The Development of Chemical Industries in India.*

By H. E. Watson.

In 1913 the profession of chemistry in England was ill paid and the services rendered by chemists to industry were barely recognised. A few years later, the demand for enormous quantities of high explosives, and the simultaneous shortage of dyes, drugs and photographic developers drew public attention to the chemist to an extent which could barely have been expected in fifty years of normal development. The great scarcity of chemists and particularly those with industrial experience at once became evident but it was too late to train new ones and it was necessary to carry on with the available material. However a stimulus to adopt the profession of chemistry was given and as it was evident that after the war many more chemists would be required than there were before, there has been a great influx of chemical students to the universities which is quite out of proportion to the number which will be required. As is so frequently the case, the pendulum has swung to the other extreme and it is difficult to see what is going to become of all these men when they have finished their education.

In this country something of a similar nature has been taking place, but in this case it is not a question of chemical students but of chemical industries. There has been a boom in industries generally, but it seems to me that almost undue prominence has been given to chemistry. Perhaps to a chemist this should only be a cause for rejoicing, but the light hearted way in which people with no experience are making attempts to start chemical industries which are predoomed to failure can do nothing but bring chemistry into disrepute and hinder its normal development.

It is therefore perhaps not out of place to take advantage of this meeting of the chemists of India to utter a note of warning. I wish first of all to emphasise the fact that the chemist who wishes to deal with industrial questions must not look at a process solely from the point of view of its possibility as a chemical operation. The question of cost is equally important and so are the other factors which I will mention later.

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Perhaps I may make my meaning clearer by an actual example. Mr. X writes to say that he owns considerable deposits of gypsum and would like to manufacture two hundredweight of plaster of Paris a day, can he be supplied with details of the necessary plant. Here is a simple chemical problem, but would it be fair to Mr. X to do what he asks? Examination of his gypsum shows that it is unsuitable for making good plaster of Paris, and even if it had been of sufficiently good quality, there appears to be no market in which he could sell his produce at a profit. Obviously, therefore, the reply is a suggestion that he should not embark on this undertaking.

This is a very simple example, and doubtless any Director of Industries could give dozens of similar ones, but there are many far more complex cases which require the utmost care before any opinion can be pronounced and it is in order to assist in this direction that I have endeavoured to put together the following facts. They are not new, and to many of you they may seem commonplace: perhaps, however, there are some among you who intend to devote yourselves to industry, but so far have studied only pure science. If to these my remarks may prove of some value I shall feel amply rewarded.

In the first place there are certain general considerations which apply to any industry although they may take a rather specialised form when applied to the chemical industry. These are

1. Capital.
2. Raw materials.
3. Plant.
4. Technical advice and control.
5. Labour.
6. Disposal of products.

1. *Capital.* The subject of capital is not one for the chemist to discuss at any length and I will merely mention that within the last few years capital has always been forthcoming for any thoroughly sound industrial scheme, and there appears to be every reason for believing that it will also be available in the future.

2. *Raw materials.* India is pre-eminently a country of raw materials and in fact it has been stated that India can produce a sufficient diversity of natural products to render her independent, in theory at least, of almost all outside sources of supply, should the necessity arise. On closer investigation it would be found

that the list of raw materials which are not available, or which are not available in sufficient quantity is a considerable one, for example, although copper is actually produced in the country, the quantity manufactured is only a very small fraction of the total imports owing to the smallness of the ore deposits. Similar cases are those of antimony and graphite, while the very important element nickel does not appear to have been found in appreciable quantities at all. However, this is a consideration of more importance from the standpoint of national defence than from the point of view of the immediate development of industries and what I wish to speak about to-day is not what chemical industries could possibly be developed in an emergency, but those which appear to have the greatest prospect of success at present.

To resume then, we have in this country large quantities of raw materials, and the first thing we must do is to examine not only their quantity but their quality. A very large proportion of India's raw material is not of the best quality. In South India there are immense deposists of kaolin which is just not pure enough for porcelain manufacture, bauxite of poor quality is plentiful, while low grade ores of iron, chromium and manganese are to be had in almost limitless amounts. Turning to the vegetable kingdom, the camphor tree when grown in India appears to yield a far lower percentage of camphor than it does in Formosa, and the same is true of many other plants, while even the indigenous trees when distilled give lower yields of acetic acid than those of Europe and America. Undoubtedly a large proportion of the work to be done by the chemist and economic botanist of the future will consist in discovering means for efficiently utilising what may be called second quality raw materials, and in improving the yields of the important constituents of plants, but at present owing to the plentiful supplies of first quality raw materials the subject is not of such vital importance as it will be in the future.

Supposing that we take for granted the existence of raw material of the requisite quality and quantity, the problem is by no means solved. Except when established for the purpose of dealing with natural products which have not previously been utilised, a new industry on any but the very smallest scale is bound to have a certain effect on local markets or vested interests. This applies more particularly to materials of vegetable origin. The Indian is very conservative and if he has been in the habit of selling his produce through certain channels it may be found difficult to induce him to sell to a local factory except at a considerably enhanced price. The original buyers are not likely to

let the trade slip from their hands without a struggle, and in many cases they may have such control over the producers through having made financial advances that they can entirely prevent the purchase by the new competitor of his raw material except at a rate which would render manufacture unprofitable.

This question, namely, the ability to purchase, is of the utmost importance, and its neglect may well lead to failure of a whole enterprise. It is impossible to discuss it in detail to-day, but I would warn chemists and all others engaged in drawing up estimates to give it most careful consideration and to remember that an unwanted material which may be had in small quantities for practically nothing, may become of almost fabulous value as soon as a demand for it arises.

I will now consider another aspect. A cotton mill, given a supply of cotton and small quantities of certain auxiliary materials, can turn out a large variety of products. A chemical factory on the other hand usually requires a number of raw materials to produce one chemical and in addition gives rise to by-products of which it may be difficult to dispose. Apart from the question of objectionable by-products, the multiplication of raw materials at once introduces a complication involving transportation to the factory. This in turn leads to the question of railway freights and transport generally. It may be found that certain raw materials, otherwise most suitable, cannot be used at all because of their inconvenient situation; for instance thousands of trees have been cut down to make clearings for tea, and left to rot because it would not pay to move them to a place where the wood could be utilised, while there seems little hope of ever working up the immense iron deposits of South India owing to their distance from the coal fields.

If on the other hand the raw materials or the finished products will bear the cost of transport it is theoretically possible to calculate the most suitable position for the factory, but in doing so account must be taken not only of the freight charges on the raw materials. The sites of the probable markets for the finished products must be determined and the freight charges on these considered as well, while finally the cost of fuel, power and water must be worked out. Fuel is a very important item in most chemical factories as it is required frequently not only for the production of heat but in the form of carbon for reducing purposes. In many cases indeed fuel is the predominating factor in determining the position of a factory, and a good example of this is to be seen in the location of the English potteries which are situated, not in Devonshire, where the bulk of the clay is found, but in Staffordshire immediately adjacent to the collieries.

In many cases there are more complicated considerations which affect the best site for a factory than those I have outlined, but what I wish to emphasise is firstly that it is not always necessary or desirable to locate a factory on the site of one of the raw materials, and secondly that the site of a factory cannot be selected haphazard, but must be determined by definite commercial considerations. Some of you may think this latter remark unnecessary but as I have already come across two chemical factories for which unsuitable sites have been selected on purely sentimental grounds, a brief warning may not be out of place.

Before proceeding I will recapitulate the main points which it is necessary to remember in connection with raw materials. These are :

Quantity ;
Quality ;
Ability to purchase ;
Possible alteration in market value;
Accessibility ;
Juxtaposition of different raw materials ;
Transport charges to factory.

3. *Chemical Plant.* I will now pass on to the question of plant. If chemical industries are to be developed in this country it is of the utmost importance to develop simultaneously a supply of chemical plant. There are many first class workshops and capable engineers in India and there is nothing inherently difficult in the manufacture of plant for chemical purposes. Many of these workshops were originated with the object of executing repairs of all kinds and as such are admirably adapted for turning out chemical plant which, generally speaking, may be said to consist of a large number of different articles as opposed to a number of duplications of the same article. There are certain well standardised machines which require particular care in manufacture such as centrifugals, and these are probably better purchased from firms who specialise in their manufacture, but the greater part of the plant proper consisting of items such as tanks, pumps, conveyers, stills, evaporators, extractors, steam heated pans, autoclaves, filter presses and grinding, sifting and mixing machinery could quite well be made in the country and any firm which would devote some attention to the problems involved would not only render a service to India, but would very probably find that it was opening up a large and profitable branch of its business. The present time is moreover particularly auspicious for developing this industry, for with

the development of mass production it has become increasingly difficult and in fact almost impossible to obtain articles which are slightly out of the ordinary. Now a large proportion of chemical plant may be classed under this head, particularly when required for research purposes and the situation may quite possibly become more difficult as time proceeds. Indian workshops are not devoted to mass production to such an extent as those in other countries, and hence the opportunity for construction of the diverse requirements of a chemical factory.

There are however two main difficulties; firstly a purely technical one. Chemical plant requires for its construction the use of a number of different materials, the chief of which in addition to iron and brass are wood, lead, copper and aluminium, and the average Indian mechanic is not accustomed to working all of these and particularly to the very necessary operations of lead burning and aluminium welding, so that the development of an industry for making chemical plant would involve the assembly of a certain number of specially trained men, and this would not be worth while unless there was a sufficient demand for their services.

The second difficulty is a more serious one. It is the question of design. An engineer cannot construct articles without a design, and for the moment, designers of chemical plant are few and far between, not only in India but in other countries as well. During the last few years we have heard much of the chemical engineer, and great efforts are at present being made in England to train men for this profession. It is hoped that facilities for similar instruction will soon be available in this country, and when this is the case, the difficulties of the situation will be somewhat relieved, but until that time we must trust for a solution of the problem to co-operation between the chemist who knows what he wants a plant to do and the engineer who knows how to construct it.

4. *Technical advice and control.* The next subject is technical advice and control. It is unnecessary in an assembly of chemists such as the present one to emphasise the importance of having skilled chemists to direct the operations of a chemical factory, but this leads at once to the question, "Where are the skilled chemists to come from"? At present the number of chemists in India capable of running a works efficiently could probably be counted on the fingers of one hand, and in order to increase the number, chemists must either be imported or trained here. The imported expert has never been very popular; only the largest firms can afford real exports with international

reputations, and even these experts have not always accomplished all that has been expected of them, either because they have been expected to do more than they could possibly perform, or because of their inexperience of local conditions. Sometimes a specialist in some branch has been brought over to do a piece of work in his own particular line, and after a short time has been given something entirely different to look after with consequences which might have been expected. Whatever the reason, there are no doubt considerable disadvantages in employing imported experts. At the same time another class of so-called experts appears to be developing with some rapidity. This is composed of men who have learnt sufficient chemistry to allow them to take a degree, and have then obtained admission to some chemical factory in Europe or America for a year or so, and returned with the self assumed title of expert. Owing to the dearth of technical knowledge in the country, such men find little difficulty in leading others to believe that their qualifications are far greater than they really are, and in obtaining responsible positions. Now although this state of affairs is perhaps all that can be expected for the present, it will not suffice for the future. It is no doubt true that many chemical operations can be carried out fairly successfully by a chemist who has only watched them done by someone else, but up to a certain point only. Directly something goes wrong with the plant, the inexperienced man may find himself at a loss. He is also incapable of carrying out studies in the efficiency of the factory and improvement of the processes, with the result that the quality of the products suffers and the business falls into disrepute. This is an occurrence to prevent which every effort must be made, particularly in the case of a new industry, but the means of prevention, or in other words, the production of highly qualified men is by no means easy. Undoubtedly the first step is the provision of a thoroughly sound general chemical training, if possible, combined with a little physics and engineering. This training must not be of the kind which has for its end the passing of examinations, but must lead a man to think for himself, and should include independent research work not necessarily in technical chemistry. If this can be followed by a few years experience in a factory in which the man carries out in turn every operation from the first to the last with his own hands, there is a chance of turning out someone of real use to the community.

5. *Labour.* The question of labour is not perhaps of so much importance in the chemical industry as it is in some others, but the availability of labour must always be considered in locating a site for a factory. The initiation of new industries

affords most favourable opportunities for the introduction of labour saving devices, and by exercising a certain amount of ingenuity it is possible to design chemical factories which are almost automatic in action. Indian labour is frequently spoken of as being cheap, but it will probably be found in most cases that machinery to replace it is cheaper still.

6. *Markets.* The disposal of the products of a factory is perhaps the most important subject as well as the most complex we have so far considered, for it is no use manufacturing an article if it cannot be sold. In a few cases in which a substance is produced for a definite purpose such as sulphuric acid for a fertilizer factory or charcoal for iron smelting no difficulty arises except as regards by-products, but in most cases any new industry will have to compete with existing interests. Where the manufactured article is intended for export, the conditions to be satisfied are that it must be possible to make and land an article of standard quality at a foreign port at a lower cost than that for which the article is at present sold. This may be brought about by saving of freight on the raw materials, or smaller charges for labour of fuel. In the case of articles for home consumption a very difficult problem of distribution has to be faced. It is customary to regard India as one country, and one frequently sees statements to the following effect, "India imports annually so much of such and such a commodity. Why should not this article be manufactured in India?" On enquiry it will probably be found that the total quantity used is what could be produced by one medium sized, or even one small factory. Now unless the article is so valuable that freight is a matter of little consideration, it will be very difficult to sell it all over India in competition with imported goods which can be landed at the nearest port and so reduce to a minimum the costly railway charges. Take for example the case of salt. Salt can be produced at Tuticorin for about 2 as. a maund. The railway freight to Calcutta would be at least 14 as. Aden salt which is of better quality than Tuticorin salt can be produced more cheaply and can be sent to Calcutta for 16 as. a maund, while as you doubtless know, a large proportion of the salt used in Bengal comes from Liverpool, and is able to compete with both the other varieties.

This is a case of an article for which there is an exceptionally cheap rate, but many essential chemicals are carried at much higher rates and it would be impracticable to distribute them from a central factory. On the other hand it may not be advisable to erect several small factories in different parts of the country

particularly if the products are difficult to make and so require highly skilled supervision. At the same time, where the full time attendance of an expert is not necessary, there appear to be possibilities of starting a group of small factories instead of one large one. In other countries it is a generally accepted fact that large factories are the most efficient, particularly in the heavy chemical trade, but that such factories are best suited to India at present, cannot be considered proved. One has only to look at the other extreme, in the so-called cottage industries or very small factories which carry out brick or tile making, oil pressing by the ghanny, jaggery manufacture, dyeing, charcoal burning, soap making or essential oil distillation to see the advantages of work on a very small scale. It is generally admitted that the methods are crude and inefficient from the modern standpoint and the quality of the products poor, and yet these disadvantages are so set off by advantages such as very small capital requirements, availability of raw materials and in many cases a local market for the products, that the industry is a paying one. It is only when attempts are made to improve the technique of the processes, which involve the employment of highly paid advisers and consequent enlargement of the plant to enable the outturn to be sufficient to pay for their services, that the difficulties as to raw materials and markets arise, and any development of chemical industries in this country will involve the solution of the problem, "What is the smallest factory for making this product that it will pay to start"? No doubt in time it will be possible to enlarge very considerably, but at first, the installation of plant capable of producing more than the market can absorb may prove a costly affair.

So much for general principles. In the short time at my disposal I have been able to do little more than endeavour to explain what they are, but this explanation will perhaps suffice to indicate the way in which they may be applied when considering particular industries. Turning to these, you will find in the Report of the Indian Industrial Commission an interesting list of India's industrial deficiencies, but no attempt is made to indicate which of these deficiencies stand any chance of removal. The Indian Munitions Board Industrial Handbook contains a mass of most valuable information particularly on the subject of chemical industries, and here attention is drawn to some of the difficulties involved, while in many cases they are discussed at length. It is not easy to make a general survey of all these industries at one time, but here is a table which may do something in this direction. It gives a list of a number of chemical products or industries under nine headings representing the main factors which are of importance in their manufacture. These are (1)

quantity and quality of raw materials: (2) their availability which includes collection or mining, and transport to the factory: (3) the fuel and power required:(4) the cost and complexity of the plant required:(5)the ease of manufacture which is an indication of the amount which must be expended on highly skilled supervision: (6) the simultaneous production of by-products which may be difficult to dispose of but too valuable to throw away: (7) the value per unit weight, an item of great importance where transport charges have to be considered: (8) the cost of packing, which may be a serious item where liquids are concerned: and finally (9) the demand, whether for export or local consumption. Under each heading and against each material is a number, 1 denoting that the conditions are most favourable 2 less favourable and 3 unfavourable. These figures are of necessity very arbitrary and would vary with circumstances such as the site of the factory, but taken on the whole they help to indicate where the main difficulties in the manufacture of the products mentioned are to be found, while their sum for any one product gives a rough idea of the desirability of starting the industry.

	Raw Materials.	Availability.	Fuel.	Plant.	Ease of Manufacture.	By products.	Value	Packing.	Demand.	Total.
Essential Oils	1	2	1	1	1	1	1	3	1	12
Drugs	1	2	1	2	2	2	1	1	1	13
Tannin Extracts ...	1	2	2	2	2	1	2	1	3	16
Sugar	1	3	1	3	3	2	2	1	1	17
Paper	2	2	2	3	3	2	2	1	1	18
Glycerine	1	2	1	2	2	1	2	3	3	17
Soap	1	2	1	2	2	3	2	3	2	17
Edible Oils ...	1	2	2	3	3	2	2	3	2	20
Hardened Oils ...	1	1	2	2	2	1	2	2	2	15
Alcohol	1	3	2	2	2	1	3	3	3	19
Varnish	2	3	1	2	3	2	2	3	2	20
Wood Distillation ...	2	3	2	3	3	3	2	3	2	23
Casein	1	1	1	2	3	1	2	1	2	14
Glue	1	2	2	2	2	1	2	1	2	15
Asbestos & Mica ...	2	1	1	1	1	1	3	1	3	14
Magnesia	1	2	2	2	2	1	3	1	3	17
Tiles	1	2	3	3	1	1	3	1	1	16
Cement	2	2	3	2	2	1	3	1	1	17
Glass	3	3	3	1	3	1	2	3	1	20
Porcelain	2	3	3	1	2	1	2	2	2	18
Natural Pigments ...	1	1	1	2	2	1	3	1	1	13
White lead	1	2	1	2	2	1	2	2	1	14
Zinc White	1	1	3	3	3	1	2	1	1	16
Paint	1	3	1	2	3	1	2	2	1	16
Salt etc.	1	1	1	1	1	1	3	1	1	11
Sulphuric Acid ...	3	2	1	3	3	1	3	3	3	22
Soda	2	2	3	3	3	3	3	1	1	21
Bichromates	2	3	3	3	3	2	2	2	2	22
Amonia (synthetic) ...	1	1	2	3	3	1	3	1	3	18
Aluminium	3	3	3	3	3	1	2	1	2	21
Cynamide	3	3	3	3	3	1	3	1	3	23
Thoria	3	3	2	2	3	3	1	1	3	21
Aniline Dyes	3	3	2	3	3	3	1	1	2	21

Reviewing these industries in turn but in the briefest possible fashion, the following are some of the more salient points. The essential oil industry is one of the oldest in India and comparatively small quantities of raw materials are exported for distillation. The country is practically self supporting as regards turpentine while the world's supply of genuine sandalwood oil is now distilled in India. There is however considerable room for simple improvements in the methods of distillation both for the sake of fuel economy and for improving the quality of the oil. The question of extracting perfume from new sources and particularly from hitherto unused flowers also deserves attention, while the manufacture of the scents now imported and the production of a few synthetic perfumes from local raw materials are not beyond the bounds of possibility, although offering considerably more difficulties than the present simple distillation.

Drugs and more particularly the alkaloids resemble the essential oils in that they occur in the raw materials in very small quantities and fetch a high price for unit weight. Consequently a great saving in freight would be effected by extracting them before export. The process of manufacture is not so simple as that of the essential oils, but it offers no insuperable difficulties. Opium and quinine are already made and a large factory for manufacturing strychnine will shortly be erected. The two million pounds of tea fluff now exported for making caffeine should undoubtedly be worked up in the country, while there appears to be a large field for belladonna preparations. In course of time the cultivation of other drug producing plants will probably be extended and possibly new drugs isolated so that in the future an industry of considerably dimensions may result.

When we turn to tannin extracts difficulties begin to arise. These extracts are largely used in other countries and their manufacture offers no great technical diffiulties, but it appears that the majority of India tanning materials give better results when used directly than when applied as extract, while many of them are so rich in tannin that the saving of freight does not compensate for the cost of making the extract. Government is now engaged in investigating this question and until some definite results have been obtained it would seem that the erection of a factory for manufacturing tanning extracts would be a risky proceeding.

The sugar question would fill volumes by itself. The outstanding difficulty to manufacture on a large scale is the growing of sufficient cane in reasonable proximity to the factory, and a secondary one is the great cost of plant. There are already

between thirty and forty medium and small sized factories in the country and it will be interesting to compare the success of these with that of the newly formed Sugar Corporation working on a far larger scale.

If we turn to the oil industries we are still on debatable ground. The hydraulic press appears to be growing in popularity but the state of affairs in which all the oil seeds now exported will be pressed in the country seems at present beyond the range of probability. Interesting data in this direction will be shortly afforded by the large oil mill at Ernakulam. A probable line of development seems to be the installation of solvent extraction plants, especially if the local demand for oil cake can be stimulated. With regard to the secondary products of this industry viz: soap, glycerine, fatty acids and purified oils, it is rather surprising that soap manufacture is only carried out on such a small scale, but possibly the fear of the powerful combines in other countries has acted as a deterrent to the considerable extension of which this industry seems capable. The splitting of fats does not appear to offer much opportunity to the investor owing to the small quantity of glycerine required in the country and the packing and transport difficulties if an export business is to be started. On the other hand there seem to be endless possibilities in the development of refining and hardening oils for edible purposes. One has only to consider the enormous consumption of crudely adulterated ghee in this country and the extent to which the margarine business has grown in England, to realise the demand for a really wholesome substitute for ghee if once the popular prejudice against it could be overcome.

The manufacture of alcohol is of great importance because it is to tropical countries that attention is being directed in connexion with this substance as fuel for internal combustion engines. Alcohol produced in India from mahua can be sold at a price which is probably as low as anywhere else in the world, but the supplies of this material although very large as far as India's requirements are concerned, are infinitesimal if a quantity of alcohol at all comparable with the present world's output of petrol is to be produced. Similarly it is doubtful whether starchy materials can be made available as they are required in increasing quantities as food-stuffs. Apart from synthetic processes, the most promising raw material is cellulose which India can produce in enormous quantities. A process, said to be commercially successful is just being developed in France for the hydrolysis of cellulose by hydrochloric acid gas, but the consumption of acid is bound to be considerable and it is doubtful if the alcohol could

be produced at a price as low as that of petrol. The line of attack of the problem seems to be the discovery of an organism which will partly break down the cellulose and facilitate the action of the acid. If this can be done the production of alcohol in India may reach imposing dimensions.

The manufacture of high class varnish from Indian materials is an almost unexplored field, but in the meantime there is little reason why imported materials should not be used. Varnish making is not easy, and standing by itself a factory for the purpose might well meet with failure, but in conjunction with a paint industry there seems good reason for supposing that varnish could be made here at least as cheaply as the imported article.

I now come to what may be considered as the most highly developed and complicated chemical industry connected with vegetable products namely wood distillation with recovery of by-products. This has perhaps been more discussed in India than any other chemical industry, but the only real argument in favour of its establishment is the existence of large quantities of wood which give, as already mentioned, a lower yield of valuable by-products than the wood in other countries. Most of the other factors are adverse, especially after the war, owing to the enormous extensions of American factories and the advent of synthetic acetic acid. However, most valuable data will shortly be afforded by the large plant now being erected by the Mysore Government, and the practical results achieved will do more to elucidate the question than any amount of theoretical discussion.

If we now turn to the animal products casein and lactic acid and glue and gelatine, circumstances seem well in favour of their manufacture in localities where the raw materials are plentiful, and with the former might be combined the preparation of tinned and dried milk.

Coming next to the simplest mineral products, asbestos mica and magnesia which require little more treatment than mining and in the latter case burning, much Indian asbestos is very short fibred and so has been classed at worthless. This is by no means the case, as it can be used with great advantage as a lagging material. Experiments now in progress at the National Physical Laboratory seem to show that asbestos and magnesia or mixtures of these materials are the best heat insulators known and with the exceedingly cheap raw materials available it should be possible to manufacture high quality boiler compositions even for export at a price which would defy competition.

In the case of mica it would be possible to utilise the dust and small pieces for the manufacture of micanite articles, but the local demand is small and foreign competition might be too great to admit of export.

The next substances on the list come under the heading of ceramic industries. The manufacture of tiles appears to be rapidly increasing and it should be possible eventually to turn out really first class articles as well as the present quality. Pottery making is on the increase and modern cement plants are in operation, but the glass and porcelain industries in spite of many attempts never seem to have made much headway. Possibly this is due to lack of capital and really efficient organisation and it should not yet be said that it is impossible to establish the manufacture of glass on a paying basis.

We now turn to pigments and paints. The supplies of natural pigments are very large and what seems most to be needed is a really systematic survey of the various deposits. As regards artificial pigments, the manufacture of red and white lead, for which there are large demands appears to offer excellent prospects and if the Burma zinc concentrates are worked up, zinc white could be made as one of the products. If a large paint factory were established it would probably pay to instal a plant for the manufacture of lithopone and colouring matters such as lakes and the chrome pigments. For the production of paint itself oils and turpentine are available and although the process of manufacture is not easy, the demand is so great that the establishment of this industry is one of the first to which attention should be directed.

Coming to what are usually known as "heavy chemicals" the first item is salt, the product of India's chemical largest industry. The question of common salt is too complex for discussion in this place but I must refer to the enormous waste of the by-products magnesium sulphate and chloride which now takes place. The former could easily be produced at a price barely exceeding that of salt, say 4 or 5 annas a maund, and yet in Bombay magnesium sulphate is being made from magnesite and sulphuric acid, while thousands of tons are being run into the sea within a few miles of the factory. The production of magnesium chloride requires fuel, but certain quantities are already being made and an output sufficient for India's whole requirements seems quite within the bounds of possibility even in face of German competition.

Sulphuric acid is an essential substance, but unfortunately the difficulties of transport have led to the establishment of a number of small factories which for technical reasons are

very inefficient, and owing to the enforced use of sulphur as a raw material the price of acid is many times what it is in other countries. The war has made great additions to our knowledge of contact plant, but the smallest sized unit hitherto in use produces about 10 tons a day. It would be interesting to see if efficient smaller units could be made which would run almost automatically, and if so it might be advantageous to erect such units in this country and possibly save freight by transportation of oleum instead of concentrated acid.

Great assistance will be afforded to many industries in the neighbourhood of Calcutta when the proposed manufacture of sulphuric acid from zinc blende is started, but owing to transport difficulties this cannot have much more than local interest.

Soda is a substance evoking much interest, as the requirements of the country are large, but it is difficult to hold out any hope of the establishment of its manufacture. The Le Blanc process has been almost displaced in other countries by the ammonia soda process, and it is difficult to see how the former process in India could compete with the imported product made by the latter, especially in view of the very powerful combine which is interested. The ammonia soda process itself is not well suited for a hot climate, and if electrolytic methods were adopted, there would be no outlet for the surplus chlorine produced. In addition, there is the heavy competition of the Magadi soda to be faced. We are shortly having an interesting peper on the commercial exploitation of the natural soda deposits in the United Provinces and this will afford an opportunity for further discussion.

One of the several secondary chemicals made from the above is sodium bichromate. Although at first sight general conditions and in particular the complicated plant required do not seem particularly favourable for its production in India, yet the large demand for tanning purposes combined with the high price of the imported materials make it probable that its manufacture on a medium scale may yield very considerable profits.

Among the more complicated processes may be ranked the production of fertilisers from atmospheric nitrogen. Statements are frequently made showing the benefits which result from the application of various fertilisers, but I have never seen even an approximate estimate of what quantities are likely to be required, and what the cultivator can afford to pay. Until some such data are forthcoming, it is waste of time to consider the erection of the expensive plant required either for synthetic

ammonia or for cyanamide. If it is borne in mind that it is necessary to export the greater part of the small quantity of ammonium sulphate now produced, it would seem that the time is not yet ripe for the introduction of these more complex products.

Another important branch of electro-chemical industry is the manufacture of aluminium. It has been urged that as bauxite is availble and electric power cheap, aluminium should be made in the country. Now the quantity of bauxite and its suitability for aluminium manufacture have not yet been determined ; Indian electric power when compared with that of many other countries is not cheap ; suitable materials for electrodes might have to be imported, while the preparation of pure alumina required for the electrolysis is said to be one of the most difficult chemical processes known. Consequently great care should be exercised by any who may feel desirous of starting the manufacture of aluminium.

I have added the preparation of thoria to the list as an example of a material which is never likely to be produced in this country although monazite of good quantity is abundant. In an assembly of chemists I need give no reasons.

Finally we come to the question of aniline dyes, perhaps the most popularly discussed chemical industry in existence. To any who have followed the history and development of this branch of chemistry, and who are acquainted with its present critical state even in England it must be clear that aniline dyes will not be made in India for many years to come.

I have omitted from the list the great metallurgical industries which have recently been developed as it is more profitable to study them directly than to talk about them, but there is one point is connection with them which is worthy of serious attention on the part of all who are contemplating the development of industrial work on a very large scale. This is to be found in the evidence of Mr. Marshall before the Railway Committee and is to the effect that unless 133 miles of railway are doubled, and 222 engines and 13,000 trucks supplied within 5 years the proposed extensions to the works will not be possible. To those acquainted with Indian railway development I need say no more.

This completes the list of chemical industries, or rather the more important of them. It is not a long one and of the total number a considerable proportion do not seem well adapted for expansion or introduction to this country at the present time

In a few cases the reasons are technical, but in the majority it is com mercial considerations which form the adverse factors, and that is why I have endeavoured at the beginning of this paper to point out the comparatively small part played by chemistry even in a chemical industry. I do not mean to suggest that the chemist should in addition to his own part enact those of engineer, financier and merchant, but at the same time he should avoid the other extreme of paying no heed to any considerations but purely chemical ones. A little consideration of commercial principles by the chemist is indispensable in the initial stages of an enterprise, although the final decision must always rest with those who are experts in such matters.

With regard to the industries themselves I have purposely laid more stress on the difficulties than on the opportunities and this may lead you to accuse me of pessimism, but surely there is little merit in starting an industry which from the first is almost destined to failure. There is quite a number of directions in which a start can be made, and these I have tried to indicate. A complete chemical industry is not born in a year or even in a decade, but by making small beginnings, by slow and patient endeavour, and by grasping every opportunity which may present itself, the time may yet come when India's chemical industry is no longer an insignificant factor in her national economy but a great and lasting source of prosperity.

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