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POPULATION IN RELATION TO CREATABLE NON-BIOLOGICAL RESOURCES

Among the major industrial changes that have occurred during the course of this century have been the development of synthetic nitrogenous fertilisers; the introduction of synthetic fibres and plastics; and the elaboration of a vast range of novel chemicals. These changes are part and parcel of a new industrial revolution which has also seen the emergence of the light metals (aluminium, magnesium and titanium) and the exploitation of such new sources of power as natural gas. They are all expressions of highly evolved industrial societies, and of highly developed technical knowledge; and all have been dependent on the deployment of vast capital resources that had been created through the operations of older industry. Similarly, all have been conditioned by the balance and interplay of a variety of social forces - such as the conservatism of established practice and the technical superiority of things new; of the tendency of long-established enterprises to defend their independence against the inroads of new and large manufacturing enterprises, whose development automatically revolutionizes the inter-relations of different industries; and of the understandable tendency of investors to take a short-term view of what constitutes a profitable outlay of capital, and the social need to look to the kind and scale of demand for resources which the future will reveal. Up to now new industrial developments that have meant the creation of new resources have seldom been inspired by an objective and far-sighted assessment of a common social good, except, paradoxically, in those cases where autarchic developments have been stimulated by immediate economic and political necessity.

The extent to which so-called creatable non-biological resources can help to meet demand over the next 25 years or so will probably be conditioned by similar social considerations. Fundamentally our material resources remain the same as those which were available to the ancient Greeks. The fact is that while man can transform matter into energy, he has not yet succeeded in transforming energy into matter, or of creating matter or energy from the void. What we can do, but at vast cost, is make new elements, synthetic chemicals or large macro molecules from existing materials by the skilful rearrangement of the forces between nuclei, atoms and electrons in a closed system. Since these new patterns cannot be detected in natural products, something new has been created. We can also re-create old materials as, for example, when amino-acids are produced by combining methane, ammonia and steam in an electrical field. Moreover, we know how to meet scarcities of raw materials by policies of conservation and economy, and by fabricating articles from alternative raw materials.

It is essential to remember, however, that the "we" happen to be those who possess the knowledge and the capital, and that the demand for new creatable non-biological resources of the kind similar to those we already know will grow most quickly in those parts of the world which are already highly advanced, rather than in the more undeveloped areas where the greatest increases in population are likely to occur in the course of the next few generations. On the other hand, as population increases in these areas, and if their standard of living also rises, the demand for raw materials is bound to spread and increase. Thus, if new land is brought into cultivation, and if agricultural productivity is to rise where it is now low, tractors and other products of manufacturing industry will be required at a rapidly increasing rate. The poverty which exists in the world of to-day is as much a poverty of clothes, houses and tools as it is of food. Poverty is, in general, indivisable.

The 1951 United Nations Scientific Conference on the Conservation and Utilization of Resources mostly used the term "creatable resources" in the restricted sense of substances that can be made out of materials that are at present unused (in particular agricultural **surpluses**). From the point of view of the present conference, it would be wiser to use the term more generally, as implying any new resources which have been, or can be, made available through the application of recent scientific knowledge; or old resources which can be elaborated through the use of new techniques. In the space of a short article it is impossible to deal with more than a few illustrations of creatable non-biological resources. The three that have been selected are, however, among the "major" ones there are.

Nitrogenous fertiliser - our major creatable resource

Man's nurture depends essentially on the efficiency of the green plant in utilising the energy of solar radiation to abstract the 0.03% of CO_2 in the air, to fix the carbon, and to store the energy as carbohydrate, protein and fat. Our major concern should, therefore, be aimed at the elimination of the factors which limit the photosynthetic activity of the growing plant. The most useful way of doing this is to increase the use of fertilisers. Even in countries with a highly developed agriculture, fodder crops rarely receive sufficient fertiliser even in cases when **cash crops are adequately fertilized.**

Phosphoric fertilizers do not come under the category of creatable resources. Nitrogenous fertilizer does, and in most countries the returns expected from its application are much greater than those from phosphorus or potassium (an average estimate is that nitrogen would give three times the yield of an equal quantity of phosphorus or potash fertiliser). One ton of fixed nitrogen will, in fact, produce enough extra food to feed about 40 people a year. It seems reasonable, therefore, to use our supplies of fixed nitrogen to increase the efficiency of photosynthetis, by removing the limiting factor of the supply of nitrogen, rather than to use nitrogen to synthetize proteins by chemical processes which are lependent on our reserves of fuel.

Our reserves of fertiliser nitrogen are limited by the supply of energy needed to convert atmospheric nitrogen into a form available to the plant. Where the energy for synthesis is derived from fossil fuels, the balance of the carbon cycle depends on our agricultural efficiency. Thus, approximately five tons of coal are needed to produce one ton of fertiliser nitrogen. This in turn produces about ten tons of starch equivalent, so that the net gain in carbon fixed over that present in the coal is not large (coal 80% C., starch 44%C.) Nevertheless it is food we want, and for years we shall have to depend on our supplies of coal in order to increase agricultural output.

Considerable capital is also needed to produce fertiliser nitrogen - as much as £200 and 1 ton of steel per ton/year of nitrogen. Moreover, the running costs per unit of nitrogen tend to be inversely proportional to the volume of output so that the process favours large-scale manufacture. For that reason, considerable interest has recently been taken in a new development for fixing atmospheric nitrogen in smaller plants. This process is based on the thermal conversion of the N_2 and O_2 of the air into nitric oxide, from which nitric acid is obtained on solution in water. Such a development could meet the local needs of under-developed countries which are favoured with a supply of fuel. Development work on pilot plant scale has taken place in the U.S., and the information about the economics of nitrogen production by this process will be of great interest.

Sulphur

Sulphur and sulphuric acid are also major factors in industrial and agricultural progress. The acid is used in literally hundreds of manufacturing processes; and in agriculture it is used to convert insoluble rock sulphate into a form soluble in water, so that the phosphorus is immediately available for plant growth. Elementary sulphur is also widely used in industry, and particularly in the manufacture of certain synthetic textiles. The overall consumption of sulphur can, in fact, be treated as an index of total industrial activity.

In recent years world consumption of sulphur has been increasing at the rate of 6% per annum, and has been largely based on the exploitation, by the Frasch process, of the sulphur domes of the Mexican Gulf. This source of supply is now showing signs of dwindling, and attention is being increasingly directed to the production of sulphuric acid from iron pyrites, the iron oxide that is used in gas works to remove H_2S, and anhydrite. The processes concerned do not represent new developments, and most are more costly than manufacturing sulphuric acid, by the contact process, from elementary sulphur. Efforts are also being made to discover a convenient and economic method of extracting elementary sulphur from these same raw materials; but so far no satisfactory way has been found. In addition, various steps can be taken, as they have been in Great Britain, to economise in the use of sulphuric acid, and to convert rock phosphate into a suitable fertiliser form by using methods other than conversion with sulphuric acid (e.g. production of dicalcium phosphate or nitrophosphate; use of ground phosphate rock).

It is essential to remember that every method that has to be adopted as an alternative to using the elementary sulphur that comes from the sulphur domes of the Mexican Gulf, represents a change in our existing cost structure and a diversion of resources which could be put to other uses.

High polymers as creatable resources

The control of the intermolecular combinations of relatively simple organic molecules in the process of polymerisation has led to the mass production of an astonishing array of new and versatile materials, such as the synthetic fibres, nylon, Terylene (or dacron), and regenerated protein fibre; synthetic rubbers; phenol - or urea-formaldehyde resins; methyl methaerylate resins; and styrene and vinyl polymers. Many of these materials have been used to replace others that have become scarce, while some have properties not found in any conventional material. Polytheme, which has excellent dielectric properties combined with chemical inertness, is a notable example; it has even been used to replace lead pipes for plumbing. In general, however, these new materials have been used not as substitutes, but as raw materials additional to those already in use.

For present purposes the raw materials for plastics and synthetic fibres may be classified into those derived from fossil fuels - coal and petroleum - which are wasting assets, and those that are obtained from renewable sources such as vegetable and animal products. In the first category coal is treated in a variety of ways (e.g. carbonisation; hydrogenation (Fischer-Tropsch [illegible]sis) in order to produce chemicals like benzene, acetylene, ethylene, all of which are starting materials in the manufacture of various plastics. Oil is put through a number of catalytic refining processes so as to improve the octane number of gasoline, and by a suitable selection of charge stocks, substantial yields of benzene, toluene and xylene can be obtained. In addition large quantities of methane are formed which may be converted to acetylene or hydrocyanic acid, both of which are raw materials for synthetics such as nylon.

In the second category synthetic fibres and plastics are made from the cellulose provided by vegetation of various kinds, and as such compete with the traditional textile crops - cotton and flax. Cotton is the major natural fibre and comprises 52% of all industrial fibres and 73% of apparel fibres. The cotton plant is a sub-tropical perennial cultivated as an annual, and requires a fairly wet growing season followed by a warm and dry picking season. The conditions are similar to those which are desirable for a number of food crops. The world acreage devoted to its cultivation is 81 million acres. Yields, which vary with season, locality, and the incidence of disease, range from about $\frac{3}{4}$ to 4 cwt. per acre. The U.S.A., with the largest acreage (about 35% of total) has a yield of $2\frac{1}{2}$ cwt. per acre, and this is probably somewhat higher than the world average.

On the other hand, the sustained yield of timber gives 2/3rds ton of pulp on poor land and over 1 ton on good land. The loss on processing is 9%, as it takes from 1.05 to 1.10 lb. of rayon pulp to make 1 lb. of yarn. (The losses are greater in the manufacture of cotton yarn). The output of rayon textile fibres per acre of poor land is thus about five times that of cotton and on good land about eight times.

The sustained yields of timber from the eucalyptus plantations in South

Africa are expected to be ten tons per acre a year. This would give three tons of rayon pulp per acre a year. In this case the output of rayon textile fibre per acre is estimated to be about 24 times that of cotton.

Similar considerations apply to flax, which has to be grown on good agricultural land. The world output of scutched flax in 1951 was 854,000 tons, produced from an area of 6,442,000 acres. The average yield per acre is therefore about 2-3/4 cwt. scutched flax per acre. While rayon fibres are unlikely to be a substitute for linen, except in fashionable apparel of short life, the newer synthetic fibres may well have properties suitable for many of the uses to which linen is now put.

Synthetic textiles and food resources

It is not improbable that synthetic textiles will be devised which have all the required properties of textiles made from natural fibres. But since non-biological raw materials depend on a large extent on the utilization of resources of land and energy, it is essential that waste in their production and use should be avoided so far as possible. Wherever possible, the creation of non-biological raw materials must be associated with measures to reduce the damage and loss in agricultural and forestry crops due to pests, weeds and disease. An important point, too, is that the competition is not only between the growth of natural fibres and the cultivation of cellulose for the production of synthetic textiles. Land that is used to provide cellulose can often (even if not always) be used to produce food, and in the future, food is likely to be in greater demand than textiles. In the light of existing knowledge, the only firm basis for assessing future world supplies of food is the traditional use of land for the production of conventional crops. The cultivation of unicellular organisms, such as Chlorella, on an industrial scale, and the conversion of the product to a utilizable food or feedingstuff, is an idea whose economic practicality has still to be proved. Furthermore, until the mechanism of photosynthesis is not only understood, but also reproduced in the workshop, we cannot look to the chemical industry for any significant addition to our supplies of food. Even if we could, we need to note that the starting material for synthetic food production would have to contain carbon, and that consequently our supplies of coal and petroleum oil would not only have to provide the raw material, but also the energy to effect the transformation into foodstuffs. If we could synthetize food in bulk from coal or petroleum products, we would, therefore, be doing so from a wasting asset. In the field of food, therefore, our efforts in synthetic chemistry should be restricted to the manufacture of vital products which are obtained at small cost in energy and materials. Thus, if the new science of nutrition is able to define quantitatively and qualitatively the needs of man's diet, then the operations of agriculture should be directed to obtaining those crops which utilize solar radiation most efficiently, and therefore produce the maximum amount of edible calories per acre. High yielding crops, such as sugar cane, potatoes, wheat and maize, are wholly or partially deficient in some essential constituent. Thus wheat lacks vitamin D, maize is poor in B12 and tryptophane, while both lack ascorbic acid. The companion science of horticulture is largely directed to obtaining crops complementary dietetically to the major crops of agriculture, and in so doing a great deal of good quality land is used which, in terms of edible calories, is of low yield. The function of the chemical industry should be to synthesize those essential food nutrients such as vitamins, certain specific amino-acids and other trace elements, and thus release the land for the production of high yielding crops.

Conclusion

Other speakers will have dealt with the possibilities of creating new sources of energy and non-fuel minerals. The picture that has been drawn in this paper of the possibilities of satisfying our needs for other main raw materials by unconventional methods of production is not an optimistic one - at any rate so far as the next twenty-five years are concerned. The principle resources which have to be called into play - knowledge, power and capital - are the very ones that are least available where the need, as opposed to the effective demand, is greatest. This is a highly important consideration, since the more conventional the product, and the more it represents the application of advanced technological knowledge, the greater the capital outlay that is demanded. Moreover, most so-called creatable materials imply a competitive use of resources (e.g. coal, oil, land) which could be put to alternative uses. In terms of the population problem, and in particular of regional population problems, it is, therefore, difficult to see that the creation of new non-biological resources is likely to play a very much greater part in the providing for man's needs over the next twenty-five years than it has in the past quarter-century, except in the one important field of nitrogen production. Things like synthetic detergents and synthetic textiles may well reduce the demand for agricultural land, and so release natural fats and food crops, but in general it is difficult to see that they are likely to play as big a part in man's social history over the next quarter-century as will increases in agricultural productivity due to the application of modern techniques, in which fertiliser usage will probably play the major part.