FERTILIZERS: THE WORLD SUPPLY

By Harry A. Curtis

IT HAS long been recognized that the harvesting of crops removes from the soil certain mineral plant foods and that permanent agriculture can be established only under a program which maintains the fertility of the soil by returning to it the mineral constituents which are likely to become deficient. The chief of these are potassium, phosphorus, and nitrogen, as practically all arable soil contains an unlimited supply of other mineral plant foods. To meet the deficiencies in these elements good methods of tillage and the intelligent use of fertilizer, based upon a knowledge of the particular soil that is to be planted and the requirements of the particular crop, are necessary. Moreover, as virgin arable land becomes less and less available, the maintenance of soil fertility becomes constantly of more importance.

In the last few decades the manufacture and distribution of agricultural fertilizers have become an industry of first rate importance. Already there is a world trade in fertilizer materials on a very large scale, as the statistics of almost every country indicate. Over six million tons of fertilizers are consumed annually by agriculture in the United States alone, and though nearly eighty per cent of this is from raw materials obtained within our own territory, yet the part which we imported in 1922 cost over thirty-five million dollars. Chile exported during the last fiscal year over two and a quarter million tons of Chilean nitrate, most of which found use as a fertilizer The Potash Syndicate of Germany sold about five million tons of potash salts in 1922, about ninety per cent of which was used as fertilizer.

As in all industries, there has been in the fertilizer industry a world-wide search for the cheapest source of raw materials. It is not sufficient that a commercial fertilizer simply contain one or more of the plant foods in question—potassium, phosphorus, and nitrogen,—for plants can assimilate mineral compounds from the soil only when these are in solution. A commercial fertilizer must contain one or more of these plant foods in a form which is water-soluble, or which quickly becomes soluble under the bacterial and chemical actions of the soil. If the raw material does not contain the plant food in such a form it must be put through some process, which of course adds to the cost of the product. In consequence, the industry has sought to find natural deposits of fertilizer materials which require no processing. In the past this has been a matter of vital importance, for any sort of chemical processing has been expensive. But as new and better methods of handling chemical projects have been developed the enormous advantage once inherent in a raw material requiring no processing has grown steadily less, and eventually a point may be reached where it becomes economical to process a domestic raw material and distribute it over a short radius rather than to import a ready-to-use product from a far distant source.

As the industry exists today, potash is derived mainly from the German and Alsatian mines; phosphorus mainly from phosphate rock and Thomas slag; and nitrogen from four principal sources—sodium nitrate from Chile, ammonium sulphate obtained as a by-product of the coke and coal industries, synthetic nitrogen compounds from the air, and a great variety of animal and vegetable waste materials.

The World's Potash Resources

In view of the threat made by certain prominent Germans during the war regarding the future use of the German potash monopoly as a weapon against enemy nations, it is of interest to consider precisely to what degree an undefeated Germany might have been able to carry out the threat. The potash reserves in the German mines are enormous, as much perhaps as 20,000,000,000 tons of crude potash salts, with which should be considered a probable 1,500,000,000 tons representing the Alsatian deposits, now under French control but formerly a part of the German monopoly. Without doubt here is one of the most valuable deposits in the world, and one from which, as a matter of course, a large proportion of the world's supply of potash will come for many years. However, not all of the world's supply of mineral potash is included in the German and Alsatian deposits. When the World War broke out other sources were sought and under the stimulus of high prices, dozens of potash producing plants were set up in the years following 1914. While production costs have been in general too high to permit competition with the German and Alsatian output since the war, nevertheless the progress made during the few years in which the German supply was cut off is indicative of how little we need fear that starvation for lack of potash which was to be the post-war fate of Germany's opponents. It is probable that one of the most arrogant monopolies ever known will pass into history.

Spain has deposits of very considerable size in Catalonia, and during the war several companies began operations in this field. Italy has a small but rich deposit in Eritrea, from which about 50,000 tons were produced in 1917. In Tunis there is a salt lake whose brines have been worked for bromine and potash. In 1917, 20,000 tons of potash were turned out from this same source, and larger plant installations were being made.

The potash resources of the United States were surveyed rather carefully after the German supply was cut off, and by the end of 1918 we were producing a very considerable tonnage of potash from a variety of sources. Of our deposits of soluble potash salts, the largest is probably that of Searles Lake, California. This old lake bed, covering an area of about twelve square miles and with a deposit of salts about seventy-five feet thick, is estimated to contain as much as 10,000,000 tons of potash. In 1917 there were two companies producing in this district, with a combined capacity of about 50,000 tons. Similar but smaller accumulations of potash-bearing brines are found in Nebraska, where by the end of the war a dozen or more small extraction plants were in operation. At Great Salt Lake, Utah, two more plants were in operation, and one had been built in the Salduro marsh of Utah. Ten little plants for extracting potash from kelp were started in California in 1917 and 1918, with a total capacity of about 4,000 tons per year. Potash as a by-product of the cement industry was produced at fourteen plants in 1918, the total recovery being about 5,000 tons, which was less than one-tenth of the potash content of all the cement dust available in the industry. One plant for recovering potash from blast furnace gases was under construction at this time, and it was estimated that at least 40,000 tons of potash per year could be recovered from the larger blast furnaces of the country. Even potash-bearing rocks, which in many countries exist in unlimited quantities and are a great potential source for potassium salts, were utilized in several small plants. Processes were developed for treating commercially the leucite rock of Wyoming, certain Georgia slates, the green sand glauconite of New Jersey and Delaware, the alunite of Utah, and the feldspathic mill tailings accumulated in Colorado. Potash was also produced from waste molasses, beet sugar wastes, wood ashes, etc.

While production from any one of these sources was small compared to the enormous output of the German mines, the development of the industry was remarkably rapid. The actual production in 1917 was about 32,000 tons of potash, and at the end of 1918 the United States Bureau of Mines estimated the production capacity at 125,000 tons per year, or about half our normal consumption. Only a few of these war-time projects have survived since the war in competition with German and Alsatian potash, and today we are producing less than ten per cent of our consumption. However, with the Alsatian potash deposits under French control, with the knowledge of our own potential resources, and with the certain discovery of new deposits of potash salts from time to time, it is unlikely that a really serious potash shortage can ever develop in this country.

The World's Phosphorus Resources

No great deposits of phosphorus bearing material in a ready-to-use form are now available, but the rock phosphate deposits from which the greater part of the world's phosphatic fertilizer is obtained are large and widely scattered. Those most exploited at present are the Florida and Tennessee deposits, while next come those of Tunis, Algeria, and Egypt. Phosphate rock, so-called, is also shipped in considerable quantities from a number of islands, notably Christmas Island (British) in the Indian Ocean, Ocean Island (British) in the Gilbert Archipelago, Aruba and Curacao in the Dutch West Indies, Anguar (Japanese) in the Pelew group, and several others. For the most part these island deposits are limestone and coral formations which have been impregnated with phosphatic material leached from guano.

But the world's rock phosphate resources are by no means limited to those now being utilized. Deposits are so numerous and so widely distributed that only the richer and more accessible have been worked as yet. In the United States, the phosphate rock deposits of Wyoming, Idaho, Montana, and Utah are much larger than those now exploited in Florida and Tennessee. We also have deposits in Arkansas, Kentucky, South Carolina, and elsewhere. In Canada there are enormous beds in Ontario and Quebec; in Russia great deposits are found in the provinces of Moscow, Vladimir, Kostroma, and elsewhere; in Spain the deposits in Caceres are worked to some extent; Great Britain controls, beside the Egyptian and Canadian deposits, phosphate beds in Natal, Australia, and several ocean islands; and France has deposits in several of her ocean islands, in addition to the great beds in Tunis and Algeria. There is also low grade phosphate to be had in the Somme and Oise regions, and Belgium has similar deposits. In all, the world's phosphate rock resources are enormous and there is no likelihood of monopolistic control such as has existed in the case of nitrate and potash production. Raw phosphate rock, when finely ground and applied to the soil, becomes very slowly available as a plant food; for immediate results in crop production, therefore, phosphate rock must be processed before use. In spite of the cost of processing, phoshorus remains the cheapest plant food sold by the fertilizer industry today.

Moreover, in addition to rock phosphate, which accounts for about seventy-five per cent of the phosphorus used in fertilizer, there are several other sources, the chief being the basic slag from steel-making furnaces. This material, often called Thomas slag, is a by-product and the amount produced is therefore limited not by the demand for it, but by the demand for certain kinds of steel. In the United States little if any Thomas slag is worked up as fertilizer, but in Germany, Belgium, France, and the United Kingdom over 3,500,000 tons are so used annually. Guano, of which the natural accumulations have been practically exhausted, bone meal, fish scrap, and other waste materials afford an additional small supply.

The World's Nitrogen Resources

As already indicated, there are four principal sources from which the fertilizer industry draws its nitrogenous material. It is customary to consider this material in two categories. Under the heading "inorganic nitrogen" are grouped Chilean nitrate, nitrogen compounds from coal, and synthetic air-nitrogen compounds; while under the "organic nitrogen," or "organic ammoniates," are included a large variety of vegetable and animal waste materials such as cottonseed meal, castor pomace, meat packers tankage, fish scrap, leather scrap, etc.

The general trend of the industry is away from the use of organic nitrogen, which is a low grade fertilizer. Let us begin with this category, however. In the United States organic nitrogen has been used extensively in mixed fertilizers, not alone because of its nitrogen content, but also because it "conditions" the mixed fertilizer, *i.e.*, puts it in better condition for handling and drilling. A number of years ago the big meat-packing concerns organized fertilizer companies as a means of disposing of the waste from their plants. Likewise, the big fertilizer companies own many of the cotton oil plants, and formerly utilized the cottonseed meal as one of their main sources of organic nitrogen. The total amount of fertilizer so used cannot be estimated accurately, but in 1919 somewhat more than half of the total nitrogen in all fertilizer in the United States was of the organic class.

Since that time the shift toward inorganic nitrogen has shown itself and today nearly all of the tankage and much of the cottonseed meal and fish scrap produced in the United States are sold as food for cattle, hogs, and poultry, at prices which are higher than they command as fertilizers. It will benefit the American fertilizer industry to be rid of these low-nitrogen fertilizers. There is an obvious absurdity in assembling, processing and distributing millions of tons of fertilizer containing more than eighty-five per cent of inert material. A thoroughgoing revolution in the American fertilizer industry is overdue.

The amounts of inorganic nitrogen compounds obtained from the three main sources are known fairly accurately. For many years the nitrate supply of the world came from Chile, and in forty years over two billion dollars' worth of Chilean nitrate was bought. But there have been great changes in the last ten years. Whereas in 1913 Chilean nitrate supplied 54 per cent of the world's inorganic nitrogen, the coke and coal gas industries 38 per cent and the air-nitrogen industry 8 per cent, in 1922 Chilean nitrate supplied only 23 per cent of the total, the coal processing plants 35 per cent and the air-nitrogen industry 41 per cent. Since more of the Chilean nitrate goes into non-agricultural uses than does the nitrogen from either of the other sources, the relative importance of Chilean nitrate in the world's fertilizer industry is really less than indicated by the above figures.

The Chilean nitrate industry is an item of unusual interest in connection with the world's supply of fertilizer chemicals, because of the dependence of the Chilean Government on revenue from the sale of nitrate lands and from the heavy export tax on nitrate. For forty years the nitrate tax has been the mainstay of Chilean finance, from 40 to 75 per cent of the total government income being derived from this source alone. Originally the nitrate was exploited by foreign capital, and for many years the British companies in Chile and the British selling organization in London controlled the industry. There has, however, been a gradual shift of ownership to Chilean citizens until today over sixty per cent of the production is by companies of Chilean registry. Naturally, the Chilean Government has taken an active part in all affairs touching the industry, and has joined with the producers in carrying on world-wide advertising of nitrate for agricultural use. In late years the Chilean Government has sought to revise its financial system so as to make it less dependent on the nitrate tax, perhaps realizing that there will come a time when this tax must be reduced or abolished in order that Chile's natural nitrate may better compete with synthetic air-nitrogen products.

The nitrogen obtained as a by-product of the coke and coal-gas industries is limited by the amounts of coal treated, but since there is an enormous annual production of coke and of coal-gas, the quantity of nitrogen is large. The United States in 1922 produced about 99,000 tons of nitrogen from coal, equivalent to about 495,000 tons of the ammonium sulphate used as fertilizer. The world's production of nitrogen from coal in 1922 was about 311,000 tons.

More of the inorganic nitrogen used in fertilizers now comes from synthetic air-nitrogen compounds than from any other one source. This is rather a remarkable fact when it is remembered that the air-nitrogen industry is less than twenty-five years old, and that, from a chemical engineering standpoint, the project of manufacturing nitrogen compounds from the air is one of the most difficult ever actually put into operation. The chemical element nitrogen is a gas when in its free state, and only by applying drastic chemical measures can it be "fixed" in chemical compounds. Even then it does not entirely lose its natural preference for individual existence, and throughout the chemistry of nitrogen we note a tendency for the element to escape chemical bonds and revert to the free state. Until the modern chemical processes for "fixing" nitrogen were developed bacteria formed practically the only link between the great reservoir of free nitrogen and those "fixed" nitrogen compounds which constitute the indispensable protein food of man. But this slender link has held and we are still dependent on it, as the amount of nitrogen annually supplied by bacteria in the crop-producing areas of the earth is so enormous that all our commercial fertilizer tonnages appear minute in comparison.

The commercial production of nitrogen compounds from the free nitrogen of the air was first attained in Norway in 1903. It is interesting to note that the arc process of nitrogen fixation, which was the first process to reach commercial success, is the only successful nitrogen *oxidation* process which has been developed to date. All other commercial nitrogen fixation processes are nitrogen *reduction* processes, speaking chemically. This arc process, as is well known, requires a very large use of power in comparison to other fixation processes, and for this reason has not been much used outside of Norway. Where very cheap electric power is available the arc process can turn out nitric acid at less cost than it can be made by any other process. In order to convert this acid into a fertilizer compound, the only practical procedure yet worked out is to treat it with limestone and so produce lime nitrate, or "Norwegian saltpeter." Unfortunately this material is not suitable for making the mixed fertilizers commonly used in the United States and therefore has not been as generally used here as in Europe. Of the nine arc plants existing today, only five are operating, and there has been no increase in production capacity in four years. Unless some radical improvement is made in the power economy of the arc process, it does not appear that this process will play a very large part in the production of air-nitrogen compounds in the future.

The cyanamid process for fixing air-nitrogen was introduced in Italy in 1907 and during the next five years plants were built in several countries. Here again it was found that cyanamid fertilizer is not adapted to American methods of agriculture, and the Canadian plant, whose normal market lies in the United States, has remained the only cyanamid plant operated on this continent. During the World War the United States Government built the largest cyanamid plant in the world at Muscle Shoals, Ala. This plant has remained idle since the war, there being no way apparent by which its operation could be profitably continued. At the time it was built there was no reasonable alternative, and it is still possible that a way can be found to utilize this great plant in peace time without decreasing its military value as a potential source of nitrogen compounds for military use.

In 1912 Professor Haber, of Germany, developed a third successful air-nitrogen process, generally known by his name. During the war this process was used in two huge plants at Oppau and Merseburg, and this addition to her nitrogen-producing capacity made Germany independent of the Chilean nitrate supply. This was a matter of the utmost importance, for it happens that all modern military explosives are nitrogen compounds, and therefore no modern war can be undertaken unless a sure supply of nitrogen is available. This fact has no doubt been a spur to the establishment of nitrogen-fixing plants in nearly every country of the world, for under modern conditions of war a complete blockade of any country would speedily defeat it unless there existed a sufficient domestic source of nitrogen compounds to meet its war needs.

The process originally devised by Professor Haber is today probably the most promising of the air-nitrogen processes. Many modifications of it have been made, and we have at present several commercially successful processes of this type, such as the Casale Process, the Claude Process, etc., all of them based more or less on the original Haber scheme. There are today nine small commercial plants outside of Germany using modified Haber processes, and several others in course of construction. Germany's Oppau plant is in the occupied territory and has been idle since the French regime, but plans are now under way to put it into production again.

The Future of the Fertilizer Industry

To sum up. We may say that the tendencies in the business of producing the three great groups of fertilizers—a tendency starting before the war, but intensified by the war,—are such that the danger of national centralization or control is steadily being diminished. Chile is no longer practically the sole source of nitrogen supply. Germany, though still predominant, is by no means the sole source of potash supply. Whatever may be said concerning the raw materials of other industries, the necessity for centralization in the fertilizer industry has become less rather than greater.

Further, there are reasons to expect that, large as the world's fertilizer industry is today, it will expand, and that eventually fertilizer material will become one of the great commodities of world trade, comparable with coal, steel, and wheat. As virgin agricultural land becomes less and less available the need for increased food production per acre will naturally increase, and in the end the population of the earth will be fixed by the maximum amount of human food which can be produced by means of the utmost refinements of agriculture. Since the proper application of fertilizer offers a means of substantially increasing the production per acre, it appears inevitable that the use of fertilizer will increase to the economic limit set by the food producing power of fertilizer. Our knowledge of all the interlocking factors of soil fertility does not yet permit prescription of the exact amounts of the three fertilizer elements needed for a given soil and a given crop, but a vast amount of experimental work is now in progress, and as our knowledge of the returns to be expected from the use of fertilizer becomes more exact the use of fertilizer will become more general. Reduction in the costs of producing fertilizer will also, of course, permit its wider use. In order for the cultivated fields of the United States to receive as much as 250 pounds of fertilizer per acre there would have to be a 600 per cent increase in our total fertilizer consumption. What is true in this country applies also to nearly all of the more recently settled areas of the earth where the natural fertility of the virgin soil is being depleted. Eventually fertilizers must be used in all of them.

When one considers this vast potential world market for fertilizers, and the present state of the art of their production, it appears that here is a field offering an unusual opportunity for chemical engineering endeavor and for broad commercial enterprise.

ITALIAN COLONIAL POLICY IN NORTHERN AFRICA

By Carlo Schanzer

THE Italian colonies, which cover altogether an area of about 780,000 square miles and contain a population of over a million and a half, are entirely inadequate to care for Italy's economic needs or to provide proper room for the expansion of her growing population. Italy was last to join in the contest of the powers for the appropriation of African resources, and consequently all she could do was to take what the others had left. The territories most suitable for European immigration, such as North Africa from Morocco eastward to Tunis and the coastal countries of South and East Africa, were already in the possession of other states or else were populated to their full capacity by other nationalities. Following the far-reaching vision of her great statesman Cavour, Italy succeeded in gaining a foothold on the shores of the Red Sea between the Anglo-Egyptian Sudan and French Somaliland. On the shores of the Indian Ocean she combined the efforts of her explorers with an official assertion of her sovereign rights over the country lying between British Somaliland and the mouth of the Juba River, and stretching inland from the seashore to the confines of Ethiopia. Finally, in 1911, came Italy's occupation of Libya, dictated by inexorable economic and political necessity.

Thus the colonial dominions of Italy came to be composed of countries representing diverse functions in the life of the nation. Because of the fact that Libya is contiguous to Tunis and is directly across the Mediterranean Sea from Italy proper, and because of its sparse native population and age-long connections with Sicily, these two colonies are best suited for European colonization within bounds imposed by the native population and special local conditions. Italian immigration into Libya has been on the increase, and in 1921 totaled 27,495. On the other hand, the two East African colonies, Eritrea and Somaliland, are clearly typical territories for economic exploitation. Ethnic and cultural conditions differ in these latter colonies also. Although before the Italian occupation Libya was considered one of the most backward countries of Africa, its population possessed a certain stationary if retarded civilization and a monotheistic