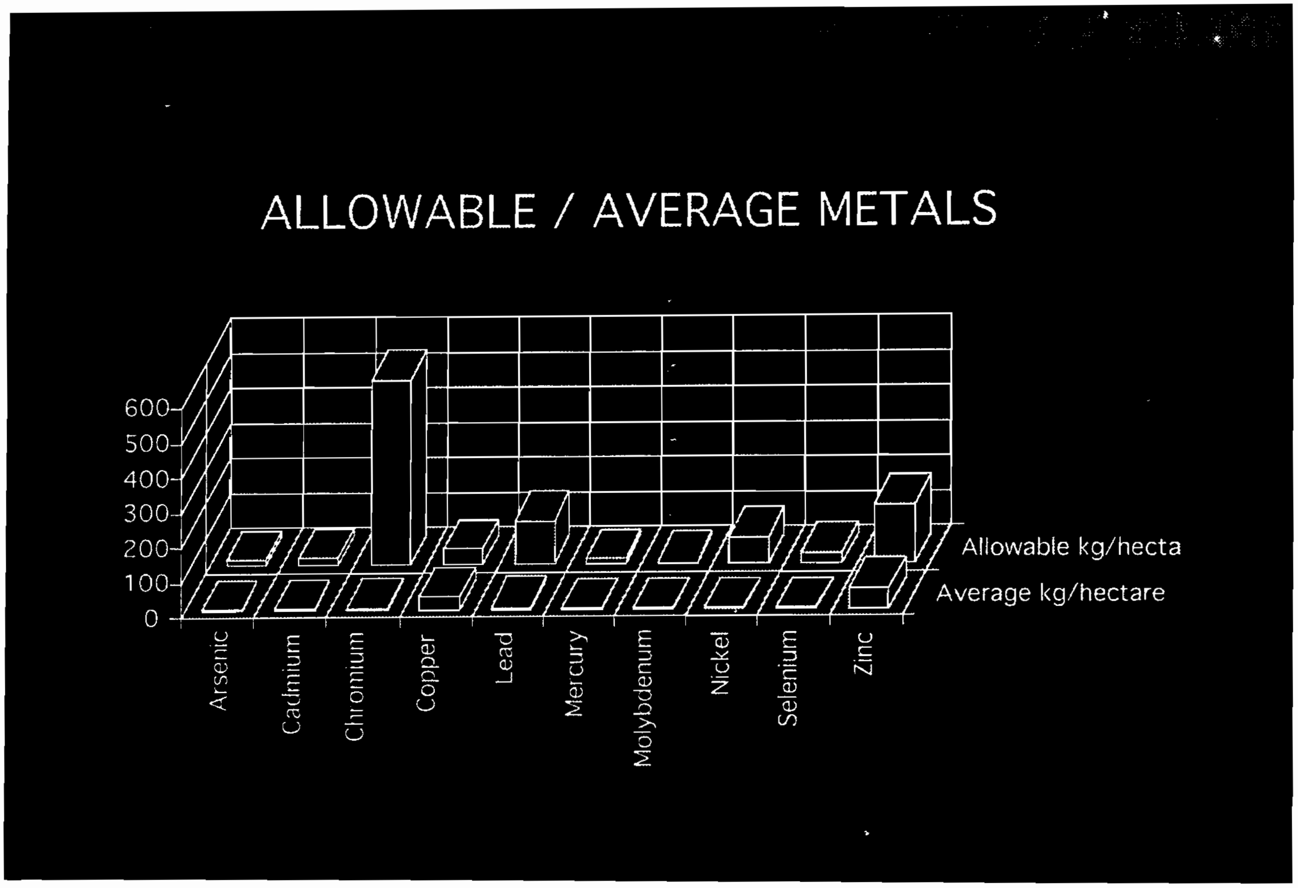
6. **Summary-** A vast majority of the testing, research, and production, to date, has been done by people and organizations outside the Fertilizer Industry. In my opinion, there is no one better equipped to take this product to the farmer, than you. And with the government's final version of the regulations due out next month, now is the time to begin your planning.

SEWAGE SLUDGE DISPOSAL

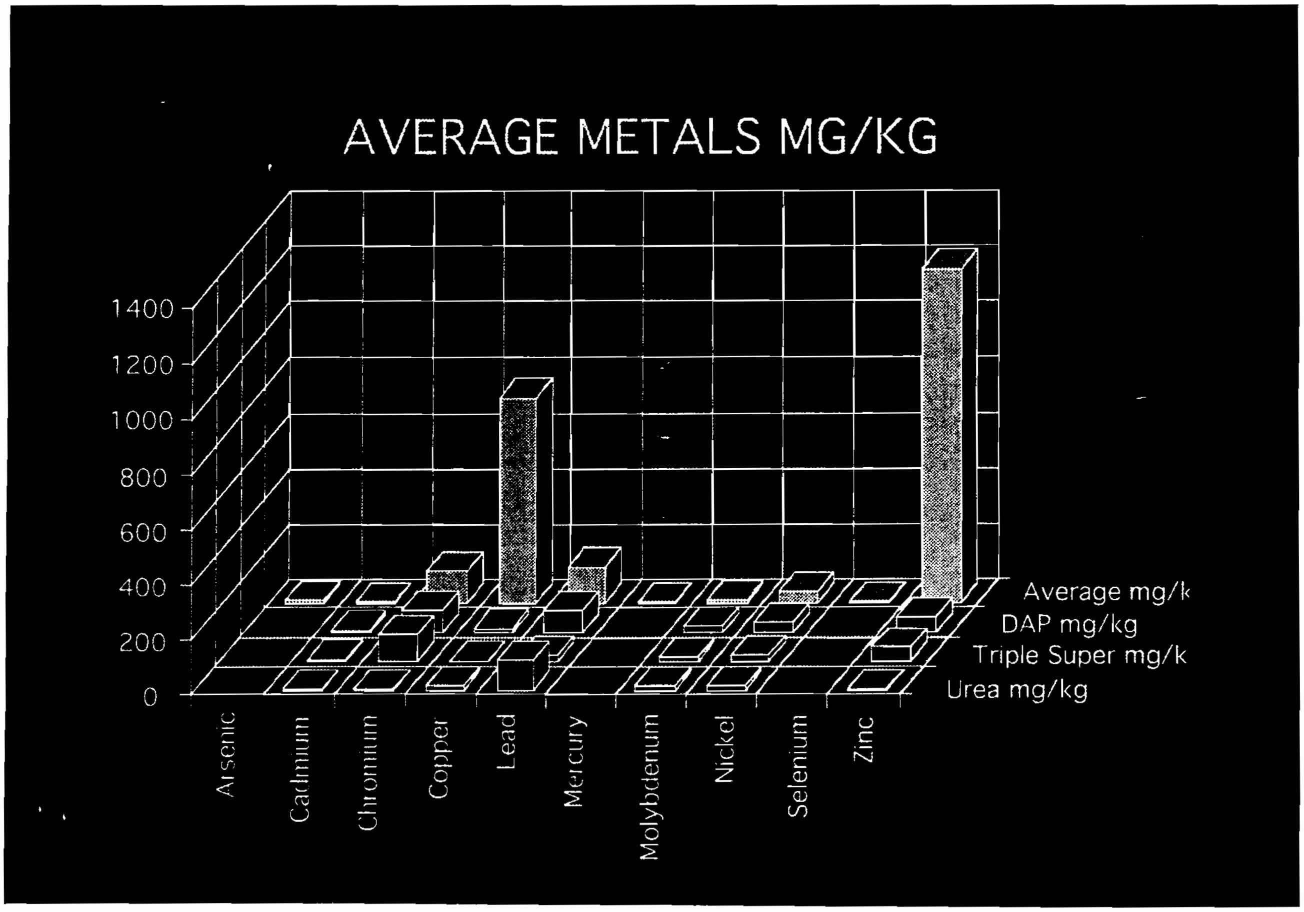


SEWAGE SLUDGE DISPOSAL





ALLOWABLE / AVERAGE METALS



AVERAGE METALS MG/KG

Trace Elements In Phosphate Rocks Problems With Build Up In Soil Fact Or fiction?

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Norsk Hydro, Research Centre, Porsgrunn, Norway

TERMINOLOGY OF HEAVY METALS - TRACE ELEMENTS

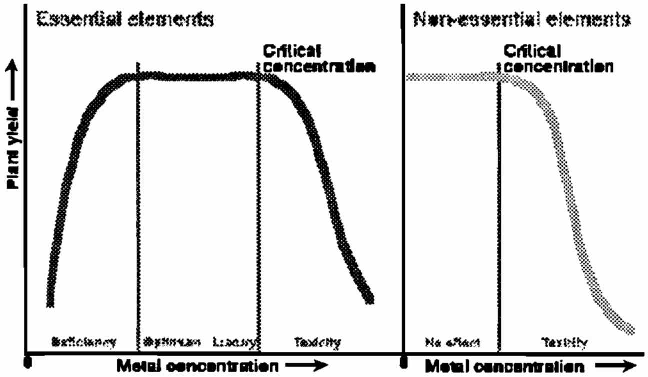
There is no generally agreed definition of the term "heavy metals". They have been defined as the group of metals with a specific density higher than 4, 5, 6 or 7 g/cm³. However, in nutrition physiology, the term "heavy metals" is used to describe the toxic elements arsenic, lead, mercury and cadmium. Metals necessary for life processes are named "essential elements".

"Trace elements" and "trace metals" are common terms for all elements and metals occurring in low concentrations, generally less than that of iron. We will use the above terms in these senses.

INTRODUCTION

Trace elements occur naturally in the earth's crust and our ecosystems. Some of them are essential for growth and other vital processes in living organisms. Deficiencies rarely occur as trace elements are usually needed only in tiny amounts. When the concentration increases above a certain limit, symptoms indicating toxicity will appear as illustrated for plants in figure 1 (Alloway, 1990).

Figure 1. Toxicity profile for trace elements on crops



Human activities mobilise trace elements through many processes like incineration, ore processing, management of soil etc.. This generally makes them more available for living organisms. Nriagu (1984) estimated that the anthropogenic input of heavy metals into our ecosystems is several fold that from natural sources.

Soil is the most important ecosystem factor, essential for growth of plants and recycling of dead biomass, and as a buffer for contaminates. Fertile soil is the basis for agriculture and thus vital for the human society. Even a slow deterioration of soil quality due to trace element pollution is unacceptable.

In principle, it is possible to eliminate trace element input to soil from most anthropogenic sources (industry, fossil fuel, waste, etc.). This will, however, result in social restrictions and considerable costs for which the consumer must pay. Trace element separation involve technical problems which can not be solved with existing techniques. Time and money are required to overcome such obstacles. Authorities should be aware of this, and strike a balance between cost and benefits. The challenge to industry is to develop products and processes that satisfy environmental considerations, and at the same time remain in business with a sound economy.

In this paper, we will compare the soil input of trace elements generated from phosphate rocks with inputs from air and sewage sludge, and evaluate these inputs in relation to the soil content and phytotoxic threshold values.

EXPOSURE AND EFFECT OF TRACE ELEMENTS

Man is exposed to trace elements through accidental exposure, air pollution, occupational exposure and diet (eating habits). Trace elements in the diet originate from raw materials (crops and animal products), water, food processing equipment and food additives.

The health concerns of trace elements in the diet are related to the intake level. Is the intake of essential elements sufficient, is the intake well balanced to ensure good health, and is the intake of the individual elements too high? Toxicological and dietary data can be found in standard reference sources such as Klaassen et al. (1986) and in MAFF (1985).

Cobalt, copper, manganese and zinc are all required by plants or man. Harvesting of crops removes up to 7 times more of these trace elements than supplied with a typical phosphate fertilizer. Arsenic, chromium and nickel may also be essential either to plant or man, but the requirements are minute and soil deficiency probably does not occur. Vanadium and tungsten may be essential, at least for some bacteria. Cadmium, mercury and lead have no known beneficial biological function, their effect is exclusively detrimental. A short review of the behaviour of the most important trace elements involved in agricultural food production is given by Kongshaug et. al. (1992).

USE OF TYPICAL VALUES FOR TRACE ELEMENTS

Trace metal concentrations in soils depends on numerous factors like composition of parent rock, weathering and soil processes (leaching, clay formation, ion exchange, etc.) and anthropogenic and natural inputs.

Notable changes of trace metal content in soil caused by anthropogenic activities are typically measured in decades to centuries. As inputs vary, average or typical input values are most relevant for discussions on the possible effects of accumulation. This is especially so for fertilizer application as raw materials originate from many sources, and international trade serves to even out and dilute the extremes in concentrations of specific elements in some rocks. Typical global values of trace element inputs to soil have been assumed based on literature data.

AGRICULTURAL BALANCES

Figure 2 shows the material inputs and outputs in agriculture.

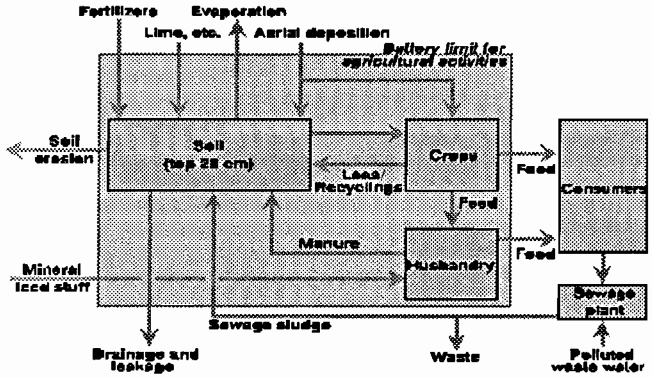


Figure 2. Material flow sheet for agriculture

The task of making agricultural balances for trace elements is difficult. Our intention is to focus on the long term accumulated inputs to the top soil compared to typical soil concentrations. Regulations exist giving maximum concentrations of trace elements acceptable for cultivated soils, but so far these limits are only applicable for the special case of applying sewage sludge to agricultural land.

TRACE ELEMENTS IN SOIL AND THRESHOLD VALUES

The accumulated inputs of trace elements to soil will be compared with phytotoxic excessive levels in soils (threshold values). Estimates of such levels given by 6 authors have been published by Kabata-Pendias and Pendias (1984).

Appendix 1 gives minimum, maximum and typical concentrations for trace elements in soil from different countries, as well as reported common and mean values. The global average of trace elements in soil are shown in table 1:

We note that it has been suggested that the appropriate threshold value for vanadium should be below the global average, and for zinc equal to this average. We do not discuss the arguments for the proposed threshold values, merely note their existence as a pointer towards a soil concentration range where some authors find that problems may occur. Generally, crops grown on soils with less than these toxic levels of trace metals will be safe for human consumption (Kabata-Pendias and Pendias, 1984).

Some soils have exceptionally high concentrations of trace metals, either due to natural causes or to pollution. Such soils can give local problems but they are not representative of agricultural soils. Examples of such extremes that are greatly in excess of proposed threshold values are listed in appendix 1.

FACTORS GOVERNING PLANT UPTAKE OF TRACE ELEMENTS

The availability of trace elements for plant uptake varies. Ions in soil water are available for uptake while ions bonded to clay particles may become accessible through ion-exchange processes. In contrast, components present in refractory minerals can be regarded as unavailable to plants.

The plant uptake of trace elements increases with increasing soil concentration, but the correlation varies for different elements (figure 3).

The soil acidity (pH) is the most important factor effecting trace element mobility and plant uptake. Generally trace elements are most mobile under acid conditions. Molybdenum, arsenic, uranium and tungsten are exceptions as shown in figure 4.

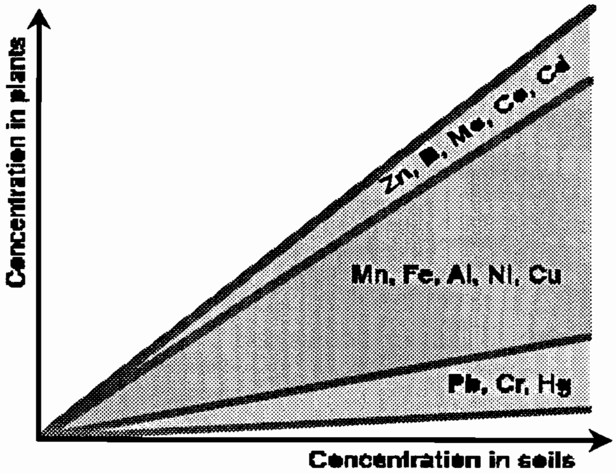


Figure 3.Trace elements in plant and soil.

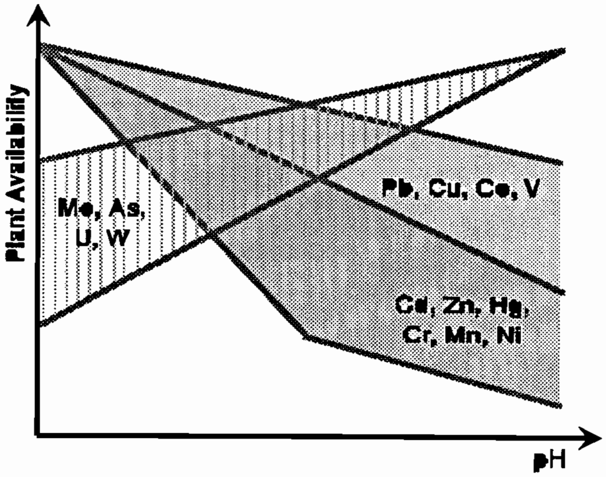


Figure 4. Trace metal availability

Other factors effecting plant uptake of elements are mineral and organic matter in the soil, ions and redox potential in soil solution, the rhizosphere chemistry, transportation of ions to the root surface and into the root, and ion translocation from the root to the shoot.

Translocation of the metal ions vary greatly inside the plant. Manganese, zinc, cadmium and molybdenum are readily translocated to the top of the plant, while most of the chromium, lead and mercury remains in the root. Different plants also behave differently with respect to translocation of trace elements.

All elements are toxic to plants when applied in extreme amounts. For essential trace elements the margin between deficiency and phytotoxicity can be quite narrow. The toxic levels vary for different plant species. Some are very sensitive while others have developed extensive tolerance against one or more trace elements.

Plants also take up trace elements directly from atmospheric deposition. For lead atmospheric depositions are the main source as only minor amounts are translocated from the roots to the upper part. Studies also indicate that 40 - 60 % of the cadmium content in some plants is caused by atmospheric deposition.

ATMOSPHERIC DEPOSITION OF TRACE ELEMENTS

Atmospheric concentrations of trace elements vary with distances from sources and meteorological conditions. The effect of long range atmospheric transport of trace elements on surface soil concentration has often been ignored. Published material deals almost exclusively with areas in the vicinity of some local source. Investigations in Norway show that long range atmospheric transportation might significantly increase the concentrations of certain trace metals in the surface layer of soils (Steinnes, 1984a, Steinnes, 1987, Hanssen et al., 1980). In Norway, mainly V, Zn, As, Cd and Pb are associated with long range atmospheric transportation.

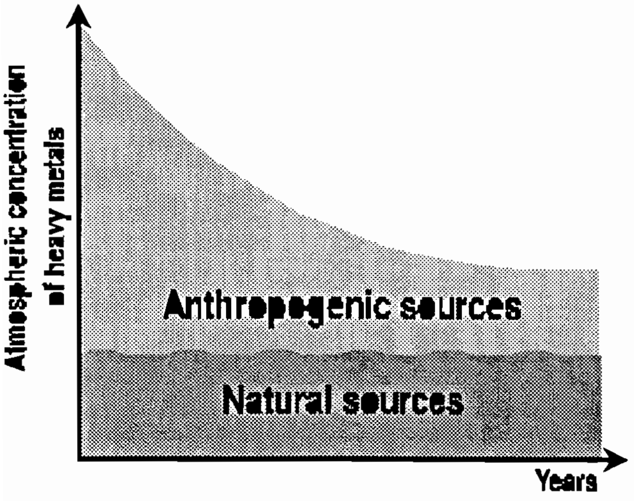


Figure 5. Future air pollution by metals

In Europe, the air concentrations of most metals have shown trends toward a lower level since the late 1970s (Amundsen et al. 1992, SFT 1988, SFT 1991). This indicates that there may be a general decrease in atmospheric deposition in the future. In the long run, we expect the anthropogenic pollution of the atmosphere to be reduced as indicated in figure 5.

Appendix 2 gives reported data from several countries. Based on these data, typical values for atmospheric deposition have been assumed (Kongshaug et.al.1992).

TRACE ELEMENTS WITH FERTILIZERS

Unwanted trace elements in fertilizers have their origin in phosphate rocks. The concentrations vary considerably as shown in Appendix 3. The average trace element concentrations in known phosphate reserves have been calculated based on available data (Kongshaug el. al. 1992).

Some phosphate fertilizer production routes give gypsum waste which remove 20 to 90 % of the trace elements. For all other processes, the trace elements end up in the fertilizers. The calculations in Appendix 4 are based on the following assumptions:

- average concentrations of trace elements in the known phosphate reserves,
- complete retention of elements from raw materials in the products,
- an average application rate of 20 kg P/ha·year (46 kg P_2O_5/ha·year).

TRACE ELEMENTS IN OTHER COMPOUNDS USED IN AGRICULTURE

Appendix 5 lists trace elements in manure, pesticides, limestone, feed stuffs and sewage sludge. Trace metals do not occur in significant amounts in pesticides unless they are added separately. Substitutes should easily be available for unwanted trace elements in pesticides. Limestone is generally low in heavy metals, and the few exceptions should be avoided. Manure and organic feed stuffs do not, in principle, represent a net addition, only a circulation of elements originating from agricultural soils.

Several areas, especially around large cities, are polluted by extensive use of sewage sludge with high heavy metals content. Today, most European countries have introduced limits for heavy metals in sewage sludge and cultivated soils where sewage sludge is applied (see Appendix 5 and 1). During the last 5-8 years, the heavy metal concentration in sewage sludge has been significantly reduced. Thus, we should anticipate an increased use of sewage sludge in agriculture. The long term concentrations of the trace elements in sewage sludge is assumed to be equal to or below the lowest permitted value for each element (Kongshaug el. al. 1992). The annual input of trace elements to soil is estimated by assuming 10 metric tons of dry sludge per hectare every 5 years (2 t/ha·year).

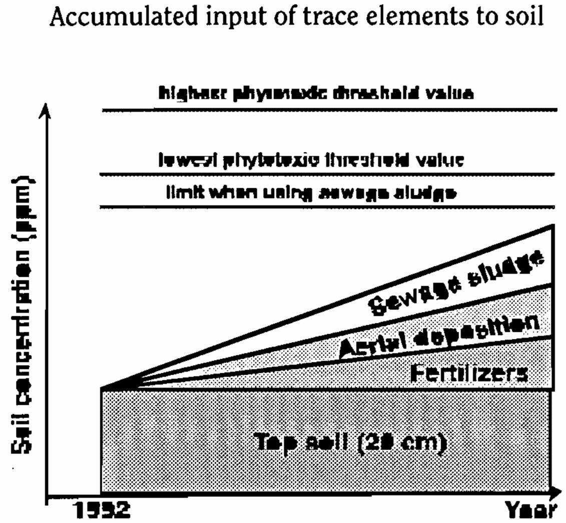


Figure 6. Accumulated input to soil.

The accumulated inputs of a trace element to soil should be compared to typical top soil concentration, limits and physotoxic threshold values for the given element, as illustrated in figure 6. The accumulated increase of trace elements in the soil is assigned to the top soil (top 20 cm with dry volume weight 1.2 kg/dm^3). See Appendix 6. In view of the efforts currently being made to reduce pollution, and given the pace of technical developments, a 100 year time horizon seems most relevant. In the presentation of the data, 250 years is used to illustrate the accumulated inputs. This is because the inputs over 100 years will be hardly discernible.

In table 2, the phytotoxic values and the accumulated inputs are divided with the typical global soil concentrations (given as specific values when soil conc.=1). For fertilizer input, the values are based on typical global "average" and on the rock with the highest trace element concentration. The findings are illustrated graphically in Appendix 7.

Based on these results, we have for the three areas identified the following elements which should be further investigated with respect to future restrictions:

DISCUSSION

Cadmium

Cadmium in soil tends to bind to clay minerals and organic matter, but it is more mobile and hence more available to plants than many other trace metals (like lead and copper). Plant uptake decrease with increasing soil pH and vary a lot for different species and variety Tobacco, for example, is a crop with a notably high cadmium uptake. Plants are rather insensitive to high cadmium concentrations in the soil. The main concern is associated with animal and human toxicity. Kidney damage is one of the first signs of chronic cadmium poisoning.

Human cadmium intake is mostly via food and tobacco. Smokers with a consumption of 20 cigarettes a day absorb about twice as much cadmium as non-smokers. The average cadmium intake in the European diet is some 20 mg/d, while WHO recommends 70 mg/d as the upper tolerable intake. As population exposure is uneven, some people may be at risk even with the average intake.

Cadmium occurs naturally with zinc and lead in sulphide ores, and high concentrations in the environment are commonly associated with industrial emissions. Nriagu estimated in 1979 that the anthropogenic emission of cadmium was more than 90 % of the global cadmium emission to air. Primary metal production was the main source (70 %). Most European countries have introduced strict cadmium emission regulations. In Sweden the total cadmium emission was reduced by 90 % during the 80's. Thus, we can expect the atmospheric deposition to decrease in the coming years.

Phosphate fertilizers based on phosphate rocks from North Africa and US have the highest cadmium content. Even though much effort has been made to separate cadmium from phosphate fertilizers, no commercial process is yet available. Norsk Hydro has temporarily "solved" the cadmium problem by utilising Kola rock which has a very low cadmium content, through a joint venture in Russia. However, Kola rock is of limited availability, and research aimed at cadmium removal has still a high priority.

In phosphoric acid plants, 30-50 % of cadmium originated from the rock is removed by the gypsum waste. This should be taken into consideration when evaluating cadmium containing fertilizers for polluted areas.

The solubility of cadmium in DAP/MAP-based compound fertilizers (NP and NPK) is very low compared to the cadmium solubility in superphosphates (P and PK fertilizers). It is, however, not known if this difference is of real importance in the dynamic, but slow chemical processes in soil.

Investigations in Denmark by Hovmand (1982) show that an average crop receives 1.4 g Cd/ha·year, of which only 0.04 g/ha·year goes to human consumption. Most of the cadmium bound in harvested crops is recycled. Hovmand also calculated that 0.5 g Cd/ha·year is removed from the plough layer by percolation. Only 0.2 g/ha·year of this goes to the drainage water.

Johnston and Jones (1992) conclude that phosphate fertilization for more than 100 years at Rothamsted in England has not given any extra accumulation of cadmium in soil or crop (wheat and barley). This indicate 2 g/ha·year run off for soil low in organic matter. The fate of cadmium inputs to soil and vegetation is presently not clear and it is a need for better data on inputs, outputs and reactions in the soil.

The plant uptake of cadmium can be reduced by liming, or by changing to a crop with a lower ability for cadmium uptake. Remediation of polluted soil is also possible. The University of Oldenburg in Germany has identified species which absorb large amounts of cadmium through the roots. Sewage sludge can, in principle, be treated for the removal of cadmium and other heavy metals, but no commercial process is yet available.

Uranium and radioactive elements

No phytotoxic threshold values are published for uranium. An increase of uranium in soil should, however, be viewed in relation to the radioactive level of the soil. There is a background of natural radiation from potassium, uranium and thorium and derived decay elements, and from artificial radioactive elements as a result of nuclear bomb testing and nuclear accidents. The radioactivity can be expressed as the amount of gamma radiation, as Bequerel/kg soil (Bq/kg).

Potassium salts contain 0.0118 % as the K-40 isotope. An annually application of 25 kg K/ha·year to cultivated soil, increases the radiation of the top soil by 0.04 Bq/kg. The potassium is however, only substituting the removed potash and will thus not increase the long term soil radiation.

The radiation of phosphate rocks seem to be highest for Florida rocks, while that from magmatic rocks like Kola is very low. In Florida, uranium has been extracted for sale from some phosphoric acid plants. Typical radiation is 2400 Bq/kg phosphate rock and 1200 Bq/kg fertilizer when the P-content is 7.5 %.

Typical radiation from the cultivated soil in Scandinavia seems to be in the order of 600-2000 Bq/kg soil, mainly the K-40 isotope (SIS, 1990). Thus fertilizer does not give more radiation than typical soils. 100 years of fertilization will increase the radiation by about 13 Bq/kg top soil if all the uranium, thorium and derived elements accumulate.

Nuclear test explosions in the atmosphere during the 50's and 60's increased the radiation of soil in Western Norway by some 33 Bq/kg top soil, 8000 Bq/m2 (Salbu, 1992).

The Chernobyl accident caused manifold increases in the background radiation levels over much of Central Norway (50-5000 Bq/kg in 20 cm cultivated top soil (SIS, 1990)). This increase will remain for decades. There is much concern about this and for the amount of radioactive elements in foods, where a maximum level of 600 Bq/kg is in force. The difficulties in satisfying this regulation is entirely due to the deposition of artificial nuclides. Plant uptake of natural radioactive elements is not an issue.

Mercury

The major source of atmospheric mercury is the natural degassing of the earth's crust, including land, rivers, and the ocean. Mining, smelting, and industrial discharges have also been factors in environmental contamination in the past, but these sources are now greatly reduced. Metallic mercury in the atmosphere represents the major pathway in the global transportation of mercury. Regardless of source, both organic and inorganic forms of mercury may undergo environmental transformations. Volatilisation of mercury (metallic mercury and dimethyl mercury) from soil depends on the fixation strength of the soil, microbial activity, pH, and temperature. There is a notable cycling of the element by this process. It seems that general anthropogenic activity, e.g. acid rain, is increasing the rate of this bio-geochemical cycling of mercury. At present, no realistic quantification of Hg losses from soil to the atmosphere under natural conditions is reported (Rundgren et al., 1992).

The concern with mercury is human toxicity. The toxicity depends on the chemical form, and the manifestations of mercury poisoning is mainly neurological. Fish is the dominating dietary source of mercury.

Plant uptake of mercury from soils is insignificant as it tends to remain in the roots. The mercury content of fertilizers and of crops grown on fertilized soils is so low that this topic does not cause concern.

Lead

The main anthropogenic sources of lead are sewage sludge and atmospheric deposition. Lead additives in petrol account for 60-70% of the lead emission to the atmosphere, but it is gradually being phased out in European countries. The deposition of lead in Norway is dominated by long range transportation. The main exposure issue is inhalation by people living in areas with heavy traffic and through lead compounds deposited on vegetables grown in the vicinity of roads. Excessive lead intake is associated with mental retardation, especially in children, and with abortion and sterility.

Lead is tightly bonded to organic matter and clay minerals in the soil. Plant uptake is insignificant except for special soil conditions like low pH, low cation exchange capacity, low content of organic matter or low content of phosphate. The lead taken up by plants from the soil tends to remain in the roots. Hovmand (1982) found that 90 % of the lead present in Danish crops came from atmospheric deposition. He calculated that the average input of lead from application of sewage sludge was 5.3 g Pb/ha·year. Only 4 g Pb/ha·year was removed by soil run off and harvested crops.

Lead pollution should be kept to a minimum, but the lead contents of fertilizers and their raw materials are so low that these are not significant sources of lead in soils and crops.

CONCLUDING REMARKS

Heavy metal balances are summarised in table 3. The topic of heavy element inputs to soils is dominated by concerns for:

- atmospheric lead deposition on crops and soils (main source is leaded petrol)
- generally increased mobility of mercury (the effect is unknown),
- fear for further soil contamination from nuclear catastrophes,

- fear of depositions originating from coal burning and metallurgical operations,
- fear for general contamination from sewage sludge application,
- fear for slow cadmium accumulation in the soils from fertilizer application

The last two issues are connected with agricultural practices and fertilizer use.

Trace elements in soil is a local problem caused by anthropogenic pollution or due to the composition of the parent rock, restrictions may be appropriate, e.g. with regards to which crops are grown or to soil management options. A farmer who is faced with such problems can take actions like:

- liming (increase soil pH),
- systematic use of acidifying fertilizers (reduce soil pH),
- change farming practice, e.g. avoid crops or varieties known to accumulate the element in question,
- avoid application of sewage sludge,
- use fertilizers low in the specific trace elements.

The concern with trace elements in soil should be taken seriously, even though increases seem difficult to confirm. The challenge for the fertilizer industry is to remove cadmium from phosphate fertilizers. Efforts are being made in the industry to develop cadmium removal procedures, but the technical challenges are great. All processes studied so far have serious limitations and problems, with regard to safety, cost, efficiency, energy consumption or environmental concerns.

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Trace elements in soils, plants and threshold values for soils

	Arsenic		As	Cadmium		Cd	Chromium		Cr	Cobalt		Co	Copper		Cu	Lead		Pb	Manganese		Mn	Mercury		Hg
All values in ppm	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.
Norwegian soil			6	0.01	3.8	0.07			40	1.0	40	7.3	2	100	15		32	14	100	1020	377			0.05
Danish soil				0.03	0.9	0.25			12			2.1			13			16			268			
Swedish soil				0.03	2.3	0.22	0.09	57	17	0.03	17	5.3	1.5	190	15	2	264	16	12	1840	456	0.004	0.99	0.06
Germany (west)	2.0	20	9	0.10	1.8	0.60	9	57	28			14.5	1	40	1.8	0.1	68	25	520	1800		0.025	1.0	0.09
England and Wales	<1	140	12	0.01	10.5	0.50	4	60	60	0.9	54	8.2	1.8	323	20	4.5	2900	40	1000	11500		0.010	2.12	0.09
Scottland			6			0.08			50	1.0	200							20	50	7000				0.10
USA	0.1	69	6.7	0.005	2.4	0.27			54	0.3	50	8.2	1	300	24	<10	70	20	7	3000	495	0.010	1.50	
Canada	1.0	30	6	0.01	0.1	0.07	10	189	47	5.0	50	17	5	50	22			20	80	1200	420	0.005	0.10	0.06
Japan	0.4	70	11	0.03	2.5	0.44	3	810	50	1.3	116	10	4.4	176	34	5	189	35				0.080	0.49	0.28
Earth`s crust (Alloway)			1.5			0.10			100			20	24	55	50			14			950			0.05
Alloways min-max	0.1	50		0.01	2.4		5	1500		1	40		2	250		2	300		20	10000		0.010	0.30	
Pendias min-max-aver.	0.1	93		0.01	4		1.4	1384		0.1	116		1	205		3	189		9	9200		0.001	1.10	
Max in "polluted" soils		2470			468			1384			520			3700			21500			11500			4.60	
Alloways common val.	1	20		0.20	1		70	100				10	20	30		10	100				1000	0.030	0.06	
Pendias mean values	2.4	25	8.7	0.06	1.1	0.46	7	221	65	1.6	21	8.5	6	60	23	10	67	32	200	800	545	0.002	0.41	0.08
Assumed global average			**9**			**0.4**			**60**			**9**			**22**			**22**			**500**			**0.08**
Threshold values in soil	**15**	**50**	**28**	**3**	**8**	**5**	**75**	**100**	**94**	**25**	**50**	**42**	**60**	**125**	**98**	**100**	**400**	**180**	**1500**	**3000**	**2250**	**0.300**	**5.00**	**3.00**
Limit using sewage sludge			**12**	**1**	**3**		**80**	**600**					**50**	**140**		**50**	**300**					**0.400**	**1.50**	
Common plant conc.	0.5	1.5		0.00	0.93		0.1	0.5		0.02	7		5	30		0.07	5.4		20	300		0.000	0.30	
Essential to plants		No			No			No			No			Yes			No			Yes			No	

	Molybdenum	Mo		Nickel		Ni	Zinc		Zn	Tungsten		W	Vanadium		V	Uranium		U	Thorium		Th			
All values in ppm	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.			
Norwegian soil				10.0	1000	25	10	300	55															
Danish soil						6			27															
Swedish soil				0.1	64	10	4	310	63															
Germany (west)				2.0	50	19	3	80	66							0.4	11		0.4	15				
England and Wales	0.03	13	1	2.0	98	22	3.9	975	80				15	200				2.6			10.5			
Scottland	1.0	5	1			25			50	0.7	2.7													
USA	0.1	30	1.2	<5	200	19	<5	300		1.2	2.5				84	0.3	10.7	3.7	2.2	21	7.6			
Canada						20	10	200	66							0.7	2.1	1.2	4.2	14	8			
Japan	0.2	11	2.6	2.0	660	28	10	622	86															
Earth`s crust (Alloway)			1.5			80			75			1.0			160			2.4						
Alloways min-max	0.2	5		2.0	1000		10	300		0.5	83		3	500		0.7	9							
Pendias min-max-aver.	0.01	30		0.2	660		3.5	622					6	460		0.1	11		0.4	21				
Max in "polluted" soils		30			1000			975			83			500										
Alloways common val.	1	2				50			50			1.5						<2						
Pendias mean values	1	3.1	2	4.0	42	20	17	125	51				8	190	90	0.8	11	3.9	3.4	10.5	7.8			
Assumed global average			**1.3**			**23**			**70**			**1.5**			**90**			**2.5**			**8**			
Threshold values in soil	**2**	**10**	**6**	**100**	**100**	**100**	**70**	**400**	**270**				**50**	**100**	**70**									
Limit using sewage sludge	**2**	**4**		**30**	**75**		**150**	**300**																
Common plant conc.	0.03	1		0.20	5		20	150				0.1	0.2	1.5				0.04						
Essential to plants		Yes			No			Yes			No			No			No			No				

Sources: Kabata-Pendias & Pendias (1984), Alloway (1990), Adriano (1989), Archer (1987), Sing (1991), Andersson (1977), Hovmand (1982), Scheffer (1989).

Trace elements in air and atmospheric deposition

	Arsenic As			Cadmium Cd			Chromium Cr			Cobalt Co			Copper Cu			Lead Pb			Manganese Mn			Mercury Hg		
	ng/m³			ng/m³			ng/m³			ng/m³			ng/m³			ng/m³			ng/m³			ng/m³		
Atmospheric conc	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ
Greenland				0.003	0.63		0.6	0.8		0.07	0.15					15	22		2.8	4.5		0.04	0.08	
Norway	0.15		0.5	<0,2	130	0.2			0.7			0.06			2.5	3.3	20000	50	1.1	5.4	3		50	0.004
Germany (West)	1.5	53		0.5	620		1	140		0.39	6.8		8	4900		120	5000		9	210		0.17	11.2	
North America	1.7	40	15	<1	41	1	1	300	60	0.13	23	4	5	1100	280	45	13000	2700	6	900	150	0.007	38	1
Europe	1.5	53	16	0.5	620		1	140	25	0.2	37		8	4900	340	55	340	120	9	210	43	0.009	2.8	
Common rural areas	1	20		0.5	10		1	20		0.1	50		2	100		5	500							
Common urban areas	5	300		0.5	200		2	200		0.2	20		10	10000		10	10000							
max in polluted area		300			11000			300			30			10000										
Atmospheric deposition	g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y		
Norway	0.2	3.5	0.5	<0.05	60	0.2	<1	30	1	0.2	10	0.2	<5	200	<5	2	150	5	<10	20	10	0.05		0.1
Sweden	1	3.4		0.7	2.2		1	25		0.2	0.6		7	40		12	50		11	46		0.07		
Denmark				1		2							1.6		17			240			78			
England	8	61		<100	200		21	190053					1.6	480								0.3	2	
Europe	2	70	4.8	2.6	35	3	0.5	10					10	200		31	620					0.2	7	
Common rural areas							<2	50	2.5							31	310					0.3	0.6	
Assumed global value			**4.5**			**3**			**4**			**1**			**20**			**200**			**40**			**2**
Main natural sources	volcanic action volatisation			volcanic action wind borne part.			soil suspension, volcanic action			wind borne part. volcanic action			volcanic action wind borne part.			wind borne part. volcanic action			wind borne part. volcanic action			volcanic action wind borne part.		
Main anthropog. sour.	copper smelting coal combustion			zinc smelting Cu-Ni smelting			metallurgical ind. coal combustion			fossile fuel comb.			copper smelting			gasoline comb. industrial emission			Cu-Ni smelting fossile fuel comb.			fossile fuel comb. petroleum prod.		

	Molybdenum Mo			Nickel Ni			Zinc Zn			Tungsten W			Vanadium V			Uranium U			Thorium Th					
	ng/m³			ng/m³			ng/m³			ng/m³			ng/m³			ng/m³			ng/m³					
Atmospheric conc	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ	min	max	typ.	min	max	typ.			
Greenland							18	41					0.8	1.4					0.02	0.04				
Norway				<2		1.2			30						1.9						0.01			
Germany (West)	0.2	3.2		4	120		550	16000					5	92					0.03	1				
North America	<1	10		<1	120	90	<10	1700	500	0.03	6	4	4	174	30			<0.5	0.05	1.3				
Europe	<0.2	3.2		4	120	25	3	16000	1200	0.35	1.5	0.7						0.02						
Common rural areas	0.2	1.29		1	50		5	100					3	50										
Common urban areas	2	18		1	500		200	2000					10	100										
max in polluted area					500			16000						174										
Atmospheric deposition	g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y					
Norway	<0.1	0.5	0.2	<2	200	<2	<20	300	20				<1	19	2	<0.1	(<0.1)	<0.1	<0.2	(<0.2)	<0.2			
Sweden				1.6	6		54	320					1.2	16										
Denmark					7.5	7			405															
England				35	220		490	1200																
Europe				5	880		100	6000																
Common rural areas				5	50	2																		
Assumed global value			**1**			**30**			**400**			**1**			**30**			**0.1**			**0.2**			
Main natural sources	wind borne part., wild forest fires			soil suspension, volcanic action			wind borne part., volcanic action, wild forest fires						wind borne part., volcanic action											
Main anthropog. sour.	fossil fuel comb., therm. power plants			oil combustion coal combustion, Ni/Cu prod.			fossil fuel comb., zinc smelting						fossil fuel comb., Cu-Ni smelting			nuclear power stations								

Sources: Kabata-Pendias (1984), Alloway (1990), Harrison (1990), Nriagu (1998), Ruhling (1985), SFT (1982, 1983), Semb (1988), Steinnes (1984a, 1989, 1992), Klaassen (1986), Hanssen (1980), Führer et. al. (1988).

Trace elements in phosphate rocks

		P-conc.	Arsenic		AS	Cadmium		Cd	Chromium		Cr	Cobalt		Co	Copper		Cu	Lead		Pb	Mangan.		Mn	Mercury		Hg
	All values in ppm	BPL	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.
Kola rock	Russland	86.1	0.01	1.1	1			0.1		15	13			2			30	2	4	3		465	250			0.01
North Carolina rocks	USA	72.5	7	16	13	33	46	40	129	165	155	2	10	3	9	21	15	3	20	9	25	30	27	0.01	0.04	0.02
Florida rocks	USA	72.5	3	25	9	5	15	8	60	101	75				4	46	25	4	30	14	180	390	220			0.08
West. Region rocks	USA	66	14	40	24	40	150	100	330	1000	637						80	5	16	12			75			
Palabora rock	South Africa	86.2	5	11	6			0.15		0.3	0.1	1.5	1.5	1.5	70	150	130	17	40	35	125	150	145			
BouCraa rocks	Morocco	79.2	10	14	12	26	37	35	43	133	90	0.6	0.7	0.7	8	21	15	1	9	5	25	63	35			0.06
Youssofia rocks	Morocco	72.8			10	38	46	40			305			1			16			22			20			0.01
Khourigba rocks	Morocco	71	7	17	12	11	27	18	164	350	225			1	26	41	34	2	29	6	13	20	15		0.1	0.04
Senegalese rocks	Africa	79	2	28	12	60	120	80			140						60	2	10	5			360			0.33
Togolese rocks	Africa	79	8	15	13	47	67	53	2	110	100	5	6	6	45	52	48	9	21	12		100	90			0.05
Tunesian rocks	Africa	63	2	50	25	30		50						3			15			2			7			0.03
Isreaeli rocks	Mid.East	72	4	7	6	12	25	20			130			2			30						12			
Jordanian rocks	Mid.East	72	5	12	7	3	15	6	50	130	100			1	10	20	15	2		4			8			
Syrian rocks	Mid.East	69	1	4	3	5	8	7	120	190	180				19	120	80	3	7	4			14			0.05

		P-conc.	Molybdenum Mo			Nickel		Ni	Zinc		Zn	Tungsten		W	Vanadium		V	Uranium		U	Thorium		Th	Gamma radiation		
	All values in ppm	BPL	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	kBq/kg		
Kola rock	Russland	86.1			5	0.05		2	17	21	19			110			100	2.6	3.4	2.8	20	28	22	0.8		
North Carolina rocks	USA	72.5			10	20	24	22	310	410	360			25	19	37	30	41	110	90		9	5	1.1		
Florida rocks	USA	72.5			8	30	56	40	67	100	90			30	70	160	105	63	280	120	6	50	40	4.1		
West. Region rocks	USA	66						85			870									660						
Palabora rock	South Africa	86.2				20	40	35	2	6	6			11			3			9	88	97	90			
BouCraa rocks	Morocco	79.2			3	7	25	19	69	160	120				80	88	80			60			4	1.6		
Youssofia rocks	Morocco	72.8			4						490															
Khourigba rocks	Morocco	71			9	25	50	32	170	300	240			30			106		141	100			8			
Senegalese rocks	Africa	79						53			500			3			524			190						
Togolese rocks	Africa	79			4	30	60	35	100	580	320				60	90	85			85			220			
Tunesian rocks	Africa	63						16	290	390	350			4						90						
Isreaeli rocks	Mid.East	72						40			450						203	76	150	106	4	24	23	2.8		
Jordanian rocks	Mid.East	72			10	15	20	17			250			30	40	70	50	38	100	60			4	1.5		
Syrian rocks	Mid.East	69				18	41	25	200	320	240				100	144	110									

Sources: Norsk Hydro, Schultz et.al. (1992), Gunnarson (1983).

Trace elements in phosphate rocks and input to soil by fertilizer

		P-conc.	P-conc.	As	Cd	Cr	Co	Cu	Pb	Mn	Hg	Mo	Ni	Zn	W	V	U	Th	Gamma rad.	
Typical values		BPL	% P	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	kBq/kg	
Kola rock	Russland	86,1	17.2	1	0.1	13	2	30	3	250	0.01	5	2	19	110	100	2.8	22	0.8	
North Carolina rocks	USA	72,5	14.5	13	40	155	3	15	9	27	0.02	10	22	360	25	30	90	5	1.1	
Florida rocks	USA	72,5	14.5	9	8	75		25	14	220	0.08	8	40	90	30	105	120	40	4.1	
West. Region rocks	USA	66.0	13.2	92	100	637		80	12	75			85	870			660			
Palabora rock	South Africa	86,2	17.2	6	0.15	0.1	1.5	130	35	145			35	6	11	3	9	90		
BouCraa rocks	Morocco	79,2	15.8	12	35	90	0.7	15	5	35	0.06	3	19	120		80	60	4	1.6	
Youssofia rocks	Morocco	72,8	14.6	10	40	305	1	16	22	20	0.01	4		490						
Khourigba rocks	Morocco	71.0	14.2	12	18	225	1	34	6	15	0,04	9	32	240	30	106	100	8		
Senegalese rocks	Africa	79.0	15.8	12	80	140		60	5	360	0.33		53	500	3	524	190			
Togolese rocks	Africa	79.0	15.8	13	53	100	6	48	12	90	0.05	4	35	320		85	85	220		
Tunesian rocks	Africa	63.0	12.6	25	50		3	15	2	7	0.03		16	350	4		90			
Isreaeli rocks	Mid.East	72.0	14.4	6	20	130	2	30		12			40	450		203	106	23	2.8	
Jordanian rocks	Mid.East	72.0	14.4	7	6	100	1	15	4	8		10	17	250	30	50	60	4	1.5	
Syrian rocks	Mid.East	69.0	13.8	3	7	180		80	4	14	0,05		25	240		110				

	P-conc.	P-conc.	As	Cd	Cr	Co	Cu	Pb	Mn	Hg	Mo	Ni	Zn	W	V	U	Th	Gamma.	Reserves
Typical values	BPL	% P	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	kBq/kgP	mill. t.
Kola rock , Russland	86.1	17.2	1	0.10	13	2.0	30	3	250	0.01	5	2	19	110	100	3	22	5	1330
USA assumed average	70.0	14.0	12	11	109	2.9	23	12	163	0.05	8	37	204	27	82	116	34	25	4440
Palabora rock , South Africa	86.2	17.2	6	0.15	0.10	1.5	130	35	145	0.06	6	35	6	11	3	9	90	5	2530
Morocco assumed average	72.5	14.5	11	30	225	1.0	22	7	22	0.04	5	26	261	30	87	73	6	15	21440
Other North Af. assumed av.	75.0	15.0	15	60	105	4.5	45	6	90	0.05	6	33	420	4	300	128	203	30	490
Middle East assumed av.	71.5	14.3	6	9	129	1.4	43	4	11	0.05	4	29	315	29	122	86	14	15	515
Average 91 % of reserves	76.6	15.3	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	kB/kg	
ppm in phosphate rock			11	25	188	1	32	10	64	0.05	6	29	239	32	88	77	21	2.4	30745
			mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	mg/kgP	kBq/kgP	mill. t.
mg / kg P in phosphate rock			71	165	1226	10	209	66	421	0.29	38	189	1561	212	578	500	136	15	30745
			g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	g/ha·y	kBq/ha·y	
gram/ha·year with 20kP/ha			1.4	3.3	24.5	0.2	4.2	1.3	8.4	0.01	0.8	3.8	31.2	4.2	11.6	10.0	2.7	0.3	

Trace elements in compounds used in agriculture.

		Arsenic		As	Cadmium		Cd	Chromium		Cr	Cobalt		Co	Copper		Cu	Lead		Pb	Manganese		Mn	Mercury		Hg
		ppm			ppm			ppm			ppm			ppm			ppm			ppm					
	% P	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.
Manure	2.5	3	25		0.3	1.8		5	55		0.3	24		2	1990		6.6	15		30	550		0.090	0.20	
Pesticides	0	22	60											12	50				60				0.800	42.00	
Limestones	0	0.1	24		0.04	0.1		10	15		0.4	3		2	150		20	1250		40	1200				0.05
Feed stuffs	<1	10	50		0.07	1.9	0.11							4	945	69	0.15	3.4	0.38						
Sewage sludge																									
Sewage sludge data	1	2	26	1	<1	3650		20	40600		2	260		50	3300		50	3000		60	3900		0.100	55	
Common values for sewage	1				<1	14	4	8	3770	233				57	1650	474	5	432	118				0.600	290	12
Upper limits in 14 countries		10	150		4	40		150	1000		20	150		500	3000		200	1200		500	3000		5	25	
Assumed global value				10			4			150			15			400			120			400			5
Sewage to soil		g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y			g/ha·y		
Input to soil by sewage				20			8			300			30			800			240			800			10

		Molybden.		Mo	Nickel		Ni	Zinc		Zn	Tungsten		W	Vanadium		V	Uranium		U	Thorium		Th			
		ppm			ppm			ppm			ppm			ppm			ppm			ppm					
	% P	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.	min	max	typ.			
Manure	2.5	0.05	3		7.8	30		15	250																
Pesticides								1.3	25																
Limestones		0.1	15		10	20		10	450																
Feed stuffs	<1				0.3	7.9	2.5	28	3868	122															
Sewage sludge																									
Sewage sludge data	1	1	40		16	5300		700	49000																
Common values for sewage	1	2	30	5	3	270	42	57	1567	687															
Upper limits in 14 countries		20	25		50	500		1000	5000																
Assumed global value				10			40			650															
Sewage to soil		g/ha·y			g/ha·y			g/ha·y																	
Input to soil by sewage				20			80			1300															

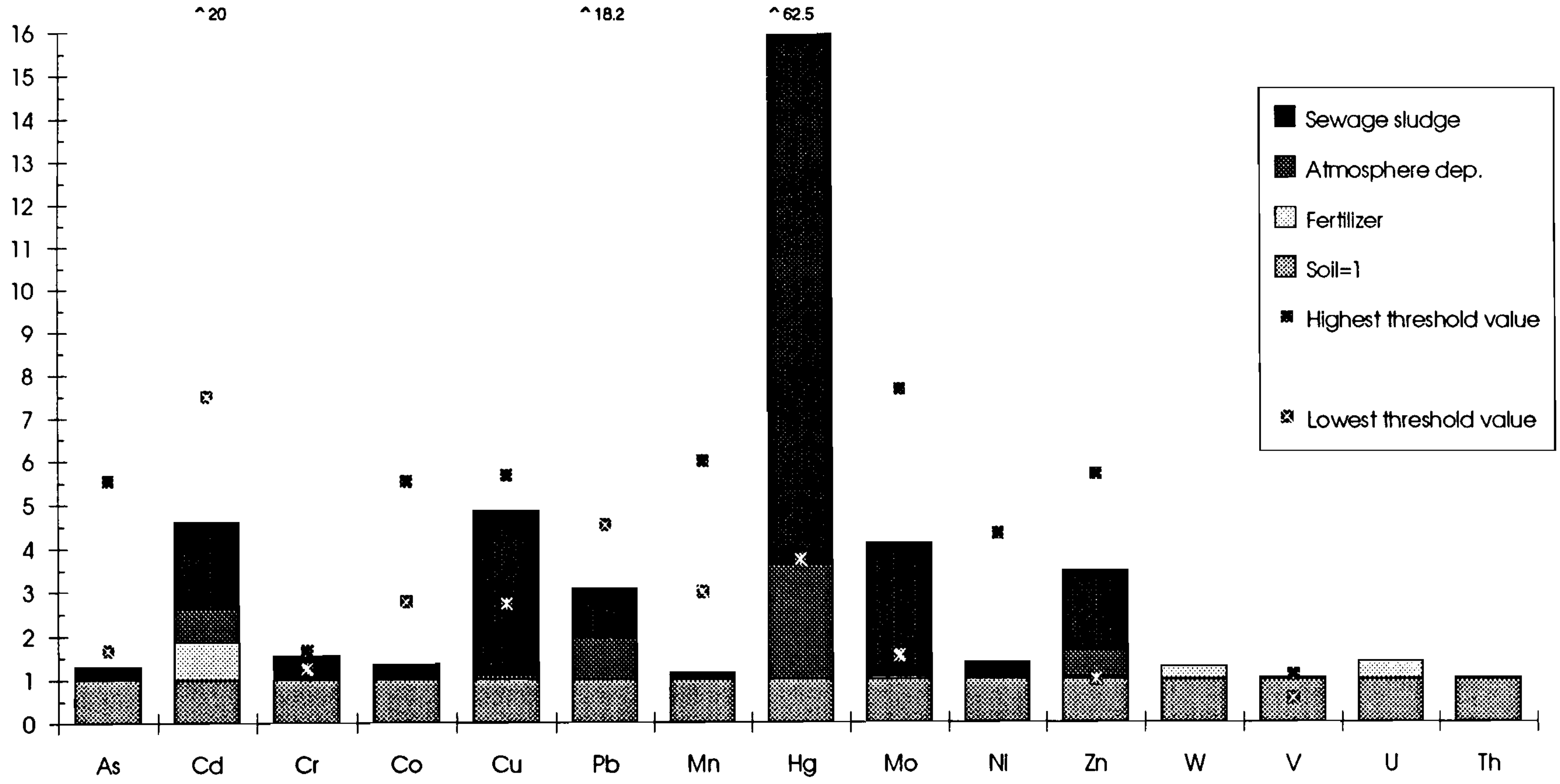
Source: Kabata-Pendias (1984), Adrioano (1990), Vigerust (1988)

Input of elements to soil by fertilization, atmospheric deposition and sewage sludge

Input to soil	As g/ha·y	Cd g/ha·y	Cr g/ha·y	Co g/ha·y	Cu g/ha·y	Pb g/ha·y	Mn g/ha·y	Hg g/ha·y	Mo g/ha·y	Ni g/ha·y	Zn g/ha·y	W g/ha·y	V g/ha·y	U g/ha·y	Th g/ha·y
Input by fertilizers	1.4	3.3	24.5	0.2	4.2	1.3	8.4	0.01	0.8	3.8	31.2	4.2	11.6	10	2.7
Atmospheric fall out	4.5	3	4	1	20	200	40	2	1	30	400	1.0	30	0.1	0.2
Sewage sludge	20	8	300	30	800	240	800	10	40	80	1250				
Concentrations in soil	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**
Typical soil concentration	**9**	**0.4**	**60**	**9**	**22**	**22**	**500**	**0.08**	**1.3**	**23**	**70**	**1.5**	**90**	**2.5**	**8**
Max in common soil	25	1.1	221	21	60	100	800	0.4	3.1	42	125		190	11	21
Max in "polluted" soils	2470	468	1384	520	3700	21500	11500	4.6	30	1000	975	83	500		
Lowest threshold value	**15**	**3**	**75**	**25**	**60**	**100**	**1500**	**0.3**	**2**	**100**	**70**		**50**		
Highest threshold value	**50**	**8**	**100**	**50**	**125**	**400**	**3000**	**5**	**10**	**100**	**400**		**100**		
Lowest limit using sewage sl.	12	1	80		50	50		0.4	2	30	150				
Long term accumulated input															
250 years of fertilization	**0.15**	**0.34**	**2.6**	**0.02**	**0.44**	**0.14**	**0.88**	**0.001**	**0.08**	**0.40**	**3.3**	**0.44**	**1.2**	**1.0**	**0.3**
250 years of atm. deposition	0.47	0.31	0.4	0.10	2.1	21	4.2	0.21	0.10	3.1	42	0.10	3.1	0.01	0.02
250 years of sewage sludge	2.1	0.83	31	3.1	83	25	83	1.0	4.2	8.3	130				

HYDRO

Threshold values and accumulated inputs after 250 years, value divided with global soil conc. today (specific values). Based on "average" global values.



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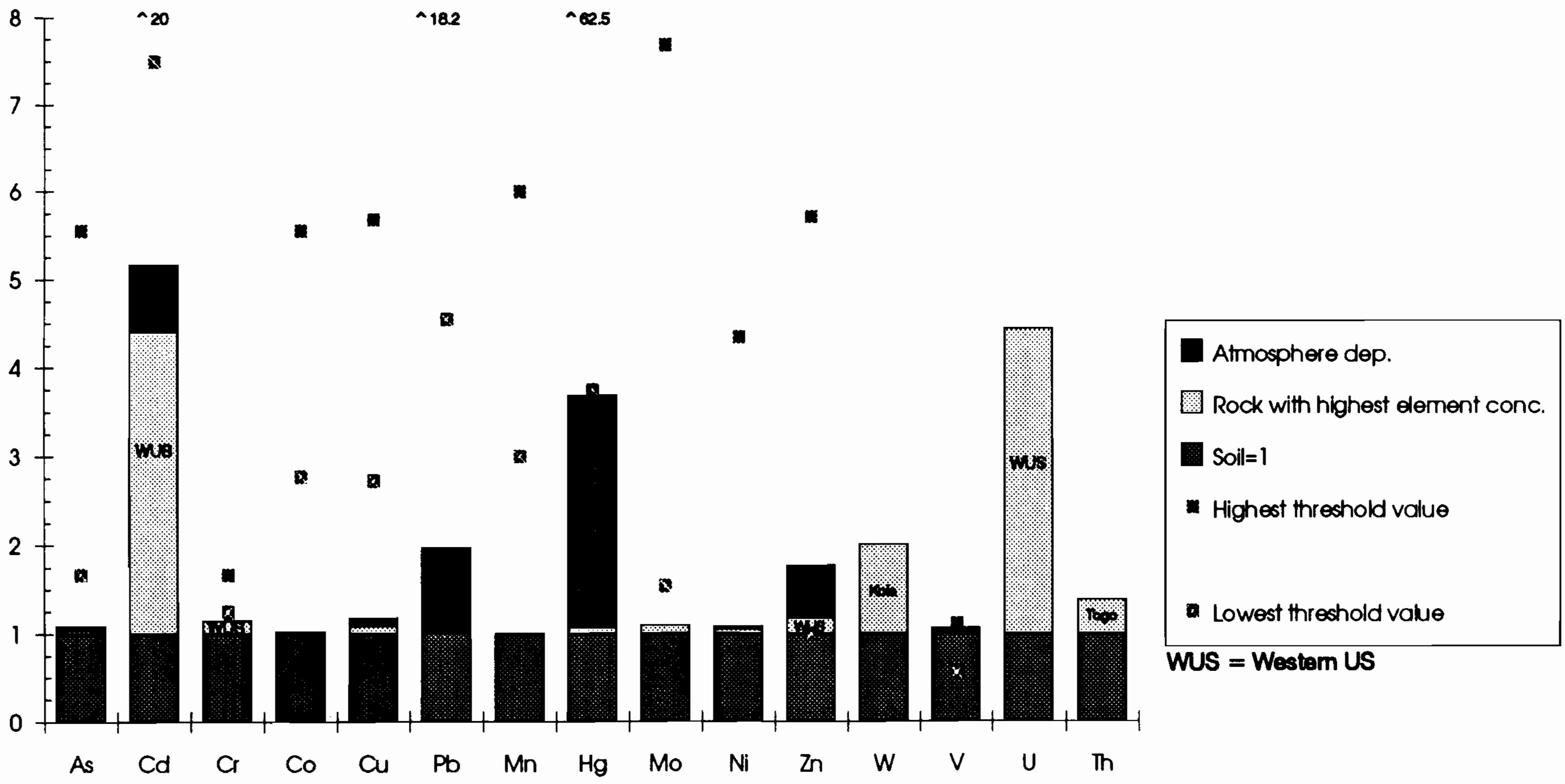
Threshold values and accumulated inputs after 250 years, value divided with global soil conc. today (specific values). Based on Rock with highest element conc.



Wednesday, October 28, 1992

Session V

Moderator:

James C. Wilson

Hazardous Waste: From Waste Management To Waste Avoidance

Hugh F. Holman
Alex. Brown & Sons Incorporated

SUMMARY

We are seeing signs of an emerging technology play in the hazardous waste management industry. Responding to tougher regulations, higher costs, adverse publicity, and liability exposure, generators increasingly seek to treat, recycle, and mininmize the generation of hazardous waste, as opposed to simply disposing of wastes. We expect decreasing reliance on "brute-force" waste management practices (such as land disposal) and increasing use of sophisticated technology-based waste management strategies. Three trends are evident:

- From *pollution control* to *pollution avoidance*–to the extent possible, generators want to avoid generating wastes altogether;
- From *physical* waste management practices to *chemistry-based* approaches–we believe the hazardous waste management industry in the year 2000 will more resemble the chemical industry than it will the waste management industry of today; and
- From *undifferentiated* waste management practices that apply to all wastes indifferently (e.g., landfills) to technologies that *target specific waste streams*–regulation and technology are "unbundling" the wastestream.

My remarks this morning address the future of the hazardous waste management industry. The trends that I identify are the logical, and, I believe, inevitable consequences of the forces at work in the industry today. These trends will create investment opportunities in companies that bring emerging technologies to the waste management industry. Conversely, they will potentially disadvantage some mainstream industry players of today, those overly reliant on technologies that may become obsolete, or least-preferred, in the future. Finally, the trends that I observe in the hazardous waste management industry may presage similar changes in other segments of the pollution control business.

FROM LOW-TECH TO HIGH-TECH

The key forces at work in the hazardous waste management industry today are pushing the industry away from traditional low-tech waste management practices toward new high-tech approaches. These forces include:

(1) tougher EPA rules;
(2) the rising costs of hazardous waste management;
(3) increasingly adverse publicity for polluters; and
(4) the ever-present fear of liability.

I. EPA Rules Are Unbundling the Wastestream and Forcing Waste-Specific Management

Historically, we have relied on brute-force, low-technology approaches to hazardous waste management. Land disposal of hazardous wastes, untreated and without secondary containment, was the most common disposal option until the 1980s. EPA's implementation of Subtitle C of the Resource Conservation and Recovery Act (RCRA) began to change hazardous waste management practices in the early 1980s. First, EPA decreed that landfills should meet the "better bathtub" standard, providing full containment, with backup liners, to prevent the migration of hazardous wastes out of landfills and into groundwater. Then, in the mid-1980s, EPA went a step further: it dictated that not only must the bathtub be designed to ensure containment, but the wastes themselves must be pretreated–stabilized–so as to ensure no leakage even if the bathtub itself failed.

As EPA began to implement its pretreatment program—the "land ban" program—it began to peel off certain wastestreams that historically had been allowed in landfills and to require alternative treatment approaches for these wastes. First, EPA prohibited disposal of liquid wastes in landfills on the grounds that these wastes, by their very nature, posed a significant threat to groundwater should the bathtub spring a leak. Secondly, EPA began a general program of banning organic wastes from landfills on the grounds that these wastes were amenable to a simple alternative treatment practice, incineration. Finally, for a large number of other hazardous wastes, EPA specified acceptable treatment or recycling practices that were waste-specific–for example, EPA established the high-temperature metals recovery as the appropriate treatment practice for dust from electric arc furnaces.

The general thrust of EPA's regulation has been to force higher-tech solutions to waste management problems and to break apart what was initially a large, undifferentiated waste stream going into landfills, into a large number of smaller, differentiated wastestreams, each with its own treatment modality.

II. Tougher Regulations Have Driven Waste Management Costs Higher, Further Stimulating Waste Unbundling

EPA's new rules had the general effect of driving up the cost of waste management. Land disposal prices rose from less than $20/ton in 1980 to $200-250/ton by the end of the decade. The cost of commercial incineration rocketed, as well. Despite the fact that waste management costs may represent a small, even trivial, fraction of total industrial production costs, cost increases of this magnitude got the attention of generators.

Rising disposal costs encouraged generators to look for ways to unbundle their wastes. Generators began to break their waste into differentiated wastestreams, looking for the least-cost management option for each. Nonhazardous wastes were segregated from hazardous wastes. Recoverable solvents were targeted for recycling. Wastes that had to go to hazardous waste landfills were squeezed and dried, dewatered to the maximum extent, to reduce their weight.

III. Adverse Publicity for Waste Generators Encourages Waste Minimization

One of the least-recognized factors affecting waste management practices in U.S. industry is the Toxies Release Inventory (TRI). Since 1987, industrial polluters have been required to submit data to EPA detailing the amount of pollutants released into air, water, and land. These data are available to the public and now appear in the news media–*USA Today* and the *New York Times,* for example, both ran articles ranking the top polluters in the U.S. based on the 1989 TRI survey.

We believe the publicity given the polluter rankings will prove to be a powerful stimulus for companies to reduce emissions. No one wants to be singled out as one of the top-ten polluters in the U.S. For many of these companies, such as DuPont, being identified as a major polluter runs counter to corporate culture and to the public image that the company wishes to project. The debate in these corporate boardrooms is not over whether the company is spending too much on waste management, but over whether the company is spending enough.

IV. Liability Exposure Continues to Encourage Treatment vs. Disposal

All other things being equal, generators prefer waste management solutions that terminate generator liability: treatment and recycling, versus land disposal. The Superfund Statute established the principle of joint and several liability for the cleanup of orphaned contaminated sites. Deep-pocketed companies could end up paying huge cleanup bills for sites, although they may have contributed very little to the problems at the sites. This liability exposure has had a profound effect on generators' willingness to use landfills, and has encouraged use of alternative waste management practices and waste minimization.

THREE TRENDS ARE EMERGING

Within the general theme of transition from low-tech to high-tech, at least three significant trends are emerging. These are:

- from *pollution control* to *pollution avoidance*;
- from *physical* waste management practices to *chemistry-based* approaches; and
- from *undifferentiated* waste management practices that apply to all wastes indifferently to technologies that *target specific wastestreams.*

I. Pollution Control to Pollution Avoidance

Examples of this trend are the replacement of solvent-based printing inks with water-based inks, the desulfurization of fuels, and the displacement of traditional organic chemical pesticides and herbicides with biopesticides and bioherbicides. *Recycling* is central to many avoidance strategies. In the petroleum refining industry, K048-K052 wastes that otherwise would have to be incinerated are being treated to extract recyclable product before disposal. Recycling has replaced land disposal for many metal-bearing wastes. Electric are furnace dust, for example, is now largely treated in high-temperature metals recovery facilities to recover zinc. At the beginning of the 1980s, almost all electric arc furnace dust was landfilled.

II. Physical to Chemical Waste Management Practices

Most early waste management strategies relied on the physical transfer of waste from one medium to another: basically, solids were pulled out of air and water and put into landfills. We are now moving up the waste management hierarchy into more complex technologies that rely less on media transfer and more on actual solutions to problems. We are attacking wastes through chemistry, to break down and destroy the contaminants, rather than simply containing or stabilizing the toxic constituents. Bioremediation, the use of microorganisms to degrade wastes, is replacing "hog-and-haul" offsite disposal for cleanup of Superfund sites. Carbon filtration and biodegradation are replacing airstripping, which simply transfers volatile organics from water to air, for cleanup of contaminated groundwater.

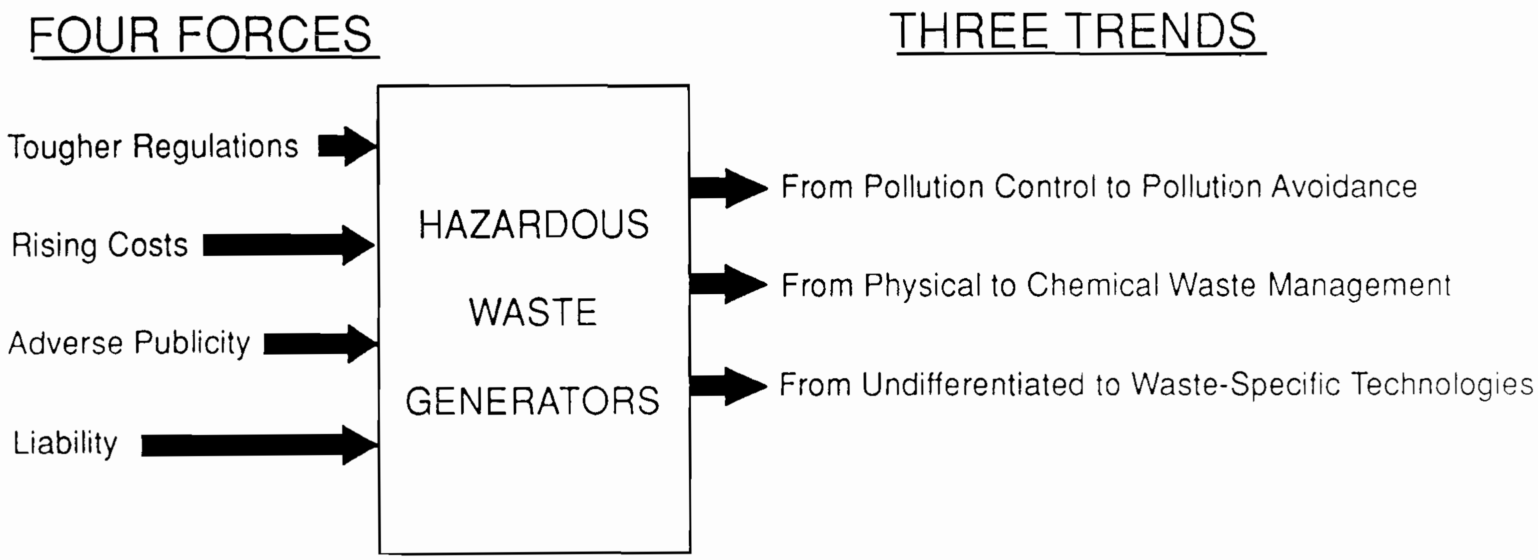
III. Undifferentiated to Differentiated Waste Management Practices

Moving up the technology hierarchy requires finer and finer differentiation between wastes. Wastestreams that have resource value—containing recoverable metals or organics—are picked off for recycling. Chemistry-based solutions target specific wastes for treatment. Bioremediation, for example, attacks PCB-contaminated soils within a 5-500 parts per million band, and alternative treatment approaches tackle soils outside the bioremediation range. Increasing waste differentiation reduces the amount of wastes headed for undifferentiated solutions such as land disposal and incineration.

CONCLUSION: TECHNOLOGY WILL TRANSFORM INDUSTRY IN 1990s

We believe the key forces at work in the hazardous waste management industry —tougher rules, increasing costs, adverse publicity, liability—will lead to significant changes in waste management practices in the 1990s. The 1980s saw the weeding out of small commercial waste management companies that could not meet EPA's permitting standards, but the decade saw relatively little change in the basic technology infrastructure. We believe the 1990s, by contrast, will be a decade in which new technologies emerge to take market share away from traditional waste management technologies. Ultimately, we think many new technologies will prove to have significant economic advantages over current waste management practices, adding greater impetus to the evolutionary forces at work in the industry.

FROM WASTE MANAGEMENT TO WASTE AVOIDANCE



FOUR FORCES

THREE TRENDS

- Tougher Regulations
- Rising Costs
- Adverse Publicity
- Liability

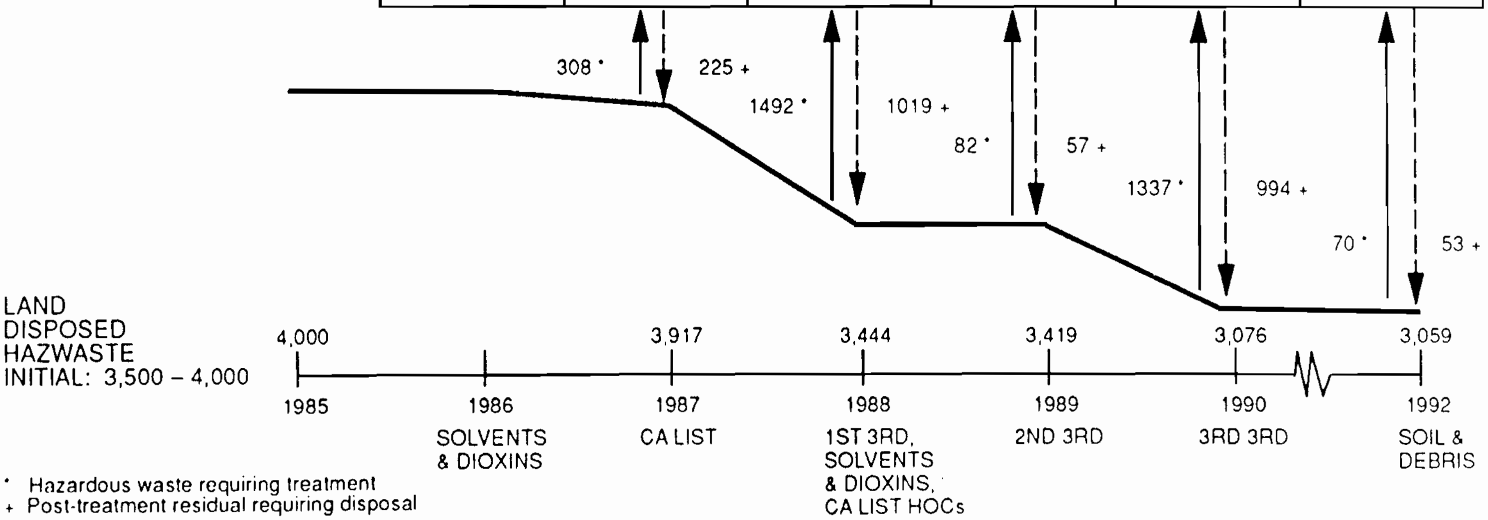
HAZARDOUS WASTE GENERATORS

- From Pollution Control to Pollution Avoidance
- From Physical to Chemical Waste Management
- From Undifferentiated to Waste-Specific Technologies

FORCES AT WORK: EPA Rules Are Unbundling the Wastestream

INCREMENTAL VOLUME CREATED BY LAND BAN RULES

	1987	1988	1989	1990	1992
INCINERATION	103	144	37	66	33
STABILIZATION		1094	16	648	
OTHER	205	254	29	623	37



* Hazardous waste requiring treatment
\+ Post-treatment residual requiring disposal

Source: Amounts are estimates based on various EPA documents.

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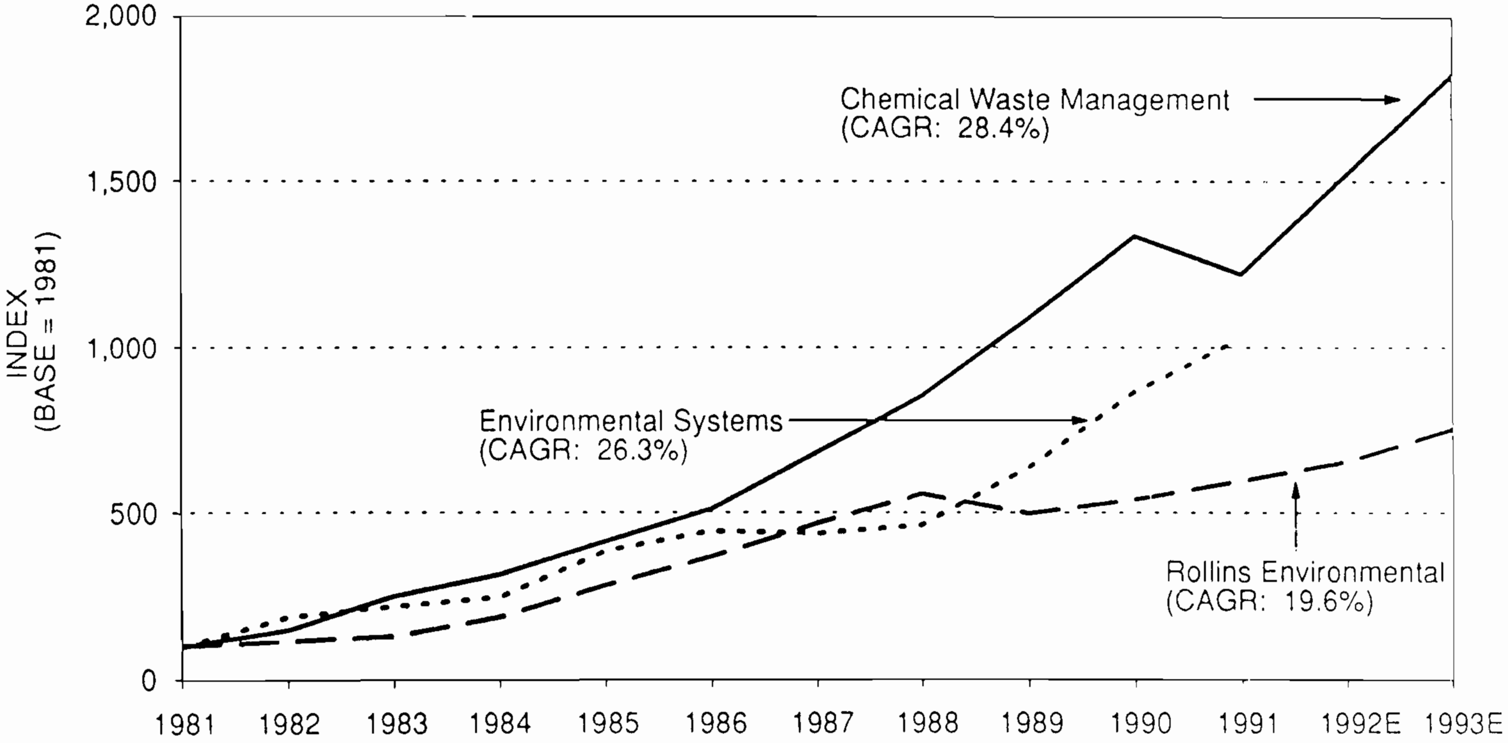
FORCES AT WORK: Rising Costs Also Encourage Unbundling

TOTAL REVENUES



CAGR: Compound Annual Growth Rate, 1981–1991

Source: Alex. Brown & Sons Incorporated

FORCES AT WORK: Toxics Release Inventory Is Force for Change

TOP TEN POLLUTERS IN THE U.S.
Based on 1989 Toxics Release Inventory

TOTAL EMISSIONS *

Company	Toxic Chemical Emissions Pounds (MM)	% of Total
DuPont	343.8	6.02%
Monsanto	294.1	5.15%
American Cyanimid	202.1	3.54%
B.P. America	123.9	2.17%
Renco Holdings	119.3	2.09%
3M	108.5	1.90%
Vulcan Materials	93.1	1.63%
General Motors	85.7	1.50%
Eastman Kodak	79.4	1.39%
Phelps Dodge	77.7	1.36%
All Others	4,182.8	73.25%
Total Emissions	5,710.3	100.00%

AIR EMISSIONS

Company	Toxic Chemical Emissions Pounds (MM)	% of Total
Renco Holdings	119.2	4.91%
3M	72.6	2.99%
Eastman Kodak	69.2	2.85%
DuPont	53.4	2.20%
General Motors	46.9	1.93%
Courtaulds Fibers	44.7	1.84%
Ford	31.8	1.31%
Hoechst Celanese	29.9	1.23%
BASF	28.9	1.19%
General Electric	28.9	1.19%
All Others	1,902.3	78.36%
Total Emissions	2,427.7	100.00%

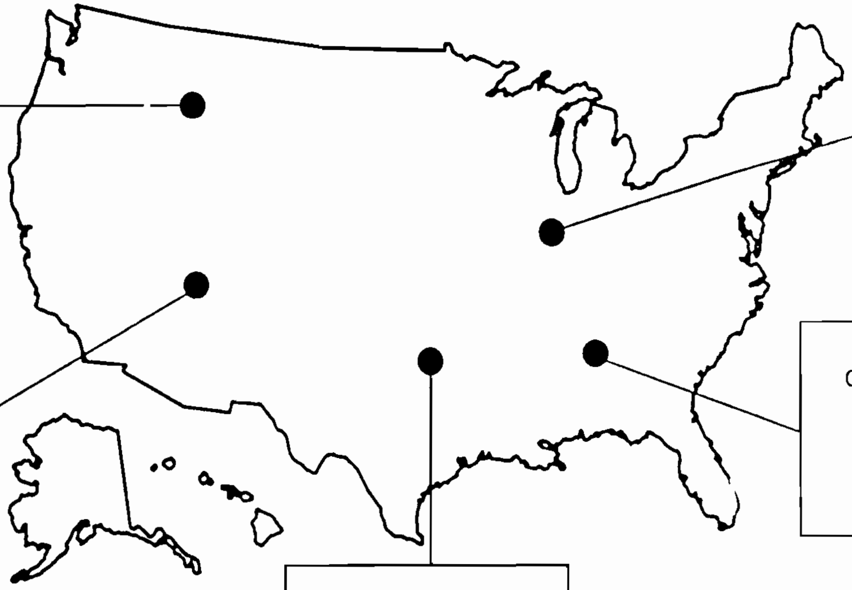
WATER EMISSIONS

Company	Toxic Chemical Emissions Pounds (MM)	% of Total
Arcadian Corp.	22.4	11.86%
3M	15.5	8.20%
Freeport McMoran	14.6	7.75%
I.T.T.	11.4	6.05%
Allied Signal	9.8	5.19%
Louisiana Pacific	9.2	4.86%
Weyerhaeuser	8.4	4.47%
Strategic Minerals	7.8	4.13%
Monsanto	5.1	2.71%
Simpson Investment	4.5	2.39%
All Others	80.1	42.39%
Total Emissions	189.0	100.00%

* Includes air, water, land, underground, public sewage and off-site releases nationwide.

Source: *The New York Times*

FORCES AT WORK: Liability Increasingly Factored into Waste Management Decisions



Department of Defense

7,300 Sites

$30 Billion

Superfund

3,000 Sites

$350 Billion

Department of Energy

37 Installations

$240 Billion

Corrective Action

37,622 Sites

$240 Billion

Underground Storage Tanks

1.8 Million

$30 Billion

Source: Waste Management Research & Education Institute, U. of Tenn., Knoxville

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TRENDS: From Pollution Control to Pollution Avoidance

TECHNOLOGY ROADMAP

	WASTE ADVOIDANCE		WASTE MANAGEMENT		
WASTE GENERATORS	PRODUCT ALTERNATIVES	PRODUCT REFORMULATIONS	RECYCLING	TREATMENT	DISPOSAL
Industrial Process Wastes					
Chemical Industry			Chemical Recovery		
Primary Metals Industry			Metal Recovery	Incineration Organics	Land Disposal Solids
Petroleum Industry					
Fabricated Metals Industry					
Rubber/Plastic Production				Other Inorganics	Deepwell Dilute Solutions
Other			Solvent Recovery		
Release to Environment from Use/Consumption					
Utilities	Alternative Energy	Desulfurized Fuels	Lead Battery Recycling Used Oil Recovery		
Automobiles	Electric Autos	Clean Fuel Technology			
Agriculture	Biopesticides/ Bioherbicides				
Other	CFC Alternatives	Water-based Inks	Post-consumer Recycling		
Remediation Residues Process Plants Disposal Sites Federal Facilities			Separation Technology	Bioremediation Incineration	Land Disposal

Source: Alex. Brown & Sons Incorporated

← ← ← ← ←

DIRECTION OF INDUSTRY TREND
Increasing Reliance on Technology
Increasing Differentiation Between Wastes

TRENDS: From Physical Practices to Chemistry-Based Approaches

TRADITIONAL PHYSICAL PRACTICES	INNOVATIVE CHEMICAL/BIOLOGICAL PRACTICES
Land Disposal	Treatment
Containment	Transformation
End-of-Pipe	Process Change
Media Transfer	Zero Discharge

TRENDS: From Undifferentiated Practices to Waste Specific Approaches

LAND BAN RULES
TREND TOWARD WASTE-SPECIFIC TREATMENT ALTERNATIVES

Land Ban Rule:*	CA List	1st 3rd	2nd 3rd	3rd 3rd	3rd 3rd	Total
Effective Date:	1987	1988	1989	1990	1992	
Number of Waste Codes:**	18	63	32	220	16	349
Treatment Technology		Number of Wastes Specifying Treatment				
Rotary Kiln Incineration	2	44	22	175	7	250
Stabilization		37	11	36	14	98
Precipitation	10	29	6	26	10	81
Liquid Injection Incineration	2	5	9	35	2	53
Chromium Reduction	3	18	4	11	3	39
Cyanide Oxidation	4	2	12	6	2	26
Fuel Substitution		2		15	2	19
Activated Carbon Adsorption	1	3	1	9	1	15
Vitrification	9			1	3	13
Solvent Extraction		2		5		7
Drum Rinsing				3	3	6
Fluidized Bed Incineration				5		5
Slurrying				2	3	5
Biological Treatment			1	3		4
Mercury Retort	2			1	1	4
General Oxidation		1		1	1	3
Neutralization	1			2		3
Steam Stripping		2	1			3
Sulfide Oxidation				1	1	2
Acid Leaching		1				1
High Temp. Metal Recovery				1		1
Secondary Smelting					1	1

* EPA split the waste codes into thirds, called First Third, Second Third & Third Third wastes

** Each code includes one or more waste streams for which one or more treatment trains or altenatives have been specified. Includes wastes with no specified treatment alternative

Source: Various EPA documents
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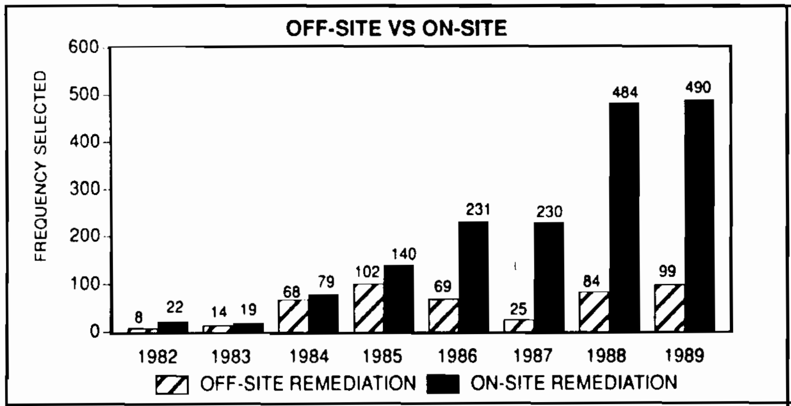
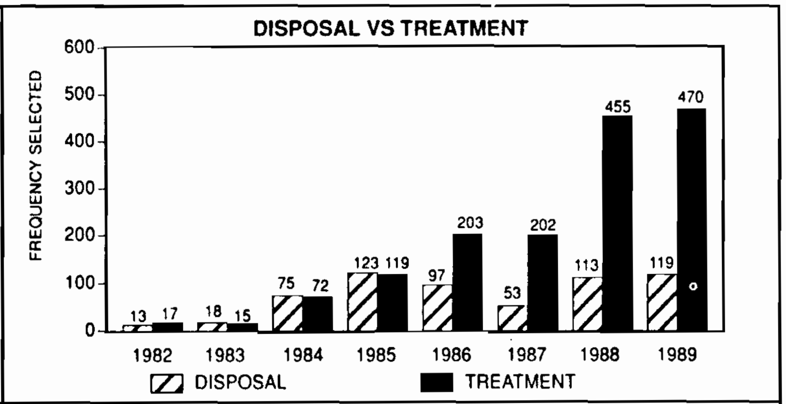
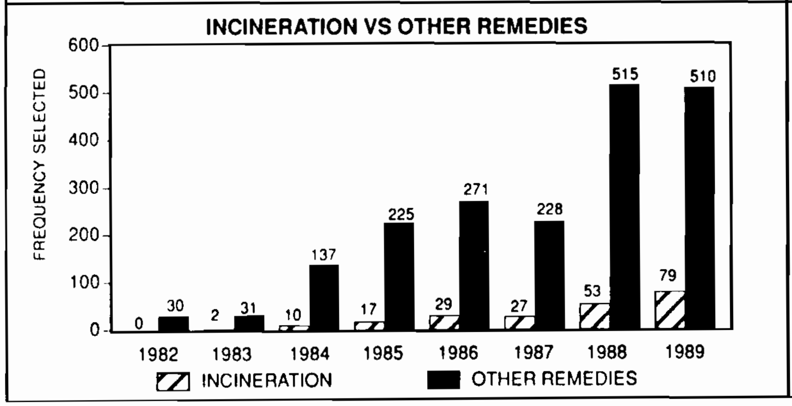
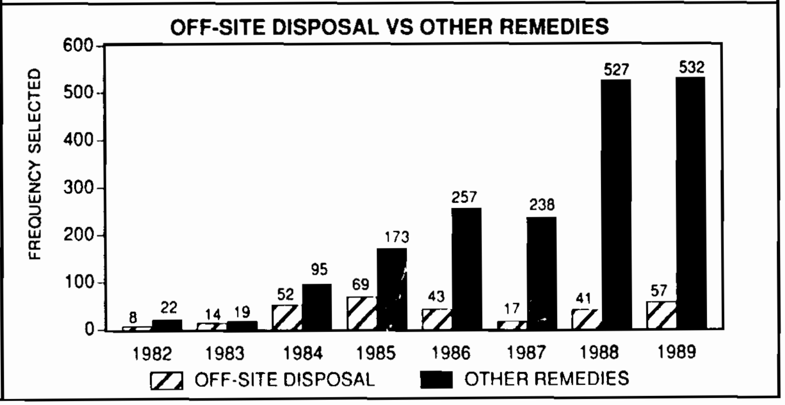
TRENDS: Superfund Site Remedy Selection


OFF-SITE VS ON-SITE


DISPOSAL VS TREATMENT


INCINERATION VS OTHER REMEDIES


OFF-SITE DISPOSAL VS OTHER REMEDIES

Source: NETAC, Alex. Brown & Sons Incorporated

CONCLUSION: Technology Will Alter Industry in 1990s

- 1980s: Consolidation around existing technology infrastructure
  - Regulation weeded out smaller, marginal facilities, but did not change basic technologies in use
  - Profitability of industry probably discouraged innovation from within industry
- 1990s: Emergence of new technologies
  - Conditions are ripe for emergence of new technologies
  - Costs of new technologies are declining, versus rising real costs of existing technologies
  - It is unlikely that the issues of today — interstate waste transport, siting — will be the issues of the future

Bulk Blends In Western Europe A Comparison Between Complex And Blends

A. Winther Andreasen
Kemira Denmark A/S

I would like to thank The Fertilizer Industry Round Table for inviting me to this meeting in Baltimore. It is indeed a great privilege for me to attend this meeting and to have the opportunity to provide you with results from studies regarding comparisons between complex fertilizers and bulk blends in Western Europe.

During the previous 3-4 years, the Western European fertilizer producers have included such studies in their research programe, and in my presentation, I would like to provide you with the results from these trials.

The main problem in bulk blends is the segregation. This has been pointed out very clearly in numerous publications,especially from the US,where blends cover a substantial part of the NPK-consumption. However, the question for the European farmers is, whether this segregation and uneven distribution in the field might cause economical losses and give ecological problems.

Western Europe has for years been a NPK-complex area, and bulk blends have covered only a minor part of the fertilizer consumption. But during the previous 4-5 years, there has been a growing interest in agriculture in Europe for using bulk blends. The world market price for DAP and urea has periodically been very low, giving blends some economical advantages, in spite of their inadequate N-efficiency.

EUROPEAN AGRICULTURE

Agriculture in Western Europe is quite different from agriculture in the States.

In general, Europe is a small farming area with 7 mio. farmers, of which 50% have less than 5 ha (12 acres). The average size of farms is 17 ha (42 acres), which is only 1/10 of the average size of farms in the States. But of course, there is a tremendous difference between the countries, from 5 ha in Greece to 69 ha in the UK, and 33 ha in Denmark.

In Central Europe, the UK, Germany, Denmark, Benelux and France, agriculture is very intensive and efficient.The level of fertilization is considerably higher than in the US, typically 250-350 kg of nutrients (N, P205, and K20) per ha against 150 kg in the States, and the yield of the crops is usually high: 7-10 tons of wheat per ha and 70-80 tons of sugar beet.

The typical European farmer is far more fertilizer-conscious than his Northern American colleague. Systematic fertilization is an essential component of the intensive production system in European arable farming. There are hardly any farms, on which the farmer or his employees do not carry out the fertilization themselves.

Complex NPK-fertilizers fit well in such a system. Exact uniform distribution of the nutrients on the fields is essential. An uneven distribution leads to deviations from the optimum nutrient rates, and in crops like wheat, malting barley, oil seed rape, sugar beet,and potatoes,which are important crops in Europe, an uneven distribution results in lower yield, poorer quality, and economical losses for the farmer.

Furthermore, the need for special- or micronutrients like Mg, S, Cu, B, etc is growing very fast, and in complex fertilizers it is possible to incorporate small amounts of these nutrients into the NPK-granules giving a much better distribution of the nutrients.

EUROPEAN FERTILIZER INDUSTRY

The conditions for the European fertilizer industry differ also completely from those in the USA. Most European countries are completely dependent on imports of raw materials or have only one raw material available (potash or rock phosphate).The fertilizer industry has, therefore, located the complex fertilizer plants near to ports, where all raw materials can be unloaded without additional costs. The manufactured products are often transported directly to the farmers.

The fertilizer plants are large cost-effective plants with annual capacities of 1-mio.tons of complex fertilizers. And the product is superior in quality: dustfree, free-flowing with uniform size and density. Well-rounded and hard granules.

BULK BLENDS

In Europe, blends are mainly manufactured in very simple, small scale plants of the Doyle-type or of the Rittbergwerke-type, and most blends are delivered in bulk.

Bulk blends were introduced in the early 70's but without success.The price difference between blends and complex was only marginal, and most farmers found that the segregation problems by handling and application were so severe that blends were a step backwards in fertilizer technology. Blends were, therefore, not accepted in Western European agriculture.

In the late 80's, blends have gained more and more access into the European market, due to the low world market prices for DAP and urea, and today blends cover approx. 14 per cent of the NPK-fertilizer consumption in Europe as a whole.

In Europe, only three countries have a substantial market for blends - Ireland, the UK, and France.

In Ireland, 50% of the compound market is supplied with blends packed in 50 kg bags or 500 kg big bags. But agriculture in Ireland is quite different from that of other European countries. 92% of the agricultural area is covered with grass, and the fertilizer consumption per unit of land is lower than in most other countries in Europe.

In the UK, blends account for 20 per cent of the NPK market.The blenders are mostly small producers purchasing spot materials at the most advantageous prices and selling the product within a limited radius from their plants.

In France, blends cover 17 per cent of the NPK-market. The blenders in France are mostly located along the Atlantic coast, where retailers find it convenient to import relatively cheap TSP, DAP and urea.

In other Western European countries, blends play a minor role, only.

SEGREGATION - A LARGE PROBLEM

As mentioned earlier, segregation is the main problem in bulk blends. It is well-known, that blends are made by a physical blending or mixture of separate solid fertilizers as urea, CAN, DAP, TSP, and MOP, and in general, the components have different sizes, shape, and density, and during handling, transportation, and spreading the different components will segregate. The result is an uneven distribution of the nutrients in the field.

A German study illustrates this very clearly. A blending was made of CAN, DAP, and MOP, and the desired formula of the blend was NPK 15-15-15. After blending, samples were taken in different places in the cone and analysed for N, P and K.

The difference in grade from the top of the cone to the bottom was tremendous. From a 9-11-11 grade in the top to a 16-7-16 grade at the bottom. The deviations in % from the calculated formula are 34% for N in the top and 52% for P at the bottom of the cone. The segregation is a result of the variation in particle size. Due to the physical laws, small particles will tend to occupy the centre of the cone, while the larger ones will roll to the outside.

Segregation will take place each time a fertilizer is handled. Even complex fertilizer, but due to the fact that in complex each single granule contains the prescribed ratio, no segregation of the nutrients will take place. But one can imagine what will happen to the farmer buying such a blend. He purchases a NPK 15-15-15 grade, which he has calculated to be the correct one for his field, and the product he gets is quite different from that. He loses yield and money.

One could now argue that most of the risk for segregation may be avoided by using components with identical particle size and specific density. And this is correct, anyway, theoretically. And maybe this is the case in the US, but it is not in Europe. In Europe, blenders generally use a variety of imported materials, and extensive trials, which results have been published, confirm that usually a severe segregation takes place.

Last year 1991, the Danish Fertilizer State Inspection controlled a number of blenders. They tested the blendings, and in the samples they found that in more than 27% of the samples, the deviation from the desired grade was more than three times the latitude allowed.

UNEVEN APPLICATION

At the time of application, segregation will occur in the hopper, or when the blend is flowing out of the hopper of a fertilizer spreader. Different sized particles travel at different speeds and land at varying distances from the point of distribution. If the larger particles contain one particular nutrient, and the smaller ones another, then the amount of nutrients applied will vary according to the distance from the spreader.

Studies can be made by spreading out trays in the fields to intercept the fertilizer. The trays are passed 3 times by the spreader to cover the fullworking width. The content of the trays is then collected and analyzed for nitrogen, phosphate, and potash.

In Denmark, the Danish Agricultural Advisory Center has made several of such field studies. This is an example from a bulk blend with a good physical quality and a similar size of the granules. In the graph, you will find the percentage of nutrients in the trays, indicated at the vertical line. The bottom line illustrates the soil surface. In the middle, the center line of the applicator. The trays were placed in the center and 3 and 6 metres, respectively, away from the spreader. The working width of the spreader was 12 m, only.

In this case, the smallest deviation seems to occur for nitrogen (red colour). From 12% N in the trays in the center line to 15% N 6 meters from the center.

In the case of phosphate (blue colour) and potash (green colour), the segregation is much larger. For P from 10% P in the center to 14% P or 40% more some meters away. For potash from 12% K to only 8% K or only 2/3, where the spreading pattern is overlapping.

Looking at the results from the spreading of a blend with uneven granule size, which is the most common in Europe, you will find a much larger segregation. For N from 13% N to 18% N, and for P and K from 11% P to 6% P to from 11% K to 14% K or from a grade in the center 12-10-13 to 18-6-12 in the overlapping zone.

The working width in these studies have been 12 metres, only. Today this is unusual. Most farmers demand to spread fertilizers with a working width of 18-24 metres, and under such conditions, the segregation is much more worse.

In addition to that, there is a substantial variation in the formula from start of the spreader to the end.

In conclusion, the Danish Agricultural Advisory Center pointed out that due to differences in the particle size of the different components, a "severe segregation has occurred", and that the results demonstrate that "blendings have to be omitted from the market".

FIELD TRIALS

The main question for the farmer in relation to bulk blends is whether an uneven distribution of the nutrients in the field will cause yield decrease and economical losses. And the only way to get an answer is by conducting field trials.

In the US, a considerable research work has been done over the years, which has proved the superiority of complex fertilizers over blends.

In Western Europe, no or very few trials comparing blends with complex fertilizers have been conducted.

For that reason, the Western European fertilizer producers have included such field trials in their research programme since 1989.

TRIALS IN GERMANY

In 1989, trials were conducted in Germany, comparing NPK 13-13-21 complex with blends with two different forms of N, CAN, and urea. The trials were conducted in winter barley and winter wheat.

The yields are indicated in kg/ha and for your information, in relative figures as well.

In winter barley, there were no significant differences between the treated plots due to an early and substantial lodging in all the plots, the control plot, and the three treated plots, as well.

On the other hand, in winter wheat there were significant lower yields with bulk blends than with complex NPK's, 820 kg/ha and 940 kg/ha of grain, respectively, for the CAN and urea blend. The N-form, whether it was CAN or urea, seems to have no significant influence on the yield reduction. Please observe that the yield has doubled from the control plot to the fertilized plot.

In 1991, a study in winter wheat and winter rye illustrated the same result. In wheat and in rye, as well, NPK-complex is superior to bulk blends.The difference between the two treatments is 500 kg of grain per ha, corresponding to 10%.

In 1991, four trials were conducted in winter wheat, comparing complex with a blend mixed from urea, DAP and MOP.

On an average of four trials, the plots applied with complex gave 500 kg/ha or 11% more than the plots applied with blends. In spite of the lower yields in the plots treated with blends, the content of crude protein in the grain was on an average 0.8% lower than in the complex treated plots, 14.1% protein after complex and 13.3% after blends.

Trials in Denmark

In 1992, a study was made in Denmark in winter wheat and winter barley. The results were similar to those in Germany. A surplus in yield in favour of complex fertilizers.

The blends were delivered from local blenders and in the product, the components were very similar in size. In wheat, the entire amount of fertilizers were given in one split, while in winter barley, the fertilizers were given in two splits. The fertilization was 190 kg N/ha in wheat and 170 kg N/ha in winter barley.

It was interesting to note that during the whole growing season, no differences could be observed in colour between the two treatments, but in spite of that, there were differences in yield. In wheat, a surplus of 130 kg grain/ha and in winter barley, 560 kg grain per ha all in the favor of complex fertilizers.

QUALITY

All the field trials illustrate very clearly that complex fertilizers are superior to bulk blends applied with the same amount of nutrients. And there is a difference in yield, even though no difference in colour can be observed in the field. The surplus in yield by applying complex is in the range from 100 kg/ha to almost 1 tons of grain per ha, dependent on the quality of the blends.

In addition to that, bulk blends often give a reduction in the quality of the grain. The uneven distribution of nutrients in the field often results in the well-known "striping" of the crop with bands of sappy growth, and as time goes by a tendency to lodging or fall over, and uneven ripening due to an overdose of N. In bands which have been underdosed, there might be losses of yield.

The consequences are a drop in the quality, which is particularly evident in the case of milling wheat and malting barley.

ECONOMY

As demonstrated, trials have proved that there is a difference in yields between 100-1000 kg grain per ha in favour of complex. But due to a low prices of DAP and urea, and a more simple process, blends can be sold at a lower price than complex.

In Europe, blends are usually sold at a price of 1–2.50 US$ lower per 100 kg than complex, corresponding to a difference in price of 7 - 20 US$ per ha, dependent on type and amount of fertilizer

For wheat and winter barley, farmers in Europe have been paid 210-230 US$ per tonne of grain, which gives a balance between the differences in costs and yields from 30 kg to 90 kg of grain per ha. If the difference in yield is higher than 30-90 kg grain per ha, then complex is more economical to use by the farmers than bulk. And in addition to that, the quality problems come.

According to the trials, complex gives a surplus in yield from 100-1000 kg per ha, so the result for the European farmer is that complex NPK fertilizers are still the most economical source of fertilizer to use.

ENVIRONMENTAL PROBLEMS

In Western Europe, concern about environmental issues takes a major political significance and this paper would not be complete without some references to environmental considerations.

An uneven distribution may result in leaching of nutrients, particularly nitrogen. As long as optimum amounts of fertilizers are applied, no leaching of N will occur, but if an overdose is applied, the growing plants will not be able to utilize the excess of N fully, and N will leach into streams, rivers, and the underground, and will pollute the water.

Research in different European countries has clearly demonstrated that if the economical optimum application rate of N is exceeded, then leaching of N will increase. In the diagram, the leaching is indicated on the vertical line at the right side, the yield at the left side. The bottom line is the application rate of N. The leaching curve illustrates very clearly that leaching only increases very slowly from 0 to optimum N-application.When optimum is exceeded, then the leaching will increase dramatically.

Data from a study in Germany, comparing complex with blends, have shown that the N-removal in grain was much lower after blend than after complex, due to lower yield. This has worsened the N-balance in the soil by 35 per cent and increased the risk of leaching. The N surplus of 39 kg N/ha in the complex treatment increased in the bulk blend treatment by 35% to 53 kg/ha.

CONCLUSION

In my paper, I have highlighted some of the advantages and disadvantages for bulk blends in Western Europe.

Bulk blends are based on the price per unit of nutrient cheaper than complex fertilizers, but there is a number of distinct disadvantages, which more than offset the price difference.

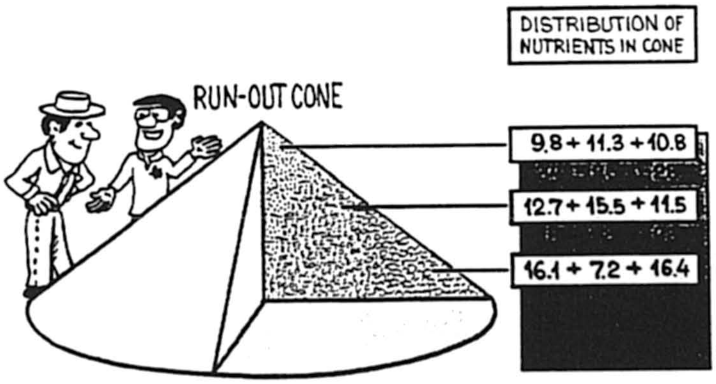
Studies have clearly demonstrated that segregation of the components always will occur during storage, handling and distribution, and that this segregation frequently lead to an uneven distribution of the nutrients in the field.

The impact is lower yield, uneven ripening,and a reduction in crop quality and financial losses for the farmer.

There are still in Western Europe farmers who only look at the fertilizer costs and not at the bottom line, but more and more farmers realize that the additional costs of buying complex fertilizers are offset by better yield and better economy.

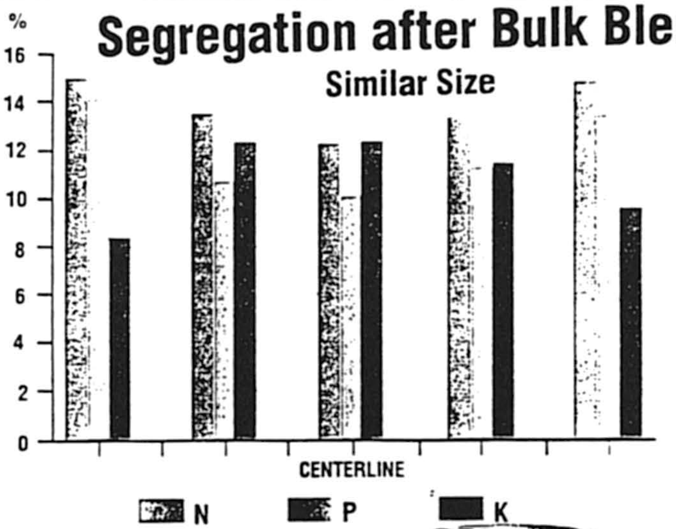
Distribution of nutrients in a run-out cone after mixing the components calcium ammonium nitrate, diammonium phosphate and coarse potash (with 5% MgO)

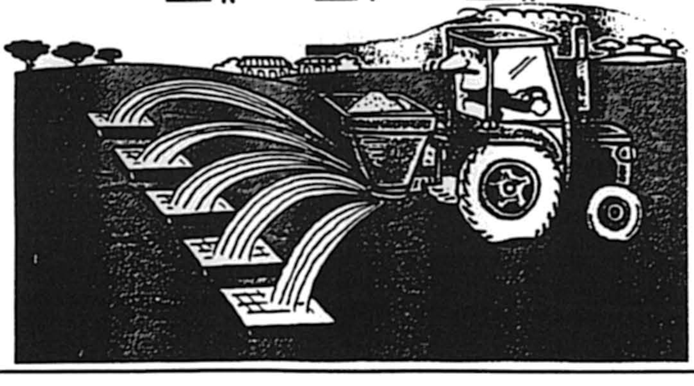
Desired formula of bulk blend 15+15+15



Segregation after Bulk Blend

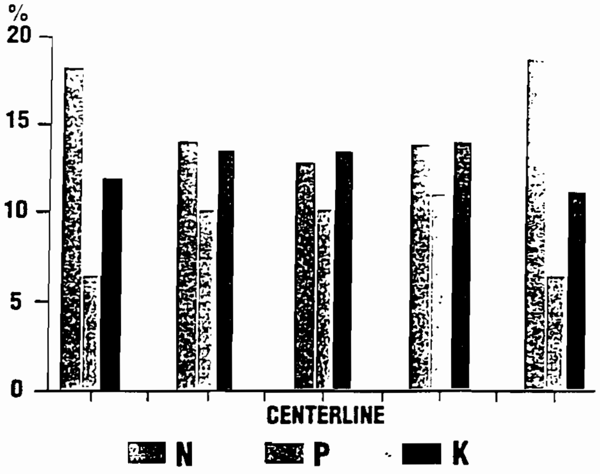
Similar Size

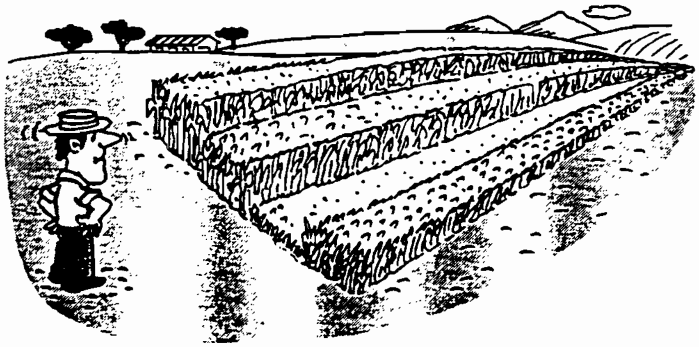




Segregation after Bulk Blend

Uneven Size

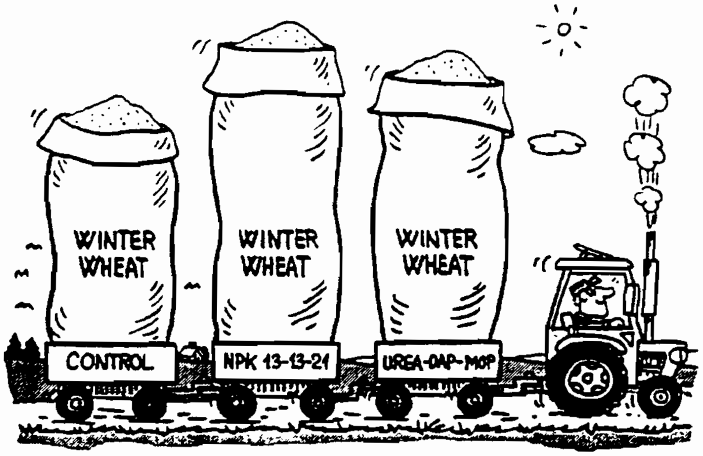




COMPLEX VS. BULK BLENDS

	Winter Barley		Winter Wheat	
	kg/ha	Rel.	kg/ha	Rel.
Control	3,700	81	3,780	50
NPK 13-13-21	4,570	100	7,580	100
KAS+DAP+MOP	4,550	99	6,760	89
Urea+DAP+MOP	4,480	98	6,640	88

COMPLEX VS. BULK BLENDS



	Winter Wheat		Winter Rye	
	kg/ha	Rel.	kg/ha	Rel.
Control	3,120	73	4,010	78
NPK 13-13-21	4,270	100	5,130	100
Urea+DAP+MOP	3,780	88	4,620	90

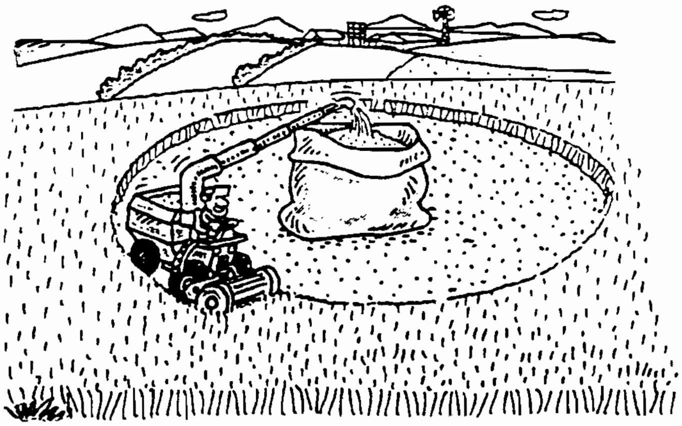
(1991)

COMPLEX VS. BULK BLENDS

	Winter Wheat		
	kg/ha	Rel.	%Protein
Control	3,570	76	11.7
NPK 13-13-21	4,700	100	14.1
Urea+DAP+MOP	4,200	89	13.3

(1991)

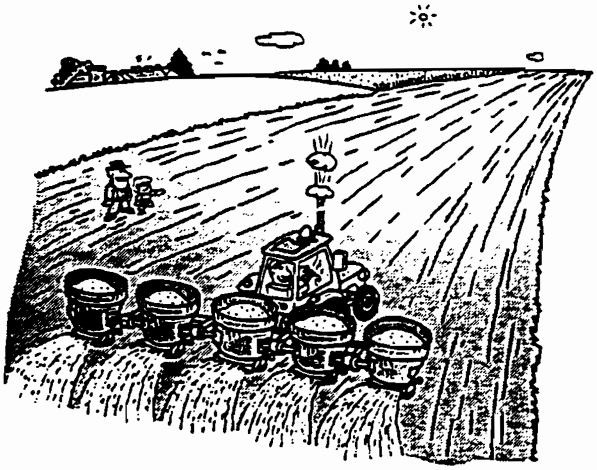
COMPLEX VS. BULK BLENDS



	Winter Wheat kg/ha	Winter Barley kg/ha
Complex NPK	8,060	5,040
Bulk blends	7,930	4,480
Difference	130	560

(1992)

COMPLEX VS. BULK BLENDS



	Winter Wheat		
	kg/ha	N-Removal	N-Balance
Control	3,570	57	- 57
Complex	4,700	91	+39
Bulk blends	4,200	77	+53

(1991)

Fluid Bed Granulation Of Nitrogen Fertilizers: A Status Report On Technology And Products

Andy F. Kayaert
HYDRO AGRI LICENSING

1. HISTORY OF SOLID UREA FINISHING.

Solid particulate urea was initially obtained by crystallization from saturated solutions.The product suffered from irregular small size and was very sensitive to caking.

It was only acceptable for small scale plants with direct product bagging.

This technique was soon replaced by prilling, where droplets of nearly waterfree melt are allowed to solidify during their free fall within air-swept vertical towers.

Prilling had an overwhelming impact on urea production since it was a simple operation well suited for the large unit capacities that were emerging in the early sixties.

It still occupies a dominating position nowadays.It suffers however from several drawbacks stemming from its solidification principle (large air flows related to the solidification heat load and the limited air heating, dust load and its fineness as a sublimate from liquid sprayed at high temperature) and from its product structure (size limitation, low crushing strength).

As urea became the major nitrogen fertilizer, it also had to fulfill more elaborate market requirements relating to :

1) Product size : bulk blending formulations, and more recently forest grade and rice paddy grade, call for larger product than alternable with prills.
2) Intensive bulk handling : prills lack the crushing and shatter strength to withstand bulk handling with high fall heights in stores and shipholds and wide even mechanical field spreading.

These requirements prompted new finishing techniques like drum granulation (Ref. 1) and pan granulation (Ref. 2). These techniques were, however, characterized by small unit capacity at the time when unit capacities of the urea synthesis units were rapidly increasing, pushed by the scale economy made possible by centrifugal compression of feedstocks and stripping process technology.

Fluid bed granulation overcomes this limitation since it involves no extrapolation and can thus offer single train design up to the highest synthesis unit capacities (2 000 MTPD and still increasing).

The first industrial fluid bed granulation plant was commissioned in 1979 with nameplate capacity of 800 MTPD at Hydro Agri Sluiskil (NL), previously called NSM and here further identified as HAS.

2. GENERAL DESCRIPTION OF HAS FLUID BED GRANULATION.

The feedstock is urea solution concentrated to approximately 96 percent, which is obtained through one evaporation step using low pressure steam from the urea synthesis plant.A formaldehyde based anticaking agent is mixed with the urea solution as it comes from the evaporator.

In the granulator, the unit at the heart of the HAS process, the solution is sprayed onto granular urea seed material held in fluidized suspension (Fig. 1).Low pressure compressed air fed to the urea solution atomizing system is preheated to slightly above the solution crystallization temperature, thus also acting as a jacket for the solution spray nozzles.

Since fluidization air is fed at ambient conditions, no dehumidification is required even where the climate is hot and wet.The air is distributed under the fluidized layer and, together with the atomization air, is extracted from the top of the granulator.

Basically, the rectangular granulator vessel consists of a perforated plate, lower casing, upper casing, and feed solution injection headers.The perforated plate acts as a distributor to evenly spread incoming fluidization air.The plate also acts as a grid to support the granule bed when it is at rest.

The lower casing supports the perforated plate, houses the solution injection piping, and is the plenum chamber which receives fluidization air.The injection headers in the lower casing deliver feed solution to the nozzles from which the solution is sprayed onto seed particles.

The upper casing is partitioned into chambers by baffles that prevent backmixing.The fluidized layer is confined to the upper casing where the seed particles grow.In the "disengaging" space above the fluidized layer, coarse product dust is separated from the upflowing air and is retained within the granulator, circulating back to the fluidized layer.

Initially, seed material is introduced to the granulator.The seed is continuously coated by urea droplets from the spray nozzles.The average diameter of the droplets is much smaller than the final diameter of the granules, and thousands of droplets are required to form a single granule.

Known as slow accretion, this mode of growth gives each granule a homogeneous structure, considerable hardness and low residual moisture, even though the feed solution contains about four percent water.

With the HAS granulator's specially designed spray nozzles, the urea solution is atomized at low air pressure.The nozzles are located at the bottom of the fluidized layer and their upward spray cones are completely submerged.Urea droplets are, therefore, prevented from entering the disengaging space and being carried along with the exhaust air.Keeping the spray cones confined within the fluidized layer also prevents urea buildup on the walls of the granulator.

Any agglomerate that would settle is laterally thrusted by aerodynamic forces arising from the design of the perforated plate.In contrast to overflow bleeding utilized by other fluidization processes, bottom bleeding effectively avoids the accumulation and further build-up of agglomerates, thus ensuring steady state operation.

Another important principle operative in the HAS design concerns the balance of heat within the granulator. For processes which granulate from a melt feed of 99+ percent urea, either a very large amount of air or a very high solid recycle ratio to the granulator is needed to dissipate the heat released by urea solidification.However, since the HAS feed is a 96 percent urea solution, heat generated during urea solidification is transferred to the accreting granules, vaporizing the water contained in the atomized feed solution.

Product extracted from the granulator flows to a standard fluidized bed cooler which uses air as the fluidizing and cooling medium. If the ambient air is sufficiently cold, further dehumidification and cooling are not necessary. For plants in tropical and sub-tropical areas, refrigeration is usually provided to chill and dehumidify that portion of the air to the cooler which will be in contact with the granules at the lower temperature. In large capacity plants, this is more efficiently achieved in a second cooler which treats only the screened end product.

After cooling, the granules are screened and separated into three fractions.Appropriately sized product granules are sent to storage after final cooling.Undersized and coarse granules are recycled to the first chamber of the granulator as seed material (Fig.2).

Adjustment of the roll mill crusher controls the amount of seed available per unit of granulator feed solution.By adjusting the crusher and the air flow, an HAS granulation plant can produce either agricultural urea or larger bead size granules.Average particle diameter for the first type ranges from Tyler 10 to Tyler 6, while large product can be up to Tyler 2 1/2 in diameter.

Under normal operating conditions, the solid recycle ratio between recycle and product is very stable and low.It is 0.5 : 1 as opposed to a higher, less efficient ratio of 2 : 1 or even more for other urea granulation processes.

Because of the moderate air flow involved, the level of dust in the granulator air stream amounts to only four to five percent of plant capacity.Air extracted from the granulator and from the cooler(s) is scrubbed with process condensate from the upstream solution plant.

Virtually all of the dust from the granulator is removed in the scrubber(s).The recovered dust forms a 40-50 percent urea solution which is recycled to the evaporation section of the urea synthesis plant.The quantity of dust vented from the scrubber(s) falls easily within limits specified by the most stringent air pollution requirements.

The HAS fluid bed granulation process has a variety of features that greatly enhance technical efficiency and cost effectiveness.Since the feedstock solution is concentrated to about 96 percent only, the evaporation section of the synthesis unit can be a single stage.This also reduces the load on the condensate treatment section of the synthesis unit.The result is lower investment for equipment as well as decreased steam and cooling water requirements.

As a direct consequence of the thermal balance in the granulator, less fluidization air is needed and the fluid bed granulator can be physically smaller than drum or pan units.In turn, this means smaller investment and operating costs for the system's blowers and heat exchangers. Additionally, minimal dust loading in the exhaust stream entering the scrubber contributes to a low solution recycle ratio to the synthesis unit, which further reduces the duties of the synthesis evaporation and condensate treatment sections, thereby achieving even greater operational and investment economy.

Along with a low solution recycle ratio, the HAS granulation process has a very favorable solid recycle ratio.This is due to continual "disengagement" of dust particles from the air stream moving through the granulator and retention of particles in the granulator until they grow to product size.A low solid recycle ratio eliminates the need for a large capacity recycle loop, which affects the size and cost of units such as conveyors, screens and crushers.

In the design of the HAS granulator, the number of spray nozzles per unit of fluid bed area remains constant regardless of plant capacity.Only the overall area of the fluid bed and the total number of spray nozzles will vary with capacity.Since other design parameters such as nozzle size, air velocities, fluid bed depth and residence time are constant despite plant size, the granulator is well suited for large, very economical single-train designs.

Having no moving parts, the granulator is essentially free of maintenance.Since only the fans and blowers require scheduled maintenance under normal conditions, a typical plant has on stream performance identical to its upstream synthesis plant.

3. CLIMATIC INFLUENCE ON INDUSTRIAL REALIZATIONS.

From the process description, it can be concluded that climatic extremes only affect the product cooling equipment.This is illustrated by the industrial realizations already in operation/erection.

1) "arctic" climate as in Western Canada (Edmonton/ Alberta and Belle Plaine/Saskatchewan) where the Sherritt Gordon Mines plant is in operation since 1983 : the 2 trains of 600 STPD each include only one cooler within the solid loop with ambient air as cooling medium ; significant air heating capacity by direct gas firing is included for winter operation under extremes of - 40°C and design final product temperature of 45°C ; later on the customer added extra final product cooling by plate heat exchange (Ref. 4) to achieve a lower final product temperature of 35°C even in hot summer conditions.

2) "temperate" climate as in Western Europe (Sluiskil, The Netherlands) where the HAS plant is trendsetting since 1979, a single unit of 800 MTPD includes an ambient air cooler in the solid loop and a final cooler with 2 sections, the former with ambient air and the latter with chilled air for product cooling to 30°C.

3) "tropical" climate as in Malaysia (Bintulu,Sarawak) where the Asean Bintulu Ferlitizer single train plant has operated since 1985 and has been recently expanded: a single 1 850 MTPD unit includes an ambient air cooler in the solid loop and a final cooler with chilled air for product cooling to 40° C. The 2 trains of 810 MTPD at TTUC (point Lisas, Trinidad) each include only one cooler within the solid loop, but split in two sections, the former with ambient air feed and the latter with chilled air feed for similar product cooling.

4) "desert" climate as in Saudi Arabia (1 500 and 1 800 MTPD in Jubail), where fluidisation air to the granulator is quenched by evaporative water cooling to avoid overdesign for the extremely high temperature in dry summer peak conditions.

5) "monsoon" climate as in Bangladesh (1 700 MTPD Jamuna Fertilizer), where fluidisation air to the granulator is cooled by indirect heat exchange.

Numerous cooling combinations are possible according to the local climatic extremes and their frequency.

4. PRODUCT CHARACTERISTICS.

The distinctive features of granular urea as opposed to prilled urea are best illustrated in Table 1.

The difference in shatter resistance to free fall is even more astonishing (Fig. 3).

Table 1

Urea comparative product characteristics

		Prilled (standard)	**Granular** (bulk blend)	**Granular** (large size)
Moisture	%	0.30	0.20	0.25
Biuret	%	0.90	0.70	0.70
Formaldehyde (injection)	%	0.45	0.45	0.45
Average size	mm	1.7	2.5	7.0
Crushing strength	kg	0.6(2mm)	3.0(2.5mm)	10.0(6.3mm)

5. ANTI-CAKING ADDITIVE.

Unless residual moisture is below 0.1 % and absolutely no moisture is absorbed during further handling, all forms of solid urea are very sensitive to caking through a mechanism of recrystallization within the mother liquor phase nourished by this residual moisture.

Under practical industrial conditions, it is not possible to decrease the moisture content to such a low level.Recourse to an additive is therefore mandatory.Formaldehyde is one such additive (Ref. 3) that also suppresses the ammonia smell of the product and is compatible with most of its non-fertilizer uses.

After injection of the formaldehyde compound in the granulation feedstock, the end product exhibits no caking at all in the standard 3-months storage test (no lumps in bags under a load equivalent to the bulk pile height).

6. STORAGE AND HANDLING.

Product treatment with an anti-caking agent only gains its full free-flow potential during further storage and handling operations if it is completed with the following provisions :

1) avoid moisture migration within the product piles by ensuring low and uniform product temperature, without the day-night variations that usually typify the layered structure in prilling plant product piles.

2) avoid moisture uptake from the surroundings by heating air at least until the threshold of critical vapor pressure of the product at the same temperature and by further keeping the average temperature of the product in the bulk of the piles a few degrees above this air temperature for additional margin and positive air draft.

These requirements are not solely reserved to granules.Their validity is true for prills as well.As a general rule, the advent of ever larger plants concentrated in dense industrial areas sets ever more stringent quality requirements for bulk product distribution.

Since granules carry a much higher quality brand, they also raise much higher expectations from the customer.

Strictly considered raw prilled product should be compared with granular product at 60-80°C, the usual temperature range at prill tower outlet.Even then the granular product features the advantage of constant temperature, without day-night variations.

State-of-the-art urea production should, however, always include a final cooling step with design specifications closely matching the best storage conditions.

For granular urea, this extra cooling step can be well integrated with the main upstream equipment, sharing a common scrubbing system for example, while for prilling an extra set of equipment has to be added.

7. OTHER NITROGEN FERTILIZER PRODUCTS.

Urea - ammonium sulfate cogranulation (40 % N - 14 % SO3)

This product, initially introduced by TVA (Ref. 5) in the early seventies was an early offspring of standard granular urea, with similar process flowsheet but a dedicated granulation additive, and a sulfur-like colouring agent.

A final coating drum is added to apply an organic surface coating to avoid moisture absorption in bulk storage and handling.

Ammonitrates (AN 33.5 - 34.5 % N) and calcium ammonitrates (CAN 22 - 27 % N).

In comparison with urea, these products are characterised by a much lower crystallization heat release and by several solid recrystallization steps which require :

a) a modified process flowsheet where fluidization air is heated up to nearly reach bed temperature and where the recycle features lowest possible temperature loss compatible with its processing (screening, crushing), thus without intermediate fluid bed cooler ;
b) the selection of granulation additives and associated final product cooling pattern which maintain the integrity of particle structure over the successive recrystallization steps ; by doing so, the pure ammonitrate also does not become sensitive to detonation ;
c) the CAN filler material (dolomite powder) generates a highly erosive slurry which dictates a careful process and piping concept (extra filters, special slurry spray nozzles).The solid product is also erosive.All solids processing items and especially the granulator are provided with hardened materials or with wear plates.

Slurry spray nozzles and wear plates are inspected and/or periodically replaced typically at the occasion of the. planned shutdowns of the upstream nitric acid plant(s).

8. CONCLUSION.

Solid fertilizers manufactured by the HAS fluid bed granulation have proven their qualities in the most extreme climatic conditions, from arctic to tropic.To live up to their market image, granular products should receive an efficient anti-caking treatment and a carefully designed cooling step.

Then they are able to cope with the most demanding modern storage and handling systems over the whole distribution grid until the end user.

LITERATURE

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(2) "The Granulation of Nitrogenous Fertilizers"
Nitrogen no.131, pp. 39-41, May/June 1981.

(3) CNA/NSM (now HAS)
"Improvements in or relating to urea crystals, pellets, prills and the like"
US Patent 4160782 dated July 10, 1979.

(4) "Bulk Flow Heat Exchanger : New Technology for Cooling Granular as Prilled Fertilizer"
Nitrogen 91 International Conference, June 4/6, 1991

(5) TVA
Fertilizer Manual 1985, p. 272.

FIGURE 1 : HAS Fluid Bed Granulator

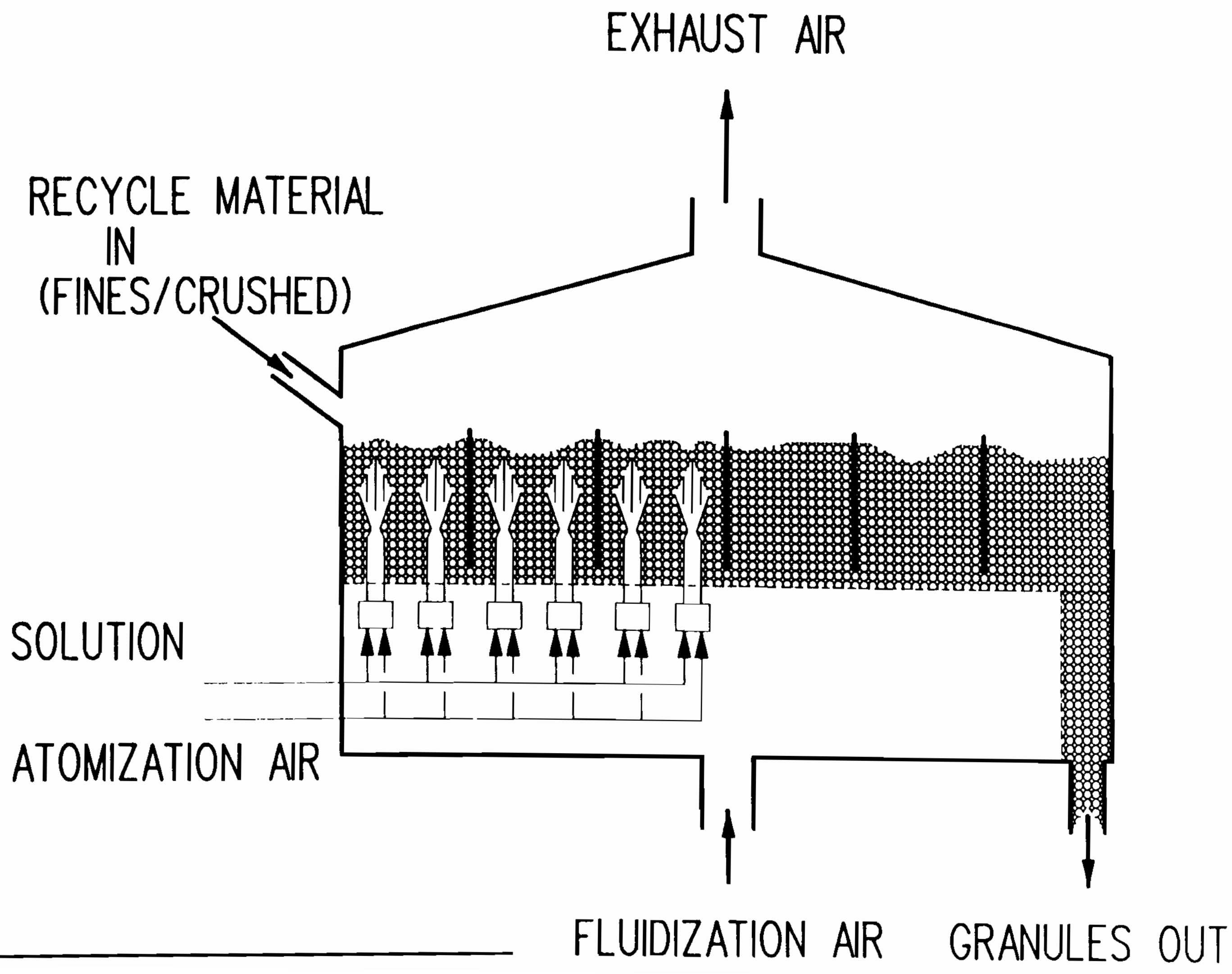


FIGURE 2 : Fluid Bed Granulation Flowsheet

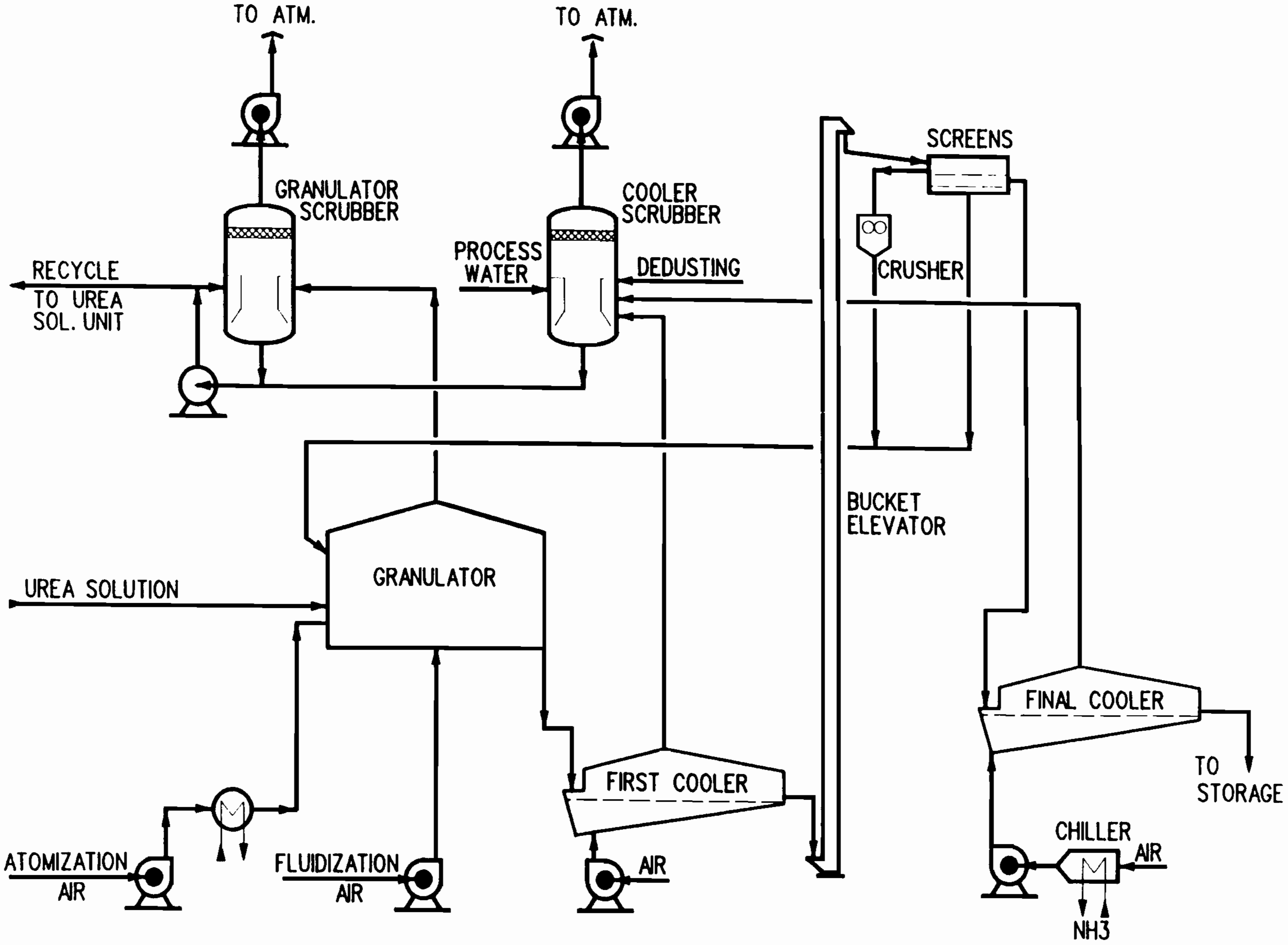
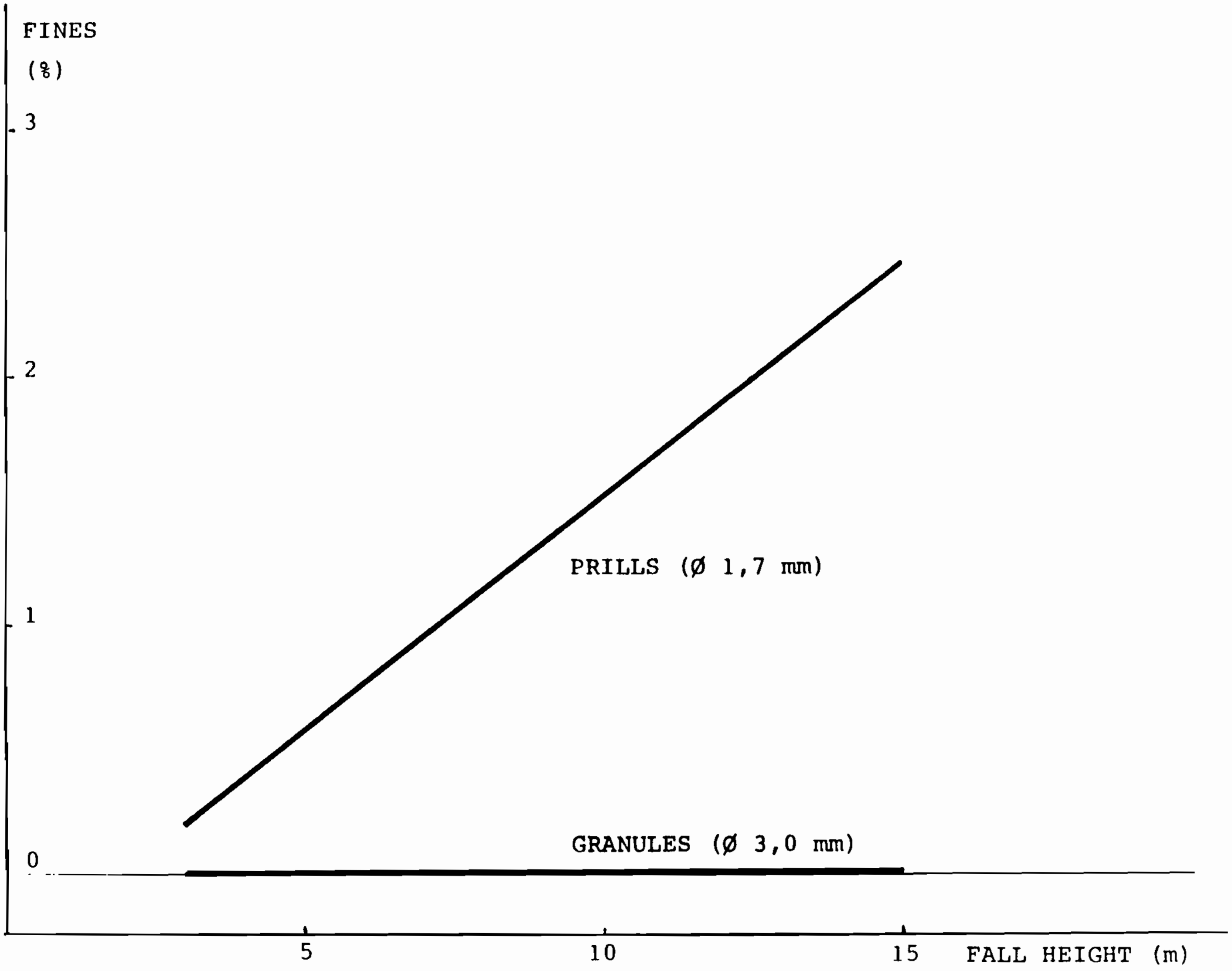


FIGURE 3 : Fines (below 1 mm) after Free Fall



Bulk Flow Heat Exchanger – New Cooling Technology For Bulk Fertilizers

Neville P. Jordison
Cominco Engineering Services

SUMMARY

The Bulk Flow Heat Exchanger is a simple and effective way to cool fertilizer prills or granules by direct contact with water cooled plates. The principal advantages of this method of cooling compared to fluid bed or drum coolers are:

- zero emissions
- compact design
- lower operating cost
- generally lower installed capital cost

This combination of features fits well with revamping objectives in the prill or granule section of the plant.

Bulk Flow Heat Exchangers have been operating successfully at the Cominco plant at Carseland, Alberta since 1988. Within the past 2 years, 3 more fertilizer installations have been commissioned cooling urea and ammonium nitrate.

INTRODUCTION

The current pressures facing fertilizer operations are stricter environmental standards and industry wide low market prices. Consequently revamp work undertaken today in the prill or granule section of the plant is geared towards the objectives of:

- meeting new emission standards
- improving product quality
- changing from prill to granule to take advantage of a better price
- debottlenecking

The Bulk Flow Heat Exchanger is innovative, yet very simple technology for cooling prills or granules. The major advantages of this cooling method are lower cost and zero emissions as compared to drum or fluid bed coolers (previously the industry standard).

This combination of features can lead to an attractive payback for a revamp project in the prill/granulation area, whereas with air cooled units the project may not prove financially viable.

To provide a brief background to the technology; the Bulk Flow Heat Exchanger was developed by Cominco Fertilizers at Carseland, Alberta, to cool urea after a spherodizer. The urea granules are cooled from approximately 600C to 400C (1400F to 1040F). Four units have been in operation since 1988.

DESCRIPTION OF HEAT EXCHANGER

Figure 1 shows a 3-dimensional cutaway view of the cooler.

The concept of the heat exchanger is very simple. The unit comprises a vertical bank of hollow, stainless steel plates. The bulk solids pass slowly between the plates and cooling water is passed counter-current through the hollow plates. Cooling is achieved by direct contact between the solid particles and the plates. Feed and discharge hoppers complete the unit, distributing material to the plate bank and regulating the discharge from the cooler.

PLATE BANK AND CASING

The plate bank is a series of closely spaced cooling plates; spacing is critical and selected to ensure good material flow without bridging. The plates are formed from dye-formed panels, resistance welded together. Each plate has welded tube connections to the inlet and outlet manifolds. Internal baffles are formed in the plates to maintain an adequate water velocity. The plates and manifolds are fabricated and hydrostatically tested in accordance with ASME pressure vessel standards.

The plate bank is housed in a stiffened casing with a removable, full size, back panel that provides access to the plate bank.

The manifolds are a split design which provides access to the tube/manifold weld.

MATERIALS OF CONSTRUCTION

The plates and manifold are fabricated from stainless steel, with grades 304L or 316L most common, depending on application. Higher alloy grades can be used if service conditions demand.

The casing is of carbon steel for non-corrosive conditions, or stainless steel, if required.

FEED HOPPER AND SOLIDS DISTRIBUTION TO PLATE BANK

The feed hopper is a straightforward box above the plate bank - see Figure 1. Distribution to the plate bank is easily achieved by allowing the solids to form a simple conical pile above the cooling plates.

The figure shows an open top design, however, the top normally would be closed with a solids inlet connection and inspection hatches.

DISCHARGE HOPPER

Discharge from the plate bank is by means of a mass flow hopper, carefully designed to ensure even flow of material over the full cross-section of the plate bank. The discharge hopper contains a gate that regulates solids flowrate through the cooler. The gate is of a no-shear design to avoid product degradation.

Figure 2 shows a typical cross-section through the discharge hopper, the inverted 'V' forms the gate. The plates which form the gate are fixed at the apex, but otherwise are free to bend, so by a small rotation of the shaft, a slot is created between the gate plates and the side wall. By adjusting the width of the slot, the flowrate is controlled.

The shaft rotation is by means of a pneumatic, quarter-turn actuator with positioner.

CONTROL

The unit is operated "full", (ie. the plates covered), by maintaining a set level of material in the feed hopper. This is achieved by means of a control loop comprising:

- level probe and transmitter
- controller with pneumatic output
- pneumatic actuator with positioner

The control system is configured to maintain a constant product level (set-point) in the top hopper as flowrate changes.

The controller continuously detects the difference between the process signal from the level transmitter and the set-point. The output air signal generated is a function of the difference and is transmitted to the positioner on the actuator. This controls the opening of the gate and hence the flowrate.

The controller can be of either a local unit or part of a plant Distributed Control System (DCS).

DISCUSSION TOPICS

ABRASION

Pure AN and urea are considered non abrasive, however, with NPK's or if dolomite is added to make CAN, abrasion becomes a factor.

Abrasion rates are a function primarily of velocity, and secondly pressure. In the Bulk Flow Heat Exchanger, velocity past the plates is extremely low, typically 0. 15 - 0.3 m/min (0.5 - 1 ft/min); pressure is also very low. Based on these factors, we anticipate extremely low abrasion rates.

For abrasive applications, heavier gauge plate can be used, in addition, some of the duplex alloys offer improved abrasion resistance compared to austenitic stainless steel.

FOULING/SCALING

To avoid settling out of solids, water velocity is controlled by the spacing of internal baffles in the cooling plates, however, cooling water lines should be protected by a strainer.

The heat exchanger is usually designed for a cooling water temperature differential of approximately 3°C (5°F). This minimizes scaling since there is virtually no change in carbonate solubility.

PRESSURE DROP

Typical pressure drop across the exchanger is 0.3 to 0.6 bar (5 -10 psi)

COOLING PLATE REPLACEMENT

In the event of a leak in the cooling plate (this has not happened yet!), the tube manifold weld can be ground out, the plate removed through the access panel in the casing and a new plate installed. As a quick fix, the tubes can be plugged just as in a shell and tube exchanger.

FEATURES OF THIS METHOD OF COOLING

EFFECTIVE COOLING

- cooling can be achieved over a wide temperature range in a single unit:

  Single stage cooler: 120°C to 35/40°C
  Secondary cooler: 55°C to 35/40°C

- cooler is effective for both prills and granules;

- operating experience and test work indicates no degradation in product quality, (ie. hardness or abrasion resistance), compared to drum or fluid bed coolers;

- phase change in ammonium nitrate at 85°C does not create problems;

- operates on regular plant cooling water, it is cost effective to achieve a 10°C approach to cooling water temperature;

NO EMISSIONS

- no air flow through unit;

- indirect contact with water, so no water effluent;

GENTLE PRODUCT HANDLING

- product moves very slowly through unit, there is no measurable creation of dust or product breakage resulting in fines;

COMPACT DESIGN

- the unit is very compact compared to a fluid bed or drum cooler and does not require the ancillary equipment needed with the air cooled units;
  See figure 4

LOW OPERATING COST

- The only power costs are for low head water circulating pump; circulating pump; See Figure 5 for typical power costs

INSTALLED CAPITAL COST

- It is very difficult to present typical installed capital costs since every installation is different, however some factors to consider are:

- generally fewer pieces of equipment

- no scrubbing or dust collection system

- no air dehumidifying system (typical on a final stage fluid bed cooler)

- no major drives

- compact layout to minimize building size

An example of installed capital costs comparing a fluid bed cooler and Bulk Flow Heat Exchanger are shown in Figure 5.

APPLICATION IN FERTILIZER PLANTS

The need for revamp work in the prill or granule section of the plant is generally driven by the following objectives:

- reduce or eliminate emissions
- improve product quality
- change to a more desirable product and a better priced product (eg. prill to granule)
- debottleneck to increase capacity (and decrease unit production cost)
- reduce operating and maintenance cost

The Bulk Flow Heat Exchanger can play an important role in meeting these objectives, frequently resulting in gains in more than one of the above categories as described in the following section.

REDUCE OR ELIMINATE EMISSIONS

Environmental requirements become stricter and this trend will certainly continue. In many older plants dust control systems from the air coolers are not adequate and changes are mandatory to keep operating.

Studies to replace an existing fluid bed or drum cooler with a Bulk Flow Heat Exchanger have shown that this approach has a lower capital cost than the installation of a scrubber or baghouse emission control system, plus it has the advantages of:

- zero emissions
- overall reduction in power cost rather than additional cost
- overall reduction in maintenance cost rather than additional cost

IMPROVE PRODUCT QUALITY

Cool to 35/40°C to avoid caking. The relationship between storage temperature and caking is well known.

CHANGE FROM PRILL TO GRANULE

With either prill fattening or full granulation, cooling is an integral step following granulation. The Bulk Flow Heat Exchanger has been used successfully with spherodizer and fluid bed granulators.

DEBOTTLENECK TO INCREASE CAPACITY

Many fertilizer plants are built with inadequate cooling for summer conditions with the result that the plant has to operate below capacity to maintain an acceptable discharge temperature. The Bulk Flow Heat Exchanger is a straight forward solution.

REDUCE OPERATING AND MAINTENANCE COST

The low operating costs of the Bulk Flow Heat Exchanger offer major energy savings over the large drives required for a fluid bed or drum granulator. A comparison of energy costs for the coolers at Cominco Fertilizers' Carseland Plant compared to fluid bed coolers for the same duty, are shown in Figure 5.

The simple design also results in low maintenance costs.

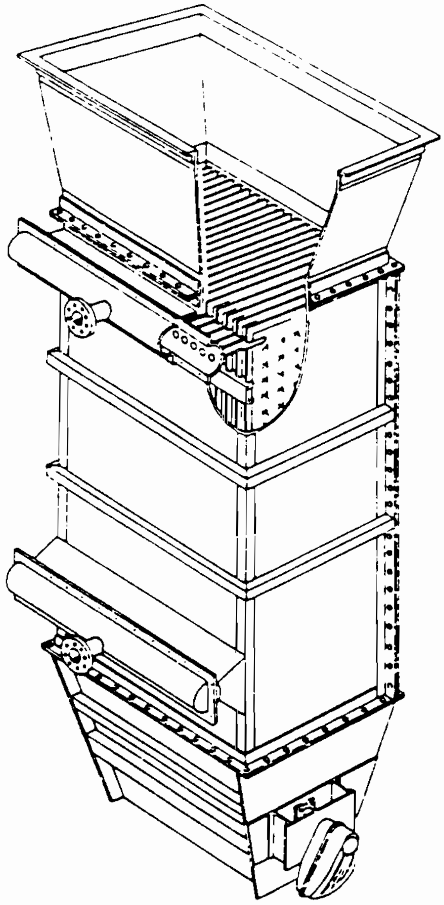


Figure 1

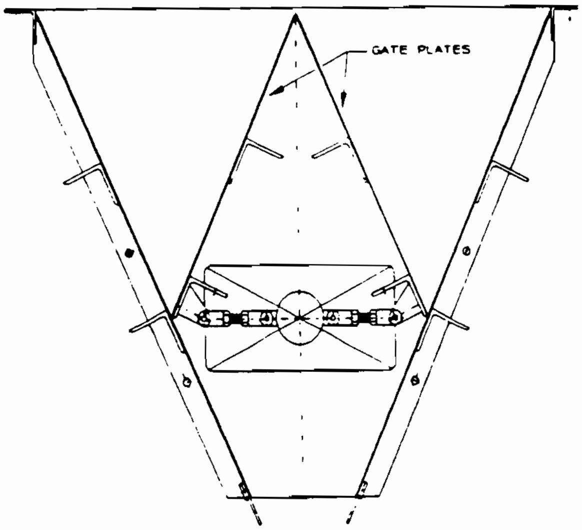


Figure 2 - Cross section through discharge hopper gate.

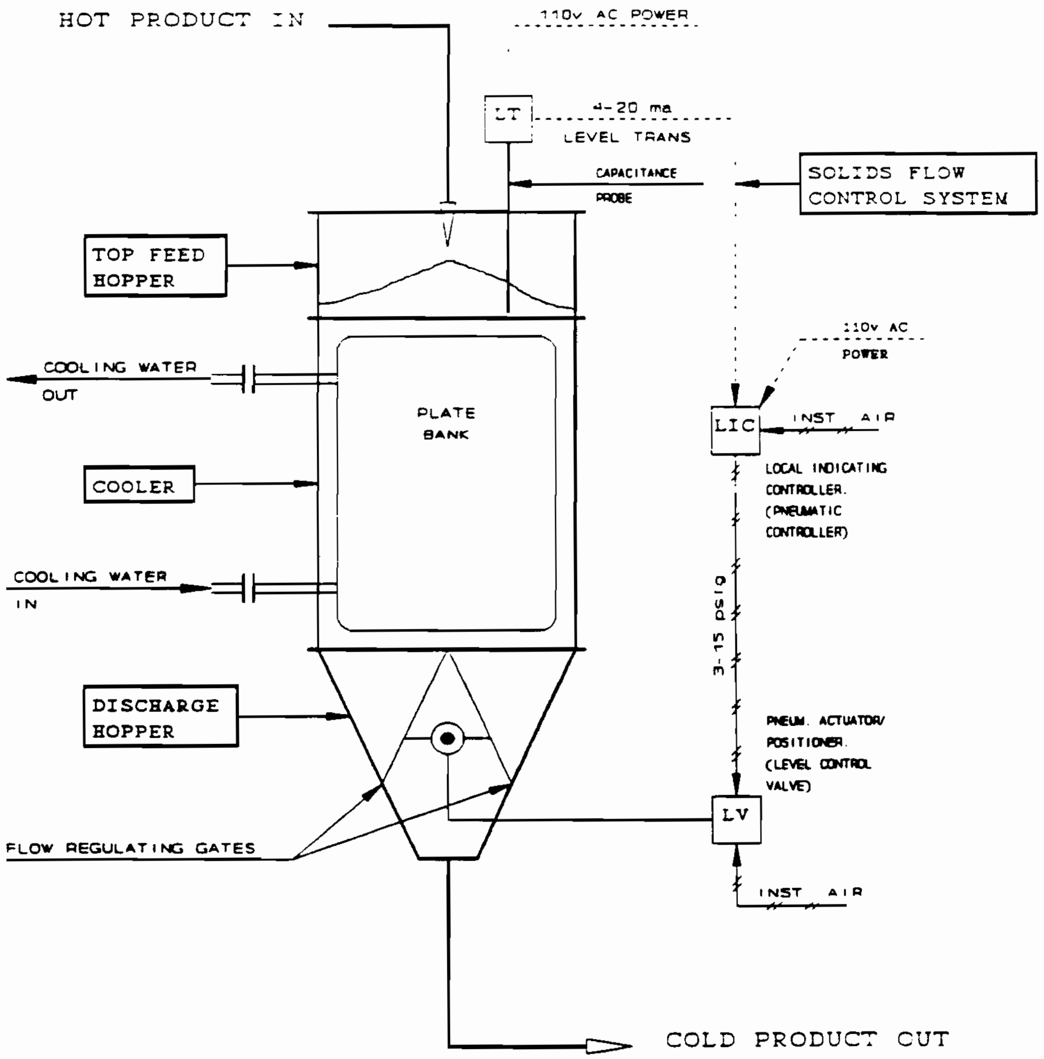
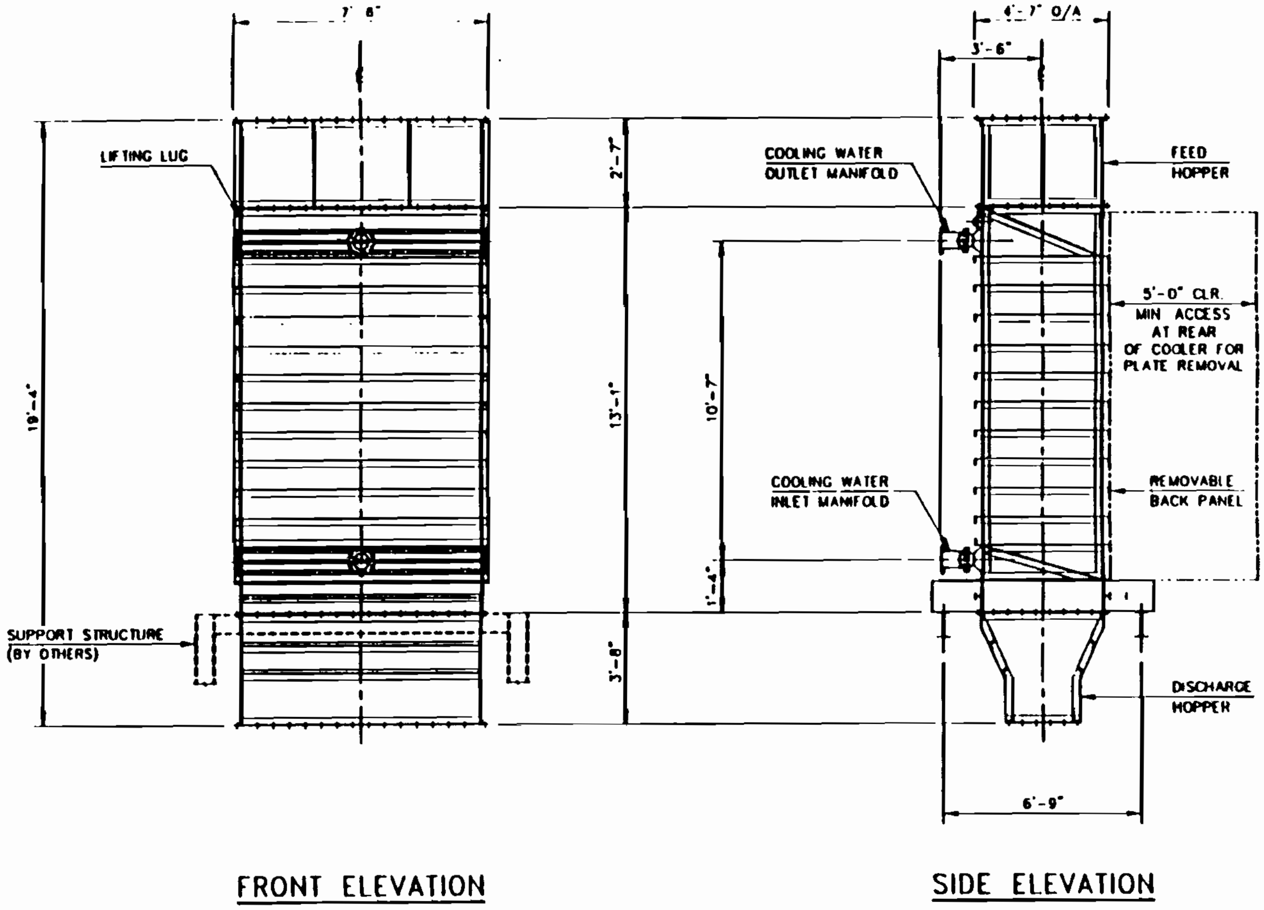


Figure 3 - Control Schematic



Rev	REVISION DESCRIPTION	Date	By
A	ISSUED FOR QUOTE	92/10/5	NPJ

WEIGHTS

TOTAL EMPTY
= 19673 lbs

TOTAL FULL
= 34054 lbs

CESL
Cominco Engineering Services Ltd

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CESL
Bulk Flow Heat Exchanger Division

Drawn By	BFL	92/10/5	Job No. PG01
Scale	N.T.S.		

Title
BULK FLOW HEAT EXCHANGER
GENERAL ARRANGEMENT

Drawing No PG01-001-D-342
Rev A

Figure 4

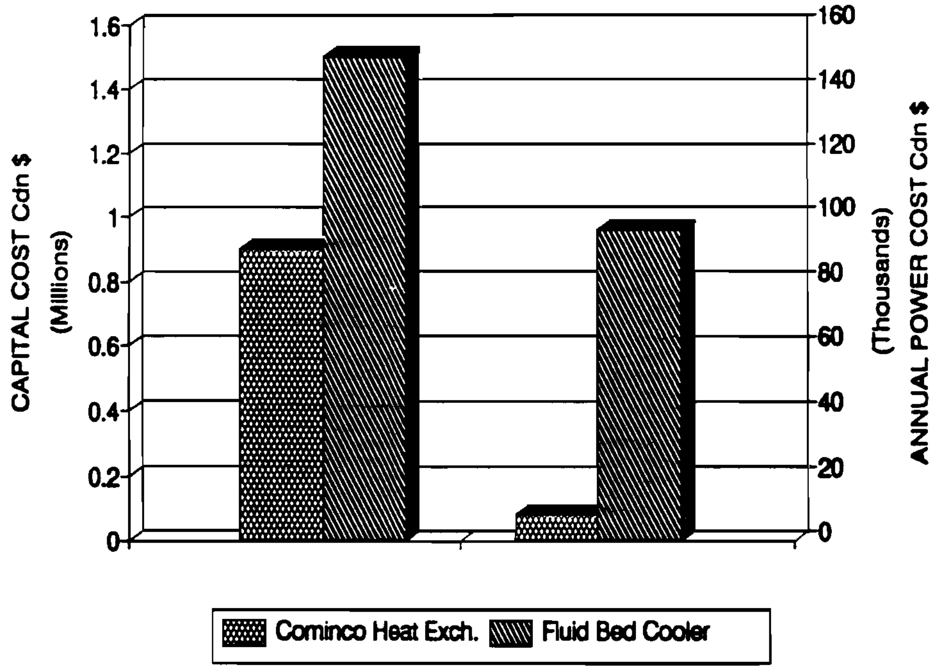


Figure 5 - Example of installed capital and operating cost for Bulk Flow Heat Exchanger compared to a fluid bed cooler for a 1364 t/d urea plant, cooling from 60°C to 40°C (1500 STPD, 140°F to 104°F)

REFERENCE LIST

DATE COMMISSIONED	***COMPANY***	***LOCATION***	***APPLICATION***
1988	*Cominco Fertilizers Ltd.*	*Carseland, Alberta*	*Urea*
1991	*Simplot Canada Ltd.*	*Brandon, Manitoba*	*Ammonium Nitrate*
1991	*Irish Fertilizer Industries*	*Co. Cork, Ireland*	*Urea*
1992	*UOP*	*Shreveport, LA*	*Catalyst Base*
1992	*Sherritt Gordon Ltd.*	*Fort Saskatchewan, Alberta*	*Urea*

A Zero Defects Program For Small Fertilizer Plants

John L. Medbery
Consultant to the Fertilizer Industry

ABSTRACT

All too often there exists a passive acceptance by many fertilizer producers that off-spec. product is inevitable. The purpose of this paper is to outline a method for identifying the causes for product defects and then propose some ways by which a manufacturer and his employees can work together to eliminate these causes. The causes are termed "errors". They are typically errors of omission and errors of commission.

The plantwide teamwork approach for *Error Cause Removal* has the goal to make all products free of defects. This is commonly referred to as a *Zero Defects Program.* It is management's responsibility to establish standards and to motivate employees toward achieving an error-free workplace.

INTRODUCTION

As the title infers, this paper focuses on the quality problems of small fertilizer plants, which are currently mostly blending plants, customarily involved in the dry mixing of various N, P and K materials to make graded products with certain analysis guarantees.

The regulatory agencies of the various states sample and analize a portion of the production to ensure that consumers are provided with the chemical analysis for which they are invoiced.

A large number of such plants consistently fail to meet the product analysis guarantees within the stated tolerances. Their defect rates range from about 6% to 80%. The 1988 average deficiency rate for all states was 17.7%. Some states sample only materials, not blends, so they tend to lower the average. Also, some states do not report the deficiency data and are omitted from the average.

A significant aspect of the regulatory program is that overall quality seems to improve somewhat in certain states but not in others. Also, some manufacturers have made much progress and others are doing no better than in prior years.

It is not the intent of this paper to dwell upon the sampling methods, tolerances or penalty assessment practices of any particular state. Rather, this paper will focus on how any plant in any location can eliminate errors and consequently improve their analytical standing under the fertilizer regulations that apply to them.

IDENTIFYING THE PROBLEM

Quality control in blending is a subject that has been addressed many times and in many venues. TVA has provided excellent advice on how to eliminate segregation in blends. Best Management Practices is a term that can be applied to any aspect of plant operation and has been the subject of many a sermon.

The approach that I propose is very direct. When a report of an analysis deficiency is received at the plant, the plant superintendent immediately studies the analytical data and determines the cause of the deficiency. He then fills out a simple form called "Report of Off-Spec.Sample". He assigns a reason for the product defect. Occasionally he may misjudge the cause, but in over 90% of cases, he can readily identify the problem. An example is provided as Figure 1.

Because of a strong desire to improve their quality standings, IMC applied this technique at three dry blend plants in Florida. The data for a two-year period was collated. A summary of the plant superintendents' explanations for off-spec. product is as follows:

CAUSES OF DEFICIENCIES

Human Mistakes	17%
Weighing Errors	7%
Contamination	10%
Segregation	
Major Nutrients	59%
Minors	7%

CORRECTING THE PROBLEM

Now let us deal with each of these causes individually. First, *Human Mistakes.* It is a hard thing for any superintendent to admit that either he or one of his_employees would make a mistake that would result in an off-spec. product. Yet, when the subject is approached openly and without bias, this is what is found. Upon further study, the mistakes can be broken down into categories. In the case of the three Florida plants, we found three reasons for these mistakes:

- Lack of Knowledge
- Lack of Proper Facilities
- Lack of Attention

A program was then introduced which attacked each of these causes.

Lack of Knowledge was corrected by holding plant meetings during which each aspect of the plant's operation was openly discussed. Deficiency data was reviewed and causes for off-spec. product were identified. Employee participation is essential to the success of this approach and usually the corrective action is suggested by the employees themselves. No longer do workers do foolish things through lack of knowledge.

Lack of Proper Facilities is usually pointed out by the employees during these meetings. Of course, management should have been aware of equipment shortcomings, and probably were aware even before the meetings were held. However, when the employees themselves complain about these problems, it becomes awkward to procrastinate in taking corrective action. Management must follow through.

Lack of Attention gets to the root cause of human behavior. Careful pre-employment screening is necessary, but once people are on the payroll, they must be inculcated with a desire to excell. An incentive program will help keep their minds on their work. Group pressure then comes into play as a motivator.

I used to do a lot of league bowling where individual performance contributes to the score of the team. Some members use this night out as a social event and pay little attention to improving their skill. The better bowlers, however, treat this as a challenge and they strive to excell. Every nerve and every sinew is focused on one thing, get that ball in the right groove and hit the Pocket for a strike! It is management's responsibility to imbue the employees with this level of zeal. The Japanese are well known for the quality of their products and individual workers always strive for excellence in performing their jobs. The expression for this is "issko kemmei", meaning "total commitment". We must attain total commitment at all levels, management down to the lowliest job holder.

Weighing errors contributed to 7% of the deficiencies according to our study. They can be caused by many things, not all of which are readily apparent.

An example would be a scale hopper that consistently gets out of calibration. A simple calibration test should then be done each morning before the scale is used. By alternating test weights and materials in the weigh hopper, the calibration can be verified for the entire weighing range.

Another cause of weighing error is parallax. This often happens with dial scales because of the offset of the dial pointer from the dial. This can be a significant source of error when the dial is observed from a distance and from an angle by the batch weigher. Locating the dial directly in front of the weigher helps. This is not always possible when the weigher is also operating a shovel loader. The answer then is an electronic digital read-out. I recommend, however, that the dial head be retained as back-up in event of circuit board failure.

Contamination was judged to be responsible for 10% of the product deficiencies. The most common cause of contamination is spillage of one material into another that occurs prior to weighing and mixing. This can occur at the receiving system where materials are unloaded into the plant, either at the unloading site or in the distribution of materials into bins. Other causes are overflowing of bins, leaking bin partitions and floor spillage which is not properly separated or recovered.

A more subtle form of contamination can occur within the blending mill itself. Figure 2 is a flow sheet of a fairly complicated blending plant in Florida. In this plant layout, I have identified 16 places where contamination can occur. Leakage through flow control gates and hang-up in hoppers is common in a plant of this type.

The answer to all of the above error causes is an alert work force, an effective plant maintenance program and a responsive management.

Segregation is the most common cause of a product's failure to meet specifications when sampled. As we previously stated, segregation of major nutrients (N-APA-K 20) was found to account for 59% of deficiencies our three Florida plants. Segregation of minor nutrients, which are included in most Florida formulations, was responsible for 7% of the deficiencies. This is largely due to the fact that many of the minor source materials are available as fine crystals or powders.

The magnitude of this problem is immense when the entire industry is considered. One illustration is the 1984-85 data from Iowa involving the most popular grade blended, 9-23-30. This is a very simple mixture, 50% DAP (18-46-0) and 50% MOP (0-0-60), and yet 49 out of 97 samples reported were deficient in one or more nutrients. Variation in particle size was judged to be the explanation.

When particles of differing diameters are mixed together and then deposited in a conical pile, they will separate, whereas mixed particles of matched sizes will remain uniformly distributed throughout the pile. Size Guide Numbers were developed as a handy means of identifying the particle size of a blending material. (1) Raw materials producers now provide this information to buyers. SGNs are intended to enable the blender to select well-matched materials for use in blended fertilizers made at his plant. When all other conditions are brought under control, well-matched SGNs will ensure a good quality product.

It is not always possible or most economic for blenders to use well-matched particle sizes. In those cases, the tendency to separate must be controlled. Hoppers for blended products should be provided with "egg crate" partitions. I have found this to be very effective, especially if the product is to be bagged out of the hopper, or loaded directly into a vehicle from the hopper.

For bulk shipments, segregation can still occur if the material is allowed to form a cone when the hopper is discharged into a transport vehicle, or when a mixer is discharged into a vehicle. There are two sampling protocols that apply to bulk materials in vehicles. (2) One involves the use of the Missouri D-tube and the withdrawal of cores from the loaded material according to a prescribed pattern. The other method requires the sampling cup to be used to cut the stream at specified time intervals. This can be quite difficult if it has to be done while standing in the vehicle while it is being filled. It is quite possible that samples are frequently taken under adverse conditions and consequently reflect segregation that may not actually exist.

A common misconception in stream cut sampling is that the fertilizer falls off the end of a conveyor in a nice uniform flow. In real life this seldom occurs and special adaptations must be made to obtain an unbiased sample. For instance, the fertilizer particles take a trajectory as they come off the rotating head drum. The larger particles travel farther than the fines. Likewise, if the mixed particles have traveled some distance on a belt conveyor, the larger particles tend to roll to the outer edges of the stream on the belt. For these reasons, it is best to provide a small hopper or chute at the end of the conveyor to confine the stream dimensions to ensure that 100% of the flow at the moment of sampling enters the sampling cup. (Figure 3).

A further improvement is to place the cup on a track and slide it horizontally across the flowing stream using some kind of handle extension to control the movement of the cup. It then becomes much easier to maintain the exact timing sequence for cup transits. It also guarantees that the entire width of the stream is sampled.

A rubber flap can be added at the hopper exit to smooth out surges in the flow rate which often occurs when flighted drag conveyors are added.

The Canadian Fertilizer Institute developed the concept of The Uniform Index in addition to the Size Guide Number mentioned earlier (1). The purpose of the Uniformity Index is to provide information on the size distribution or range within a fertilizer material purchased for blending purposes. The higher the U.I. number, the less the material is likely to separate into sizes (segregate) when transferred into storage bins at the plant.

Segregation can be minimized in several ways, including filling the bins to a uniform height by use of flow diverters and frequent changing of the drop point of the inloading conveyors. Also, a shovel loader operator can remove materials of varying sizes from the bin when transporting the material to the blender.

Frequently there are higher deficiency rates in bagged blended fertilizers than in bulk goods produced at the same plant. This could be attributable to segregation occurring before bagging or segregation of materials within the bag.

The sampling protocol for bagged fertilizers involves the removal of cores from selected bags by use of a trier (2). To verify the validity of samples taken in this manner some special tests were conducted. A large riffle was purchased, one capable of handling an entire 50-lb. bag of fertilizer. The riffled fertilizer was remixed via the riffle several times before any was discarded. Finally, the reduced whole-bag sample was obtained. The analysis of this sample did not always confirm the sample taken from the bag by the trier. Generally the whole-bag samples were more often "on spec". This verifies the assumption that segregation occurs within a bag. Accordingly, it is most important that only well size-matched materials be used to avoid deficiencies in bagged blends.

The American Association of Fertilizer Control Officials, AAFCO, in Policy Statement No. 19 states as follows: "A deficiency in an official sample of mixed fertilizer resulting from non-uniformity is not distinguishable from a deficiency due to actual plant nutrient shortage and is properly subject to official action". Accordingly, when the industry produces a segregated blend, it can expect to be found deficient when inspected.

Obtaining a truly representative sample of a blended product is extremely difficult at best. As stated years ago by Dr. W. F. Hillebrand of the U.S. Bureau of Standards, "The sampling of the material that is to be analyzed is always a matter of importance, frequently a more important operation that the analysis itself". This being the case, the blend plant's management must do everything within reason to aid the inspector in obtaining the best possible sample. This, in itself, will reduce the number of deficiencies.

CONCLUSION

In conclusion, let me repeat ERRORS are the cause of off-spec. product. These are both errors of commission and errors of omission. Eliminate errors, reduce defects to zero, and product deficiency reports will be a thing of the past.

Our customers are much like Churchill.Sir Winston said this in regard to quality, "I am easily satisfied with the very best".

Happy customers are repeat customers and a source of profit for our blenders for many years to come. A Zero Defects Program is vital to the success of our blending operations.

References

(1)SGN, A system of Materials Identification, Canadian Fertilizer Instute, 280 Albert St., Suite 301, Ottawa, Ontario KIP5G8.

Also see:

(a) Material Selection for the Production of High Quality Blends, Jean Cheval, Proceedings of the Fertilizer Industry Round Table, 1986.

(b) Measures of Quality in Fertilizer Blending, Jean Cheval and Paul Branconnier, Proc.F.I.R.T., 1988.

(c) Least Cost Formulation of Granular NPK Fertilizers, Jean Cheval, Proc.F.I.R.T., 1990.

(2) Bulk Blend Quality Control Manual, The Fertilizer Institute, 1015 18th St., NW, Washington D.C. 20036, Section I "T F I Methods".

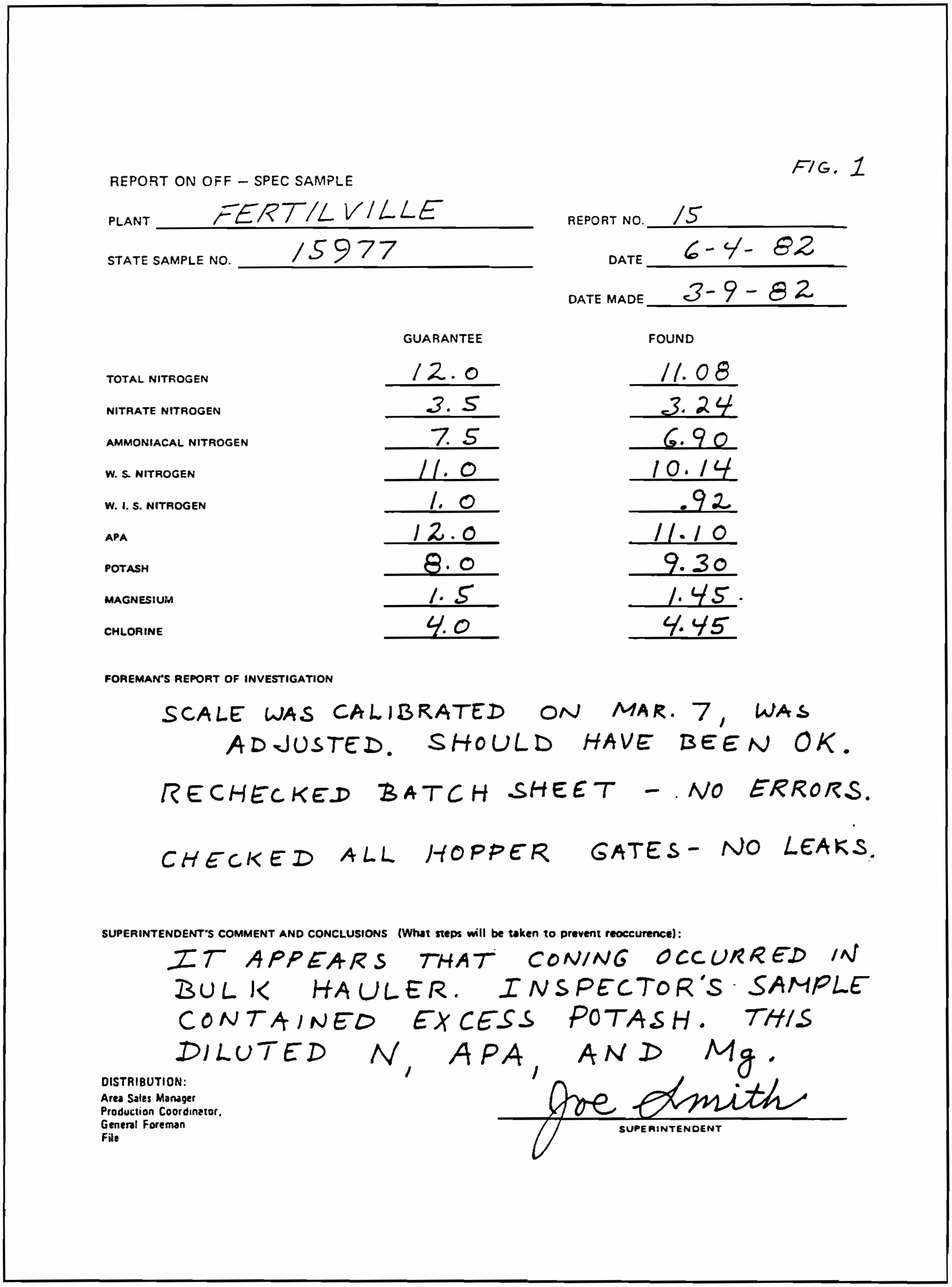


FIG. 1

REPORT ON OFF – SPEC SAMPLE

PLANT FERTILVILLE

REPORT NO. 15

STATE SAMPLE NO. 15977

DATE 6-4-82

DATE MADE 3-9-82

	GUARANTEE	FOUND
TOTAL NITROGEN	12.0	11.08
NITRATE NITROGEN	3.5	3.24
AMMONIACAL NITROGEN	7.5	6.90
W. S. NITROGEN	11.0	10.14
W. I. S. NITROGEN	1.0	.92
APA	12.0	11.10
POTASH	8.0	9.30
MAGNESIUM	1.5	1.45
CHLORINE	4.0	4.45

FOREMAN'S REPORT OF INVESTIGATION

SCALE WAS CALIBRATED ON MAR. 7, WAS ADJUSTED. SHOULD HAVE BEEN OK.

RECHECKED BATCH SHEET – NO ERRORS.

CHECKED ALL HOPPER GATES – NO LEAKS.

SUPERINTENDENT'S COMMENT AND CONCLUSIONS (What steps will be taken to prevent reoccurence):

IT APPEARS THAT CONING OCCURRED IN BULK HAULER. INSPECTOR'S SAMPLE CONTAINED EXCESS POTASH. THIS DILUTED N, APA, AND Mg.

DISTRIBUTION:
Area Sales Manager
Production Coordinator,
General Foreman
File

Joe Smith
SUPERINTENDENT

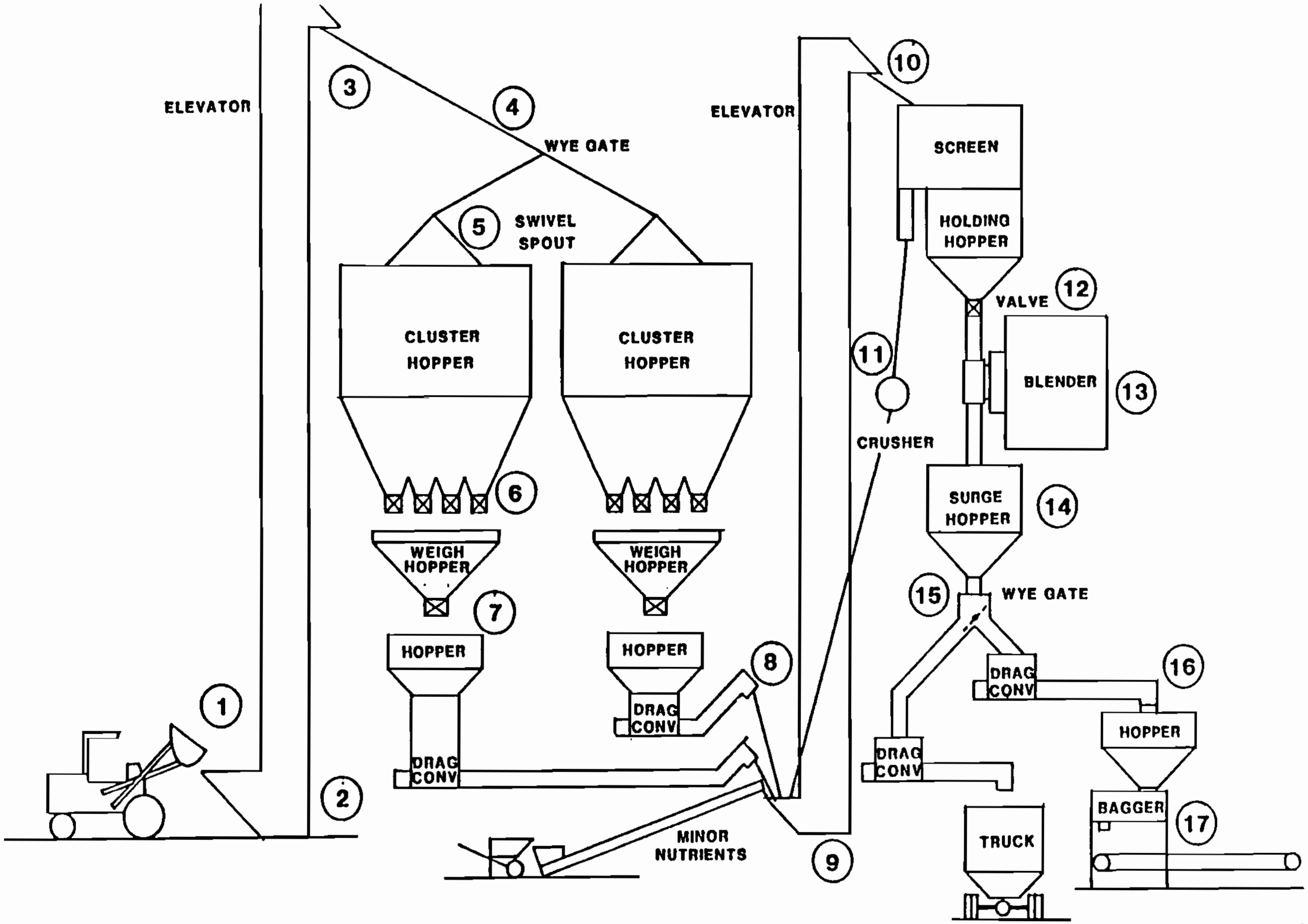
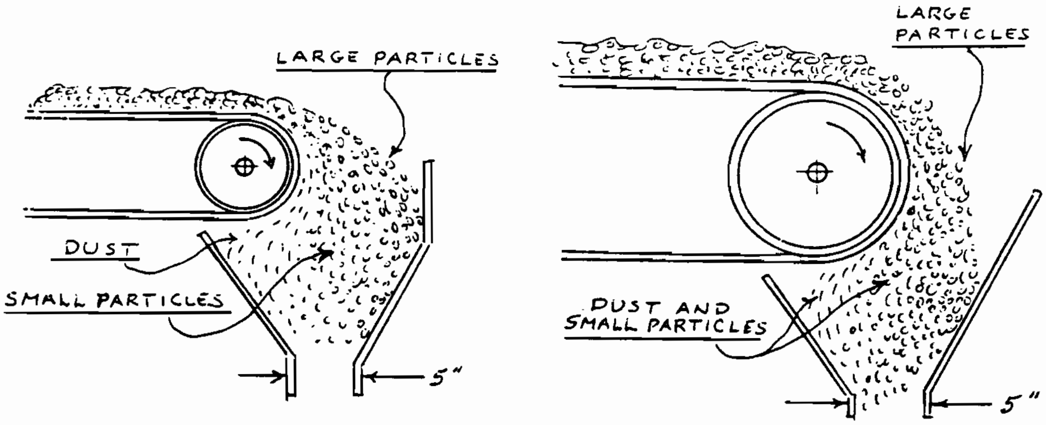

ELEVATOR
1
2
3
4
WYE GATE
5
SWIVEL SPOUT
CLUSTER HOPPER
CLUSTER HOPPER
6
WEIGH HOPPER
WEIGH HOPPER
7
HOPPER
HOPPER
DRAG CONV
DRAG CONV
8
MINOR NUTRIENTS
9
ELEVATOR
10
SCREEN
HOLDING HOPPER
11
CRUSHER
VALVE
12
BLENDER
13
SURGE HOPPER
14
15
WYE GATE
DRAG CONV
16
DRAG CONV
HOPPER
BAGGER
17
TRUCK

Fig 2

Figure 3



SMALL DRUM - HIGH SPEED

LARGE DRUM - SLOW SPEED

Small drum conveyors usually run at very high belt speeds, thus imparting considerable trajectory to the fertilizer particles. The ballistic character of these particles is dependent upon many factors including size, density and where they are situated on the belt at the time of "take-off".

Large drum conveyors usually run much slower and consequently impart a greatly different discharge pattern to the materials being conveyed.

In either case, it is unlikely that a standard 10" wide cup could capture a cross-section of the entire stream. This problem is easily solved by installing a small hopper at the discharge end of the belt. The hopper should have a narrow discharge opening at right angles to the direction of belt travel. The opening should probably be no more than 5 inches wide to ensure that a 10-inch cup can cut the stream without difficulty.

In the case of drag conveyors such as Sackett's "Bulk-Toter", the discharging stream comes in pulses. Conceivably, when sampling by passing the cup at uniform time intervals, the sampler would get a distorted sample by catching a disproportionate number of high-load surges or low-load surges. This condition can be mitigated by providing the discharge hopper with a rubber flap which regulates the volume of flow exiting the hopper.

FINANCIAL STATEMENT

October 20, 1991 to October 22, 1992

Cash Balance October 20, 1991		$26,236.86
Income October 20, 1991 to October 22, 1992		
Registration Fees - 1991 Meeting & Cocktail Party Receipts	9,467.20	
Sale of Proceedings	1,908.84	
Registration Fees - 1992 Meeting & Cocktail Party Receipts	15,210.00	
Total Receipts October 20, 1991 to October 22, 1992		26,586.04
Total Funds Available October 20, 1991 to October 22,1992		$52,822.90
Disbursements October 20, 1991 to October 22, 1992		
1991 Meeting Expenses (Incl. Cocktail Party)	10,004.86	
Misc. Expenses Incl. Postage, Stationery, etc.	474.66	
Directors Meeting	1,387.06	
1991 Proceedings Incl. Postage, etc.	8,425.60	
1992 Meetings - Prel. Expenses	12,051.51	
Advertising	164.60	
Total Disbursements October 20, 1991 to October 22, 1992		32,508.29
Cash Balance October 22, 1992		$20,314.61

Respectfully submitted,

Paul J. Prosser, Jr.
Secretary/Treasurer

Meeting Attendance: 120