A COOPERATIVE APPROACH TO A STREAM POLLUTION PROBLEM IN MASSACHUSETTS

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One of the major problems facing industry today is stream pollution. The rapid expansion of industry following World War II has resulted in increased production, as well as increased quantities of waste waters. In many industrialized areas it has been possible to dispose of the liquid organic wastes into municipal sewers along with the domestic sewage. The combined wastes are treated in the municipal sewage treatment plant before final disposal to the receiving body of water. This type of operation is the ideal solution to industrial waste disposal both from the industrial and municipal standpoint. Each contributes its share of the capital investment and the operating expenses. But as in any ideal solution to waste disposal problems, it can be abused by either or both sides failing to cooperate with one another.

There are many industrial areas where adequate municipal facilities are not available to handle the combined sewage and industrial wastes. These are the areas where the majority of waste disposal problems are occurring. Normally, the liquid organic wastes from the various industrial processes are run directly to a nearby receiving body of water for ultimate disposal. If the organic content of the wastes is small and the dilution in the receiving body of water is large, satisfactory stabilization of the organic matter can take place without the creation of nuisance conditions. On the other hand, if the organic content of the wastes is high and the dilution factor is small, the receiving body is unable to assimilate the organic matter without creating nuisance conditions such as destruction of fish and obnoxious odors. The presence of nuisances of this type leads to complaints from abutting property owners. The complaints are usually referred to the State Health Department for appropriate action. In most states the State Health Department is charged with stream pollution control; but some states have given both the State Health Department and the

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Fish and Wildlife Commission authority over stream pollution depending on whether the problem is one primarily of health or the destruction of fishlife.

Once a nuisance has been created the State Health Department's first job is to determine the source of the problem. A brief stream survey is usually all that is necessary to ascertain the source of the wastes. The industry or industries creating the wastes are notified of the situation and are requested to alleviate the nuisance. It is at this point that most of the misunderstandings between the state officials and the industry result. Oftentimes the State Health Department issues an order that the nuisance is to be eliminated by a certain date and then sits back and waits for the problem to be solved. If the problem has not been solved by that date, the industry usually finds itself facing a court order prohibiting further waste discharges. This can be tantamount to an order closing the plant since the industry cannot operate without producing wastes. Some industries feel that wastes are a natural byproduct of operations and that disposal of these wastes should not be their problem. These industries usually ignore the State Health Department's order or make only a small effort to solve the problem. For the most part, these are delaying tactics since the industry knows that State Health Departments will resort to court orders only after considerable effort has been exhausted in finding an amiable solution. A mild effort towards a solution will usually stall the State Health Department even longer. By playing the game to the hilt, the industry can postpone treatment of their wastes for many years. And by using their trump card of threatening to move to another area of the country, the industry can even scare the politicians into conditions favorable to the industry. Needless to say, both examples are extremes but both reflect the attitudes which have been used in stream pollution problems in various parts of the country. There are various shades of intermediates between these two extremes; but there is only one real solution to stream pollution problems and that is cooperation between industry and state.

When an industry moves into an area, it has something to offer that community. The two major benefits, increased employment and additional taxes, tend to stabilize the community by competing for the local labor force, bringing in additional citizens, increasing the total money in circulation, increasing the demand for consumer goods, increasing the money available for community expansion and capital investments in municipal financing. In return the industry expects something from the community in good municipal government, adequate housing for employees, adequate transportation facilities for employees and for shipping their products to markets, reasonable cost of living and acceptance as being part of the community. The success of the community and its industries is dependent upon their cooperation on all problems. Industrial waste disposal is one of these problems. It does not belong entirely to the industry nor entirely to the community, it belongs to them both. Alone, there can be no satisfactory solution to the problem but together there can be.

An example of excellent cooperation between the State Health Department and industry can be cited for the stream pollution problems existing on the Chicopee River in central Massachusetts. The problems have not all been solved but the pattern for their solution has been set and there is little doubt that the nuisance conditions now being created can be satisfactorily alleviated.

The Chicopee River is formed from the combined flow of the Ware River, the Quaboag River and the Swift River. The Ware River begins north of Barre, Massachusetts, and is joined shortly by the Burnshirt River which has its head waters just over the Massachusetts border in southern New Hampshire. The Ware River meets the Quaboag River just south of Thorndike, Massachusetts, and becomes the Chicopee River. The Quaboag River starts below Brookfield, Massachusetts, and flows past Warren and Palmer before meeting the Chicopee River. The Swift River is made up primarily of water released from Quabbin Reservoir and meets the Chicopee River at Three Rivers, Massachusetts. The Chicopee River flows past Ludlow, Springfield and Chicopee before emptying into the Connecticut River. The drainage area of the Chicopee River covers 688 square miles and yields a two (2) per cent flow of 86 c.f.s. Like most of the rivers in New England, the Chicopee River is dotted with dams which regulate the flow of the river. Many of these dams were built by industries which found that the rapidly flowing Chicopee River offered a good source of power. The Swift River and the Chicopee River fall from an elevation of 530 feet at Quabbin Reservoir to an elevation of approximately 50 feet at the Connecticut River.

The Chicopee River broadens out just east of Chicopee Falls as a result of a dam at Chicopee Falls, Figure 1. The islands help create unusual flow patterns and stagnant areas in the river. It was at this point that nuisance conditions resulted. Additional nuisance conditions also resulted below the dam and along the river to its junction with the Connecticut River. A survey of the Chicopee River and its tributaries by the Massachusetts State Health Department indicated that the small industries located along the upper reaches of the Chicopee River were not making any significant contributions to the nuisance conditions arising around Chicopee and Chicopee Falls. The nuisance conditions below Chicopee Falls were found to be caused by domestic sewage and industrial wastes from Chicopee and Chicopee Falls. This condition will be alleviated by the construction of an in-

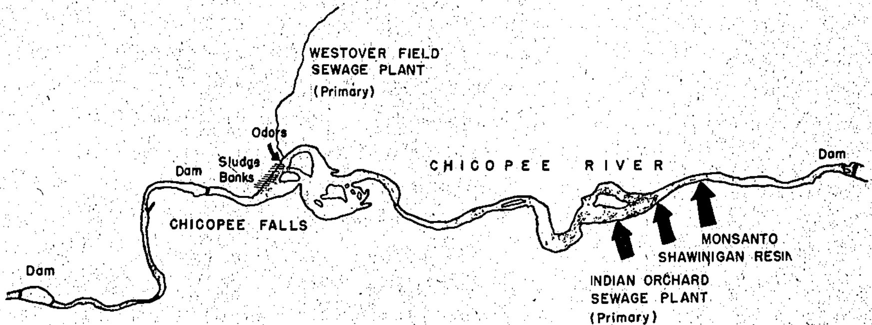

FIG. 1.—MAJOR SOURCES OF POLLUTION ON CHICOPEE RIVER BETWEEN INDIAN ORCHARD AND CHICOPEE FALLS.

tercepting sewer along the Chicopee River and a treatment plant which will discharge its effluent into the Connecticut River. The nuisance conditions above the dam at Chicopee Falls were found to be caused by the industrial wastes from Monsanto Chemical and Shawinigan Resins along with the settled domestic sewage from the Indian Orchard Sewage Treatment Plant. In the summer of 1948, both Monsanto Chemical and Shawinigan Resins were notified by the Massachusetts State Health Department that the discharge of their wastes into the Chicopee River was creating nuisance conditions and that appropriate action should be taken at the plants.

Shawinigan Resins is a subsidiary of Shawinigan of Canada and Monsanto Chemicals; but the Monsanto Chemicals plant and the Shawinigan Resins plant at Springfield are operated as separate divisions. Shawinigan Resins produces plastics from the vinyl chain. Safety glass interlayer and wire insulation enamel are the primary usages of the plastics produced at this plant from the basic raw material of vinyl acetate. The wastes from the various processes contain short chain simple organic compounds resulting from the degradation of vinyl acetate and are almost entirely soluble.

When Shawinigan Resins received notification of pollution of the Chicopee River in 1948, the Research Department took composite samples of all of their waste streams. A portion of the composite sample was neutralized to pH 8.5 with lime and aerated for two hours. A second portion was neutralized to pH 8.5 and aerated for 16 hours. Treated and untreated effluent samples were submitted to the chemist of the Springfield Sewage Treatment Plant for 5-day biochemical oxygen demand (B.O.D.) analyses. The results were as follows:

Sample	*5-Day B.O.D.*
Raw	650 ppm
Neutralized, 2 hours aeration	190 ppm
Neutralized, 16 hours aeration	160 ppm

The data showed promise for a relatively simple chemical treatment of the wastes and was presented to the State Health Department at a meeting later that year. Other methods of treatment were discussed at that meeting. The State Health Department officials suggested that biological treatment on trickling filters might prove satisfactory and offered the assistance of the Lawrence Experimental Station in making preliminary tests.

A sample of wastes from the strongest waste stream was sent to Lawrence and found suitable for biological treatment. The State Health Department suggested that further studies be made at Lawrence and that a pilot plant be built at Shawinigan based on the expected results of the Lawrence experiments. Late in January, 1949, a 50 gallon drum of wastes from the strongest waste stream was sent to Lawrence where lime treatment was found to result in a 50 per cent B.O.D. reduction. The remaining B.O.D. was readily stabilized on trickling filters. In April, 1949, two 50 gallon drums of wastes from other waste streams were sent to Lawrence to try on their trickling filter pilot plants. The State Health Department submitted a report on the Lawrence studies in September, 1949. The report recommended that a trickling filter pilot plant be set up at Shawinigan

Resins in order to determine operating characteristics which could be translated into ultimate design. Since none of the personnel at Shawinigan Resins was familiar with biological treatment methods, the State Health Department offered to advise the Engineering Department on the design and operation of the pilot plant.

By June, 1950, the pilot plant had been designed; the expenditure approved and the materials ordered. The schematic layout of the pilot plant is shown in Figure 2. The translation of the plans into

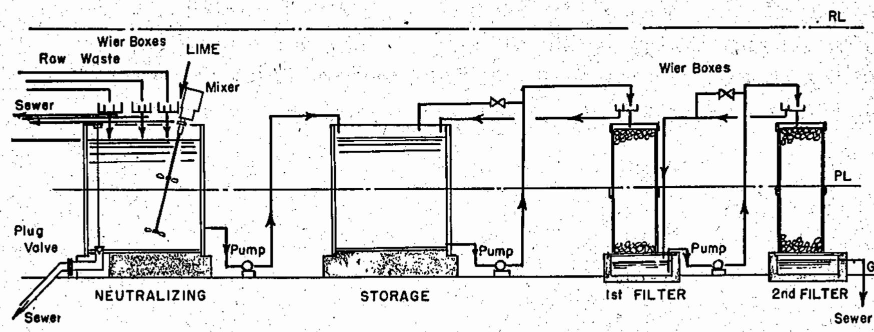

FIG. 2.—SCHEMATIC LAYOUT OF SHAWINIGAN RESINS TRICKLING FILTER PILOT PLANT.

the actual pilot plant was not an easy task and it was June, 1951, before the pilot plant was put into operation. Actually, two pilot plants were built, one having 12 inch trickling filters and the other having 24 inch filters.

The trickling filters were started on domestic sewage obtained from the Indian Orchard Sewage Treatment Plant. After 12 days operation considerable growth had built up on the stones and the filters were ready for plant wastes. The pH of the initial wastes was 3.1 and was adjusted to 6.7 with lime. Ten per cent raw wastes were fed with sewage at the rate of 13.3 M.G.A.D. on the 12 inch filter and 7.7 M.G.A.D. on the 24 inch filter. The filter growth increased rapidly as the load was slowly raised. After 8 days operation the rate of application was cut to 3.2 and 3.3 M.G.A.D. loadings and 100 per cent plant wastes were fed to the filters. As in the case with most pilot plants, troubles developed and it became impossible to obtain wastes from the strongest waste stream. But the filters operated satisfactorily on the remaining wastes. Four days after starting the 100 per cent waste feeding, the rate of application to the 12 inch filter was raised to 7.2 M.G.A.D.

The filters were operated successfully over the next two months with an average influent B.O.D. of 450 ppm and average effluent of 250 ppm on the primary filter and 170 ppm on the secondary filter. The major problem encountered was the tremendous quantity of algae and fungi which overgrew the pilot plant and created an almost continuous maintenance program to keep the filters free and in proper operation. Anaerobic conditions set in during the summer and obnoxious odors were present. In September, 1951, a portion of the strong wastes was added to the filter. After a month's operation cold weather set in and the filters froze.

Based on the data that was obtained on the filters and on strength of the raw wastes, it appeared that loading the filter at an organic load of 0.62 pounds B.O.D. per cu. yd. stone per day and a hydraulic load of 3.2 M.G.A.D. would reduce the strength of the wastes 60 per cent. Shawinigan Resins personnel did not think that this reduction would be adequate and focused attention on a preliminary chemical treatment followed by trickling filters.

Since composite samples of the plant wastes indicated that the wastes entering the Chicopee River contained 9,000 pounds 5-day B.O.D. daily, a study was made to ascertain the source of all of the wastes, their volume and their strength. It was found that the wastes contained ethyl acetate, ethyl alcohol, acetic acid, formaldehyde, butyraldehyde, ammonium hydroxide and sulfuric acid. The enormity of this task was such that it was September, 1952, before the filters were started again. They were acclimated in the same manner as before. While the filters were being acclimated, aeration studies were carried out on the strongest wastes, still house wastes, to determine if the volatile compounds could be stripped out easily. It was found approximately 32 per cent of the 5-day B.O.D. of the "B" still wastes could be removed by aeration and that an over-all efficiency of 89.6 per cent removal was possible by combined aeration and filtration.

The pilot plant had not operated on composite samples of the entire plant wastes and efforts were made to obtain continuous samples of all the waste streams during the summer of 1953. The acid content of the wastes rapidly corroded pipes and pumps while slime growths tended to clog them. It was never possible to obtain proper samples and after considerable frustration, the pilot plant was abandoned.

In the spring of 1954, Shawinigan Resins decided to hire Rolf

Eliassen Associates as biological consultants to determine the most economical treatment for their wastes. Studies conducted during the summer of 1954, showed that the wastes contained approximately 1090 ppm 5-day B.O.D., approximately the same organic concentration as in 1951. The total organic content as measured by the chemical oxygen demand test (C.O.D.) averaged 1910 ppm. The wastes contained ample nitrogen but were deficient entirely in phosphorus since the sanitary sewage was diverted to the Indian Orchard Sewage Treatment Plant. The pH of the wastes ranged from 2.5 to 4.2. Treatment of the raw wastes by plain aeration or by lime as used in the earlier studies resulted in only slight B.O.D. reductions.

Laboratory activated sludge units were used to study aerobic treatment of the wastes. A two stage aeration unit with a 30 hour aeration period was able to give better than 90 per cent B.O.D. reduction. The system was extremely stable to overloading, showing decreased efficiency at 100 per cent shock overload but rapidly recovering if the high loading persisted or if it were reduced. The mixed liquor suspended solids were maintained at approximately 1500 ppm in the first unit and approximately 4000 ppm in the second unit. A batch-fed activated sludge unit operated on a 24 hour cycle, 23 hours aeration and one hour's settling, using 1:1 diluted wastes produced an effluent under 40 ppm B.O.D. with 6400 ppm mixed liquor solids. Wasting one-third of the mixed liquor suspended solids daily to simulate high-rate activated sludge dropped the mixed liquor suspended solids to an equilibrium of 450 ppm at the start of the aeration period. The efficiency of B.O.D. removal dropped from 97 per cent to 80 per cent. These experiments showed that activated sludge treatment of the wastes should be able to produce an effluent of 50 ppm B.O.D. for ultimate disposal in the Chicopee River.

Anaerobic digestion studies were carried out on the sludge produced in the aeration studies. The excess activated sludge was readily digested at 37° C in a batch-fed digester with a 10 day retention period. Digestion of the raw process wastes was tried and found quite successful with a 10 day retention period. The gas yield at this loading was almost equal to theoretical. Efforts to shorten the retention period to more practical limits resulted in loss of activity in the digester.

While the laboratory studies were primarily carried out on activated sludge systems, the results indicated that either of the two common aerobic treatment systems, activated sludge or trickling filters would be satisfactory. Cost analyses showed that a capital investment of between $600,000 and $1,000,000 would be necessary for either system. The large quantity of recirculation required on the trickling filters tended to offset the cost of the aeration equipment in the activated sludge system.

In October, 1954, a meeting was held at the Massachusetts State Health Department in Boston to present the work to date and to plot future action. Emphasis was placed on trickling filters rather than activated sludge as the best method for biological treatment since the filters required lower maintenance and absorbed shock loads more readily. It was suggested that trickling filter pilot plant studies be made to confirm the suggested design criteria. It was also suggested that Shawinigan Resins make a reevaluation of all their processes to determine if it were not possible to reduce the total waste discharge. The State Health Department undertook the task of making stream surveys on the Chicopee River to determine the relative share of pollution caused by Shawinigan Resins and to determine the river's capacity for absorbing organic matter.

Examination of the chemical processes by Shawinigan Resins failed to show where waste reductions could be made more economically than by biological methods. Plant expansion during the year actually resulted in stronger wastes and prevented the Engineering Division from setting the Shawinigan Resins trickling filter pilot plant in operation. Instead, Rolf Eliassen Associates was retained to make the filter study. Two filters were studied, one with 2 to 3 inch stone media and one with tile media. The filters were two stage filters with intermediate and final sedimentation. Each stage was three feet deep. Recirculation of final effluent was used to reduce the organic concentration on the first stage. Both filters were designed for a hydraulic loading of 20 M.G.A.D. and an organic loading of 2 pounds B.O.D. per cubic yard filter media. Initial waste samples indicated a relatively large increase in the strength of the wastes. In order to get an accurate sample of wastes, Shawinigan Resins personnel made a 1000 gallon composite of all of their plant wastes over a week's operation. Analyses of this composite showed 2030 ppm 5-day B.O.D., 3160 ppm C.O.D., 140 ppm total nitrogen and pH 2.4. It appeared that the B.O.D. of the wastes had doubled in a year's operation.

Optimum efficiency for the filters resulted at 98 per cent for the tile filter and 96 per cent for the rock filter at a raw waste loading of 1.4 pounds B.O.D. per cu. yd. filter media. A 18:1 recirculation ratio was required. Efforts to raise the loading on the filters were fairly successful. The rock filter gave 94 per cent efficiency at 1.8 pounds B.O.D. per cu. yd. with 9.5:1 recirculation ratio and dropped only to 78 per cent at 3.9 pounds B.O.D. per cu. yd. The tile filter operated at 98 per cent efficiency at 3.9 pounds B.O.D. per cu. yd. with a 10:1 recirculation ratio and dropped only to 90 per cent at 5.0 pounds B.O.D. per cu. yd. Although the efficiency of operation was high at these loadings, septic conditions resulted in the filters and H_2S was noticeable. The demand for oxygen far exceeded the filter's ability to supply it. It appears that nuisance odors will be the primary limiter for filter loadings.

When it became obvious that the trickling filters would be larger than originally estimated, a modified activated sludge system was set up to overcome the objections of high maintenance and shock loadings. The system was designed to operate on the principle "endogenous metabolism", i.e. complete oxidation of the wastes aerobically. Equilibrium was reached at a mixed liquor suspended solids concentration of 17,500 ppm with a 90 hours aeration period and an oxygen uptake rate of only 18 mg. per liter per hour. The effluent B.O.D. was estimated at 20 ppm. Optimum operation occurred during growth of fresh solids rather than during endogenous metabolism. The mixed liquor suspended solids were 22,800 ppm and increasing rapidly with two-thirds of the B.O.D. going into fresh solids. An effluent B.O.D. of 58 ppm was produced in 21 hours aeration and the oxygen uptake rate of the sludge was only 36 mg per liter per hour. Translating the pilot plant data into design criteria and making cost estimates of the high rate trickling filter and the modified activated sludge system resulted in the following figures:

High rate trickling filters	$1,500,000
Modified activated sludge	$ 400,000

In August, 1955, State Health Department personnel began the survey of the Chicopee River. Just as the study was getting under way, floods washed the survey out. A second flood in October prevented a further attempt this year. Even though it was not possible to make the survey as planned, it was possible to make a reasonable estimate as to the river's ability to assimilate organic matter. Examination of U. S. Geological Survey records shows that the flow of the Chicopee River is controlled by a power dam a short distance above the Monsanto Chemicals Plant. During periods of low flow the dam is closed from midnight to six a.m. on weekdays and all day Sunday. In spite of this 30 to 100 cfs manage to pass. At six a.m. the dam is opened and the flow is adjusted to the power demands. The dam at Chicopee Falls below the industrial plants in question tends to absorb the flow variations by backing the river up. It is obvious that the wastes will flow rapidly down to the dam at Chicopee Falls since the river drops 50 feet in about four miles between the two dams. The dam prevents rapid discharge of the river and it is here that the critical oxygen conditions result. While the exact amount of organic matter which can be assimilated by the Chicopee River below Shawinigan Resins has not been determined, the nature of the river prevents adsorption of much organic matter. The critical portion of the river lies in a quiescent zone where there is little chance for reaeration.

The pollution problem on the Chicopee River has not been solved at this time but a start to its solution has been made. The two industries primarily responsible for the pollution problem have recognized the problem and by a cooperative effort with their own consultants and the Massachusetts State Health Department have made an effort to alleviate the situation. It has not been an easy problem and there have been many false solutions. It has taken seven years to find a satisfactory method for treating the wastes from Shawinigan Resins, for an entire new field had to be learned. Old concepts had to be discarded and new ones found. The lessons learned from this example of cooperation between industry and state offer the real solution to stream pollution problems.

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