FACTORY EFFLUENTS FROM THE METTUR CHEMICAL AND INDUSTRIAL CORPORATION LTD., METTUR DAM, MADRAS, AND THEIR POLLUTIONAL EFFECTS ON THE FISHERIES OF THE RIVER CAUVERY.*

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(*With Eight Tables and one Map.*)

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INTRODUCTION.

With the increased industrialization of the country, the part that chemical works and other similar industrial concerns play in the reduction of food supplies from fisheries, is becoming more and more pronounced. The toxic effluents from the different industries like chemical works, paper mills, artificial silk factories, sewage works, beet sugar factories, food canning factories, etc., which are generally discharged into the national waterways, are polluting vast stretches of natural waters rendering them uninhabitable for fish life. With the realization of the dangers of this pollution and the consequent destruction of tons of edible food fish, it has become a necessity to devise ways and means for the safe disposal of these industrial wastes. In India, while the problem is still not very acute, the few contributions already existing on the subject (Hora, 1942; Hora and Nair, 1944; Malden, 1943 among others) and the country's comprehensive industrial programmes are sufficient warnings for having careful vigilance on the nature and extent of pollution of the major rivers which besides affording very lucrative fisheries, sustain the almost entire tank fisheries in India by supplying fish seed.

The Godavari, the Kistna, the Thungabhadra and the Cauvery are the major rivers of Madras; and of these, the Cauvery alone fetches over two-thirds the total revenue from inland fisheries in the province. In the present communication an

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instance of pollution of the river Cauvery and the consequent large-scale mortality of food fishes, particularly in a conserved area, is discussed at length.

The factory effluents from the Mettur Chemical and Industrial Corporation, Mettur Dam, are polluting the river Cauvery at Mettur and cause large-scale mortality of fish. It is evident that if this practice is allowed to continue unchecked, the fisheries of one of the major rivers of the province will be seriously jeopardized sooner or later. Remedial measures have therefore to be promptly taken up in the interests of preservation of valuable food and game fish. The efficient and economical method of disposal of the factory effluents, depending upon their nature and local conditions is thus an urgent necessity. A detailed investigation of this biochemical problem was therefore carried out for three years (1945 to '48), and the results obtained, with certain recommendations for the future, are presented in the succeeding pages.

Mettur Chemical and Industrial Corporation, Ltd., Mettur Dam.

(a) *Location*: (Fig. 1. Map).

The factory is located very close to the Mettur reservoir at a fairly high level at the foot of a hillock which has a natural slope towards the Ellis surplus course. The area surrounding the factory is of a rocky nature. The nearest place where the factory effluents can be discharged is the reservoir, but the effluents will have to be pumped. The Ellis surplus course is also closely situated and because of the natural slope towards it the wastes can be easily discharged into it by gravitational flow. The rocky nature of the surrounding land precludes the possibility of disposal of the effluents on land.

(b) *The Factory Effluents :*

Quantity.—A fair·idea of the quality and quantity of the pollutional wastes could be formed from the following list of the important products manufactured by the concern:

Caustic soda, bleaching powder, vanaspati, refined oil and bleach liquor.

It is obvious that waste products from sections producing caustic soda, bleaching powder and bleach liquor are likely to render the greatest harm to fish and other animal life. The approximate total quantity of the wastes emanating from the chemical works is estimated on an average at 10,000 gallons of liquid per day; but a much higher quantity, as many as 23,000 gallons per day, of the wastes will be produced when the plants are working at maximum capacity.

Quality.—Samples of the effluents have been examined and the results of a typical analysis are given in Table I. The carbonates and chlorides of calcium and sodium are found to be the dominant salts in the effluents. The large amounts of caustic alkalis and the excess of suspended matter are, no doubt, deleterious to fish life.

Weekly analyses of the factory effluents were carried out for over a year (April, 1946 to June, 1947) for studying the variations in the most important harmful substances such as hydroxide, carbonates, free chlorine and combined chlorine; and the range of variations and the monthly averages of these are furnished in Table II. The hydroxide content varies from 1·36 to 75·3 parts; carbonates (expressed as CO_3) from 0·8 to 27·53 parts; free chlorine from nil to 19·6 parts and total chloride chlorine from 31·5 to 424·8 parts per 100,000.

Welles (1915) found that fishes do not thrive in highly alkaline waters, but become sluggish and inactive. 'Salts present in excess or without the proper antagonistic salts or ions, and salts not commonly present in quantity in freshwater are toxic to freshwater animals' (Ward and Whipple, 1918). Carbonates are not essential to the life of fishes and when present alone, are rapidly fatal because of their alkalinity. It is also known that the presence of an excess of calcium causes the tail fins of certain species of fish to degenerate and also tend to lower the metabolic activity of organisms.

EFFECT OF THE FACTORY EFFLUENTS ON THE WATER AND FISH IN POOLS FORMED IN THE ELLIS SURPLUS COURSE DURING DIFFERENT SEASONS OF THE YEAR.

Figure 1 illustrates clearly the location of the Stanley reservoir, the Mettur dam, the course of the Cauvery in the area, the Ellis surplus channel and the series of rock pools formed therein, in relation to the Chemical factory discharging effluents. The surplus course runs almost parallel to the river course, amidst large rocks and joins the main river at Kollanayagampatty, about three miles below the dam. The entire surplus course, from the point of view of pollution, may roughly be divided into two sections; the first, from the Ellis bridge down to Mattathuparai, and consisting of five almost continuous pools, and the second, from Mattathuparai (indicated by the line XY in Fig. 1) to the confluence with the main river and consisting of another set of six pools. Pools 2 to 5 of the first section which are smaller and are located at a comparatively higher level are inter-connected and are directly polluted by the factory effluents. The first pool is situated slightly above the point of discharge of the effluents and is therefore not ordinarily contaminated. The pools in the second section are bigger and deeper and are at a lower level than the first set of pools. These pools are not directly contaminated by the effluents.

The factory effluents from the Mettur Chemicals flow by gravity through a meandering channel (Fig. 1) in the rocky ground for about a furlong and are discharged into the nearest pool in the surplus course. As the toxic effluents accumulate they flow into the neighbouring pools and pollute them. Pools 2 to 5 are most affected and during the non-surplussing months the water in these pools turns whitish with the accumulation of the effluents and is absolutely unsuitable for fish life.

With the construction of the Mettur dam across the river Cauvery the natural highway for the fishes from the lower reaches to the upper is cut; the flow of water through the high and low level supply channels and the power house turbines being of tremendous velocity the fishes are seldom found to negotiate these successfully and migrate to the reservoir. However, when the level of water in the reservoir reaches 100 feet the Ellis surplus begins to function, when the fishes are able to freely migrate upstream and thus overcome the barrier of the dam. The economically important carps and catfishes of the Cauvery breed during the rainy months, June to August and October to December. Depending upon the annual rainfall in the catchment area of the reservoir and the source of the river, the period of surplussing of the Ellis channel varies, and the migration of fishes for breeding purposes directly depends on the period during which the surplus channel functions. The following table gives the period during which the surplus functioned for the years 1945 to 1948:

Year.	*Dates on which surplussing commenced.*	*Dates on which surplussing stopped.*
1945	.. 1-1-1945	20-1-1945
1946	.. 8-8-1946	31-12-1946
1947	.. 1-1-1947	13-2-1947
1947	.. 1-6-1947	20-6-1947
1947	.. 27-8-1947	26-11-1947
1948	.. 26-7-1948	7-11-1948

Since during their upstream migrations thousands of fish (the major carps *Catla catla, Cirrhina cirrhosa, Labeo kontius, L. fimbriatus, L. calbasu, Labeo* sp., *Barbus dubius, B. carnaticus, B. hexagonolepis*, etc. and the catfishes *Mystus seenghala, M. aor, Wallagonia attu, Pangasius pangasius, Silonia silondia*, etc.) congregate in the supply channels and the Ellis surplus course, a three miles stretch of the river, from the Mettur dam downwards has been declared a conserved area. The necessity for ensuring free movement of fish through the Ellis surplus course is thus obvious and any pollution of the waters in this only natural highway for the migration of brood fish is to be considered most seriously.

In the present instance, while the steady, year-round discharge of the effluents into the river system may have a cumulative effect on the waters, their pollutional effects are felt only during the summer months when the surplus channel does not function. The conditions of existence in the rock pools in the surplus course were studied both during the 'non-surplussing' as well as the 'surplussing' periods and the effects of the factory wastes on the fishes observed. The physico-chemical conditions of the wastes during the different seasons are furnished in Table III.

The effluents as they flow from the effluent pit in the factory to the surplus channel, undergo certain changes. The suspended solids largely settle down at the bottom of the drain and by the time they reach the surplus course, generally appear as a more or less clear fluid. When water overflows in the surplus channel, the effluents get readily diluted and except in the immediate vicinity of the point of discharge, the characteristic whitish discolourization of water is not seen. Chemical analysis of water samples also show that only the first pool is appreciably affected during this period (Table III, A). The very low chloride contents in samples from the first three pools clearly indicate the enormous dilution of the pollutants. The fishes are apparently not affected then by the pollutional discharges, and shoals of them could be seen migrating upstream. Several specimens of *Barbus carnaticus, B. filamentosus* and *Xenentodon cancila* were found in the immediate vicinity of the point of discharge of the effluents; and no dead fish were observed during this period.

With the fall in level of water in the reservoir, the flow in the surplus course also decreases. The conditions of existence in the surplus pools were studied during the last stage of overflow from the reservoir, for 6 days, from 18th to 23rd November, 1947 (III-A). The surplus course ceased to function on 26-11-1947. On 18th November, the level of water in the reservoir was 106·95 feet and 23,143 cusecs of water were overflowing. By 23rd November the level had come down to 100·35 feet, when only 17,437 cusecs of water were overflowing. The above flow was quite sufficient to dilute the toxic effluents and render them harmless for fish life. The biological conditions were more or less similar to the former period of full overflow and shoals of fish were moving upstream (Table IV-A). The first pool which received direct discharge of the effluents, was, however, avoided by fishes. The high alkalinity of water in this pool is to be attributed as the reason for this behaviour of fish.

With further fall in the reservoir level and the cessation of overflow through the Ellis surplus, the deep rock pools become isolated, and the thousands of carps and catfishes that were struggling to negotiate the torrential flow, get trapped in them. The neighbouring pools are connected together only by a meandering flow through narrow streamlets. With the steady accumulation of the toxic effluents, the hydrological conditions in the pools soon become absolutely unsuitable for fish life and large-scale mortality of the trapped fish takes place generally within a week or ten days after the surplus has stopped functioning (Tables III-B and IV-B). Even though this has become more or less a regular annual feature, no effective rescue operations like collecting the fish and releasing them into the reservoir, etc., are feasible since the rock pools are very deep, with steep sides and accessible only with difficulty. Thus the number of fish destroyed is very large and the significance of this is increased severalfold when it is remembered that the fish trapped are mainly carp breeders and fingerlings. With the continued accumulation of the effluents the entire fish population in the first four pools is destroyed (*vide* Table IV-C and D).

A critical examination of the data furnished in Table III will show that the presence of toxic substances like free chlorine and hydroxide is mainly responsible for the mortality of fishes. When there is overflow through the surplus course free chlorine and hydroxide are absent in pools 2 to 5, but soon after flow of water stopped in the surplus channel, these toxic substances began to increase in all the pools and reached lethal proportions in a week's time. It is also seen that even with continued stagnation, lethal amounts of the toxic substances are present only up to the fifth pool and not beyond. However, during advanced periods of stagnation, the toxic substances undergo certain fluctuations probably due to the process of mixing, sunning and sedimentation and occasionally the free chlorine and hydroxide contents are diluted. A thick whitish slimy deposit of lime covering almost the entire bottom surface of the pools is characteristic during these periods of stagnation.

A general picture of the biological conditions of the polluted pools is obtainable from Table IV. As already stated, during the period of overflow, due to the excessive dilution of the effluents the fishes are not adversely affected. The rocky beds of the pools are almost bare without supporting any considerable algal growth, probably because of the torrential flow of water. Plankton is also very poor under the lotic conditions. With the fall in level of water, when lentic conditions prevail in the pools, algal growth is appreciable, but the first two pools are so surcharged with the toxic effluents that they do not support any plankton growth. Detailed observations (*vide* Table V) made on 26-6-1947, six days after the overflow through the surplus had stopped, show that fish life was absent in the first three pools, while in the 4th and 5th pools some fish were still present. Water in the latter pools was greenish in colour, mainly due to thick growth of *Oscillatoria*. Insect life was not very plentiful, though specimens of *Nepa* (with a white encrustation on the body) were seen swimming even in the first pool which received direct discharge of the effluents. Chironomid larvae were common in the marginal slimy encrustations. An uncontaminated pool (marked 'A' in Fig. 1 and item 8, Table V) above the point of discharge of the effluents, contained abundant fish life (*Cirrhina cirrhosa*, *C. reba*, *Labeo kontius*, *L. fimbriatus* and *Barbus carnaticus* were the dominant species) and no mortality had taken place in this pool. With continued stagnation and accumulation of effluents the conditions of existence in the first set of pools become more and more rigorous. Special observations made on 21st and 26th February, 1948 (*vide* Tables VI and VII) about three months after the surplus flow of water had stopped, indicate that while fish are still absent in pools 1 to 4, a large number of them were found in the fifth pool. Water in pools 3 to 5 was bluish-green or green in colour and a thick growth of *Oscillatoria* was characteristic. Dark, floating masses of this alga were numerous in pools 3 and 4. Several frogs could also be seen but no fish could either be seen or netted. In the shallower portions of the three pools (3 to 5) thousands of aquatic oligochaetes (Tubificids) could be seen and these rendered the bottom appear reddish in places. Their chloride contents are also considerably higher. Dissolved oxygen in the water (sample taken at noon on a bright sunny day) varied from 'nil' in pool 3 to 1·9 c.c. per litre in pool 5 (Table VII). The very low oxygen content and the abundance of worms at the bottom indicate excessive organic decomposition. Phytoplankton was not very rich and was represented in fifth pool by *Anabaena*, *Pediastrum* and *Pleurococcus* in the order of abundance. Zooplankton was fairly rich, consisting mainly of copepods (*Cyclops*) and rotifiers (*Polyarthra*). *Barbus carnaticus* was the dominant species of fish while few specimens of *Labeo kontius* were also present. Ripe males, 8″ to 9″ in length, were common in the former species, while all the Labeos were of the fingerling stage.

The biological conditions of the pools (Nos. 6 and 8 in Table VII) in the second section of the surplus course, adjoining the fifth pool of the first section, offer interesting contrast. No mortality of fish had taken place in these pools and shoals of large fish, *Cirrhina cirrhosa*, *Labeo kontius*, *B. carnaticus*, *Labeo calbasu*, *L. fimbriatus*, *Labeo* sp., smaller barbels like *B. filamentosus* and fingerlings of *L. kontius*, *Labeo* sp., *B. carnaticus* and *C. reba* in hundreds could be seen in the surface waters, while the frequent scattering of these shoals by the violent movements of some larger fish clearly indicated the presence of predators like *Wallagonia attu* *Mystus seenghala* and *Silonia silondia.* As is clear from Table VIII the harmful effects of the pollutants are not felt in these pools and even in advanced periods of stagnation (20th March, 1948, i.e. about 4 months after the overflow had stopped) free chlorine and hydroxide are generally absent. Their chloride contents are also comparatively lower. An abundance of plankton (zoo-plankton dominating) in spite of the presence of a rich fish crop, and the moderately high *p*H and dissolved oxygen values indicate the greater organic production in these pools as compared to the polluted ones.

Experimental Observations :—

The physiological responses of the fishes to varying concentrations of the factory effluents were studied under laboratory conditions and the results are tabulated below.

No.	Fish experimented.	Size in inches.	Proportion of effluent to Corporation water.	*p*H.	Parts per 100,000.		Fate of fish.
					Free Cl_2.	Chloride.	
	A. Control						
1.	*Catla catla* .. *Etroplus suratensis* *Rasbora daniconius*	4·0 3·0–4 2·0	Corporation water only.	7·2	nil	10·4	All alive till end of experiment.
2.	Do. ..	do.	Factory effluent alone	>9·6	0·8	460·0	Instantaneous death.
	B. Dilutions						
3.	*Catla catla* .. *Etroplus suratensis* *Rasbora daniconius*	do.	1 : 1	>9·6	0·6	235·2	All died in 5 minutes.
4.	Do. ..	do.	1 : 10	9·2	0·4	51·27	Do.
5.	Do. ..	do.	1 : 50	9·0	Trace	19·20	All died in 20 minutes.
6.	Do. ..	do.	1 : 100	8·6	Do.	14·85	All died in 6 hours.
7.	Do. ..	do.	1 : 1000	8·0	nil	10·84	All alive after 8 hours.

It is evident from the above that the three species of fish representing the major carps (*Catla catla*), the semi-exotic perch (*Etroplus suratensis*) and the carp minnow (*Rasbora daniconius*) were able to survive for over 8 hours in dilutions of about 1 : 1000, while in 1 : 100 dilution all of them succumbed within 6 hours. It is likely that the death of fish was due to the presence of free chlorine in the diluted samples.

A second series of experiments, using the top minnow *Gambusia affinis*, was therefore carried out to find out the lethal doze of free chlorine. Using bleaching powder containing 30·5% of available chlorine, chlorine-water was prepared such that 0·164 ml. of the solution was equivalent to 1·0 p.p.m. of chlorine. Seven beakers, each containing 500 ml. of pond water were arranged and three fish, 1·5″ to 2·0″ in length, were introduced in each. Varying volumes of chlorine water, as detailed hereunder, were added to the beakers of which one was kept as control. The following results were observed:—

No.	*Chlorine-water added.*	*Duration.*	*Fate of fish.*
1.	93·75 p.p.m.	3 minutes.	All died.
2.	62·50 ,,	5 ,,	1 died.
		15 ,,	2 died.
3.	18·80 ,,	15 ,,	1 ,,
		18 ,,	1 ,,
		20 ,,	1 ,,
4.	12·50 ,,	23 ,,	1 ,,
		30 ,,	1 ,,
		40 ,,	1 ,,
5.	6·25 ,,	90 ,,	3 ,,
6.	1·00 ,,	2 hours.	All alive.
7. Control.	Nil.	2 ,,	,, ,,

It therefore appears that *G. affinis* is able to withstand 1 p.p.m. of chlorine in pond water. In the factory effluents free chlorine content has been found to vary from nil to 196 p.p.m., an amount that is more than double the doze that caused death of *Gambusia* in three minutes. The free chlorine content of the effluents is really high and is not ordinarily met with in any drinking water.

Attempts at Disposal of Wastes.

With a view to find out effective remedial measures to check this annual heavy toll on the Cauvery fisheries attempts were made to neutralize the toxic effluents and dispose of them in such a manner as to be innocuous to fish life. Three methods were tried as follows:

(a) *Neutralization with Hydrochloric Acid :*

This method was tried by the factory authorities on their own initiative, since the required acid was being manufactured in the factory itself. They aimed at producing a neutral effluent with no trace of free chlorine, by installing an acid vessel from which pre-determined quantities of acid were allowed to mix continuously with the effluents as they were pumped out from the settling tank. However, the results of examination of the wastes before and after one such acid treatment showed that in more than 50% of the samples handled the hydroxyl (OH) alkalinity was still present as also traces of free chlorine, and the pH of the samples was as low as 5·7. From the economic aspect the cost of treating 1,000 gallons of the effluents in the above manner amounted to Rs.3.

A sample of the effluents, treated as above, was used to find out whether fish could thrive in it for any length of time. Using the reservoir water as control, it was found that fingerlings of *C. cirrhosa* and *C. reba*, 4 inches in length, died within 15 minutes when placed in a sample of the treated effluents. The low *p*H and the presence of caustic alkali and appreciable quantities of free chlorine (Trace to 0·2 parts per 100,000) were probably responsible for the death of fish.

(b) *Recovery of the Effluents by utilization for water purification purposes.*

The effluents contain appreciable quantities of caustic lime, free chlorine, chloride chlorine, fat, etc. Lime and free chlorine are two important substances generally used in water purification. The former is ordinarily used for increasing the alkalinity of presedimentation waters before coagulation with alum as is now being done at Trivandrum, Bangalore and Mettur water-works. Houston's 'Excess lime' method of purification of river waters is also based on the same method. Chlorine is used in all water-works for the final disinfection of purified waters before distribution to a town's water supply.

In the present instance the excessive chloride chlorine and fat contents of the effluents might be objectionable for their use in water purification. The waste oils and fats mixed in the effluents could, however, be prevented from mixing with those from the alkali and other sections by suitable device. Laboratory experiments were therefore carried out with the effluents to ascertain the minimum amount of the wastes required for purifying raw river water from the Cauvery. Samples of river water were treated with the effluents at the rate of 0·5, 1·0, 1·5, 2·0 and 2·5 grains of calcium oxide (CaO) per gallon of water, and then with one grain of alum. A sample treated at the rate of 0·5 grains of CaO per gallon was analysed at the King Institute, Guindy, Madras, and was reported: 'Colourless and clear and appeared to be of very good quality from the chemical point of view.'

Finding that the effluents could thus be utilized for water purification purposes, it was necessary to ascertain whether all the effluents could be used locally. The 'Mettur Chemicals' are using about 0·17 million gallons of water daily for industrial and domestic purposes. If this water is to be treated with the effluents at the rate of 0·5 grains of CaO per gallon, the quantity required will be only 11% of the total effluents produced, the bulk of which will therefore remain undisposed.

The suspended solids in the effluents are now being trapped in large settling tanks inside the factory and occasionally discharged outside. The solids contain 60 to 70% of calcium oxide, but is relatively valueless as lime, owing to the presence of other constituents like basic salts of calcium chloride, etc.

(*c*) *Dilution.*

The possibility of effective dilution of the effluents before discharging into the reservoir, so as to bring down the caustic alkalinity within harmless limits to fish life, was considered, since plenty of water is always available (drought years excepted) in the nearby reservoir and since electrical energy at cheap rates is also available for pumping sufficient water to dilute the wastes. The effluents were diluted in the ratio of 1 : 9, 1 : 99, 1 : 999 and 1 : 9999, under laboratory conditions and the diluted samples were examined for their alkalinity, chloride chlorine and *p*H. It was found that 1 : 99 dilution of the wastes was most economical and safe from the point of view of alkalinity, chloride and *p*H, but the dilution experiments with Corporation tap water have already shown that even in 1 : 100 dilutions fishes could not survive for more than six hours. The cost of pumping 1,000 gallons of the effluents, together with water from the reservoir for the different rates of dilution was ascertained as follows:—

Dilution.	*Cost in Rupees.*
1 : 9	0·38
1 : 99	3·80
1 : 999	38·00
1 : 9999	380·00

The maximum daily discharge of 25,000 gallons of the effluents, if to be diluted in the ratio of 1 : 99, would thus cost about Rs.95 per day (approximately Rs.30,000 per annum). An attempt was therefore made to dilute the effluents in the ratio of 1 : 10 on a large scale in the process rooms by pumping raw water from the reservoir. The hydroxide alkalinity of the diluted samples was, however, found to be harmful to fish life and was therefore considered unfit for discharge into the Ellis surplus course.

Discussion of Results and Recommendations.

The effluents from the Mettur Chemical and Industrial Corporation, Ltd., Mettur Dam, Madras, are essentially liquids containing a high percentage of suspended solids due to calcium carbonate and fatty substances. They are also noxious due to the presence of free and caustic lime and free chlorine, but are potentially valuable on account of the presence of about 70% of lime (CaO). However, no recovery and treatment plants for CaO have so far been set up by the factory authorities, either because they tend to be costly or because pure calcite (96·0 to 98·0% CaO) is easily available in enormous quantities and at cheap rates from a neighbouring locality called Sankaridrug. The effluents were therefore being merely discharged into the nearby Ellis surplus course which serves as the overflow channel for the Stanley reservoir when its water level rises above 100 feet. But, as already detailed, the Ellis surplus course is a conserved area for the fisheries of the Cauvery and is the only natural highway for the spawning migrations of the economically important major carps of the river. It is also seen that so long as there is regular and continuous flow of water through the Ellis regulator, the fishes are unaffected by the effluents discharged into the channel; that when once the overflow is stopped, eleven pools of different sizes are formed in the bed of the channel; that the first five pools, extending from the Ellis bridge to Mattathuparai receive direct discharge of the effluents, resulting in total mortality of all fish life in at least the first four pools, and constitute the zone of pollution; and that the second set of six pools extending from Mattathuparai to the confluence of the channel with the main river, forms the zone of recovery. The accumulation of caustic alkalis and free chlorine in the water has been found to be the cause of mortality of fish trapped in the pools. The series of laboratory experiments carried out showed that even if the effluents are diluted with 100 times water, traces of hydroxide and free chlorine were still present and proved lethal to fish within six hours. Attempts were therefore made to find out some satisfactory method of disposal of these toxic effluents. The presence of considerable quantities of lime and free chlorine in the effluents made the same potentially valuable; and laboratory experiments showed that these wastes could be used for water purification purposes. It is therefore worth while to ascertain whether the raw water treated with the effluents would come within the standards of quality and purity generally set for a drinking water supply; and if so whether treatment and recovery plants for the effluents will be economically feasible. While it has been shown that the total daily requirements of water for industrial and domestic purposes of the 'Mettur Chemicals' will utilize only 11% of the effluents for purification purposes, the bulk of these industrial wastes could probably be disposed off if the Mettur and Salem town water supplies are also to be purified by using the same. If this is found a workable proposition, it will then be required to devise means to prevent the wastes from the alkali plants from mixing with those from the oil refining sections.

While recovery of the effluents for useful purposes, if feasible, is the best means of disposal, in the present instance the easy availability of pure calcite in sufficient quantities in the neighbourhood might render attempts at setting up recovery plants uneconomical from the company's point of view. Dilution of the wastes and thus rendering them innocuous to fish life would therefore seem to be the safest method now feasible and this can be effected by pumping the required quantity of raw water from the reservoir into the factory where the effluents are stored, and later diluting them in the ratio of 1 : 99 before discharging into the Ellis surplus channel. However, as already shown, this will involve some recurring expenditure and also will not ensure absolute immunity for the trapped fish since the diluted effluents will be accumulating in the pools when the overflow stops in the surplus channel. Viewing the whole problem from the financial and practical aspects it is suggested that the effluents be taken by pipes to a place in the main river, below the in-take for the Mettur water works where the constant flow of water from the tail-race of the power house will ensure thorough mixing and dilution of the wastes. The lowest rate of flow from the tail-race is about 10,000 cusecs. Even at this rate of flow the maximum daily discharge of about 25,000 gallons of the effluents into the river will effectively be diluted over 5,000 times, so that no harm will be caused to the fishes in the area. The proposed site where the effluents may be discharged into the river is indicated in Figure 1. The effluents are to be taken by hume pipes from the factory, along the Ellis bridge and discharged into the main river. Since the level of the Ellis bridge is slightly higher than that of the effluent pit, it may be necessary to pump the effluents periodically.

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Summary.

Since the construction of the Mettur dam it has become an annual feature that a series of connected rock pools are formed in the bed of the Ellis surplus course when the water ceases surplussing. Thousands of carps and catfish are then entrapped in these pools. The factory effluents from the Mettur Chemical and Industrial Corporation are at present discharged into these pools. These effluents consist of an excessive amount of dissolved and insoluble solids, chlorides and free chlorine, and are highly alkaline due to the caustic lime used in the manufacture of bleaching powder. Since the pools are stagnant, the addition of these toxic wastes pollutes the waters and invariably results in large-scale mortality of the trapped fish, during summer months. With the Ellis surplus functioning, the pools overflow and the pollutional wastes are considerably diluted and rendered harmless to fish life.

With a view to prevent this annual mortality and the consequent depletion of fish stock in the conserved area, the conditions of the pools were investigated at different seasons during the years 1945 to 1948. While biotal life was not altogether absent in the polluted pools even under extreme summer conditions, those receiving direct discharge of the wastes and the neighbouring ones, with their offensive odour of caustic lime and free chlorine, were totally unfit for fish life of any kind.

Chemical treatment of the effluents and dilution before letting into the pools proved ineffective and uneconomical. The potential value of the effluents for purposes of water purification has been shown by laboratory experiments, and their recovery for the said purpose may be worth while if the bulk of the effluents could be disposed off in that manner. Since excessive dilution appears to be the easiest method to render the effluents innocuous, diverting the same to the main river to a spot close to the tail-race of the Mettur Power House has been suggested.

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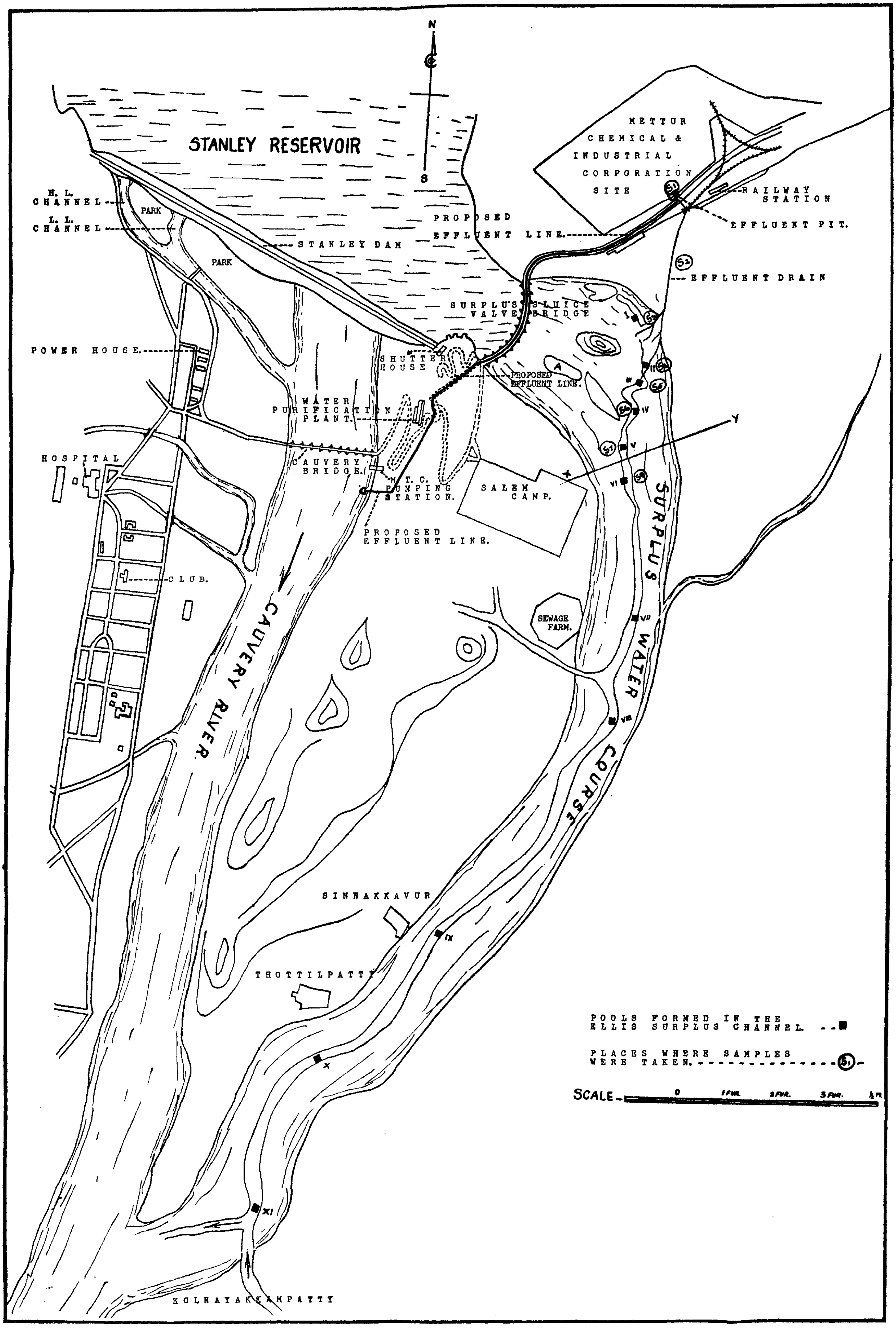
N
S
STANLEY RESERVOIR
METTUR CHEMICAL & INDUSTRIAL CORPORATION SITE
RAILWAY STATION
EFFLUENT PIT.
H. L. CHANNEL
L. L. CHANNEL
PARK
PARK
PROPOSED EFFLUENT LINE.
STANLEY DAM
EFFLUENT DRAIN
SURPLUS SLUICE VALVE BRIDGE
POWER HOUSE.
SHUTTER HOUSE
PROPOSED EFFLUENT LINE.
A
WATER PURIFICATION PLANT.
HOSPITAL
CAUVERY BRIDGE.
M. T. C. PUMPING STATION.
SALEM CAMP.
X
Y
PROPOSED EFFLUENT LINE.
CLUB.
SEWAGE FARM.
CAUVERY RIVER
SURPLUS WATER COURSE
SINNAKKAVUR
THOTTILPATTY
KOLNAYAKKAMPATTY
POOLS FORMED IN THE ELLIS SURPLUS CHANNEL.
PLACES WHERE SAMPLES WERE TAKEN.
SCALE
0
1 FUR.
2 FUR.
3 FUR.
½ M.

APPENDIX I

TABLE I.

The Results of a complete analysis of a Sample of the Effluents.

Date of Collection, 26th March, 1948.

(Results expressed in parts per 100,000.)

A. *Physical :—*

1.	Appearance	Turbid.
2.	Colour	Nil.
3.	Odour	Nil.
4.	Turbidity	4·2.
5.	Sediment	0·82 ($CaCO_3$).
6.	Reaction	Alkaline (*p*H 10·20).

B. *Chemical :—*(After filtering the sample.)

Determinations made :

1.	Total solids (dried at 100°C.)	199·23
2.	Alkalinity (as $CaCO_3$)	29·00
3.	Silica (as SiO_2)	1·26
4.	Oxide of Iron and Alumina	0·032
5.	Iron (as Fe)	Nil.
6.	Lime (as CaO)	38·30
7.	Magnesia (as MgO)	Nil.
8.	Manganese (as Mn)	Nil.
9.	Free Lime	29·00
10.	Free Soda	3·00
11.	Sulphates (as SO_3)	Traces.
12.	Chlorides (as Cl_2)	84·80
13.	Nitrates (as KNO_3)	Present.
14.	Free CO_2	Nil.
15.	Free Cl_2	0·20
16.	Total Hardness	40·18

Hypothetical Combinations :

1.	Calcium carbonate	17·80
2.	,, sulphate	Nil.
3.	,, chloride	9·90
4.	Magnesium carbonate	Nil.
5.	,, sulphate	Nil.
6.	,, chloride	Nil.
7.	Sodium carbonate	12·00
8.	,, sulphate	Traces.
9.	,, chloride	136·77
10.	Potassium nitrate	Traces.
11.	Silica	1·26
12.	Fe_2O_3 and Al_2O_3	0·082
13.	Combined water	Nil.

TABLE II.

The monthly averages and range of variations of the alkali and chlorine contents of the untreated effluents from the Mettur Chemical and Industrial Corporation, Ltd., Mettur Dam.

(Period: April, 1946 to June, 1947.)

(Results expressed in parts per 100,000.)

Period. April '46–June '47.		Alkali.			Chlorine.	
		OH.	CO_3.	Total.	Free.	Chloride.
April, 1946	Average. Range.	28·58 8·6–75·3	. . . .	28·58 8·6–75·3	3·23 Nil-4·9	180·58 122·5–246·0
May, 1946	Average. Range.	11·86 3·4–22·6	. . . .	11·86 3·4–22·6	0·48 Nil–2·4	210·7 131·4–420·0
June, 1946	Average. Range.	27·06 2·2–47·6	12·5 12·0–13·0	31·45 15·2–47·7	1·4 Nil–5·6	219·72 71·0–424·8
July, 1946	Average. Range.	15·08 1·36–34·0	7·73 3·0–18·0	22·81 6·16–52·0	0·71 Nil–2·4	263·3 31·5–560·0
August, 1946	Average. Range.	21·18 1·7–51·2	8·2 3·0–24·0	29·38 4·7–75·2	3·76 Nil–8·4	175·0 84·0–490·0
September, 1946.	Average. Range.	13·76 7·8–22·6	3·6 1·2–6·0	17·36 9·0–28·6	0·82 Nil–2·1	100·33 35·0–161·0
Dec., 1946	Average. Range.	11·0 7·1–15·6	2·0 1·2–3·0	13·0 8·3–18·0	2·45 Traces–5·3	135·13 38·5–252·0
Jan., 1947	Average. Range.	14·16 8·4–25·6	2·48 1·2–6·2	16·64 10·0–31·8	2·0 Traces–5·2	134·4 86·0–256·0
Febr., 1947	Average. Range.	15·75 6·5–37·4	10·21 0·8–27·53	25·96 9·2–41·57	6·92 Traces–13·82	86·1 64·0–94·0
March, 1947	Average. Range.	25·53 12·4–30·4	3·48 0·8–5·5	29·01 13·2–34·0	1·9 Traces–7·6	141·1 48·4–296·0
April, 1947	Average. Range.	16·18 5·8–25·8	2·76 1·1–5·8	18·94 7·3–31·2	4·92 Nil–15·2	153·8 115·0–210·0
May, 1947	Average. Range.	17·42 12·4–20·8	2·28 0·8–5·4	19·70 13·2–26·2	3·36 Nil–13·0	222·8 162·0–258·0
June, 1947	Average. Range.	15·7 12·4–21·3	3·33 1·7–6·2	19·03 14·8–24·5	5·75 Nil–19·6	177·5 128·0–264·0

Table III.

*Physico-chemical conditions * of the Series of Polluted pools in the Ellis Surplus Course, Mettur Dam, during different phases of overflow and stagnation.*

(Results expressed in parts per 100,000.)

Period	Samples. No.	Samples. Location.	Colour.	Smell of	Temp. °C.	Free CO_2	Hydroxide. Range.	Hydroxide. Average.	Carbonates. Range.	Carbonates. Average.	Bicarbonates. Range.	Bicarbonates. Average.	Total Alkalinity. Range.	Total Alkalinity. Average	pH.	Free Chlorine. Range.	Free Chlorine. Average	Chloride chlorine. Range.	Chloride chlorine. Average	Total chlorine. Range.	Total chlorine. Average
(A) Period of overflow; pools connected—November, 1947.	1	Effluent pit in the factory premises	Whitish	Chlorine	40·7	Nil	Nil–14·3	7·39	1·2– 6·0	3·84	Nil–7·32	1·46	3·75–17·9	12·27	>9·6	Nil–7·8	1·84	..	170·0	46·0–175·0	99·4
	2	Effluent drain—midway to surplus course	Do.	Do.	34·2	Nil	Nil–78·2	20·05	3·0–12·0	5·4	Nil–2·44	0·488	5·44–90·2	25·94	>8·8	Nil–17·0	4·75	..	100·0	28·4–119·0	65·3
	3	First pool receiving direct discharge of effluents	Do.	Do.	28·8	Nil	Nil–4·93	1·43	1·2– 7·8	5·4	Nil–9·76	2·43	6·50–12·73	9·26	>9·6	Nil–25·6	5·58	..	40·0	8·5–99·4	47·92
	4	Second polluted pool	Pale, greenish	Nil	29·4	,,	Nil	Nil	Nil–1·8	0·72	8·54–11·0	10·02	10·34–11·0	10·62	8·7	Nil	Nil	..	1·6	2·13–3·90	2·96
	5	Third polluted pool	Do.	Nil	28·8	,,	Nil	Nil	Nil–3·0	0·66	10·37–12·2	11·03	10·67–15·2	11·69	8·7	Nil–0·35	0·07	..	1·0	..	2·45
	6	Fourth polluted pool	Do.	Nil	28·0	,,	Nil	Nil	Nil–0·3	0·12	9·7–12·2	10·92	10·00–12·2	11·16	8·7	Nil	Nil	..	1·0	1·8–3·9	2·34
	7	Fifth polluted pool	Do.	Nil	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
(B) Period of commencement of stagnation; a week after overflow had stopped. 28-11-1947 to 6-12-1947.	1	Effluent pit in the factory premises	Whitish	Chlorine	..	..	Nil–39·0	17·47	Nil–3·6	0·72	Nil	Nil	..	..	..	Nil–31·0	7·97	..	..	..	..
	2	Effluent drain—midway to surplus course	Do.	Do.	31·2	Nil	Nil–16·3	4·76	Nil–4·8	2·76	Nil–12·2	2·94	4·36–21·1	10·46	8·4	Nil–80·0	16·78	..	38·0	17·8–192·0	76·12
	3	First pool receiving direct discharge of effluents	Do.	Do.	29·4	0·858	Nil–1·50	0·48	Nil–4·8	2·76	Nil–17·0	4·14	3·6–17·0	7·38	6·3	Nil–39·0	16·42	..	42·0	26·2–99·3	71·5
	4	Second polluted pool	Whitish green	Do., faint	27·8	2·20	Nil–3·2	0·64	Nil–2·4	0·48	Nil–21·3	14·62	5·6–21·3	15·74	7·0	Nil–28·0	5·96	..	32·0	31·5–121·0	60·33
	5	Third polluted pool	Green	Nil	28·6	0·418	Nil–1·02	0·204	Nil–4·8	3·36	Nil–17·1	9·3	5·82–21·3	12·86	7·8	Nil–26·6	9·42	..	60·0	41·2–90·7	75·8
	6	Fourth polluted pool	Do.	Nil	29·8	1·485	Nil–1·5	0·3	Nil–4·8	3·12	Nil–14·1	6·48	5·4–14·1	9·9	7·1	Nil–21·0	9·65	..	54·0	48·6–115·0	84·36
	7	Fifth polluted pool	Do.	Nil	29·8	1·353	Nil–0·5	0·1	Nil–3·0	0·78	3·5–17·1	12·78	3·5–17·1	13·66	7·2	Nil–7·1	1·83	..	46·0	33·7–79·7	65·66
(C) Period of stagnation; two months after overflow had stopped—February, 1948.	1	Effluent pit in the factory premises	Whitish	Chlorine	40·2	Nil	Nil–204·0	34·8	2·4–30·0	11·74	Nil	Nil	5·8–234·0	46·53	>9·6	0·71–15·2	5·02	..	..	29·1–993·0	223·54
	2	Effluent drain—midway to surplus course	Do.	Do.	30·4	..	Nil–165·0	32·26	Nil–24·0	11·23	Nil–11·0	2·08	9·0–189·0	45·6	>9·6	Nil–24·8	3·89	..	..	25·5–482·0	165·6
	3	First pool receiving direct discharge of effluents	Do.	Do.	28·6	..	Nil–12·2	3·64	Nil–12·0	4·94	Nil–15·0	2·14	2·7–18·2	10·87	9·4	Nil–44·0	10·89	..	..	59·6–496·0	167·4
	4	Second polluted pool	Whitish green	Do., faint	27·4	..	Nil	Nil	Nil	Nil	13·2–18·3	16·01	13·2–18·3	16·01	9·6	Nil	Nil	..	..	53·3–79·7	71·64
	5	Third polluted pool	Do.	Do., faint	29·0	0·469	0·7–12·2	4·76	4·8–11·4	6·77	Nil	Nil	5·5–17·6	11·53	7·5	0·36–18·4	7·97	..	..	63·9–231·0	141·44
	6	Fourth polluted pool	Green	Nil	28·8	0·741	Nil–8·3	3·2	Nil–6·6	4·7	Nil–15·2	3·2	3·8–18·2	10·07	7·5	Nil–10·5	2·93	..	..	99·3–234·0	143·1
	7	Fifth polluted pool	Do.	Nil	29·0	1·346	Nil	Nil	Nil	Nil	10·3–17·0	13·31	10·3–17·0	13·3	7·3	Nil	Nil	..	..	114·0–142·0	125·74
(D) Period of advanced stagnation; immediately before commencement of overflow—July, 1946.	1	Effluent pit in the factory premises	Whitish	Chlorine	..	..	Nil–26·7	8·03	Nil–6·78	3·08	Nil–15·7	8·29	13·77–31·02	19·4	8·8	Nil–2·31	0·65	9·41–226·0	59·74	..	..
	2	Effluent drain—midway to surplus course	Do.	Do.	..	..	Nil–26·03	6·85	1·23–12·3	8·38	Nil–32·0	7·03	13·01–34·05	22·26	9·4	Nil–32·7	6·77	24·1–145·0	89·66	..	..
	3	First pool receiving direct discharge of effluents	Do.	Do.	..	..	Nil–13·63	4·24	4·93–13·6	8·14	Nil–1·25	0·25	6·85–21·65	12·63	>9·6	Nil–1·38	0·41	15·4–89·2	44·12	..	..
	4	Second polluted pool	Pale Whitish	Do., faint	..	..	Nil–14·13	9·45	1·23–16·02	6·9	Nil–14·4	2·88	9·04–25·81	19·23	9·4	Nil–3·0	0·83	36·9–151·0	86·5	..	..
	5	Third polluted pool	Yellowish green	Do.	29·6	0·505	Nil–1·4	0·28	Nil–5·55	1·36	Nil–30·7	16·43	6·95–30·7	18·07	8·3	Nil–0·23	0·05	68·5–104·7	85·1	..	..
	6	Fourth polluted pool	Bluish green	Nil	29·6	0·954	Nil	Nil	Nil	Nil	30·1–37·6	34·74	30·10–37·6	34·74	7·7	Nil	Nil	61·0–84·7	74·16	..	..
	7	Fifth polluted pool	Do.	Nil	29·2	0·353	Nil	Nil	Nil	Nil	..	20·13	..	..	7·3	Nil	Nil	..	89·0	..	..

* Showing the average and Range of variations of 5–7 observations.

Table IV.

Biological conditions of the series of polluted pools in the Ellis Surplus Course, Mettur Dam, during different phases of Overflow and Stagnation.

	Samples. No.	Samples. Location.	Phytoplankton.	Zoo-plankton.	Macro-flora.	Macro-fauna.	Fish Life present.
(A) Period of overflow: pools connected.	1	First pool receiving direct discharge of effluents.	Nil.	Nil.	Nil.	Nil.	*B. carnaticus*; *B. filamentosus*; *X. cancila*; *Danio* sp.
	2	Second polluted pool.	Stray specimens of *Pediastrum*, *Synedra*, *Chroococcus* and *Oscillatoria*.	*Diaptomus*—few. *Moina* (?)— „	Nil.	Chironomid Larvae on marginal encrustations.	All carps and Catfishes in large numbers.
	3	Third polluted pool.	Ditto.	Do.; *Cyclops*.	Nil.	Ditto.	Ditto.
	4	Fourth polluted pool.	Ditto.	Ditto.	Nil.	Ditto.	Ditto.
	5	Fifth polluted pool.	Ditto.	Ditto.	Nil.	Ditto.	Ditto.
	6	Uncontaminated pool near Ellis bridge.	Ditto.	Ditto.	Nil.	Ditto.	Ditto.
	7	—	—	—	—	—	—
(B) Period of commencement of stagnation; a week after overflow had stopped.	1	First pool receiving direct discharge of effluents.	Nil.	Nil.	Nil.	Stray specimens of *Nepa*.	Nil.
	2	Second polluted pool.	Nil.	Nil.	Nil.	*Nepa*; aquatic beetle; Frogs.	Nil.
	3	Third polluted pool.	*Oscillatoria*, *Nitzschia*.	*Cyclops*—few.	Nil.	*Nepa*, corixid bugs, Chironomid larvae.	Nil.
	4	Fourth polluted pool.	*Oscillatoria*, *Navicula*.	Ditto.	Nil.	Ditto.	Few specimens of *C. cirrhosa*, *L. kontius*, *B. carnaticus*.
	5	Fifth polluted pool.	*Oscillatoria*, *Pediastrum*, *Scenedesmus*; *Navicula*.	*Cyclops*, *Diaptomus*, *Ceriodaphnia*, *Polyarthra*.	Nil.	Ditto., Snails, Frogs.	Plenty; all Cauvery Carps.
	6	Uncontaminated pool near Ellis bridge.	*Microcystis*, *Oscillatoria*, *Anabaena*, *Nitzschia*, *Scenedesmus*.	*Difflugia*, Nematodes; *Polyarthra*, *Cyclops*.	Nil.	Insect life—plenty. Frogs. Snails common.	Ditto.
	7	—	—	—	—	—	—
(C) Period of stagnation; two months after overflow had stopped.	1	First pool receiving direct discharge of effluents.	Nil.	Nil.	Nil.	*Nepa*, Frogs.	Nil.
	2	Second polluted pool.	Nil.	Nil.	Nil.	Do. Chironomid larvae.	Nil.
	3	Third polluted pool.	*Oscillatoria*, *Anabaena*. *Navicula*.	*Cyclops*.	Nil.	Ditto.	Nil.
	4	Fourth polluted pool.	Do.; *Pediastrum*, *Euglena*.	Do.; *Diaptomus*, *Moina*(?); *Noteus*.	Thin mats of *Spirogyra* at the shallows.	Ditto. oligochaete *stylaria*(?)	Nil.
	5	Fifth polluted pool.	*Oscillatoria*, *Pediastrum*; *Scenedesmus*; *Fragillaria*	*Cyclops*; *Diaptomus*, *Ceriodaphnia*; *Triarthra*.	Ditto.	Ditto. few snails.	*L. kontius*, *Labeo* sp., *Danio* sp., *B. carnaticus*. *C. reba*.
	6	Uncontaminated pool near Ellis bridge.					
	7	—	—	—	—	—	—
(D) Period of advanced stagnation; immediately before commencement of overflow.	1	First pool receiving direct discharge of effluents.	Nil.	Nil.	Nil.	Nil.	Nil.
	2	Second polluted pool.	Nil.	Nil.	Nil.	Nil.	Nil.
	3	Third polluted pool.	Floating black masses of *Oscillatoria*.	*Cyclops*: *Moina* (?) *Pedalion*.	Nil.	Bottom, in patches, covered by Tubificid worms. Insects, Frogs.	Nil.
	4	Fourth polluted pool.	Do.; *Navicula*, *Synedra*.	Ditto.	Thin mats of *Spirogyra*.	Ditto.	Nil.
	5	Fifth polluted pool.	Do.; *Anabaena*, *Pediastrum*, *Pleurococcus*; *Scenedesmus*; *Crucigenia*, *Oedogonuim*, *Fragillaria*.	*Cyclops*, *Diaptomus*, *Ceriodaphnia*, *Noteus*, *Polyarthra*.	Ditto.	Ditto.	7" to 8" sepcimens of *B. carnaticus*.
	6	Uncontaminated pool near Ellis bridge.					
	7	First pool of the second section.	*Scenedesmus*, *Pediastrum*, *Oscillatoria*, *Schizothrix*, *Westella*, *Caelastrum*, *Navicula*, *Fragillaria*, *Amphora*.	*Cyclops*, *Diaptomus* (Swarms) *Ceriodaphnia*; *Moina*, *Brachionus*, *Noteus*, *Triarthra*.	Nil.	Insect life—plenty. Snails common.	Large specimens and fingerlings of *C. cirrhosa*, *L. kontius*, *B. carnaticus*, *C. reba*, *L. calbasu*, *L. fimbriatus*, *Labeo* sp.; and catfishes.

TABLE V.

Showing the Hydrobiological conditions of the pools polluted by the Factory effluents in the Ellis Surplus Course, on 26th June, 1947.

Serial No.	Description.	Time A.M.	Physical.			Chemical—parts per 100,000.							Biological.		
			Colour.	Smell.	Temp. °C.	Free CO_2.	CO_3	HCO_3	*p*H	Dissol. oxygen. C.C./L.	% sat.	Chloride Cl_2.	Presence or absence of fish.	Other animals.	Dominant plankton.
1	From the effluent channel before discharging into the first pool in E.S.C.	9·15	Whitish	Nil	31·2	Nil	1·20	32·530	8·4	..	..	38·0	Nil	Nil	Nil.
2	From the upper end of the first pool in E.S.C. where effluents enter.	9·00	Whitish green.	,,	29·1	0·198	Nil	25·315	7·4	3·490	61·9	12·0	Present	Present	Nitzschia* Oscillatoria.
3	From the lower end of the 1st pool ..	9·10	,,	,,	29·4	0·858	,,	4·270	6·3	5·304	94 3	42·0	Absent	Nil	Nil.
4	From the lower end of the 2nd pool ..	9·30	Brown	,,	27·8	2·20	,,	55·205	7·0	Nil	..	32·0	..	Frogs	,,
5	From the lower end of the 3rd pool ..	9·40	Green	,,	28·6	0·418	,,	11·590	7·8	4·467	78·4	70·0	Absent	Nil	,,
6	From the lower end of the 4th pool ..	9·45	,,	,,	29·8	1·485	,,	17·385	7·1	0·279	4·9	54·0	Some	,,	,,
7	From the lower end of the 5th pool ..	10·00	,,	,,	29·8	1·353	,,	17·080	7·2	0·489	8·7	46·0	Present	Present	Microcystis Oscillatoria.†
8	A separate pool 'A' near the Ellis bridge, never contaminated by the effluents.	8·45	Dark green	,,	29·0	0·198	,,	22·570	7·9	6·142	100·8	2·0	,,	Present	Do.

Date of stoppage of overflow from the reservoir—20-6-1947. Rate of discharge of factory effluent—16,000 gallons per day.

* Pediastrum, Cyclops, Polyarthra. † Anabaena, Nitzschia, Difflugia, Nematode worms.

TABLE VI.

Showing the Hydrobiological conditions of the pools polluted by Factory effluents in the Ellis Surplus Course, Mettur Dam, Madras. No flow from the reservoir. A trickling flow from one pool to another. 21st February, 1948.

Serial No.	Description.	Time A.M.	Colour.	Physical.		Chemical—parts per 100,000.								Biological.		
				Smell.	Temp. °C.	Free CO_2	CO_3	HCO_3	OH	*p*H	Chloride	Dissol. oxygen C.C./L.	% sat.	Fish	Other organisms.	Dominant plankton.
S_1	Factory effluents—sampled just outside the factory	11·15	Whitish	Chlorine	40·2	Nil	204·0	..	130·0	>9·6	340·0	..	..	Nil	Nil	Nil.
S_2	Factory effluents—Midway between S_1 and their entry into Pool 1	11·00	,,	,,	30·4	,,	316·0	..	95·0	>9·6	270·0	..	..	,,	,,	,,
S_3	From the first pool in E.S.C.	10·40	,,	Nil	28·6	,,	3·3	2·44	..	9·4	160·0	..	..	,,	,,	,,
S_4	From the second pool in E.S.C. ..	10·30	Bluish	,,	27·4	,,	9·0	..	2·0	9·6	170·0	..	..	,,	,,	,,
S_5	From the third pool in E.S.C.. ..	10·20	Pale green	,,	29·0	0·449	..	13·42	..	7·5	180·0	..	..	,,	Frogs.	,,
S_6	From the fourth pool in E.S.C. ..	10·15	,,	,,	28·8	0·741	..	15·555	..	7·5	220·0	..	..	,,	,,	,,
S_7	From the fifth pool in E.S.C.	10·00	,,	,,	29·0	1·346	..	15·555	..	7·3	123·0	..	..	,,	,,	,,
S_8	From an uncontaminated pool near the bridge in E.S.C.—'A'	9·40	Yellowish green.	,,	28·2	Nil	0·9	11·285	..	8·5	1·5	5·600	68·2	Plenty	,,	Oscillatoria Microcystis.*

* Closterium, Nitzschia, Scenedesmus, Nostoc, Pandorina.

TABLE VII.

Showing the Hydrobiological conditions of the Pools not directly polluted by Factory effluents in the Ellis Surplus Course, Mettur Dam, Madras, on 26th February, 1948. No flow from the reservoir into Ellis Surplus Channel.

Serial No.	Description.	Date.	Time A.M.	Physical.			Chemical—Parts per 100,000.								Biological.		
				Colour.	Smell.	Temp. °C.	Free CO_2	CO_3	HCO_3	OH	*p*H	Chlorides	Dissol. oxygen. C.C./L.	% sat.	Fish	Other organisms.	Dominant plankton.
S_1	From Pool No. 3 ..	26-2-48	11·30	Bluish green	Nil	29·6	0·505	Nil	14·340	..	7·5	124·0	Nil	..	Nil	Nil	..
S_2	,, No. 4 ..	,,	11·20	Pale green	,,	29·6	0·954	,,	18·610	..	7·2	124·0	0·419	7·4	,,	,,	..
S_3	,, No. 5 ..	,,	10·45	Dark green	,,	29·2	0·853	,,	20·130	..	7·3	89·0	1·955	34·6	Plenty	Present	Microcystis
S_4	,, No. 6 ..	,,	10·20	,,	,,	30·0	0·797	,,	22·570	..	7·85	73·0	3·630	65·1	,,	,,	,,
S_5	,, No. 8 ..	,,	10·50	Yellow green	,,	29·4	0·505	,,	21·350	..	7·90	73·0	3·630	64·3	,,	,,	,, Oscillatoria.

TABLE VIII.

Results of analysis of samples of water taken from the eleven pools in the Ellis Surplus Course: Date 20th March, 1948—about 4 months after overflow in the surplus channel had stopped.

(Results expressed in parts per 100,000.)

Sample Number	Location.	OH.	CO_3.	HCO_3.	Chloride.	Total solids.	Free Cl_2.
1	First pool in the Ellis Surplus Course where the effluents fall.	Nil	Nil	12·0	98·15	170	Nil
2	Second Do. ..	13·94	12·0	Nil	305·8	652	"
3	Third Do. ..	0·68	6·0	"	105·9	164	"
4	Fourth Do. ..	Nil	Nil	10·98	105·9	238	"
5	Fifth Do. ..	"	"	19·52	120·8	246	"
6	Sixth Do. ..	"	"	23·18	77·91	130	"
7	Seventh Do. ..	"	"	28·06	35·72	96	"
8	Eighth Do.	"	"	29·28	35·72	152	"
9	Ninth Do. ..	"	"	26·84	35·72	128	"
10	Tenth Do. ..	"	"	21·96	29·21	158	"
11	Eleventh Do. ..	"	"	23·18	25·97	198	"