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the use of high rate biofiltration in hot and humid climatic conditions

INTRODUCTION

The introduction to a watercourse of biodegradable organic matter which consumes dissolved oxygen and promotes the growth of micro-organisms leads to water pollution. If oxygen is re-introduced as with naturally flowing water by diffusion from the atmosphere, the organic matter and deleterious micro-organisms will be destroyed and oxygen in the water will again be available for beneficial marine growth.

The trickling or percolating filter is a recognised device for rapid aeration of domestic or industrial wastes containing biodegradable organics. The heart of the filter is the media or packing. The media serves as the support system on which a slime of micro-organisms grows. The waste flows or trickles by gravity over the slime covered packing. Air rises through the packing by natural draft counter current to the down flowing waste and the aerobic micro-organisms in the slime digest the organic matter in the presence of the oxygen diffusing into the slime.

Trickling filters are used extensively for wastewater treatment because of the following major advantages:

1. Simplicity of construction.
2. Ease of operation.
3. Low operating costs.
4. Minimum maintenance requirements.

Over 66% of the municipal treatment plants in Western Europe and the USA use this type of oxidation system. The system was first used on a large scale in 1893 at the Salford Sewage Works.

However, conventional media in the form of clinker, slag, stone, gravel, coke and in some cases coal, is limited in its ability to provide high surface area per unit volume due to its geometric configuration. As the purpose of the media in a biological filter is to provide a large surface area for the aerobic growth of attacked micro-organisms, it can be said that there is a relationship between surface area and numbers of organisms and the greater the number of organisms, in general terms, the greater the weight of BOD removed per unit volume of media. With mineral media there is not only insufficient area for the formulation of beneficial thin-film slime, but oxygenation is poor due to the limited natural draft. In addition, uneven build-up and sloughing-off of sludge contribute to the plugging of the irregular and varied crevices between the rocks.

THE DEVELOPMENT OF PLASTIC MEDIA

The physical deficiencies of mineral media plus low hydraulic and organic loading capabilities has led to a considerable effort being expended in the search for a superior packing media, with a concentration of effort on synthetic materials exhibiting the desirable properties.

The ideal media was defined by Chipperfield as follows:

1. It should be capable of removing high weights of BOD per unit packed volume.
2. It should be capable of operating at high hydraulic loadings per unit volume and unit area.
3. It should possess a significantly open structure to avoid blockage by the accretion of solids and to ensure an adequate supply of oxygen without recourse to forced aeration.
4. It should be sufficiently strong structurally to bear its own weight and the weight of overlying layers of medium, together with the attached growths of bios.
5. It should be sufficiently light in weight (even when loaded with bios) to enable a significant reduction to be made in the civil engineering costs of plant construction.
6. It should be biologically inert, neither attacked by nor inhibiting growth of the treatment bios.
7. It should be chemically stable, not degrading with use or in the presence of small quantities of solvents, organic chemicals etc.
8. It should have as low as or cheaper cost per kg of BOD removed when packed as conventional biological purification processes.

These characteristics have become the standard by which all media are assessed, and it is clear from these characteristics that plastics offer the best chance of developing an ideal media.

However, biological filtration systems may be broadly categorised as either:

- low rate
- intermediate rate
- high rate

depending on the hydraulic or organic loading applied to the medium. It is generally agreed that sharp demarcations do not exist between the successive categories and that to some extent the descriptions are interpreted differently according to local practice. It is however becoming universally accepted that high rate biofiltration starts at approximately 3.0 m^3/m^3 day hydraulic loads or with organic loads in excess of 0.6 kg BOD/m^3 day.

Common experience has shown that a high rate filter will not produce economically a high quality effluent and high rate filters are not normally used to produce well purified effluents.

The development of high rate plastics media originated both in the UK and in the USA, the earliest experiments being carried out in the USA by Dow Chemical Co (Dowpac and Surfpac), B F Goodrich (Koroseal) and the Fluor Corporation (Polygrid). Although initially polystyrene was used in manufacturing plastics media, PVC (polyvinyl chloride) is now generally preferred, as it has better chemical resistance and is self-extinguishing.

In the UK most of the work carried out on plastics media was initiated by Imperial Chemical Industries Ltd with a view to developing an ideal biological filter medium. This resulted in the design of a PVC packing known as Flocor, which has been commercially available for fifteen years. During this time considerable operational experience has been gained on large and small installations.

Since the early work some 1000 plants employing plastics media have been built on a world wide basis on all five continents including the countries of Iran, South Africa, Caribbean, Singapore, Malaysia, Hong Kong, Japan, Australia and New Zealand.

HIGH RATE MEDIA (ORDERED)

Flocor E, the most widely used high rate roughing ordered media, consists of alternating plane and vacuum formed corrugated sheets of PVC foil bonded together with a PVC based adhesive. Flocor E is built up to form standard modules 1200 mm x 600 mm x 600 mm. The top and bottom of the modules are then flanged by a heating process. These modules in their turn can be fitted into any regular shaped containing structure, with cutting if required.

However, when the material is exported from the UK to areas other than Europe it is usually in the unassembled form i.e. flats and formings and assembled on site. Under these conditions flanging equipment may not be available locally.

The corrugations are arranged so that there can be no free fall through the vertical channels and the applied liquid over a wide range of application rates flows in a thin film over the corrugated surfaces without collecting into drops at the angles of the corrugations. Exhaustive physical and biological test work has been carried out to determine the present form of the product.

The packing should be stacked in tower-like structures, but by virtue of the low bulk density of the media the 'towers' need only be of lightweight construction e.g. a comparatively lightweight mild steel frame or even wood framework clad with say PVC sheets. The cladding serves to contain the liquid rather than support the packing in this case.

The effluent to be treated is fed to the top of the 'towers' continuously and distributed evenly over the cross-sectional area of the tower at a minimum irrigation rate of 1.5 $m^3/hr\ m^2$ cross-section of packing. The advent of plastics roughing media has made it a practical proposition to pack the media to depths of 7.8 m for flanged modules and 3.0 m for unflanged modules.

Because of the high compressive strength of the packing it is possible to pack to these depths without an intermediate support for the packing. This when necessary need only be simple in design, e.g. narrow parallel beams 40 mm wide, spaced ideally as the module is placed with its 1.2 m length horizontal: at 200 mm centres.

As well as the module having its 1.2 m length horizontal, the module would be arranged so that the flat sheets would be vertical. The second layer of packing up the tower would be placed again, so that the 1.2 m length is horizontal, but at right angles to the layer below and above.

Ideally within the limits of 1.8 to 7.8 m packed depth (the volume of packing being fixed for a given applied load), the cross-sectional area of the packing is usually arranged so that the volume of effluent to be treated is at least as close to the minimum irrigation rate for the maximum period of time, since if the volume is less than the minimum irrigation rate, re-circulation must normally be employed.

As a design principle with high-rate plastics media re-circulation should be kept to a minimum for economic reasons. It is comparatively easy, however, by the arrangement of levels and baffles in sumps, to arrange for automatic recycling, should the crude supply of effluent fail or drop to a low level, without employing expensive electrical switchgear.

Effluent flows down the packing and bios in a thin film, and because of the uniform void structure a supply of air is allowed to rise through the filter and a supply of oxygen is transferred through the falling film to the bios. This enables the process of BOD reduction to take place with high efficiency.

Similarly, as with conventional percolating filters, where the following humus settlement tanks are an integral part of the treatment process, a settlement process is required after high rate treatment on plastics packing. Here the settlement process is also an integral part of the treatment.

The effluent is collected from the base of the tower and then passed to a settlement system, ideally under gravity flow. Experience has shown that the upward flow type with a 60° included angle in a conical base and tanks of the radial flow type, are equally successful. Experience has also shown that the previously considered normal design parameters for settlement tanks do not apply when treating effluent from high rate systems, as the solids voided from these systems settle very readily. As a result upward flow velocities of 2.4 m/hr have now become standard parameters to be considered.

Experimental evidence and experience on full scale plants have shown that with an intelligent approach to the desludging of these settlement tanks, a sludge of 3-4 per cent w/w solids can normally be removed and that the sludges produced by this process are certainly no more difficult to dewater than the sludges produced by the more conventional biological treatment. Evaluations of the specific resistance filtration of sludges of biological origin arising from Flocor systems have been made and show a normal specific resistance of $10\text{-}20 \times 10^9/sec^2/g$.

The sludges are also typically amenable and reduction of specific resistance to filtration by chemical treatment (e.g. flocculation) and have no greater, if any, adverse effect upon the dewaterability of primary sludges with which it is common practice to treat in admixture, than do conventional filter humus solids.

Conventional primary sedimentation can be eliminated when feeding Flocor systems with macerated or screened wastewaters, and solids that would normally settle in the primary settlement tanks do not undergo any significant biological degradation on passage through the system, since their passage through the regularly ordered medium is unimpeded.

In addition, fine particles resulting from maceration effectively act as nuclei for flocculation when absorbed at bios surfaces, with the result that many colloidal materials, previously non-separable by sedimentation, become settleable after biophysical flocculation and desorption.

Thus one effect of the Flocor treatment in this form, as distinct from bio-oxidation effects, is to make it possible to separate by sedimentation a greater proportion of the suspended materials present than is possible without such treatment, and to employ higher flow rates in sedimentation vessels.

Depending on the strength of the effluent being treated and on the discharge standard required, the settled effluent from the settlement tank would be discharged partially treated to a coastal discharge. Alternatively, it could be passed to a polishing filter type using either stone or plastics media or to a 'fining' activated sludge plant.

TYPICAL APPLICATION

One area where high rate plastics media is beginning to play a significant part in the protection of the environment is Malaysia. The Malaysian Government under its 1974 Environmental Quality Act has taken the initial steps for the future protection of the environment. This act is shortly to be enforced and the standards proposed under this legislation are shown in Table 1.

TABLE 1: Four-generation sets of effluent standards

Parameter	Standard A 1.7.78	Standard B 1.7.79	Standard C 1.7.80	Standard D 1.7.81
Biochemical oxygen demand (BOD), 3-day, 30°C; mg/l	5000	2000	1000	500
Chemical oxygen demand (COD), mg/l	10 000	4000	2000	1000
Total solids, mg/l	4000	2500	2000	1500
Suspended solids, mg/l	1200	800	600	400
Oil and grease, mg/l	150	100	75	50
Ammoniacal nitrogen, mg/l	25	15	15	10
Organic nitrogen, mg/l	200	100	75	50
pH	5.0 - 9.0	5.0 - 9.0	5.0 - 9.0	5.0 - 9.0
Temperature, °C	45	45	45	45

It is claimed that there are approximately 150 Palm Oil Mills in Malaysia of which some 100 are in Peninsular Malaya. These mills produced some 1 000 000 tonnes of crude oil with a parallel effluent production of 3 000 000 tonnes containing some 57 000 tonnes of BOD. This BOD load is equivalent to the BOD load of a population of 70 000 000. When it is realised that the real population of Malaya is of the order of 10 000 000 the magnitude of the effluent problem facing the Palm Oil Industry in Malaysia is appreciated.

Production methods do vary from mill to mill but in general terms a typical effluent from a mill would have the following composition:

TABLE 2

	Crude	After flotation
pH	3.5	3.6
COD	64 000	6400
BOD	42 000	3500
PV	12 000	1250
Suspended solids	27 000	400
Total solids	52 000	
Oil	4000	20
NH_3	20	7
Organic N	800	

After flocculation, using say 100 ppm Ferric Chloride and 10 ppm of a cationic polyelectrolyte and flotation the polluting strength of mill effluent is substantially reduced to values shown in Table 2.

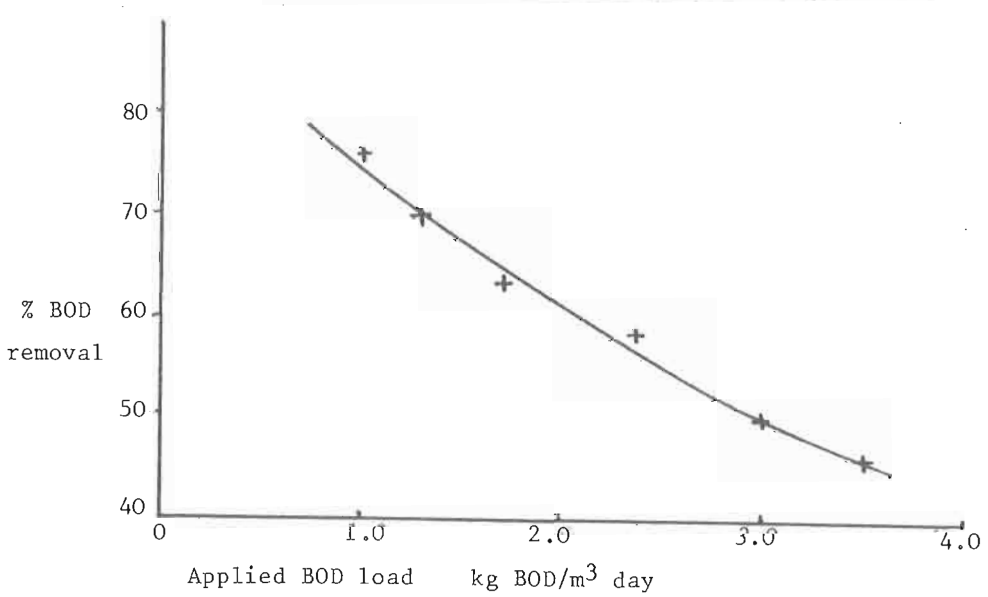
A float of the order of 15-20% solids being removed from the flotation stage.

Although flotation substantially reduces the polluting load it can be seen that the effluent is still significantly stronger than the ultimate standard required by Government.

Following flotation the effluent is deficient in nutrients and extremely acidic. However, following adjustment of these deficiencies the effluent is in an ideal condition for the optimum use of high rate biofiltration to meet the ultimate discharge standard. To achieve this standard, two stages of high-rate biofiltration are required operating in series.

Following laboratory and pilot-plant studies the treatability curve shown in figure 1 was obtained for Flocor E plastics medium.

FIGURE 1: High-rate biofiltration using plastic filter media (Flocor E) for the treatment of effluents from palm oil mills following 'microflotation'



A typical plant design (biological data) is shown in Table 3 and a typical flow sheet in figure 2.

TABLE 3:

Type of effluent:	Palm oil mill effluent
Volume:	30 m^3/hr = 720 m^3/day
BOD concentration:	3500 mg/litre (after flotation)
Daily BOD load:	2520 kg BOD/day
Special features:	Screening, Chemical flocculation, Flotation, pH adjustment, Nutrient additions
Treated effluent standard required:	500 mg/litre BOD 400 mg/litre S solids

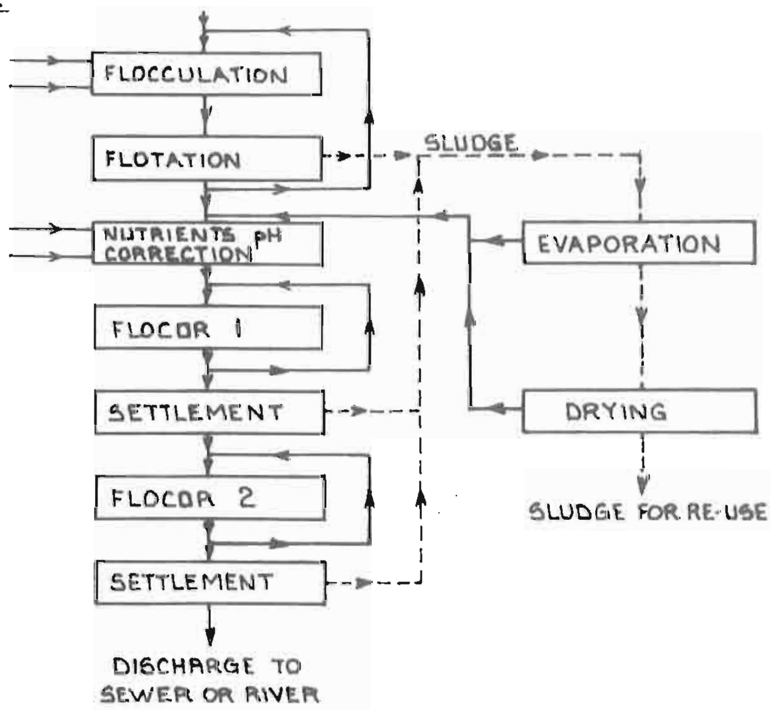
Design Proposals

Stage	Stage Load kg BOD/DAY	Stage Load kg BOD/m^3/DAY	'Flocor' Volume m^3	Anticipated efficiency %	BOD mg/litre Inlet	BOD mg/litre Outlet
1	2520	2.0	1260	60	3500	1400
2	1008	1.8	557	65	1400	500

Stage	Tower Details: Packed depth m	Tower Details: Plan dimensions mxm	Tower Details: Plan area m^2	Minimum Irrigation Rate m^3/hour	*Hydraulic Load m^3/m^2/day	*Surface Load m^3/m^2/day
1	5.4	21.6 x 10.8	233.28	343	0.6	3.1
2	5.4	9.6 x 10.8	103.08	153	1.3	7.0

*based on crude flow

FIGURE 2:



CONCLUSION

The experiences gained in the Western World using high-rate plastics media can be applied in hot and humid climatic conditions providing adequate attention is paid to the engineering design of equipment and the treatability of the various wastewaters are considered under local conditions.