MEASURES AGAINST WATER POLLUTION IN THE FERMENTATION INDUSTRIES

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ABSTRACT

The paper is a review of some current practices in the treatment and disposal of the more important fermentation industry effluents. Reference is made to the production of whisky and other potable spirits, malt, beer, vinegar, yeast, cider, antibiotics and vitamins.

The most important means of treating distillery effluents is by recovering the soluble and some insoluble material in the liquid residue from the distillation of fermented wash. The process involves evaporation and drying to produce dry, nutritionally rich animal feeding materials by the sale of which the capital cost of the plant may be recovered. Condensate from the evaporation process contains organic acids and must be treated biologically before discharge to rivers, as must other watery residues from the distillery. Treatment may be on conventional mineral packed biological filters, on plastic filled towers or by an activated sludge process. Other methods of disposal of distillery wastes include complete biological treatment of the mixed effluents, disposal to land, to sea and to sewers. Discharges to sewers often attract special charges by the local authority. Burning wastes with the recovery of heat and ash is also practiced.

Effluents from the malting process are easily treated biologically, whether on site at the maltings or, after discharging to sewers, at the local authority sewage works in admixture with sewage.

Brewery effluents, mostly cooling and wash waters, are usually discharged to sewers, but some biological pre-treatment may be given on site, where plastic packed biological filter units are sometimes used. Vinegar factory effluents are also usually discharged to sewers and are easily treatable.

The ease with which most fermentation wastes can be treated biologically has encouraged the industries concerned to ask local authorities to acknowledge the fact by suitably reducing charges for effluents treated at the sewage works.

Yeast manufacturing effluents comprise residual wash, yeast washings etc., and are readily treatable biologically. Fears that yeast effluents cause slime growths in sewers are not substantiated in practice, but a case is described in which yeast wastes are piped separately from sewage to the disposal site.

Cider effluents are easily treated biologically, either on site with additions of suitable nutrients, or in admixture with sewage.

Antibiotics and vitamin fermentation effluents are sometimes difficult to treat biologically, but are often so treated and are sometimes acceptable in sewers. Recovery of solids from residual washes is practiced, with the production of material suitable for animal feeding. In the UK the tendency is for factories to be sited on estuaries or the sea coast where untreated effluent may be discharged through pipelines.

Developments in the treatment of sewage and other effluents may be applicable to fermentation wastes. Total chemical treatment, the use of ion exchange resins and activated carbon, ultra filtration including reverse osmosis etc. may possibly be used to produce water of a quality suitable for re-use in the processes.

The most important criteria in the selection of any particular effluent disposal method are efficiency in operation and economics.

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1. INTRODUCTION

Papers on aspects of the fermentation industries' effluent disposal problems in the UK have been published over the last fourteen years[1–4]. This paper is a review of some current practices in the treatment and disposal of trade effluent from the most important sectors of the industry and mentions briefly such new methods as may find an application in the future.

2. THE FERMENTATION INDUSTRIES

Blakebrough[5] said of the fermentation industries 'Fermentation as an art is one of mankind's earliest achievements in the field of applied microbiology. It involves the deliberate application of the activities of microorganisms for the conversion of one substance to another'. He instances the conversion historically of milk and cream to cheese and yoghourt, cereals to beer and grapes to wine, and lists among current products alcohol, lactic, citric and gluconic acids, acetone, butanol, amino acids, vitamins, antibiotics and steroid hormones. However, the products of greatest economic importance in the UK are currently whisky, beer, gin, vodka, all produced mainly from cereals, antibiotics, cider from apples and vinegar from the conversion of alcohol in beer, cider and wine to acetic acid.

To complete the picture, the conversion of sewage and trade effluents to water, carbon dioxide, salts and microbial cell substance represents a major use of micro-organisms for purposes similar to fermentation and in the UK some 2000 tons of organic matter from human metabolism are converted daily with perhaps another 1000 tons from industry.

3. MALTINGS EFFLUENTS

Barley malt is a raw material used for the distillation of potable spirits, brewing beer and the production of malt extract and malt vinegar. In the malting process, barley is steeped in water, some of which it imbibes, so initiating germination. The water may be changed two or three times during steeping and each successive change of steep water when discharged will contain decreasing amounts of foreign matter and soluble material washed from the grain. The average concentration of such materials in the discharged steep water will depend on the volumes of water used, and whether or not the barley is first 'dressed' by treatment using compressed air.

The Royal Commission, which set the stage for the scientific treatment of sewage and other wastes in the UK at the beginning of this century, considered that normally 2.4–3 m^3 water would be used for every 1000 kg of

Table 1. Partial analysis of steep waters

	Undressed barley		Dressed barley
	1st steep liquor	3rd steep liquor	1st steep liquor
Volume (m^3 per 1000 kg)	2.4	2.4	2.4
pH	6.0	6.0	6.5
BOD (mg/l)	4470	770	720
BOD (lb 0. per quarter)	3.6	0.6	0.6
PV (mg/l)	2190	500	500
Ammonia as N(mg/l)	27	3	5
Total N(mg/l)	232	34	52

barley. Normal modern usage varies from about 0.6 m^3 per 1 000 kg and some ultra-modern processes which control the amount of imbibition water result in little or no effluent. Pettet[6] (*Table 1*) gives partial analyses of steep waters.

Multiple steeping, often called re-steeping, produces stronger effluents as the process involves steeping the sprouting grain in water sufficiently hot to kill the roots but not the shoots, which economises in the respiratory use of the grain carbohydrate, but brings added material from the roots into solution. Normal steep waters, combined and added to washings etc. are usually regarded as having a BOD of about 1 500 mg/l, and are conducive to rapid biological breakdown. This makes them relatively easy and economical to treat by biological methods and Oliver and Walker[7] showed that malting effluent could be treated on a conventional mineral packed biological filter at about 0.5–0.6 kg BOD per m^3 of filter space which is about four times the loading used to treat sewage to the same quality of effluent.

It might be relevant to mention here that effluents from maltings and indeed from any fermentation industry may be discharged to local authority sewers where these are available and that for this service charges are made which depend among other things on the BOD or some other oxygen-demand parameter such as PV or COD. Often the charges made do not reflect the ease with which the BOD etc. may be destroyed in the treatment works, the tacit assumption being that a given mass of BOD etc. requires the same volume of treatment plant as it would if it were the BOD etc. of sewage. The ease or otherwise with which BOD etc. in a given effluent may be destroyed is often referred to as the 'treatability' of the effluent, and industries try to persuade local authorities to take this factor into account when making charges. If they do not do so we may find a paradoxical situation in which it is cheaper for a maltster to build his own biological treatment plant than to pay the local authority to treat his wastes in spite of the fact that the local authority works has the economic advantages of large size, low loan charges and expertise in managing and running treatment plant.

The treatment process reported by Oliver and Walker was conventional biological filtration. Such filters may become obstructed with heavy growths of biological film if fed with wastes of 1 500 mg/l BOD, and even when working well would not be expected to reduce the BOD by more than 90 per cent. This would leave an effluent of some 150 mg/l BOD to be discharged, which is usually more than a river authority will allow in non-tidal waters. Difficulties in working conventional biological filters with high BOD loads may be overcome by the re-circulation of effluent, so giving a high rate of liquid throughput which can break up film accumulations and extend biological activity downwards through the filter bed. Similarly alternating double filtration may be used by which filters are used in series, each in turn becoming the one to receive untreated effluent so that both undergo alternate processes of film accumulation and breakdown. Biological filters containing plastic media with large void spaces are not subject to blockages by excessive film, and have been developed in the last decade for strong fermentation wastes. 'Flocor'† systems for example may be loaded at up to about 5 kg BOD per m^3 and will usually remove more than half the BOD fed at this loading. Two or more stages may be used to effect up to about 90 per cent removal and further treatment is then economical only on a more closely packed plastic medium, a conventional biological filter or by activated sludge. Plastic media are far less likely to produce channelled flows than conventional filters which means they can be used in tall towers so saving land space and because of their lightness, require less structural support.

The use of activated sludge type processes for maltings wastes is probably expanding. In the past the process has not been as popular as biological filtration for industrial wastes in general because of its need for more careful and therefore more expensive control, because of its sensitivity to shock loads and because of the greater difficulty of keeping the process active during plant shutdowns. However, the Pasveer oxidation ditch system has been used successfully for maltings effluents in the UK and the Water Pollution Research Laboratory found that one installation reduced average BOD from 1 140 mg/l to 12 mg/l and suspended solids from 313 mg/l to 18 mg/l with a loading of 0.28 kg per m^3 per day, and an average sludge concentration of 7 100 mg/l. Another installation treating 680 m^3 of effluent containing 780 kg BOD per day had cost a total of £35 000 and produced an effluent of 5–7 mg/l BOD and 3–7 mg/l suspended solids. Such an effluent might very well be available for re-use.

4. DISTILLERY EFFLUENTS

Distilleries producing alcohol in the UK are of three main types. Malt whisky is produced in pot stills in Scotland from fermented washes made from 100 per cent barley malt; grain whisky and spirit for gin and vodka manufacture are produced in patent continuous stills from fermented washes made from malted barley and other cereals, usually maize, and some forms of industrial alcohol, particularly for use in pharmacy and perfumery, are produced in patent stills from fermented molasses washes fortified with nutrients. On a BOD basis, the population equivalent of distillery wastes in the UK is about 5.4 million.

In each type of distillery the alcohol removed by distillation represents only a fraction of the volume of wash, and although a considerable quantity

† 'Flocor' is the registered trade mark of ICI Ltd. at home and overseas and relates to a plastic packing for high rate biological filters.

of the carbonaceous content is removed as carbon dioxide during fermentation, there remain considerable quantities of a potentially polluting effluent for disposal. This is known as pot ale in malt distilleries and spent wash in others. *Table 2* illustrates their composition.

Table 2. Composition of distillery spent washes

	Malt whisky	Grain whisky (screened)	Industrial alcohol
pH	3.5	3.3–3.8	3.5–4.7
		Per cent	
Soluble solids	3.0–3.5	1.0–1.1	2.5–10
Suspended solids	0.5	1.0–1.1	0.2–0.7
Protein	1.0	0.7	0.8
Fat	0.0006	0.22	—
Fibre	0.001	0.12	—
Ash	0.4	0.14	0.4–3.2
Reducing substances (as invert sugar)	0.81	0.3	1.5
		Mg/l	
BOD	22000	10000	7000–48000
COD (after 2 h settlement)	43000	15000	—
PV (after 2 h settlement)	8000	3000	—

Other distillery wastes include spent lees which is water left over from the second distillation of spirit in malt distilleries, and washings of pipes, vessels and floors. In modern times malt is often made separately from the distilleries, but some still have their own maltings and steep water is then part of the total effluent.

Gin and vodka are distilled from spirit made as described already, and to which flavourings have been added. Liquid residues are similar to spent lees, and the only other important liquid effluents are washings, etc. Solid residues from vegetable flavouring material are disposed of by tipping.

(a) Recovery of solids from pot ale and spent wash

Spent wash and pot ale contain minerals, unfermented carbohydrates, cereal residues, dead yeast and the products of yeast metabolism including protein, polypeptides, amino acids, B-vitamins and other soluble organic materials of high nutritional value. Modern treatment of spent wash makes use of these materials by recovering the soluble and minor insoluble solids as dry material for sale as ingredients of high nutritional value in compound animal feeds.

The economics of effluent disposal by the recovery of spent wash solids in single distilleries is determined by the size of the unit. In addition individual distilleries may not have sufficient space for this type of installation. In parts of Scotland, small malt distilleries near to each other are connected by pipeline and tanker routes so that pot ale may be conveyed to central plants at which economic recovery can be carried out. After screening in grain distilleries the collected spent wash, or pot ale, is kept stirred to maintain uniformity and is fed to multiple effect evaporators where 96 per cent of the water is removed as condensate containing steam-volatile materials, largely organic acids. The concentrated solid in syrup form is either mixed with the extracted cereal residues (draff) and dried in pneumatic dryers to make distillers dark grains or is neutralized with high quality hydrated lime to assist drying and to stabilize the final material, then spray-dried to form a powder known as distillers dried solubles. *Table 3* shows the composition of these materials.

Table 3. Analysis of scotch dried distillers' solubles and dark grains from malt and grain whisky distilleries

	Malt D.D.S.	Grain D.D.S.	Malt D.G.	Grain D.G.
		Per cent		
Moisture	5	5	9	10
Protein	27	27	23	25
Fat	0.16	9	4	7
Fibre	0.03	5	13	7
Ash	17	11	5	4
Carbohydrate (by difference)	51	43	46	47
Amino acids				
Lysine	1.19	0.90	0.93	0.4
Methionine	0.37	0.54	0.31	0.48
Arginine	0.45	1.18	0.93	—
Cystine	0.08	0.08	0.21	0.31
Histidine	0.43	0.63	0.47	—
Phenylalanine	0.70	2.36	1.40	—
Tryptophan	0.07	0.11	0.11	0.09
B-vitamins		Mg/kilo		
Aneurin	1.5	3.5	2.2	—
Niacin	510	76	165	55
Pantothenic acid	67	11	34	9.7
Riboflavin	21	12	11.2	7.5
Choline	2000	3100	5600	2700
Pyridoxin	19	1	4.6	—
Biotin	0.7	0.3	0.22	—
Inositol	10000	7200	2250	—

The presence of unidentified growth factors in these materials has been demonstrated by carefully controlled animal feeding trials and these factors can improve growth rates and feed conversion by up to 10 per cent when incorporated in compound diets at about $2\frac{1}{2}$ per cent. Considerable quantities are sold throughout the world.

Where it is economic to do so the recovery of distillers solubles or dark grains is a better use of capital than providing alternative non-productive biological treatment. Figures issued by a manufacturer of recovery plant are given in *Table 4*, and illustrate the relationship between size of plant and capital cost per gallon of processed spent wash.

Table 4. Capital costs of various sizes of dark grains recovery plant

Spent wash (m^3/week)	Capital cost (£)	Capital cost per m^3 per week (£)
230	80000	348
680	160000	235
1360	230000	169
1820	280000	154

Recovery processes may be applied to molasses spent washes but the product has a low protein value in comparison with that produced from cereal spent washes and has a high ash content derived from the molasses. It is not economic to produce this material in the UK although in South Africa, where fuel is cheap, considerable quantities are recovered.

Condensate from the evaporation stage in recovery plant can have a BOD of up to 1000 mg/l and requires further treatment before discharge to non-tidal rivers. A distillery in Scotland treats this and other wastes in a three stage 'Flocor' plastic medium biological filter and after admixture with cooling water achieves 20 mg/l BOD, the required effluent quality. It is, however, necessary to add nitrogen and phosphorus as nutrients as the condensate contents are almost wholly carbonaceous.

Elsewhere in Scotland modern conventional filters, enclosed as a protection against winter weather, have been used satisfactorily.

(b) Other methods of treatment

(i) *Biological treatment*—Historically, malt distillery effluents including spent wash, were treated on biological filters and some are still. The process is outlined in *Table 5.*

Table 5. Chemical and biological treatment of distillery effluent

Spent wash, 25000 mg/l BOD
↓ Mixed with other wastes and diluted with water
Mixed diluted liquid wastes, 2500 mg/l BOD
↓ Limed and settled
Supernatant from settling, 1000 mg/l BOD
↓ To dosing chambers and filters
Filter effluent, 20–25 mg/l BOD

The filters were normally 3.4–3.7 m deep and were filled with stones of roughly 7–8 cm diameter, and enclosed as a protection against frost. They were dosed at about 0.2 kg/m^3 per day. Sludge from the settling tanks was dried on prepared beds, and used by farmers on the land.

(ii) *Disposal to land*—Distillery effluents may be disposed of to land where a sufficient area of permeable soil is available. Overhead irrigation systems and tractor-drawn boom-sprayers may be used. Precautions must be taken to avoid the fouling of streams by run-off, and this may create difficulties in winter months.

(iii) *Disposal to sea*—Distillery effluents are disposed of to sea by pipeline or by surface vessel. Precautions to avoid the pollution of beaches must be taken and a suitable position for the end of the pipeline or dumping area must be calculated from considerations of wind and tide etc. Distillery wastes are not toxic and will not interfere with fishing in the open sea.

(iv) *Disposal to sewers*—In rural areas a distillery effluent may be ten times greater in strength and volume than the domestic sewage from the area. Nevertheless, effluents are in some cases discharged to sewers by agreement with the local authority with or without payment which may take the form of an agreed charge or a capital contribution to the cost of the sewage works.

Pretreatment by neutralization and possibly precipitation may be practicable to reduce the load on the sewage works and possible charges, but space is often too limited for treatment plant in distilleries.

In an urban area, a large English distillery is equipped to neutralise and cool effluents before discharge to sewers. Pretreatment costs about 0.022 per m^3 and local authority charges for treatment are about £0.09 m^3. Local authority charges would be up to four times as great in smaller towns having sewage works constructed in recent years.

(v) *Anaerobic digestion*—Distillery effluents are susceptible to anaerobic digestion but the process is sensitive to pH and temperature changes, working optimally at about pH6 and 45°C and is not in general use. At one large distillery the PV of spent wash is reduced often by more than 60 per cent in 2–4 hours in an unaerated open pit. Biological breakdown by anaerobic means is only partial and must usually be followed by a stage of aerobic biological treatment.

(vi) *Oxidation by heat*—Methods such as the Zimpro process, in which spent wash may be oxidized in water under high pressure and temperature, have been considered for treating distillery wastes but are not considered practicable.

The 'atomized suspension' process has been tested on fermentation wastes. Wastes are sprayed down a heated tower and so dried and burnt, the process being self-sustaining for heat. Ash is the only product and the process has not been seriously considered.

In Holland a beet molasses distillery employs a process by which evaporated spent wash is burnt in a special furnace and the ash which contains about 30 per cent potassium carbonate is sold as a fertilizer. The steam produced is used in the evaporators and in the distillery and the process is self-supporting economically. Sugar-cane molasses is not so rich in potassium, and where it is used the ash may not have the same sales value.

5. BREWERY EFFLUENTS

Brewery effluents consist mainly of cooling and wash waters from process vessels, tanks, pipelines, filters and floors and from bottle and cask washing. Isaac[8] has given figures contained in *Table 6*.

Volumes of effluent vary between breweries but are normally between five and twenty times the volume of beer produced. Using average figures,

Table 6. Brewery wastes results, except pH, in mg/l

	pH	BOD	SS
Fermenter washings	6.5	800	1080
Cask washings	6.4	460	168
Bottle washings	10.7	210	480

brewery effluents in the UK are equivalent to sewage from a population of about 1.5 m.

Most breweries discharge their effluents to sewers and pay charges to the local authority varying between about £0.01 and £0.04 per m^3. Brewery wastes have high BOD:nitrogen ratios and may be expected to be easily treatable with domestic sewage which has a low BOD:nitrogen ratio. Local authorities' charges might be expected to include an allowance for 'treatability'.

Few breweries treat effluents fully on site, but pretreatment is sometimes required before discharge to sewers. In one case this is done on conventional biological filters in admixture with domestic sewage from nearby houses. Chipperfield[9] indicates that plastic media is being used for biological pre-treatment of a brewery effluent sometimes exceeding 1100 mg/l BOD to not more than 300 mg/l. A three-stage system is used with an overall loading of about 2 kg BOD per m^3 per day. On average, effluents of 678 mg/l BOD are reduced to 137 mg/l. Inorganic nitrogen is added as a nutrient.

6. MALT VINEGAR EFFLUENTS

Malt vinegar is made by souring beer so that the process includes brewing followed by the conversion of alcohol by micro-organisms to acetic acid. Both microbiological processes are exothermic and are water cooled and other effluents arise from washings of filters, vessels, pipework, floors and bottles. Effluent volumes are roughly 9–10 times that of the vinegar produced, and the average BOD is about 400 mg/l. Effluents discharged from the whole industry in the UK are equivalent to sewage from a population of about 10000. The BOD is due mainly to acetic acid which is almost as treatable biologically as sucrose. No difficulties should arise during biological treatment in admixture with sewage.

7. YEAST MANUFACTURING EFFLUENTS

Yeast is grown in solution of molasses fortified with nutrients. The wash containing the grown yeast cells is centrifuged, and the yeast separated from the wash as a cream containing about 10 per cent of yeast. The spent wash is discarded. The separated yeast cells are re-suspended in water and re-centrifuged and this process is sometimes repeated. The yeast centrifugate is then pressed to a cake of 25–30 per cent dry matter. The effluent consists of spent wash, water from subsequent separations and from filter pressing, and washing waters from pipes, vessels, machinery and floors. The spent wash has a BOD of about 10000 mg/l and other waters an average of about 4000 mg/l. The combined effluent averages 7000–8000 mg/l BOD. Pilot plant experiments aimed at reducing the BOD of the combined wastes by 80 per cent have shown that conventional stone-filled biological filters are able to produce the required effluent when loaded at 0.43 kg BOD per m^3 per day. Re-circulation ratios of 20:1 were required to prevent blockage by the growth of excess film and such ratios may be difficult and expensive to achieve in a full scale plant. Trials were then carried out with plastic media biological filters. In pilot scale work with loadings of 2.8 kg BOD per m^3 on each of two stages in series, each with a re-circulation ratio of 9:1, an overall reduction of 80 per cent was achieved. Re-circulation is required with plastic media to provide complete wetting of the internal plastic surfaces and not, as in conventional filters, to prevent ponding. It seems likely that a 'Flocor' installation would be more economic than conventional filter treatment. Preliminary work on activated sludge methods showed that these would work but have no apparent advantages over conventional biological filtration.

Objections have been raised to admitting yeast factory effluents to sewers on the grounds that slimes and other growths may occur in them on admixture with sewage. In practice, however, no difficulties have arisen in a large English town where effluents have been discharged to sewers for a number of years. Nevertheless, elsewhere, because of this objection, a new sewer system has been installed in duplicate, yeast factory effluents being carried in a separate pipe several miles long in the same trench as a local authority trunk sewer.

Yeast factory effluents contain nothing which can be recovered as an animal feed.

8. CIDER EFFLUENTS

Cider is made by squeezing in presses crushed and shredded apples. The juice is fermented by natural yeasts in vats, matured in tanks and generally pressure filtered before casking or bottling.

Effluents arise from washing machinery, filter cloths, vats, tanks, casks, bottles, pipelines and factory floors. *Table 7* shows the strength of the various effluents[10]. Mixed effluents have a BOD of about 1 130 mg/l.

Cider effluents are carbon-rich. Trials with effluents averaging 600 mg/l BOD without added nutrients showed that at a loading of 0.2 kg BOD per m^3 per day on conventional biological filters a reduction of 92 per cent BOD

Table 7. Cider factory wastes results in mg/l

	Suspended solids	PV	BOD (18.3°C)
Bottle washings, spillages, and floor and equipment washings	76	985	1 770
Barrel washings	334	221	361
Filter cloth washings	5 539	921	2035
Filter-pump washings	159	28	12
Final filter washings	0	441	1 175
Storage tanks and filters	652	278	817
Press-room drainage	Trace	25	48

was obtained. With 45 mg/l of nitrogen and 10 mg/l of phosphorus added the reduction in BOD increased to 99 per cent. Equal volumes of cider effluent and sewage showed reductions in BOD as follows:

Single biological filtration	97 %
Re-circulation ratio 1:1	98 %
Alternating double filtration	99 %

Clearly, cider effluents are easily treatable in admixture with sewage at local authority works and are more treatable than sewage alone.

9. ANTIBIOTICS AND VITAMINS EFFLUENTS

Some antibiotics and vitamins are made by fermentation, aerobically or anaerobically in specialized 'mashes' usually of secret composition, by a variety of micro-organisms. *Table 8* gives examples of mash formulations which have been published[11].

Table 8. Nutrient solutions for antibiotics fermentations

Benzyl penicillin (g/l)		Bacitracin (g/l)	
Lactose	35	Starch	10
Glucose	10	Peanut meal	45
Corn steep liquor solids	35	Yeast	3
K_2HPO_4	4	Calcium acetate	0.5
$CaCO_3$	10	K_2HPO_4	1
Vegetable oil	2.5	$MgSO_4H_2O$	0.2
		NaCl	0.01

Other materials used in mashes include most common sugars, corn steep liquors, distillers solubles, fish or whale solubles, soya bean meal, fish meal and trace minerals. Sugars, alkalis, organic acids and vegetable oils are added during fermentation to maintain concentrations of nutrients, control pH and inhibit foaming.

Relatively small amounts of product are extracted from the liquor or cells, and the greater part of the organic material goes into the effluent which may be contaminated with solvents and disinfectants. The whole spent wash, or the solids, may sometimes be recovered by drying for sale for animal feeding purposes. *Table 9* shows an analysis of an antibiotic effluent.

Table 9. Analysis of a principal antibiotic waste results, except pH, in mg/l

pH	9.3
Total solids	23690
Suspended solids	18
BOD	7120
Nitrate (as N)	41
Total nitrogen (as N)	1260
Antibiotic	250

Antibiotic residues in effluents may influence the efficiency of biological treatment but biological methods are nevertheless used and effluents are sometimes accepted into sewers.

Mixed effluents seem generally to be treatable on conventional biological filters at about 0.5 kg BOD per m^3 per day, with 96 per cent reduction of BOD. Reduction of 90–95 per cent BOD have been claimed for anaerobic digestion but evidence suggests it is uneconomic in comparison with aerobic methods. Similarly filters seem to be preferred to the activated sludge process, which laboratory trials show to reduce BOD by 70 per cent in 24 hours.

The apparent BOD of some antibiotics effluents is often lower than the true value as a result of interference in the test by antibiotic residues. The presence of oxytetracycline may be offset by treatment with ferric chloride when an inactive complex results.

Various treatment plants have been described[4]. In Virginia, USA about 7 800 m^3 of effluent of BOD about 2 000 mg/l are treated daily by neutralization, solids removal, activated sludge treatment, sludge disposal to land and an admixture of effluent with cooling water before discharge to sewer. The capital cost was £540 000 and running charges are over £60 000 a year. If the capital is amortized at 15 per cent, then the cost of pretreatment is about £0.05 per m^3.

Most antibiotics factories in the UK are sited on estuaries or coasts where the disposal of untreated effluent to sea is possible. Coastal conditions, tidal currents, volume and the polluting qualities of the effluent will dictate the length of pipeline required, and the cost. Capital costs may be high. A price of about £350 000 was quoted for a pipeline 2.8 km over land and the same length on the sea bed to dispose of about 3 000 m^3 per day of antibiotics effluent. A similar capital cost (exclusive of site preparation) would have been incurred in erecting an activated sludge plant to treat the effluent which had a BOD of 3 500 mg/l. Prior air stripping would have been required to remove chlorinated hydrocarbon solvents. It was proposed then to treat the effluent by activated sludge in 32 aeration tanks, using a re-cycle ratio of 4:1, and settling sludge in a 17 m diameter tank. The pipeline was chosen because lower running costs were incurred, and because it was possible to share the capital cost of the pipeline, but not the activated sludge plant, with other users.

10. DEVELOPMENTS

Recent and renewed interest in the chemical treatment of sewage, for example by the modified Desal process, make it possible to consider such treatment for organic industrial effluents similar to those from the fermentation industries. It may become possible to treat such effluents to the extent that they may be recycled in the process more cheaply than equivalent water may be bought from suppliers. The latest types of ion exchange resins are less costly and more effective than their predecessors, and new uses are being found for activated carbon.

Ultrafiltration through either sieve membranes retaining molecules of weight greater than 2000 (the Iopor system) or through semi-permeable membranes retaining much smaller molecules (reverse osmosis) may be used not only to produce a filtrate suitable for recycling or reuse, but to concentrate solids for recovery. In this way the methods may supplement or replace such processes as evaporation.

However, the most essential consideration in any form of treatment is economics. Obviously industrialists will choose that method which while satisfying the requirements for effluent quality will incur the minimum addition to production costs. In this respect Hendrick[12] in 1901 made the following comment about malt distillery effluent:

> 'Distillers could not look on burnt ale (pot ale) as a gold mine. At the same time they had to consider how to dispose of it without loss, if possible. That could only be done by preparing from it a saleable by-product'.

What was true in 1901 still holds good today.

11. ACKNOWLEDGEMENTS

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