Water Pollution Research

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THE growth of industry and of the population during the last century, especially in the north of England, gave rise to several undesirable conditions, including gross contamination of rivers, which in some cases became little better than open sewers. A plentiful supply of water of good quality for domestic and agricultural purposes is one of the major factors in public health, and large quantities of comparatively pure water are required for many industrial processes. Available sources, both surface and underground, of unpolluted water are gradually being depleted and there is no doubt that many rivers which are at present polluted will have to be utilised in the future as sources of supply, after treatment, for both domestic and industrial purposes. Further, the problems of river pollution are of importance in that they affect not only the health and recreations of the population but also the interests of farmers, landowners and fishermen. It is not surprising, therefore, that attention has frequently been directed to the need for satisfactory methods of preventing or reducing pollution.

It was recognised by the Royal Commission on Sewage Disposal, whose comprehensive inquiry during the years 1898–1915 produced results of great value, that satisfactory methods of disposal of polluting liquids from industrial operations were in many cases either unknown or impracticable, and that the problems involved could not be solved without further knowledge. One of the recommendations of the Commission was the establishment of a central authority the duties of which should include the investigation of problems in the purification of polluting discharges and the collection and correlation of the results of investigations by others. Since 1915, the importance of the subject has been stressed on several occasions. In February 1927, public opinion was focused on the matter by a deputation, representative of the British Waterworks Association, the Salmon and Trout Association and other authorities, which was received by the late Lord Balfour, then Lord President of the Council. In consequence of the views expressed by these and other independent authorities and by several Government departments, the Water Pollution Research Board was set up in June 1927 by the Department of Scientific and Industrial Research. This Board was appointed to submit schemes for research on the prevention of the pollution of rivers and other sources of water supply and on any relevant matters affecting the purity of water supplies, and to supervise approved investigations.

Since its appointment, the Board has initiated investigations of the problem of disposal of effluents from beet sugar factories, the base-exchange process of water softening, the causes of the corrosive and plumbo-solvent action of certain waters on mains and service pipes, and of bacteriological and physico-chemical problems associated with processes of purification of sewage. In addition, a comprehensive scientific survey of the River Tees was begun early in 1929. The research staff has also assisted other investigators by directing attention to appropriate scientific and technical literature and by indicating the most promising methods of attacking the problems to be solved. In this connexion, informative summaries of current literature relating to water supplies, sewage, trade waste waters, river pollution and kindred subjects are systematically prepared and published monthly.

Of the investigations already mentioned, that dealing with effluents from beet sugar factories and the survey of the River Tees have reached the most advanced stages. It is proposed, therefore, briefly to describe these two investigations and the more important results obtained. Incidentally, as an illustration of the greater interest now being taken in the problems of water supply and river pollution, it should be mentioned that a session of Section B (Chemistry) at the recent meeting at York of the British Association was devoted to a discussion of the survey of the River Tees. In addition, Sections D (Zoology) and K (Botany) held a joint discussion on biological balance in fresh water, while the organisation required for recording water level and river flow in the British Isles was discussed in Section A (Mathematical Science and Physics).

When the Water Pollution Research Board began its activities, the beet sugar industry had only recently developed on an extensive scale in Great Britain, but already several serious cases of the pollution of rivers by the waste waters had occurred. Preliminary work soon indicated that it might be advisable to suggest modifications in the factory processes so as to reduce the quantities or alter the composition of the effluents rather than to consider only methods of purification. It was important, therefore, that the investigation should be proceeded with as rapidly as possible, before other factories were erected.

On arrival at the factory, the beets are conveyed by water carriage along flumes to washers in which they are washed to remove adhering soil and debris. In a factory of average size, 1,000–1,500 tons of beet are dealt with each day and the total quantity of fluming and washing water varies from 2·5 to 3·5 million gallons. After washing, the beets are cut into small slices or cossettes from which the sugar is extracted with hot juice or water, usually in a battery of diffusers; the diffusers are cleaned periodically by washing with water. The spent cossettes are then pressed to reduce their moisture content. Water removed from the spent cossettes, together with the washings from the diffusers, is generally known as process water and amounts to 300,000–500,000 gallons per day. Purification of the solution of sugar is effected by several processes and the purified juice is evaporated to crystallise the sugar. A large quantity of cooling water is required during the concentration of the juice, and from 75 to 80 per cent of the water in the juice is removed and condensed in the process. The total quantity of water from the condensers is of the order of 3 million gallons per 1,000 tons of beet treated; this water is often used again in the flumes for carrying the beets to the washers. From this brief description of the factory processes, it will be noted that the principal effluents for disposal are fluming and washing water, 2·5–3·5 million gallons per 1,000 tons of beet, and process water, 300,000–500,000 gallons per 1,000 tons of beet. The fluming and washing water carries soil and beet debris and contains small amounts of dissolved organic and inorganic substances. It is definitely polluting in character, but though larger in quantity it is not so objectionable as process water. This latter effluent contains 0·2–0·4 per cent of sugar, ferments rapidly on storage and takes up large quantities of oxygen from any river into which it may be discharged.

As a result of the investigation during 1927–30, the Water Pollution Research Board definitely concluded that by suitable modifications in the factory processes, the whole, or at least the major quantities, of the fluming and washing water and of the process water could be re-used, leaving little or no effluent for disposal. Certain factories have for several seasons re-used the fluming and washing water after simple treatment by screening and sedimentation to remove solid matter, and the re-use of this water has proved to be entirely satisfactory. At some factories the cossettes are extracted by a continuous process of diffusion in which the water removed from the spent cossettes is returned to the diffuser. In this process there is very little waste water for disposal. Even with the intermittent process in a battery of diffusers, large scale trials in the factory have shown that after preliminary treatment with lime or by other simple methods, the process water can in large measure be re-used in place of fresh water. If the fluming and washing water is re-used, then the effluent from the condensers requires consideration. This effluent is not very polluting in character, but it is advisable that it be cooled before discharge to a river, or it may be cooled and re-used.

Although it had been shown that the waste waters from a beet sugar factory could be largely re-used, it was realised that it might be necessary on occasion to discharge a proportion of the waste waters or that some factories might prefer to purify the wastes sufficiently to allow of their discharge into a river rather than to re-use them. After preliminary experiments in the laboratory, it was decided that, as a method of purification, the process of biological oxidation on percolating filters showed promise of success. This process, which is similar to that in operation at many sewage works, was tried therefore in laboratory and large-scale experiments. In addition to the chemical examination of the effluents before and after treatment, the fauna and flora of the filters have been systematically studied, and it has been shown that, under certain conditions, beet sugar factory effluents can be sufficiently purified by biological filtration to allow of their discharge, except into the smallest streams, without causing serious pollution. It has been demonstrated, therefore, that gross contamination of rivers by effluents from beet sugar factories can be avoided and there is no doubt that during the past two or three years this type of pollution has been much reduced.

The survey of the River Tees was undertaken with the object of obtaining more precise information than was hitherto available on the effects of different kinds of effluents, both sewage and industrial, on a river, and with the object of assessing the power of a river to recover from the effects of polluting discharges. This survey provides a good example of what can be achieved from carefully planned co-operation between specialists in different branches of science, for it has included hydrographical, chemical, bacteriological, botanical and zoological observations and experiments. In addition, records of rainfall have been collected for correlation with measurements of river flow.

From the hydrographical measurements, it has been shown that the water in the estuary at depths below one fathom has a tendency to move up river over each tidal cycle of ebb and flood. The water in the top layer, however, has a strong net movement down river, and the volume moving down river in this layer is greater than the net volume moving up river in the lower layers. A circulatory system is thus set up and is superimposed on the to-and-fro movement of the tides. It has been concluded, therefore, that polluting matter is not readily conveyed to the sea unless it is in the surface layer when it reaches the estuary.

Large quantities of crude sewage and of industrial effluents are discharged into the estuary of the Tees, especially in the section from Stockton to Cargo Fleet. The principal industrial effluents are those derived from coke ovens which contain tar acids, naphthalene, cyanide, etc., and spent pickle liquor, which is an acid solution of iron produced during the cleansing of iron and steel. Oxidation of the sewage and effluents occurs in the estuary at the expense of dissolved oxygen. The Tees was formerly a noted salmon river, but for many years large numbers of fish have been killed in the estuary, especially salmon and sea trout smolts during their migration in the spring to the sea. Various observations and experiments included in the survey have proved that in 1930 and 1931 the death of migrating smolts was not due to the deficiency of dissolved oxygen but to cyanides, which were frequently found in lethal concentrations. Other poisonous substances, including tar acids, were not found in toxic concentrations and it has been concluded that in the absence of cyanides, migrating smolts would not have been killed in 1930 and 1931. This conclusion marks a distinct step forward, for although several explanations had previously been offered, it had never before been suggested that cyanides were responsible for the death of fish in the River Tees. Another interesting result of the survey is that experiments in the laboratory and on a semi-technical scale have demonstrated that cyanides in coke oven effluents can readily be converted into relatively non-toxic ferrocyanide by treatment of the effluents with spent pickle liquor and lime.

In the non-tidal reach of the Tees, there is only one point at which any large quantity of polluting matter enters and this pollution is derived from sewage. Further downstream, for a distance of about 15 miles, there is no polluting discharge of any importance. A study has been made, therefore, of the effects of sewage pollution on the biology of the river and of the factors which influence the rate of self-purification of a river from pollution by sewage. It appears that temperature is the most important factor, so that the rate of self-purification is much greater in summer than in winter. In determining the relative rates of self-purification under various conditions, it has been necessary to calculate the total quantities of different constituents of the river water from the results of chemical analysis and measurements of volumes of water and river flows. The occurrence of certain plants and animals has been correlated with the conditions of the water as determined by chemical analysis and several new and little-known algæ have been discovered. In addition, useful additions to knowledge have been made with regard to the food of fish.

Cod in Danish Waters

COD are present in all Danish North Sea waters and extend northward through the brackish Baltic Sea into the still more brackish Gulf of Bothnia almost (but not quite) to its northern extremity. Elaborate researches upon the cod in all these waters have been carried out by a Danish investigator, Dr. E. M. Poulsen, the results of which have been published recently in a comprehensive report.*

In Section I of the report data regarding the bathymetric distribution of the fish in Danish waters are given. In the North Sea, cod are most abundant in depths of less than 100 metres. Between 100 and 200 metres they are relatively scarce, while at depths of more than 200 metres they are seldom caught. What few cod there are present in these deeper layers are almost entirely old and large fish. In the Baltic, around Bornholm, cod are most numerous from 40 down to 100 metres, at which depths the water is less brackish than in the overlying layers. In the Kattegat, on the other hand, the fish favour depths of from 40 to 60 metres.

Observations on the spawning periods of the cod in these different regions produced very interesting results. In the Kattegat, spawning begins in February, reaches a maximum in March, and finishes about the end of April. In the Belt Sea spawning may extend into the first half of May, while still farther north, in the Bornholm Deep, spawning continues from April until August with June as the main spawning month. Contemporaneous hydrographical data reveal that the cod spawn in water the temperature of which lies between 3° C. and 7° C. The displacement of the spawning season from early spring far into the summer, on proceeding from the Kattegat into the Baltic, corresponds with the different times at which the bottom waters reach this temperature.

Cod larvæ occur throughout the whole of the area investigated, but are most numerous in the North Sea, the South West Kattegat, the Sound, Belts, and Western Baltic, and are relatively very much scarcer in the Skagerak, the North East Kattegat, and in the Baltic proper. The larvæ are peculiarly abundant in front of certain marine ridges which intercept the in-going North Sea currents in the Little Belt, at the Gedser Reef, and at Dragden in the Sound. Hydrographical investigations show that the ingoing salt-water currents are largely blocked at these ridges. Larvæ from the North Sea brought in by the currents are therefore largely intercepted by them and accumulate in great numbers on their seaward sides.

During the period 1917–1927 good and bad survival years for the fry are stated to have alternated regularly, the years 1917, 1919, 1921, 1923, 1925, and 1927 having been good survival years, while the intervening years were bad. The years 1928 and 1929 are described somewhat vaguely as being neither good nor bad but "to some extent normal".

The most interesting and important part of the report is that in which the author records his attempts to determine the causes underlying these annual fluctuations in the abundance of cod fry in these waters. At the outset a certain amount of evidence is put forward which suggests that fluctuations in the number of eggs produced from year to year are not to any appreciable extent correlated with fluctuations in the number of larvæ later produced.

* Erik M. Poulsen. "Biological Investigations upon the Cod in Danish Waters". Meddelelser fra Kommissionen for Danmarks Fiskeri-og Havundersøgelser. Serie: Fiskeri. Bind IX., Nr. 1., pp. 1-148. C. A. Reitzels Forlag, København, 1931.