https://doi.org/10.29321/MAJ.10.A04963

Madras Agricultural Journal

(ORGAN OF THE M. A. S. UNION)

Vol. XXI.] JULY 1933 [No. 7.

CONTENTS

THE CASE FOR THE ELECTRO-CHEMICAL FIXATION OF ATMOSPHERIC NITROGEN IN INDIA*

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The most outstanding recent achievement of science, directly and intimately connected with food production, is the electro-chemical fixation of atmospheric nitrogen. With the aid of electricity it has been possibile to "fix" atmospheric nitrogen and produce several products for fertilising the soil, such as ammonium sulphate, ammonium phosphate, calcium cyanamide and urea. J. G. Lipman, Director of the New Jersey Agricultural Experiment Station gives in a recent number of the 'Journal of the American Society of Agronomy (March 1932)' figures for the world's electro-chemical fixation of nitrogen, as shown in the statement below:—

Statement No. I giving the world's electro-chemical fixation of nitrogen in tons per year from the year 1909 to 1930.

Year.	Nitrogen Tons.
1909	569,250
1913	899,800
1917	1,205,000
1924—1925	1,154,000
1928—1929	2,113,000
1929—1930	2,178,400

* Lecture delivered at a joint session of the Indian Chemical Society (Madras branch), the Society of Biological Chemists (India) and the Association of Economic Biologists (Coimbatore) on the 8th October 1932 under the Chairmanship of Major Howard, Chief Engineer, Hydro-electric Development, Madras.

The processes at present in use for fixing atmospheric nitrogen using electricity are

i) the 'Haber Bosch process' in which nitrogen and hydrogen combine to form ammonia
ii) the 'arc process' in which nitrogen and oxygen combine to form nitric oxide
iii) the 'cyanamide process' in which nitrogen and calcium carbide combine to form calcium cyanamide
iv) the 'catalytic process' in which ammonia obtained by methods (i) and (iii) is converted into nitric acid and nitrates by catalytic oxidation.

Several countries in the world have built plants for the fixation of nitrogen utilising one or more of the above methods as will be be seen from the statement.

Statement No. II giving the countries of production and the total capacity of the plant in tons of nitrogen per year.

Country.	Area (sq. miles).	(Lipman) Nitrogen Tons.
India including Aden	1,766,600	Nil
Belgium	11,370	106,500
Canada	3,620,000	82,500
Czechoslovakia	...	18,500
England	58,324	175,000
France	207,200	163,300
Germany	203,720	938,500
Italy	110.600	79,900
Japan	162,655	118,600
Netherlands	12,560	77,000
Norway	124,090	100,000
Poland	...	75,000
Russia (in Europe)	2,052.490	7,000
Rumania	50,700	5,000
Spain	194,740	8,500
Sweden	172,880	8,000
Switzerland	15,470	12,000
United States of America.	3,025,600	195,600
Yagoslovakia	...	28,000
Total		2,203,900

It will be noted that India is producing nothing. Why? Does she not possess the necessary materials and facilities? Let us examine. Nitrogen is available in plenty in India as in any other country. Every square yard of land has about seven tons of free nitrogen lying over it. There is abundance of coal and lime. As for electricity, we have the authority of J. W. Mears, Chief Engineer, Hydro-electric Survey, who in his triennial report for 1919--21, estimated the probable water power of India for "maximum development" as 12,680,000 kilowatts equal to two and a half million water horse power of which only 1¼ % was then either developed or was in course of development. We have now nearer home, the Pykara power. We seem to have all the facilities and yet we are not doing the first essential thing necessary for the development of agriculture and increased food production.

The problem of nitrogen fixation in India has been under discussion within the past ten years. The Indian Sugar Committee was the first to study the subject and to express the opinion that the successful introduction of synthetic process for nitrogenous fertilisers was a matter of first importance. The possibilities for the manufacture of nitrogen fixation products in India were considered by the Board of Agriculture in India, at its meeting held in Pusa in February 1922. In the opinion of the committee appointed by the Board, the field for the use of nitrogen fixation products was limited, as the cost per unit of nitrogen was too high for the ordinary ryot to manure the staple food crops, and so the prospects were not encouraging. The committee, however, were of the opinion that they could support Government efforts in the direction, in connection with ordinance factories for nitrogen products. Such factories must necessarily produce in excess of military requirements in times of peace and this excess could be used to give some indication of the limiting unit price which would make this fertiliser attractive to the Indian cultivator. The Indian Science Congress at its joint meetings in 1923 discussed nitrogen problem of India in general. In the course of the discussion Lieutenant Colonel Battye, Superintending Engineer, Hydro-electric Circle, the Punjab, examined the hydro-electric aspect of the subject. His opinion was that in Southern India where most hydro-electric developments depend on seasonal storage it might not be possible to bring down the cost of power within electro-chemical limits except in the case of large projects. In Northern India, on the other hand, river flow projects were possible and power should be available at 16 hours a day throughout the year at practically no cost to the producer. Judging from the figures supplied by the American Ordinance Office report on the fixation and utilisation of nitrogen, he estimated that, if power was available at one pie a unit, it should be possible to produce ammonia at three annas a pound as against the present price of Rs. 0–5–4 a lb. for the imported stuff. The Royal Commission on Agriculture in India examined the position afresh in 1926 and 1927 and considered that at least in the near future, the prospects for the manufacture of nitrogen products were not encouraging. I quote their views in extenso. After briefly examining the recommendations of the Indian Sugar Committee who were in favour of manufacturing nitrogen fixation products in India, the Royal Commission on Agriculture say:

"The position has changed greatly since the report of the Sugar Committee was written. The full effects of the diversion of the capital, enterprise and, above all, the research devoted to the manufacture of munitions to the production of peace-time requirements had not been felt in 1920. Since then, it has resulted in a fall in the world's price of nitrogen by fifty per cent and there are prospects of still lower prices in the near future. We see no reason to question the view which was placed before us in the course of the evidence we took in London that in present circumstances, only very large units with a minimum capacity of about 150,000 tons of pure nitrogen per annum can be expected to pay even under the most favourable conditions in Great Britain and on the Continent of Europe and that conditions in India make it much less likely that even a unit of that capacity would prove a paying proposition. The possibilities of manufacturing nitrogen from the air in India have already been exhaustively examined by a leading firm of chemical manufacturers in England which has decided against proceeding with the project. It is probable that no factory on a scale which could be contemplated by any local government, or even by the Imperial Government, would be in a position to produce synthetic nitrogenous fertilisers at a price less than that at which they can be imported. The whole object of establishing such a factory, that of producing fertilisers at a price which would place them within the reach of a far greater proportion of the agricultural community than is at present in a position to use them. would be defeated if a protective duty were imposed to enable its out-turn compete against imported supplies. It is also to be hoped that should the demand for artificial fertilisers in India make it worth while. private enterprise will come forward to erect synthetic nitrogen works in this country While the economics of the industry remain as they stand to-day, we are unable to recommend any further investigation into the subject under government auspices."

It will be noted that, in effect, the Royal Commission relegate the possibilities to a distant date. Are we to rest content here? We see that already many countries have erected plants of their own and are producing nitrogen fixation products. Is there already over production in the world? If so, there is perhaps no justification for India to produce still more. If the production is still below demand, there is every justification for India to make serious urgent efforts at least at experimental researches on the ways and means of producing different nitrogenous fertilisers under our conditions. If there is a case, the sooner we bestir ourselves the better. Already we have the handicap of being late in the field. Further delay only makes the handicap heavier. I am second to none in the view that no greater disservice can be done to Indian agriculture than to encourage the use of commercial fertilisers to the detriment of the conservation of every other source of other forms of nitrogen readily available at the disposal of the ryot. But if an examination of the world's food position generally and that of India in particular, shows that, for feeding the population, the available natural supplies are inadequate and that the artificial utilisation of atmospheric nitrogen is necessary, the position cannot be easily ignored. Let us, therefore, examine the nitrogen position in relation to food.

Lipman (*Journal of American Society of Agronomy*, March 1932) gives the world's population between 1900 and 1930 and the amount of nitrogen consumed as food in the following statement:—

Statement No. III showing the world's population and the consumption of nitrogen as food as calculated by Lipman from 1900—1930.

Year	World's Population.	Consumption of nitrogen as food as calculated by Lipman at 100 grams protein per head.
		Tons.
1900	1,500,000,000	4,390,000
1910	1,523,000,000	4,460,000
1920	1,700,000,000	4,970,000
1930	2,000,000,000	5,850,000

Thus, the present requirement of the World's population in terms of food nitrogen is six million tons. The present world's capacity for nitrogen fixation is two million tons per annum. The production of Chili salt-peter has remained stationary at two million tons a year, which is equivalent to one-third million tons of nitrogen a year. Thus we have at present two and one-third million tons of fixed nitrogen as against a requirement of six million tons for feeding the population of the world. It must be stressed here that six million tons represent nitrogen actually taken in as food. Assuming that the food eaten is vegetarian and a nitrogen efficiency of twenty per cent. in the grain as worked out for England by Slade (c. f. Chemistry and Industry, Sep. 12, 1930), it would require thirty million tons of nitrogen to be added as manures or fertilisers. For meat diet the figures are still higher. Fortunately, Nature has provided various other sources of nitrogen, so that we need not have to find this tremendously large amount of nitrogen by way of artificial fixation.

The position in India may now be examined. Lipman has taken 100 grams. of protein as the average daily requirement of an American. This is equivalent to sixteen grams of nitrogen per day. A. W. Flux, in his presidential address to the Royal Satistical Society (June 1930) on "Our food supply before and after War" fixed 86·5 grams of protein consumption per head per day in England. This is equivalent to 14 grams of nitrogen per head per day. For India, I have assumed that the food requirements are lower than for either America or England and have taken 75 grams of protein consumption or 12 grams of nitrogen per head per day. On this basis, the amount of nitrogen necessary for feeding a population of 353 millions is calculated and given in the Statement No. IV below.

Statement No. IV giving the individual and total requirement of nitrogen for consumption as food, by the population of India including the Indian States.

Poaulation.	Consumption of nitrogen per head per day.	Consumption of nitrogen per head per year	Total requirement of nitrogen by the entire population in a year.
	grams	lbs.	tons
353,000,000	12	9·66	1,522,312

Statement No. V giving the total area under, and the out-turn of, the principal food grains for the whole of India including the Indian States, together with the amounts of nitrogen removed by these. Season 1929—1930.

Grain.	Area. (rounded to thousands acres.)	Out-turn basis. (husked) per acre. lbs.	Nitrogen in grain. %	Total amount of nitrogen for the whole area. Tons.
Rice	80,479,000	900	1·2	3,88,017
Wheat	31,654,000	750	2.5	2,64,961
Barley	8,787,000	750	2·5	71,185
Millets	63,335,000	450	1·5	1,90,853
Maize	8,724,000	560	1·5	31,822
Grains	17,039,000	300	4·0	91,280
Other grains	36,982.000	200	1·0	33,020
Total.	247,030,000			1,071,138

Note:—The average amount of nitrogen removed in a year, by the above food grains is 9·71 lbs. per acre.

The statement shows the amount of nitrogen actually obtained as food grains in the season 1929—30. Thus, in so far as food is concerned, we are short by roughly five lakhs of tons of nitrogen. In other words, we are at present producing food sufficient for the proper feeding of only two-thirds of the population.

How is our nitrogen position and how are we to set about tor increasing the food supply?

Statement No. VI giving the number of livestock for all India including Indian States for the year 1929—30 and the amounts of nitrogen that may be conserved from their excreta.

Livestock	Number (rounded to thousands)	Nitrogen likely to be produced by a single animal in one year	Total amount of nitrogen.
		lbs.	Tons.
Human	353.000,000	6·7	1,055,848
Bovine-cattle & buffaloes	197.836,000	20·0	1,721,750
Bovine-goats & sheep	90,123,000	12·5	502,918
Horses and ponies	2.252,0 0	20·0	20,108
Mules, donkeys, camels etc	2.858,000	15·0	19,005
Total.			3,319,629

The statement shows the nitrogen position in regard to the available supplies. The nitrogen of the human excreta is not all lost and unutilised. Likewise the nitrogen contained in animal excreta is not all utilised. A little of the former and most of the latter are being utilised, as manure and so we may assume, that excluding the nitrogen of the human excreta, two millon tons of organic nitrogen are being used annually in the production of food and industrial crops.

On the basis of even as high a figure as twenty per cent nitrogen efficiency for grain, the present out-turn of food nitrogen connotes, on the whole, a satisfactory utilisation of the existing indigenous supplies. Further effort in the better conservation and utilisation of indigenous sources may not make up the food shortage at the expense of the industrial crops. How is the deficit to be made up? There are two ways of doing it. One is by increasing the acreage under food crops, the other is by increasing the production per acre. According to Agricultural statistics of India in 1929—30 there were 155 million acres of cultivable waste other than fallow. How much of this land should be brought under cultivation to meet the present requirements?

From statements IV and V it is seen that 247 million acres give 1,071,138 tons of nitrogen per acre in food crops; or one ton of nitrogen is obtained from 230 acres of food crops. One person of the population would require 9·66 lbs. of nitrogen as food and so a ton of nitrogen would feed 230 persons. That is one cultivated acre of India would give enough food for one person. On this basis there must be 353 million acres under cultivation. We should, therefore, get a hundred million acres of waste land under the plough. Is this feasible or profitable?

According to Slade the all-inclusive capital cost for a ton year of nitrogen is £ 70 to 100. From our experience with nitrogenous manuring for our soils, we may take nitrogen efficiency for grain production at 15% of added nitrogen. So that, every ton of nitrogen added in the shape of fertiliser on a good basel dressing of organic manure and adequate supply of phosphates would give enough food for 35 people. On this basis, taking the maximum value fixed by Slade and at one acre per head of population, the capital outlay for nitrogen production sufficient for one acre comes to nearly £ 3 or Rs. 45. Compare this with the capital outlay required for bringing an acre of waste land under the plough. It will surely be not less than Rs. 50 per acre under the most favourable conditions and even for rainfed crops and anything above Rs. 50 depending on the nature of the soil and the cost of providing for irrigation. Assuming for a moment the impossible, viz. that the nature of the waste land is such that the capital outlay for both would be the same, what should be our course of action? Should we make efforts at producing improved strains of crops and at rational intensive fertiliser practice based on incessant scientific research on plant nutrition and reduce the area necessary for supporting one person? Or should we increase our acreage by bringing under cultivation the so called available waste land and thus miss the present opportunity for fixing atmospheric nitrogen and commit ourselves and the coming generation to a serious handicap? The answer is plain.

Sir Alfred Chatterton stated in his address to the South Indian Association, Science Japanese Agriculture supports one person on less than a third of an acre. Such is not impossible for us in India. Our Botanists can and are producing improved seed to give at least an average increase of ten to fifteen per cent. A quarter of a century of experimental work has demonstrated that by rational manuring we can not only keep up the high yielding quality of the improved strains but also augment them with an average increase of at least fifteen to twenty per cent.

Recent work here and elsewhere has established the importance of organic matter in the soil both for quality and quantity of food crops. The essential point is to husband our resources of organic manures by the better utilisation of existing ones and by finding ways and means of preventing loss of material of manurial value from going out of the country. We may grow green manure crops and utilise every bit of organic manure for our food crops and use nitrogen fixation products for industrial crops, or we may use small dressings of chemical fertilisers on adequate basal dressings of organic manures. The course of action depends on whether a crop is to depend on rainfall or whether its water supply will be augmented by some source of irrigation. In any case there is need for the use of nitrogen fixation products and the case for manufacturing them in India is evident.

In regard to power, it would appear that the 'arc process' consumes about 8·35 to 8·4 kilo watt year while for the 'cyanamide process' it is 2·3 kilo watt year per ton of nitrogen fixed. That is, the consumption of power in the 'arc process' is about four times that in the 'cyanamide process'. If power is available at a cheap rate, the 'arc process' for the manufacture of nitric acid has the advantage of being direct and comparatively cheap. It is stated that the 'arc process' is advantageous in Norway, where power is available at £ 1·2 per kilo watt year. For the arc and cyanamide processes, the power should be available throughout the year as in these processes which depend on high temperatures the current cannot be switched off and on, daily as this would mean considerable loss in efficiency. Intermittent power will be useful in the manufacture of synthetic ammonia by the Haber-Bosch process in which the intermittent power can be used for the electrolytic production of hydrogen which is made to combine with nitrogen at about 600°C. under pressure.

In regard to the economic size of the plant for the production of nitrogen fixation products the Royal Commission on Agriculture have stated that the minimum manufacturing capacity of a commercial plant should be 1,50,000 tons of pure nitrogen or roughly three quarter million tons of ammonium sulphate. I may, however, point out, that of the nitrogen fixing plants in the world at the beginning of 1930 fourteen plants were of a capacity below 150,000 tons, the capacity of 12 plants was below 100, while there were five plants with a capacity below 20,000 tons. Is it not possible that what is economical and practicable for other countries may be or may be made to be so for us also? At least there is a case for the immediate institution of nitrogen research laboratories in which chemists and electrical engineers should work in close collaboration and co-ordination and tell us definitely what the position is.

For the convenience of our Readers, we reproduce below the summary of the Presidential remarks made by Major Howard, Chief Engineer for Hydro-electric Development and which was published in a previous number of this journal (Vol. xx, No. 11 P. 449). *Ed. M. A. J.*

Chairman's Concluding Remarks. Rao Bahadur B. Viswanath's enthusiastic advocacy has made me wonder whether there is any one else present in South India who would be able to present it so well as he. He has brought out very clearly the deficiency of nitrogen and how it is imminent on us to produce nitrogen. But to me the problem is how much to produce, how to go about it and how to make the people use the product that is manufactured. In my opinion the best process to be adopted here is the Arc process. The problem is also economic and must be interpreted in a much wider sense than the merely scientific. We have, at the start, to decide on giving a nationol orientation to this enterprise if it shou[d be any economic success later on. What exactly I mean hy nationalizing such industries can be illustrated by referring to Japan, and Italy, where great strides have been made in scientific progress on account of the Government taking a chief hand in such enterprises. I can also quote to you the instance of Egypt where two million pounds have been sanctioned for the erection of hydro-electric works on the Nile and another two millions for the manufacture of fertilizers. I am perfectly sure because they are state-undertaken that even this vast expenditure will be justified in bringing useful returns.

I am not very sure of Pykara being a suitable site. It is not merely from economic considerations but because also that it is not particularly suitable. Nearer to us we have Mettur, an ideal site in my opinion. It is not very safe to take our figures from Norway. Norway was the first to start nitrogen fixation electro-chemically and the figures are of pre-war days. Power in Norway is produced at £ 2 a kilo-watt a year. The Nitrogen Fixation Committee's finding is that this would be equivalent to £ 4 at present. We can produce at Mettur easily at and that with profit.

One thing however we must bear in mind and that is the competition from foreign markets. The Agricultural Commission went into this and it was this that made them argue against electro-chemical projects in this country. In the early stages at least, therefore, we must start with protection from the Government and in my opinion that is the only economic solution. I am in sympathy with the lecturer not merely sentimentally but also practically.

STUDIES IN POULTRY-KEEPING

Part I. SOME ADVANTAGES IN POULTRY-KEEPING.

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Eggs and poultry for meat are the primary edible products for those who use them in their daily diet. During recent years the demand for poultry-products has considerably increased, especially in places near towns. In such places people take so keen an interest that they are becoming specialised in poultry keeping.