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(*Paper No. 3167.*)

"The Purification of Water after its Use in Manufactories."

By REGINALD ARTHUR TATTON, M. Inst. C.E.

DURING the last few years a large amount of work has been carried out for preventing pollution of the rivers of Lancashire, Cheshire, Yorkshire and other counties, as the result of pressure brought to bear on local authorities and manufacturers by the Rivers Boards constituted under Section 14 of the Local Government Act of 1888. Until this Act was passed the Rivers Pollution Prevention Act of 1876 had been little enforced, the reason being that an authority, in order to obtain a conviction against an offender on the river above and outside its own district, had to prove specific pollution by that offender within its district; this, in the highly polluted condition of the rivers, was as a rule impossible. Under the new Act a Board can be formed, by order of the Local Government Board, with power to deal with a large area, and to treat alike all offenders within that area. Two Boards have been formed in Lancashire and Cheshire, the Mersey and Irwell Joint Committee, which deals with the Rivers Mersey and Irwell and their tributaries above Warrington; and the Ribble Joint Committee, which deals with the watershed of the Ribble. In Yorkshire a Board has been formed to deal with the rivers of the West Riding. The formation of the Mersey and Irwell Joint Committee, of which the Author has acted as engineer since it was constituted in 1891, was the outcome of a general feeling in Lancashire and Cheshire that the polluted condition of the rivers was a disgrace and a nuisance, and that it was scarcely possible to improve them under the then existing means for enforcing the Rivers Pollution Prevention Act. The construction of the Manchester Ship Canal, in which the waters of the Irwell were impounded for several days or even weeks in dry weather, rendered the improvement of the rivers a matter of urgency; public meetings were held and application was made by the County Councils of Lancashire and Cheshire to the Local Government Board. A local inquiry was accordingly held at Manchester in December, 1890, and was attended by representatives of the different counties, county boroughs, and other authorities within the area, and also by representatives of the manufacturers. The manufacturers strongly supported the application, and their views were expressed in the following words:—"The manufacturers say that without co-operation between the different bodies and the manufacturers no real improvement would be effected in the rivers. They also submit that individual cases ought not to be taken indiscriminately, or dealt with separately, without some assurance being given that others in the district in competition would be treated on the same principle." The application was granted, and the joint committee was constituted; it is composed of twenty-four members representing the County Councils of Lancashire and Cheshire, and the County Boroughs of Bolton, Bury, Manchester, Oldham, Rochdale, Salford and Stockport.

Population and Rateable Value of District.

——	Population.	Rateable Value.		
		£	s.	d.
Seven county boroughs	1,179,331	5,214,252	5	0
Eleven non-county boroughs	294,677	974,411	13	3
Sixty-two urban district councils	639,620	2,674,721	0	1
Ten rural district councils	122,313	867,623	8	0
	2,235,941	9,731,008	6	4

Number of Factories Discharging Direct into the Streams, and Population on Each of the Main Rivers.

——	Number of Factories.	Population.
Rivers Irwell and Roach	281	1,015,602
River Irk	43	308,786
River Medlock	21	273,550
River Mersey	68	638,003
	413	2,235,941

The early efforts of the joint committee were directed chiefly towards the prevention of pollution by solids, and considerable advance was made; a survey was also undertaken of all the sources of pollution by sewage and trade-waste. It was, however, soon found that the Rivers Pollution Prevention Act of 1876 was in many ways unsatisfactory and difficult of application, and it was resolved to apply to Parliament for further powers. The Bill was opposed by certain of the boroughs and local authorities, but was supported by manufacturers, who from the first expressed the opinion that they would derive benefit from the rivers being improved, and who have as a rule shown great willingness to co-operate with the committee. The Bill was passed and received the royal assent in 1892. During this time the matter was brought before the manufacturers by means of conferences and personal visits to the various works, so that when more active steps were taken later, they had had ample time to make inquiries and to decide on the means they should adopt for the treatment of their waste waters. To this gradual action on the part of the joint committee is no doubt chiefly due the success which has attended their action and the small amount of friction which has been caused.

The following Table gives the number of manufactories in each industry where, in consequence of the polluting character of the waste waters, purification-works are necessary. The respective columns A, B, C, D, give approximately their positions as regards efficiency of treatment.

Class of Pollution.	A. Efficient Works.	B. Works Constructed but not Efficient.	C. Works being Constructed.	D. No Treatment adopted.	Total.
Print-works	31	12	..	..	43
Dye-works	72	29	1	2	104
Bleach-works	44	17	..	2	63
Waste-bleach works	4	6	..	..	10
Paper-works	15	8	..	..	23
Paper-stainers	2	1	..	..	3
Tanners and leather-dressers	6	3	..	..	9
Fellmongers	1	5	..	..	6
Woollen-trades	46	21	..	..	67
Silk-trades	1	2	..	4	7
Slack-washing	8	3	..	..	11
Soap-works	1	4	..	..	5
Stone-polishers	3	3	..	..	6
Chemical-works	10	2	..	..	12
Breweries	3	6	..	3	12
Unclassified	7	22	..	3	32
Total	254	144	1	14	413

The division line between column A and B must necessarily be an uncertain one, and the standard of efficiency is based on a comparison with works in the same industry; but generally, the works in column A are capable, if properly managed, of turning out a satisfactory effluent, whilst those in column B, although intercepting the bulk of the solids, cannot be considered efficient. Amongst the latter are included many works where the available space was too limited to allow of efficient works being constructed.

The progress since 1893 is as follows :—

—	Oct. 1893.	Jan. 1898.
Works with efficient purification-plant	45	254
Works with plant constructed but not efficient.	77	144
Works being constructed	77	1
No treatment adopted	191	14
	390	413

Besides the factories included in these Tables about two hundred and fifty drain into public sewers, and the waste waters are dealt with by local authorities.

The Rivers Pollution Prevention Acts require that "the best practicable and reasonably available means" shall be adopted, and therefore more complete and efficient works can be required when the factory is situated in the country, with plenty of vacant land around, than when it is surrounded by buildings with little or no land on which to construct works. Of the works which have been selected for description two are situated where ample space could be obtained, and the third is an instance of the necessity of utilizing a restricted area of available ground. During the last few years various improved methods have been introduced for treating trade-waste by mechanical filtration after precipitation: some of these arrangements require little space, are easily cleansed, and at any rate remove the suspended solids: and they may be found very useful in cases where space for larger works cannot be obtained.

Bleach, Dye and Finishing Works of Messrs. R. Clay & Sons, Cheadle, Cheshire.

The processes carried on at these works are those of ordinary bleaching, dyeing, and finishing. Logwood and aniline dyes with mordants are used, and the waste waters consist of the contents of the exhausted dye-becks and wash-waters from the dyeing department and of the contents of the kiers and wash-waters of the bleaching department; they ordinarily amount to 300,000 gallons per day, but when there is a press of work and the bleachcroft is kept working all night, to 500,000 gallons. The whole of this waste is treated. It is collected in a chamber on the north side of the brook, Fig. 1, Plate 1, and flows thence by a trough and pipes to the chamber A, where milk of lime is added by means of a trough and mixer, B; from this chamber the water flows through 18-inch pipes to the inlet-channel, in which a screen is fixed at C, and thence to precipitation-tank No. 1. Blocks of "aluminoferric"[1] are placed in the channel near the screen to assist precipitation. Where lime is used together with another precipitant, it is important that it should be allowed to thoroughly mix with the water before the other precipitant is added. Tank No. 1 is allowed to fill, and then the water passes by an overflow, D, into tank No. 2, and thence by an overflow, E, into tank No. 3. A large amount of sludge is collected in this series of tanks, so that when the water reaches the pumps which lift it to the high-level tanks Nos. 5, 6, 7, it has been freed from a portion of its suspended solids. When No. 3 tank is nearly full, the engines working the centrifugal pumps in the engine-house are started, and the top water is drawn from the tanks through 8-inch pipes to the engine-house and is forced along an 8-inch rising main to the inlet-channel of the high-level precipitation-tanks, where aluminoferric is again added as a precipitant. From the inlet-channel the water flows into the tanks Nos. 5, 6 and 7, which are used in rotation. Each of these tanks has a capacity of 90,000 gallons and takes about 3 hours to fill; 5 hours or 6 hours are allowed for settlement. When clear, the water is drawn off by means of the automatic floating outlets, F, to the filter-beds, which are composed of 6 inches of fine ashes and 12 inches of rough clinkers, with 4-inch tile-drains below, leading into the 15-inch outlet-main, which discharges through an outlet-chamber into the brook; the effluent water is clear, and of a pale straw-colour which is imperceptible in the brook a few yards

[1] The following analysis of "Aluminoferric" is furnished by Messrs. Peter Spence & Sons:—

	Per cent.
Al_2O_3	14·0
Fe_2O_3	0·6
Free SO_3	0·4
Combined SO_3	34·1
Total insoluble	0·1
Water	50·5

below the outlet. The sludge from the high-level tanks is removed after each filling, and is discharged by 9-inch earthenware pipes to tank No. 4, which is kept as a sludge-tank for the high-level precipitation-tanks. At the end of each week the water in tanks Nos. 1, 2 and 3, is allowed to settle for about 5 hours, and is then drawn off by floating arms to filter-bed No. 1, through which it passes to the outlet-chamber. The sludge from tanks Nos. 1, 2, 3 and 4, is discharged by valves, and 12-inch pipes into a well, H, 16 feet deep, from which it is pumped by a centrifugal pump, worked by a gas-engine, into an overhead trough to the sludge-tank; the top water from this tank is drawn off into the main inlet-channel. The sludge from the tank is drawn off by pipes into the sludge-receivers in the press-house, and is pumped into sludge-presses fixed on the first floor. The solid matter from the presses falls through shoots into wagons, and is removed to a tip; the liquid from the presses is returned to the inlet-chamber for further treatment. Previous to the erection of the presses, the sludge was pumped to the west side of the brook and was deposited in a lagoon, but the quantity was so great that presses became a necessity. The machinery for dealing with the sludge consists of an engine, a 6-inch single-acting air-compressor, worked at 100 lbs. pressure per square inch, and two presses, each containing twenty-four 30-inch plates. The presses perform fourteen pressings daily, but when the tanks are worked at night it is necessary to work the presses also, and then twenty pressings are made. The sludge presses well, and it is not necessary to add lime; each pressing weighs 12 cwt. (of cake) and requires between 20 minutes and $1\frac{1}{4}$ hour; $\frac{3}{4}$ of an hour may be taken as the average time. Two men are sufficient to perform the whole of the work in connection with the tanks, engines and sludge-pressing machinery, with two additional men when working at night. Cleaning the filters is an extra item, though not of large amount; but before long it will be necessary to cart away the pressed cake to a field some distance from the works; £50 a year has been assessed as the probable cost of this.

The average composition of sludge as it passes to the presses is:

	Per cent.
Solid matter	4·37
Water	95·63

The composition of the pressed cake taken on an average of twelve pressings is:

	Per cent
Solid matter	28·55
Water	71·45

The cost of the works was as follows :—

	£
Tanks and filters with all connections, pipes and drains inside the factory	4,740
Two presses, 6-inch air-compressor, and lime-mixer	560
Engine	200
House containing engine, presses, etc.	500
	6,000

The annual cost of working, on the basis that night-work is carried on during 6 months of the year, is as follows :—

	£	s.	d.
Precipitant—			
Lime and aluminoferric	120	0	0
Wages	240	0	0
Disposal of sludge	50	0	0
Renewal of filter-beds	20	0	0
Cost of steam	100	0	0
	530	0	0

The cost of steam is difficult to estimate, but will probably amount to the sum noted. Two hundred and ten men are employed in the factory.

WOOLLEN-MANUFACTURING AND DYE-WORKS OF MESSRS. KELSALL AND KEMP, NORDEN, NEAR ROCHDALE.

The manufacturing processes carried on at these works comprise piece-scouring, manufacturing, dyeing, and finishing. The purification-works present somewhat peculiar features, not only by reason of the foulness of the waste waters with which they are designed to deal, but also from the difficulty of obtaining sufficient land on which to erect the necessary works. If the works had been constructed in their entirety at the outset, possibly somewhat better arrangements might have been made; but they have developed as the necessity for better treatment of the water arose, and at present, although somewhat complicated, are certainly very effective.

Treatment of Soapy Water from the Scouring and Finishing Departments.—The water from the washing-troughs in the mill is collected, and is delivered by an earthenware pipe into the chamber A, Fig. 4, Plate 1, where it passes through a fine copper sieve which collects the flocks or small particles of wool which are carried away in the water. The sieve is cleaned by a revolving brush, and the flocks being of value are collected. Details of this arrangement are given in Figs. 8. From the chamber A the water flows through 8-inch earthenware pipes to the pumping-chamber, where two "aqua-thruster" pumps force it through a 4-inch rising-main to the box C, where it falls on a water-wheel which works a lime-mixer in an adjacent box. The milk of lime is discharged from this box into the trough, through which the soapy water flows from C to the settling-tanks for treatment; a solution of ferric chloride is also run into the trough from the precipitant-tank at a point about 12 feet distant from where the lime is added. The series of settling-tanks Nos. 1, 2 and 3, is so served by troughs and overflows that any two tanks can be used whilst the third is being cleaned. From these tanks the water flows through a pipe and trough to further settling-tanks, Nos. 4 and 5, and thence on to the filter-beds Nos. 1 and 2, the overflows from each tank being provided with scum-boards; the water is distributed on the filter-beds by a perforated trough. The filters, which are used alternately, are composed of fine ashes with drain-pipes at the bottom, and the water passes through them into the 6-inch effluent-pipes and a trough fixed round the sides of the sludge-tanks, thence through the chamber L by a series of troughs and channels to the stream. When two tanks of the series 1, 2 and 3 have been in use for 1 week, the first tank is shut off and the third is brought into use. The top-water from the disused tank is then drawn off, after settlement, by the floating outlet-valve into the inlet-chamber of the dye-water settling-tanks, to be described later. The sludge in the tank is then well mixed with sulphuric acid, and is drawn off by the sludge-valve at the west end of the tank into the sludge-trough, and thence into sludge-filters made of cocoanut-matting. These filters are shown in section in Fig. 7. The action of the acid on the sludge is to split up the insoluble lime and iron soap, setting free fatty acid and neutralizing the lime and iron: the sludge will not press with free lime in it. The surplus acid drains through the matting-filters into the collecting area below and the sump-well O, whence it is pumped by an "aqua-thruster" into the precipitant-tank for use over again. The sludge from the matting-filters is taken to the press-house, where it is pressed and the oil from it is recovered; the solid refuse which remains is burnt. The oil is then further refined by distilling and pressing, and the stearine and oil which are produced are sold.

Treatment of the Dye-water.—The water from the dye-house is conducted by an earthenware pipe to a chamber A, Fig. 4, passing under the sieve which collects the flocks from the soapy water, from which it is kept separate, but with a similar arrangement for collecting the flocks contained in the dye-water; thence it flows through earthenware pipes to the inlet-channel of the settling-tanks Nos. 6, 7, 8, 9 and 10 (where it is joined by the water from whichever of the tanks 1, 2, or 3 is being drawn off for cleaning) over the trough V and successively through the tanks, which are used on the continuous system—scum-boards being fixed at the outlet from No. 6 tank and also from the outlet to No. 10, where the water flows on to filter-beds Nos. 4 and 5; these beds are surcharged, the water flowing from them by a vertical outlet on to either of the fine-cinder filters 6, 7, 8 and 9: the water finally flows into the effluent-channel to the stream. All the fine filters, 1, 2, 3, 6, 7, 8 and 9 are composed of clinkers at the bottom, covered by a layer of coarse cinders, with an 18-inch layer of very fine ashes on the top. The sludge from settling-tanks 6, 7, 8, 9 and 10 is drawn off into the sludge-tank No. 3, from which it is pumped into sludge-tanks Nos. 1 and 2 by an "aqua-thruster," and is afterwards carted to a tip. When filters Nos. 4 and 5 require cleaning, the water can be drawn off by earthenware pipes which discharge into the effluent-channel. The total volume of water used amounts to 180,000 gallons per day. The number of hands employed is ninety. The analysis of the untreated waste from the dye-house, Appendix, Table I, shows it is free from suspended solids. This is probably due to the fact that woollen material absorbs the dye more readily than cotton goods and therefore leaves less solid matter in the dye-becks, and also that in this mill alizarine dyes only are used, which contain very little solid in suspension; the solids are also reduced by using the bichromate of potash with which the wool is mordanted preparatory to dyeing, as boiler-composition. For this purpose a tank has been made under the floor of the dye-house into which this liquor is run after the wool has been mordanted, thence it is pumped into the boilers and used in them for the prevention of scale. Since this plan has been adopted no other boiler-composition has been found necessary, and the valves have lasted better than previously.

This example shows the most complete and elaborate arrangement to be found in the watershed for dealing with this kind of waste, but there are a large number of woollen-mills where simpler works have been constructed which give excellent results; these consist of sap-tanks, precipitation-tanks, and filter-beds. In the sap-tanks the water from the scouring processes, which contains most of the grease, is received and treated with acid, and the grease is recovered. This process has been practised in a more or less perfect form for many years, especially when the value of soap allowed it to be done with profit. The clear effluent water from the sap-tanks then joins the rest of the waste water, and the whole is treated with a precipitant and allowed to settle in the precipitation-tanks, the clear effluent water being subsequently filtered through cinders or other fine material.

The capital expenditure on these works is as follows:—

	£	s.	d.
Tanks and filters, pumps, etc.	1,250	0	0
Magma-pressing	380	0	0
Distilling and stearine-pressing	340	0	0
	1,970	0	0

The cost of treatment during the year 1898 was as follows:—

	£	s.	d.	£	s.	d.
Ferric chloride				24	3	0
Oil of vitriol				69	3	9
Lime				19	18	10
Bags (for pressing)				26	11	2
Sawdust				1	19	0
Plumbing repairs				10	12	7
Repairs to pumps, valves, etc.				17	9	2
India-rubber bungs, etc.				5	15	10
Test-tubes and chemicals					12	4
Magma-press plates				7	19	5
Sundries				7	8	8
Wages				346	13	5
Coal for distilling and steam for pumps				50	0	0
Gross cost				588	7	2
Deduct revenue—						
Sale of recovered oil and stearine	336	11	0			
Saving of boiler-composition	52	0	0			
				388	11	0
Net cost				199	16	2

Say £200 per annum.

Calico-Printing, Dye and Bleach Works of Messrs. Sydall Brothers, Limited, Chadkirk.

The processes carried on at these works, in which one hundred and ninety-five hands are employed, comprise those of an ordinary calico-print works, and the pollution is caused by alizarine and aniline dyes, logwood and other wood-extracts, soap, starch, fustic, soda, bleaching powder, etc. The whole of the trade-waste, including the wash-waters, is collected in a wooden trough which is fixed along the west wall of the works, and intercepts the water from the various outlets which formerly discharged direct into the river. This trough discharges into the small chamber A, Fig. 9, Plate 1, and the water passes under division walls into the chambers C and E and over a wall into the chamber G, where an "aqua-thruster" pump is fixed which forces it through a 12-inch iron pipe to the settling-tank: the pump is regulated by a float on the surface of the water, and, as the water rises or falls in the chamber, the float, which is connected by an arrangement of levers to the steam-supply which works the pump, increases or diminishes the supply, thus causing the pumps to work quickly or slowly according as the quantity of water from the works varies. This chamber or detritus-tank intercepts a considerable quantity of solid matter, and is cleaned out every week. The supply-pipe from the pumps terminates in the chamber H, whence the water flows under the division-wall J and over the wall L into the settling-tank, and thence by sluices at M into either of the two precipitation-tanks. A considerable amount of sludge is collected in the detritus-tank, thus relieving the pump, and also in the settling-tank, which is filled to a depth of about 4 feet before the water flows into the precipitation-tanks. Blocks of alumino-ferric are placed against the screen at M to assist precipitation. Each precipitation-tank holds about 178,000 gallons, takes 2½ days to fill, and is allowed 48 hours to settle, during which time the water is diverted into the other tank. After settlement the water is drawn from the tank by a floating outlet-valve into an 8-inch pipe, and thence through 4-inch distributing-pipes to the filter-beds Nos. 1 and 2 in succession, the water thus undergoing a double filtration; the outlet-pipes to No. 1 filter are turned up vertically at their outlet end (Fig. 10) and are brought up to the level of the surface of the filter, so that the filter when in use is fully charged; a division wall in the outlet-chamber, over which the water has to pass, causes No. 2 filter also to be fully charged before any water flows from it; this method of using the filters no doubt somewhat reduces the quantity of air admitted into them, but affords a ready means of utilizing the whole of the bed, and also of preventing the water from flowing through them too quickly. The filters are composed of 12 inches of stones, 12 inches of clinkers, and 18 inches of fine ashes on the top. The sloping sides of the tanks and filters and the bottoms of the tanks are merely pitched with 3-inch brickwork set dry. The foundation is of good clay. The sludge collected in the settling-tank is cleaned out every 3 months through a sludge-valve at the south end, into the sludge-tank, care being taken that sludge only is allowed to pass, the sludge from H being swept through openings in the walls J and L into the settling-tank. The sludge from the precipitation-tanks, after the top water has been drawn off, is also discharged by 9-inch pipes into the sludge-tank, whence it is lifted by a bucket-pump into a wooden trough leading to the sludge-drying area. The sludge when dry is spread on a grass field adjoining. The precipitation-tanks are cleaned of sludge after each filling. If the filter-beds require cleaning out, the water can be drawn from them entirely by means of a valve at P for No. 1 bed, and a valve in the outlet-chamber for No. 2 bed. The analysis of the water after it leaves the precipitation-tanks, and of the filtered effluent, shows that, contrary to the experience at Clay's dye-works, the filters make a great improvement (Tables II–IV, Appendix); this is probably due to the fact that more soap and size is used at a print-works than at a dye-works, a considerable amount of those substances being in solution can only be removed by filtration.

The total cost of these works, including the tanks, filters, pump and piping complete, was £650.

Annual Cost of Maintenance.

	£	s.	d.
Precipitant	56	0	0
Cost of steam	30	0	0
Labour, including extra labour required when tanks are emptied of sludge, but not including carting sludge on to land	63	0	0
	149	0	0

The recovery of waste products has been attended with considerable success at one print-works in the watershed. About 1,000,000 gallons of water are used in the works daily, of which about one-half requires treatment; the remainder, being clean wash-water, is allowed to flow directly into the stream. The general purification works consist of precipitation-tanks and filters, but the waters containing soap, logwood, and indigo are subjected to preliminary treatment before being passed on to these tanks, the solids in them being recovered. The soap-liquor is precipitated in a tank with lime and aluminoferric, which precipitates the greasy matter; this is pumped into a filter-press, and the cake produced is boiled by means of steam and the grease is recovered; the acid and alum which separate from the grease in the process of boiling are drawn off and used again to precipitate the next tankful of soap-liquor. The grease is worth at least £7 per ton, and it is estimated that at £4 10*s.* it pays the whole of the working-expenses of recovery, including wages and chemicals; the quantity produced is between 15 tons and 20 tons a year.

The separate recovery of indigo is generally adopted now at works where any considerable quantity is used, and is a very remunerative process—the value of the products recovered at these works amounting to about £1,200 a year on a total consumption of about £4,000 worth of the raw material. The indigo is recovered from the solid which settles at the bottom of the dye-vats and also from the wash-water, through which the pieces are passed after being dyed. The wash-waters are first precipitated in tanks under the floor of the works with aluminoferric and caustic soda, the top water is drawn off by means of a valve with a floating arm, and the solids, together with those from the dye-vats, are pumped up into a tank where they are treated chemically; this separates the pure indigo, which is used again in the dye-house.

The separate treatment of the logwood-liquor has for its object not the recovery of the waste products, which are, as far as is known as present, valueless, but the simplification of the subsequent treatment in the general precipitation-tanks, the logwood-liquor being difficult to treat and containing a large amount of solid matter, owing to the fact that the ground logwood is put direct into the dye-vats. The plan has been found of great assistance at these works and is well worth adoption. The treatment consists of precipitation with lime and aluminoferric in a tank into which the liquor from the dye-vats and the wash-waters flow; after precipitation the top water is drawn off and the solids are pumped into a vertical cylinder where as much of the moisture as possible is allowed to drain off. The residue is burnt; it has been tried as a manure but does more harm than good, producing fungus. The remainder of the polluting water from the works is collected in a culvert, into which also the partially-treated water from each of the three recovery-plants flows, and passes forward to the general precipitation-tanks and filters; the tanks have a capacity of 413,000 gallons and the filters cover an area of 2,200 square yards. Aluminoferric and milk of lime are added at points in the culvert about 20 yards apart. The accumulation of solids in the tanks is not great and the surface of the filters requires to be renewed only once in 4 months. In connection with the filters, the interesting fact has been noticed, that the surface lasts longer without requiring renewal after the filter has been in use some time than when it is entirely new. This seems to suggest that a biological action establishes itself, as in a sewage-filter. The cost of the precipitation-tanks and filters was £1,500, and the annual cost of maintenance, including labour and precipitants, is £60; this does not include the cost or the maintenance of the three recovery-plants, which, however, as pointed out, pay for themselves with a good profit.

Considerable saving is also effected in a print-works, as a result of the necessity of preventing the pollution of rivers, by the reduction of the quantity of dyeing materials and starch used, or rather wasted in the works. A large amount of starch of the finest quality is used to form the body of the colours used in printing, and formerly, when the drains of the colour-shop were connected with the river, if a mixing of colour was not correct it was sent down the drain and the principal was ignorant of it; now the drains from the colour-shop and starch-places are closed, and a spoiled mixing has to be taken to the tip, where the errors of the mixer are brought to light.

Conclusion.

The works described above may be taken as typical examples of those required for the treatment of the various kinds of trade-waste, but a few notes as to special arrangements which are advisable in certain cases are appended.

Bleach-Works.—The polluting waters from a bleach-works consist of the water from the kiers, and from the bleach- and acid-tanks, and the wash-waters from all except the final processes. One of the most polluting liquids is the water drawn from the kiers in which the pieces of cloth are boiled; it is strongly alkaline and alone is difficult to treat. At many works it is the custom to run off the kiers, perhaps eight or ten in number, in the morning within a short period of time, with the result that this strong liquor does not have a chance of being mixed with the washing and less polluting waters. This difficulty may be overcome by discharging the kier-water into a separate tank, from which it may be drawn off gradually and mixed with the washing waters as they flow to the precipitation-tanks, when no difficulty will be found with its treatment. The final washing waters may, as a rule, be admitted into the streams without treatment, but it is often found more convenient to allow them to flow to the tanks than to lay down a separate system of drains. Example No. 3 would be suitable for a bleach-works, therefore no separate example has been given. A process has lately been introduced at one bleach-works for reducing the alkalinity in the water by discharging carbonic-acid gas into the tanks; the gas is produced by means of a coke-furnace, from which it is taken to the tanks in pipes.

Paper-Works.—The materials used in the manufacture of paper vary so widely at different mills that it is impossible to describe a typical purification-works that would suit all cases. If esparto grass or straw is used, the strong caustic liquor from the boiling of these materials must be evaporated and the soda-ash must be recovered; whether this is profitable or not depends upon the price of caustic soda and whether the quantity of soda used in the works is sufficient to keep an evaporator and incinerator working; but in any case there will be some return for the outlay, and the liquor is of such a polluting character that its treatment is necessary. The wash-waters, which should be economized inside the mill by using them over and over again as much as possible, may be treated by precipitation and filtration in works similar to example No. 3; and this example is also applicable to mills in which rags, hemp, etc., are used, the polluting water in such cases being from the washing, boiling and bleaching of these materials. The recommendation made with regard to the kier-waters from bleach-works applies also to the water in which the rags are boiled at paper-works. The introduction of wood-pulp has entirely changed the preliminary processes of manufacture at some mills, and materially reduced the pollution from them; the whole of the wood-pulp, which is usually prepared abroad, is of value, and any waste of it is loss to the mill, so that a variety of "savealls" (revolving sieves of fine gauze), and settling-tanks have been introduced for the recovery of as much of the pulp as possible.

Tanners' and Fellmongers' Works.—The trade-waste from this class of works should undoubtedly be admitted into the sewers if possible, after preliminary treatment in tanks to remove the grosser solids which might cause silting in the sewers. It is so concentrated and contains such a large amount of organic matter, often in a state of decomposition, that treatment is difficult, whereas if it is mixed with the ordinary sewage of a town, the difficulties with regard to the latter are not materially increased. If separate treatment is necessary, as may be the case in a country district, the works should be constructed to conform to the same rules which apply to sewage-works; the precipitation-tanks should be arranged so that they may be easily and thoroughly cleaned, which will require to be done frequently in warm weather to prevent the sludge decomposing. If suitable land can be obtained on which to run the tank-effluent, it is preferable to artificial filtration; but if the land is of a heavy nature or a sufficient area cannot be obtained, filters must be constructed; double filtration would probably be beneficial.

Breweries.—A large quantity of water is used at breweries for cooling purposes; this does not require treatment, and should be separated from the polluted water; the latter consists of the washings of barrels, fermenting-vats and cooling-tanks, and is of a very offensive character. It may be treated by precipitation and subsequent filtration. The majority of breweries in the watershed discharge direct into the sewers.

Slack-Washing.—This is a process employed at some collieries for separating small coal, which would otherwise be of little value, from the refuse with which it is mixed when raised from the pit. The water used in the process contains a large amount of solid matter in suspension, which can readily be intercepted in settling-tanks. At some collieries a plant is used from which the solid refuse is removed during the process of washing, so that the water can be used over and over again, and none run to waste.

Chemical Works.—The waste waters from these works are so various that it is impossible to lay down any general rule for their treatment. Each case will require to be taken separately, the composition of the effluent water being ascertained; and if the waste water is found to be inadmissible into either the river or sewers, some means of chemical treatment must be adopted.

From the examples given it will be seen that the cost is variable, and that no general rules for forming an estimate of the cost of treating a given quantity of water can be laid down. The position of the works, the quality of the waste, whether pumping is necessary and to what extent, are all variable factors. In some cases manufacturers have wisely provided a well-designed and well-constructed plant at the outset, thereby reducing the cost of maintenance; whilst others, to their ultimate cost, have adopted a too economical course. In the cost of maintenance interest on capital or depreciation is not included. It has been pointed out that in the case of calico-printers and paper-makers great advances have been made in the last few years in the recovery of valuable materials which used to find their way into the rivers. So far as manufacturing industries are concerned, it seems probable that the rivers will be purified by operations inside rather than outside the works.

The Author gratefully acknowledges the assistance he has received from the owners of the works referred to, and from Mr. Scudder, who has made the chemical report, contained in the Appendix, on samples taken from the three works described.

The Paper is accompanied by six tracings, from which Plate 1 has been prepared.

APPENDIX.

TABLE I.—MESSRS. KELSALL AND KEMP'S WORKS.—CHEMICAL RESULTS EXPRESSED IN GRAINS PER GALLON.

	Suspended Solids.			Soluble Solids.			Total Solids.			Ammonias.		Oxygen absorbed from $KMnO_4$ in Acid Solution at 60° F.		Transparency as Millimetres seen through.	Alkalinity H_2SO_4 required to neutralize.	Acidity expressed as H_2SO_4.
—	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Free and Saline.	Albuminoid Ammonia.	3 Minutes' Test.	4 Hours' Test.			
1. Dec. 2, 1898, 10.45 A.M.—Soapy water before treatment[1]	22·5	122·5	145·0	77·5	184·0	261·5	100·0	306 5	406 5	0·602	4·410	8·86	41·44	Opaque	3·43	..
2. Dec. 2, 1898, 4 P.M.—After treatment[2]	0	0	0	69·0	11·0	80 0	69 0	11·0	80·0	0·245	0·483	0·23	1·04	280	Neutral	..
Percentage reduction of impurity	..	..	100	11	94	69¼	..	..	..	59	89	97½	97½	..	..	..
3. Dec. 2, 1898, 11.30 A.M.—Dye-water before treatment[3]	0	0	0	22 5	27·0	49·5	..	..	..	0·231	0·263	0·46	1·07	150	..	14·7
4. Dec. 2, 1898, 4.15 P.M.—After treatment[4]	0	0	0	20·0	8·2	28·5	..	..	..	0·035	0·043	0·18	0·63	210	..	2·94
Percentage reduction of impurity	..	..	..	..	68½	42½	..	..	..	76	83½	61	41	..	..	..
5. Dec. 2, 1898, 4.15 P.M.—General effluent as discharged into stream[4]	0	0	0	42·0	5·0	47 0	..	..	..	0·084	0·095	0·19	0·87	320	..	0·98

[1] A thick greyish-white liquid; froths on shaking; smell of wool-perspiration.
[2] A clear effluent, free from suspended solids; faint smell of wool-perspiration.
[3] A blue-coloured clear effluent, free from suspended matter; no smell.
[4] A clear effluent, free from suspended matter; no smell.

TABLE II.—MESSRS. SYDALL BROTHERS' WORKS.—CHEMICAL RESULTS EXPRESSED IN GRAINS PER GALLON.

Description of Sample.	Date, 1898.	Solids in Suspension.			Solids in Solution.		
		Mineral.	Volatile	Total.	Mineral	Volatile.	Total.
Crude waste from the works as it entered the tanks . . .	Dec. 16, 11 A.M.	4·0	26·0	30·0	29·0	21·5	50·5
Effluent from the settling-tank . .	Dec. 19, 12 noon	..	..	..	41·0	22·5	63·5
Effluent after filtration	Dec. 19, 12.30 P.M.	..	..	..	47·0	19·0	66·0

TABLE III.—MESSRS. SYDALL BROTHERS' WORKS.—CHEMICAL RESULTS EXPRESSED IN GRAINS PER GALLON.

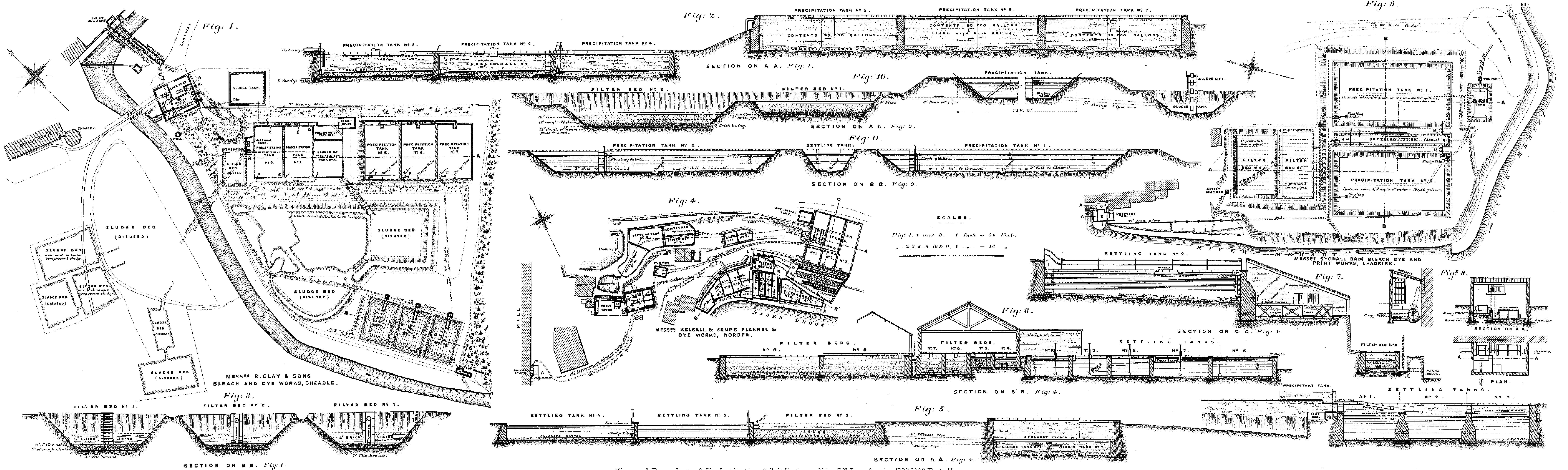
Description.	Date.	Suspended Solids.			Solids in Solution.		
		Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.
Crude waste from the sump under pump	Jan. 30, 1899, 10 A.M.	12·5	27·0	39·5	36·5	20·5	57·0
Tank-effluent passing to the filters. Standing from January 30	Feb. 1, 1899, 12.20 noon.	5·0	10·0	15·0	45·0	28·5	73·5
Effluent from the filter	Feb. 1, 1899, 1.20 P.M.	1·5	4·0	5·5	55·5	13·5	69·0

TABLE IV.—MESSRS. R. CLAY AND SONS' WORKS.—CHEMICAL RESULTS EXPRESSED IN GRAINS PER GALLON.

Description of Sample.	Date, 1898.	Solids in Suspension.			Solids in Solution.		
		Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.
Crude waste from the works as it entered the tanks . . .	Dec. 15, 11.30 A.M.	1·0	18·5	19·5	44·5	3·5	48·0
Crude waste from the precipitant-mixing tank	12 noon	31·0	2·0	33·0	97·0	12·0	109·0
Effluent from settling-tank after 3 hours' subsidence.	3 P.M.	..	..	..	96·0	20·0	116·0
Effluent from filter	3.30 P.M.	..	..	..	102·0	18·5	120·5

THE PURIFICATION OF TRADES WASTE-WATER.

PLATE 1.



THOS KELL & SON LITH, 40 KING ST COVENT GARDEN.