# PART I.—INTRODUCTION.

*By Gilbert J. Fowler.*

The practice of nitre-farming is of very ancient origin probably having been first brought to a state of proficiency in China and thence imported to Europe.

The suggestion by Pasteur that the development of nitrates from organic matter was due to micro-organisms was, however, not made till about 1878. The correctness of this suggestion was confirmed experimentally by Sclösing and Muntz, who found that nitrification in the soil was inhibited by the presence of antiseptics.

The conditions for successful nitrification have been studied by numerous investigators, but the first experiments on modern lines, directed to obtain large yields of nitrate capable of commercial application, appear to be due to Muntz and Lainé (*Ann. de la Science Agronomique*, 1926). They state that the nitrifying organisms operating at a temperature of 30° were active up to a concentration of 22 per cent. calcium nitrate, although these will not survive in a concentration of more than one per cent. of ammonium salts.

Muntz and Lainé considered peat to be the best medium on which to carry out the nitrification process and they claim to be able to nitrify per day and per cubic metre 1000 litres of solution containing 7·5 gms. ammonium sulphate per litre. They finally obtained a solution containing 5 or 6 per cent. of calcium nitrate, and state that it would be possible, according to their experiments, to obtain about 90 tons of calcium nitrate per hectare of peat-filter per day.

These experiments were taken up and developed with great care by E. Boullanger (*Ann. de l'Inst. Pasteur*, 1921, **35**, 575 and 1922, **36**, 395). Boullanger's experiments were carried out both in the laboratory and on a semi-technical scale using other media besides peat, the most satisfactory of which was found to be natural pozzuolana in granules the size of cherry-stones.

Boullanger's conclusions are of great interest and value, and the more important of them may be noticed here. It is necessary to begin the process of intensive nitrification very gradually as the nitrifying organism is paralysed by excess of ammonia. Nitrates also have an inhibitory action at the beginning of the process and therefore ammonium sulphate was used as raw material at the outset, and ammonium nitrate only later. This salt was obtained either by direct solution in water or by double decomposition of ammonium carbonate with calcium nitrate formed by the process. It was found best to use bicarbonate or sesquicarbonate of ammonia rather than sulphate, and so avoid formation of insoluble calcium sulphate.

The strongest solution obtainable was found to be 138·2 gms. of calcium nitrate per litre and this was slightly inhibitive. A regular output was obtained with 120 gms. or 12 per cent. calcium nitrate.

A very careful and special technique, for details of which the original paper must be consulted, was necessary to obtain these results, the underlying principle being to maintain the necessary minimum of ammoniacal nitrogen while allowing a gradually increasing concentration of nitric nitrogen. In order to obtain this concentration it was necessary to dissolve each fresh addition of ammonium nitrate in a portion of the liquor from the previous operation, fresh water being added equivalent to the amount of nitrate solution withdrawn for recovery of the dissolved nitrate.

All the conclusions reached in the laboratory were verified on the semi-industrial scale. If the proper conditions are fulfilled, liquors can be obtained containing 11 to 13 per cent. calcium nitrate by the use of solutions containing 15 to 18 gms. nitric nitrogen and 1·5 ammoniacal nitrogen per litre. Under these conditions about 50 gms. of nitric nitrogen per day, corresponding to 286 gms. ammonium nitrate or 293 gms. calcium nitrate, can be obtained per cubic metre of medium. A nitrifier of one hectare with a working depth of 1·8 metres or 18,000 cubic metres would give per 24 hours rather more than 5 tons of ammonium or calcium nitrate. This is about one-eighteenth of the figure given by Muntz and Lainé whose results could not be maintained in continuous practice.

Boullanger gives a detailed financial estimate of the cost of nitrate production in this way and arrives at a price of 2,200 francs per ton of ammonium nitrate, the ordinary price per ton of ammonium nitrate at that date (1922) being 1,600 francs. Except as a war emergency, therefore, the process could not be considered economical.

Joshi (*Agric. J. of India*) has made a number of interesting experiments at Pusa on the use of an intensive nitrifying bed as a means of preventing nitrogen losses from cattle urine. Joshi's results are somewhat better than Boullanger's, probably owing to the nitrogen in the urine being in a form more readily attacked by micro-organisms than the simple ammoniacal solution used by Boullanger. He was able to oxidise a solution containing 1·5 gms. ammoniacal nitrogen per litre at the rate of 100 litres daily per cubic metre of medium, or 0·15 gm. ammoniacal nitrogen daily per litre of space, which is 33 per cent. higher than the figure given by Boullanger. In the hot weather Joshi reached the figure of 0·2 gm. ammoniacal nitrogen oxidised per litre of space.

The experiments which are described in the following pages were undertaken with the object of determining how far intensive nitrification could be carried, using the principle of the activated sludge process, i.e., by moving the organisms through the solution to be nitrified instead of passing the solution over a fixed surface on which the organisms were developed. The experiments were started in 1920 before the publication of the results of Boullanger or of Joshi and although a number of interesting results were obtained in the early stages it was not until a careful study of Boullanger's paper had shown some of the necessary conditions for success that results of technical importance were reached.

Under the best conditions it has been possible slightly to exceed the highest rate of nitrification reached by Joshi. He was able to oxidise 0·2 gm. of ammoniacal nitrogen in one day per one litre space, while in his last experiment Kotwal attained a rate of 0·25 gm. ammoniacal nitrogen per litre per day.

The subsequent experiments of Norris and Ranganathan, however, seem to indicate that this high rate is not maintained as the concentration of nitrate in the solution increases.

Both Roy and Ranganathan noticed the beneficial action of traces of iron salts, an observation of interest in view of recent work by Warburg and others on the mechanism of biological oxidations. Ranganathan's results with animal charcoal lend further support to these views.

The outstanding result of all the experimental work is to show the necessity in the first place for very carefully cultivating organisms of special activity, and also for the maintenance of certain limiting conditions of concentration if the most satisfactory results are to be obtained. This is of great importance in connection with the practical technique and economical working of activated sludge plants employed for the purification of sewage, especially where highly concentrated liquors have to be used. The possibility is also indicated of employing activated sludge tanks for producing nitrates from various nitrogenous raw materials as a preliminary to their application to the purposes of agriculture.