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SEWAGE TREATMENT AND FISH LIFE

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I am not going to bore you with a sermon on stream pollution, nor with a maze of technical detail nor a babel of scientific terms. I will present no statistics, no graphs, no detailed recounting of experiments. I will merely present my views on the subject of sewage treatment in relation to fish life, just as I would if we were sitting down together to talk over this problem of mutual interest.

My purpose will be to indicate: first, the general failure to approach this problem with an open mind; second, the extreme difficulties encountered in determining the whole, varied ill-effects of sewage on fish life; third, the lack of any sound scientific basis for fixing a legal limit for pollution in terms of dissolved oxygen content, biological oxygen demand or any other single, simple test; fourth, the beneficial effects of sewage on fish life, in the increase of food organisms; fifth, the dovetailing of fishing, recreational, health and economic interests, as affected by sewage, treated and untreated.

Few of the problems arising from our expanding population and industrialized life have been tackled with a less open mind than has the problem of stream pollution. Even many of the scientists who have worked on this problem have been unable to cast aside personal prejudices and preconceived ideas.

Others who have attempted to study pollution from the scientific angle have been swayed, perhaps unconsciously, by their own personal interests, or by the viewpoint of those who have employed them to make the investigation.

Since many scientific men, who are supposed to be relatively free from prejudice and influence, have thus allowed their preconceived ideas and personal interests to mould their views and conclusions, it is small wonder that others have been even less rational in their attitude toward stream pollution. Many approach the problem with the spirit of the crusader, bound to right what they view as a great public wrong. We recognize that much of history is the record of the accomplishments, for better or for worse, of the zealot and the crusader.

But the problem of the effect of sewage on fish life, like other problems of stream pollution, is one that requires clear straight thinking, freed from prejudice and untainted by personal or financial interests, and coupled with good, hard scientific work. This follows not only from the difficulty of approaching this problem in a truly scientific way, but also from the inherent complexity of the effects of sewage of given sorts on fish life of different kinds, under varying conditions.

The effect of sewage on fish life varies greatly with the season. During the winter, when the water is very cold, fish are extremely resistant to the effects of pollution, usually surviving unless the dissolved oxygen beneath the ice is entirely or almost entirely exhausted for some time. The rapid rise in water temperature in the spring brings on a critical period, when fish are susceptible to unfavorable conditions, and often die. Again in late summer and early fall, when high water temperatures are attained, the fish show reduced resistance to low oxygen and other effects of pollution. Unless a stream or lake approaches the character of an open sewer, fish deaths in it are usually confined to a very few days in the year, when the weather is very warm and the water level low. Weeks of investigation during the summer in a given stream or lake may give little or no evidence as to any harmful effect of the sewage on fish life, though the proper combination of circumstances may suddenly lead to conditions incompatible with fish life.

The effects of sewage on fish life also varies greatly with time of day. Investigators, especially those of regular habits, may entirely miss the septic conditions which may exist for parts of a day in a stream. It is not at all infrequent for a badly sewage-polluted stream to show not only saturation with dissolved oxygen, but even a marked supersaturation, running as high as 100 or 200%. This condition holds especially on sunny afternoons. The same stream is very apt to show a great reduction, sometimes a complete removal of the dissolved oxygen during the night, especially toward morning. To cite an instance, I once studied the lower River Raisin below Monroe, where it is badly polluted by sanitary and paper-plant sewage. During the night the dissolved oxygen became entirely consumed, anaerobic decomposition set in, hydrogen sulphide was produced and reacted with the reduced iron salts in the water toproduce ferrous sulphide, so that the water ran foul and black before daylight. Then the sunlight fell upon the water, causing the algae to manufacture oxygen, which oxydized the ferrous sulphide to form white colloidal sulphur, so that the stream ran white instead of black.

It is extremely difficult to determine the kind and degree of harm that sewage may do to fish life. When the fish are acutually killed outright and in quantity, the harm is obvious. But when the fish are slowly killed off, the deaths may pass unnoticed, or may be attributed to causes other than pollution. The sewage may change conditions so that the fry only are killed, and the dead fry will not ordinarily be seen. Or the spawn may be prevented from hatching, or the development may be made abnormal, so that malformed fish result--we have often noticed a high incidence of abnormal or teratological fish in polluted waters. Or the natural spawning beds may be covered over by a deposit of septic sludge, in which the eggs can not hatch. Even if the fish clear their "beds", or redds in technical parlance, the fine sludge-silt will likely shift enough to cover and smother the eggs.

The pollution may kill the animal life on which the fish normally live, thus depriving them of nourishment. For this reason or perhaps because of the altered chemical content of the water, fish may become much dwarfed in polluted waters. Thus in the River Raisin I find two or three year carp below Monroe to be about the size of yearling carp above town, and to have only a fraction of the weight shown by the carp of their own age in the unpolluted water. This means a loss in total production, which in the case of valuable fish may well reach serious proportions, even where few fish are actually killed.

Certain chemicals, even in minute quantities, have been known to affect the taste of fish so as to prevent their sale.

Another probable effect of sewage on fish life invovlves the driving off of the fish. Fish unquestionably show a negative reaction toward water badly polluted with organic wastes, for they swim away from such waters. Thus in the mill-ponds of the River Raisin, when badly polluted by organic wastes, I have seen thousands of fish butting against the shores in their efforts to escape. Even if no definite negative reaction causing the fish to swim directly away is called forth, the fish are likely to become restless, flitting hither and yon. This may interfere with growth or make the fish an easier prey to fish-eating birds or predaceous fish. They will likely continue the uneasy movements until they finally land in unpolluted waters, where they will then settle down as good fish citizens, finding their retreats, feeding grounds, etc.

These nervous movements which may bring the fish to harm may be incited by extremely minute quantities of pollution. In experimenting with the effect of ozone on fish life, I found that less than 0.1 part of ozone in one million of water was sufficient to kill small fishes, but that much smaller quantities, perhaps less than 0.01 p.p.m., too little to be recorded by a very delicate chemical test, sufficed to throw the fish into nervous movements, from which there was no quick recovery. Since such excessively minute quantities of ozone will produce an obvious effect on fish movements, it is at least possible that traces of other chemicals in sewage may cause fishes to vacate waters which will not kill them.

A very indirect but probably real way in which sewage harmfully effects food and game fish is through the increase in coarse fish, such as carp. Such coarse fish probably tend to decrease the better fish, by eating eggs or fry, by cleaning out the shallow weed beds so that the young game fish will be deprived of their normal and needed shelter, by competing for food or in some other manner.

Another way in which sewage may affect fish other than by killing them lies in the increased incidence of disease. This is often to be observed in polluted waters. We have already mentioned that abnorally formed or monstrous fishes are sometimes common in polluted waters. Other diseases are also frequent in polluted waters. These are in part due, we may suppose, to the weakened condition of the fish. Parasitic worms may abound, especially the species which produce little black cysts on the skin. Those species of parasites may abound in polluted waters, because they must first live in a snail before infecting the fish, and snails are often increased by pollution. Bacterial diseases of fish are also common in polluted waters. One such disease for instance, causing the fins to be eaten away, was found very prevalent in the heavily polluted lower River Raisin. It is quite possible that some pathogenic bacteria are not very specific as to their hosts, and that they may be actually contributed to the stream by the city sewage. Or the sludge ~~deeps~~ deposits or the growths of slimy fungi in the polluted waters may very well harbor the disease-producing microorganisms, so as to render easier the infection of new fish. (The slimy deposits in fish troughs have been shown to uphold a growth of the bacterium causing a very serious gill disease in trout.) The bacteria concerned may even multiply in the slime or sludge.

I could cite other ways in which sewage may harmfully affect fish life indirectly. But I have perhaps gone far enough to show the extreme complexity of the problem, and the difficulty at determining just what harm the pollution may do to the fish life. Any disturbance in the natural balance of plant and animal life in the streams or lakes may seriously affect the fish life. The indirect effects of sewage in depleting or eliminating the fish supply may well be more important than the direct killing effect.

Since it is so hard to determine the way in which pollution harms the fish life, or the degree of harm produced, it follows that it is extremely difficult to fix a definite standard of allowable pollution. It is the very natural desire of sanitary engineers to have a definite measure of degree of pollution which may be regarded as legal. But the great seasonal and hourly variation in dissolved oxygen content or other pollution indices make critical, or extreme, or even representative determinations, hard to obtain. The effects resulting from the disturbance of the balance of nature, make it difficult to estimate whether a given standard level of pollution will be harmful to fish life.

The engineers or administrators or legislators who wish to fix a legal standard limit for pollution usually want to base the limit on dissolved oxygen content. They come to the fishery workers with the request for information as to the lowest amount of dissolved oxygen which fishes will tolerate without material harm. The desire is to adopt a certain legal standard, such as 2 p.p.m., 3 p.p.m., 4 p.p.m. or some other figure. The limit of 4 p.p.m. has been particularly mentioned in this state. While we do not wish to say that administrative expediency may not require such a limit, we must express our opinion that any definite limit, of 2, 3, 4 or 5 p.p.m., would have to be made without real scientific foundation. In addition to the difficulties of determining the low values existing in the stream, or of estimating the manner or degree of harm done by any degree of pollution, we encounter the difficulties arising from the varied effects of the different elements in the sewage causing the pollution, especially if the sewage be untreated.

We certainly can not give the engineer any definite figure on the amount of dissolved oxygen which is just sufficient to support fish life. An amount of say 2p.p.m. may just kill a given kind of fish in a reasonable experimental time (say 36 hours). But other fish may not be killed with this treatment; other kinds may die more quickly. The killing limit of dissolved oxygen varies of course with the temperature: the higher the temperature, the more oxygen is required to sustain life. Winter caught fish are very resistant to low oxygen, but are especially susceptible when subjected to rapid temperature increases, either in nature or in the laboratory. Spawning fish are easily killed, and fish eggs or fry may succomb to dissolved oxygen values well above those which kill the adult fish.

Even if we take fish of a single species at a single age and season, we can not give <u>the</u> death point in terms of low dissolved oxygen. The amount of oxygen just sufficient to sustain the fish's life depends also on the other material dissolved in the water. The amount of dissolved oxygen necessary is known to increase, if the amount of dissolved carbon dioxide is increased. In some experiments with sugar-plant wastes we found that sunfish would live many hours in good "control" water containing only a fraction of 1 p.p.m. of dissolved oxygen. But other fish, quite similar, were quickly killed in dilutions of an organic waste (Steffan's waste from a sugar plant), in which the oxygen level was held up to 5 or 6 p.p.m. by compressed air. In some natural waters fishes may continue to live for considerable periods of time in water almost devoid of dissolved oxygen, merely showing their distress by lapping at the surface. In other circumstances they may be killed by organic pollutions when the oxygen level is moderate. Thus in Iowa it has been found that fish may be killed by decaying algae, even though the algae not dying are able to hold the oxygen level above 4 p.p.m. (obviously through the process of oxygen production by the live algae, in the sunlight, in quantities sufficient to more than take care of the decomposition of the dead algae). It is possible of course to determine for fish of a given species, age, sex and season, just how little dissolved oxygen is necessary to support life, under any given conditions. But these conditions vary tremendously with the stream, the season and the amount of natural pollution, as well as with the nature and amount of the pollution substances being discharged into the stream. Since we can not readily determine the amount of dissolved oxygen just low enough to kill fish in natural waters, we certainly would find it a very difficult task indeed to determine the less direct, but perhaps more important indirect effects on fish life of any given low value of dissolved oxygen.

In some states, the attempt has been made to determine a low oxygen value allowabel for polluted waters, using biological oxygen demand in conjunction with dissolved oxygen. The proposed value has been called the "fish zero", or better the oxygen reserve. This is obtained by subtracting the BO. D. from the D. O. If the result is over 3.0 p.p.m., the condition is termed satisfactory; if under 3.0 p.p.m., unsatisfactory. This method has the advantage over the simple dissolved oxygen standard, in that it makes it less important to be on the ground when the D.O. is at its lowest point. The B.O.D. tells after a fashion what may be expected to happen to the D.O. under unfavorable conditions. But it does not follow that a stream with an oxygen reserve of under 3.0 p.p.m. is unfit for fish life. The water may carry a B.O.D. higher than its D.O. (thus giving a negative value of oxygen reserve), yet be rather healthy for fish, if the stream is frequently well aerated by flowing over riffles or dams.

Other states, as New York, have frankly recognized the extreme difficulty of fixing a legal limit to pollution on a chemical basis. New York has been using instead the "minnow test", to determine if there has been a violation of the law prohibiting the discharge of substances injurious to fish life. In these tests, it is determined whether minnows confined in a live box in the water die. The difficulties in this test are perhaps as great as in the chemical tests. Anyone who has tried to keep minnows alive in live-boxes, knows how difficult it is to do so, even in unpolluted streams. Then different species of minnows vary greatly in their resistance. Furthermore, whether or not the minnow will die in the test will certainly depend on how and where caught, how long and in what manner treated while being transported for the test, and on how great a differente exists between the native and polluted stream, in respect to temperature, chemical content, etc. Also, the pollution may injuriously affect the fish in other ways than by causing death; or it may be difficult to make the "minnow test" at the right time and place.

So far as I can see, no simple test for the lower limit of allowable pollution may be fixed, on any good scientific basis.

Any estimation of the effect of pollution on fish life is complicated by the fact that most sewage, especially sanitary sewage, is at least potentially beneficial to fish life. This is a point which is seldom even mentioned. It would be regarded as a heresy by the anti-pollution crusader. It is a light on the subject against which even supposedly scientific investigators have blinded themselves. It may be that recognizing the benefits of sewage to fish life would weaken the case of those striving to control pollution. But I feel that stating a partial case, hiding half of the problem, is merely a form of deception that can work no good in the long run, for the truth will come out eventually. Furthermore, as we shall presently see, recognizing the advantages of sewage to fish life strengthens the case for thorough-going sewage treatment.

The beneficial effects of sewage on fish life lie in its fertilizing qualities. Sanitary sewage is very rich in nitrogen, and has a considerable content of phosphorus, potassium and other fertilizing elements. Aquatic crops can be increased just as land plants can be, by the addition of these elements to the nutritive medium. Numerous laboratory experiments have shown that the addition of nitrates and phosphates stimulate the aquatic growths. It is becoming the standard practice in fish culture to fertilize the rearing ponds with nitrogen-rich meals, such as soy-bean meal, with phosphate fertilizers and with sheep manure. Since sanitary sewage carries very similar substances, it is clear that it is capable of increasing fish production also, through the increase in the plants and then of the small animals on which the fish feed. The accumulated experience of the centuries in Oriental fish culture has demonstrated the effect of sanitary sewage on fish production. Over there it is the custom to place the privies over the innumerable little fish ponds, so as to fertilize the ponds directly. The reason why a Scandinavian lake produces an unusually high fish production in pounds per acre per year was found to lie in the fact that the small village on the lake discharges its sewage into the lake. The fact that Lake Erie has over the years yielded approximately as much poundage of fish as all the other Great Lakes combined may well be due in part to the fertilizing of this lake by the large human population which surrounds it. After the sanitary sewage of Chicago was diverted into the Illinois River, a marked increase in the commercial fish yield of the river was recorded.

This increased yield of the Illinois River, however, did not hold up. Gradually a thick septic sludge was deposited near the head of the sanitary canal, making that end of the system unsuited to fish life. As the sludge accumulated it advanced downstream, year by year lengthening the virtually fishless section of the stream and shortening the lower portion of increased fish production. This process had continued until a few years ago, so that only a few of the lowermost miles of the stream remained in fish production, though this short section still showed a high production. Now, as Chicago is installing sewage treatment, the zone of fish production is gradually progressing upstream, as the sludge is being removed faster than it accumulates.

It is the accumulation of sludge which is one of the most baneful effects of untreated sewage. The septic bottom putrifies under conditions of anaerobic decomposition, producing substances toxic to fish life and obnoxious to men. The formation fo sludge in the great rivers is accelerated by erosion and silting. The fine soil particles pick up the sewage particles by adhesion, and carry them down to form a slowly decomposing sludgy mud of high organic content. This suffocates the useful bottom life, and in decomposing makes the overlying water less fit for fish life, or for human use and enjoyment.

Incomplete treatment of sewage is a poor ideal. It is at best an alleviative and not a cure. The make-shift of merely ponding sewage rich in organic wastes is particularly unsatisfactory. Anaerobic decomposition will set in, producing a local nuisance and at times discharging an effluent into the stream which may be more toxic than the original raw sewage. Then accidents occur. An innocent muskrat may bore his tunnel through the retaining dike. No little Dutch boy being handy to plug the hole, the whole contents of the retianing pond may be discharged into the stream. The flood of toxic waters then rushes downstream, cleaning out the whole stream of its fish life. This is not mere theory. It has happened a number of times in our own state. For instance, once in 1921, the dike of the retaining pond of the sugar plant at St. Louis broke out, resulting in the wiping out much of the fish fauna of the Pine River.

The utility of through sewage treatment is now obvious. It produces no noxious sludge deposits. The oxidized wastes virtually eliminate oxygen loss in the stream, prevent the excess accumulation of carbon dioxide and other products of aerobic decomposition, and eliminate the more obnoxious products of anaerobic decomposition. The larger part of the nitrogen, phosphorus, potassium and other desirable fertilizing elements are retained in the effluent of the treatment plant. And the nitrogen and phosphorus are added in the oxidized and soluble form of nitrates and phosphates, which are directly utilizable by the water plants. These in turn support the animal life on which the fish feed. The fish can spawn on the cleaner bottom or in the weed beds, according to their way, the young fish will find weeds in which to seek shelter and the minute organisms on which they grow, and the larger fish will find the larger food which they prefer. The treated sewage is thus turned into creased fish production.

The thorough treatment of sewage also eliminates the unsightly solids which, floating by, disgust the stream-side visitor. It eliminates the putrifying sludge, with its obnoxious appearance and odor. The water retians its oxygen, so that the organic matter remaining is disintegrated by anaerobic decomposition, thus avoiding the production of the unsaturated compounds, like hydrogen sulphide, which are so obnoxious. The pathogenic bacteria are sufficiently destroyed to make the waters safe again for boating and swimming and much more satisfactory for city water supply.

Thus the interests of better fishing are dovetailed with other recreational interests, and with property values, Summer cottages will spring up along the purified streams away from the cities, and in and near the cities the stream side property will be available for better homes. A comparison of the home-site values along the Red Cedar just above East Lansing and along the Grand below Lansing will suffice to show that the elimination of pollution has a real dollar value.

But perhaps even more important than the increased economic values which result from complete sewage treatment, are the increased recreational values. A beautiful stream-side park in a city can serve mankind more significantly even though less concretely than a mere increase in monetary wealth. Our strained and industrialized people need recreation in increasing amount. Where can man enjoy a day more pleasantly than along a beautiful stream, chosen trysting place of the young, favorite subject of the artist? And if good fishing be in order, may not the enjoyment of the day be perfect?