Ponds

Algal aid puts a sparkle on effluent

By Pieter Meiring, Peter Rose and Oleg Shipin

In harnessing the energy of solar radiation, algae fulfil a double function. Through photosynthetic production of new cells they act as a prime producer, essential to the most basic food chain.

Engineers also put algae to work in oxidation ponds, but in this instance primarily to oxygenate the water. In this very obliging and economic unit process, symbiosis is established between algae and the bacteria responsible for the biological degradation of putrescible organic matter. A final effluent is produced which, although rich in newly metabolized carbonaceous and nitrogenous algal matter represents a good improvement in water quality.

Unfortunately however, because of high algal concentrations the effluent is not always considered satisfactory. Algae are often blamed as the cause of secondary pollution, adding their own waste and decay products to the effluent. In this respect algae can constitute a real nuisance, and effective ways and means to remove them economically from an oxidation pond effluent have been investigated for many years.

A simple means to remove algae would give oxidation ponds much greater respectability and broaden their use as a wastewater treatment method. Potentially ponds have an effective role to play, both in the First World but especially in the Third World where good climate throughout the year would favour them.

In the Petro® process, which combines ponds with trickling filters, a very useful breakthrough has been achieved. As before, the objective was to remove algae, not by physical separation but rather by biological immobilization whilst also using the algae to augment the process of biological treatment.

Removal of algae on trickling filters

Through the years, design engineers have tried unsuccessfully to remove algae from oxidation pond effluents by post-treatment using either an in-line trickling filter or an in-line activated sludge reactor (Meiring 1993). Some such trickling filter plants built in the 1970s are still operational in South Africa today. All they are really achieving is the production of a nitrified oxidation pond effluent, but one which still contains high algal concentrations.

When designing a secondary facility such as a trickling filter for treating a well-stabilized oxidation pond effluent, the relatively high chemical oxygen demand (COD) of the effluent can be misleading. This demand largely consists of intractable algal cells which are not readily available as a food source to the trickling filter. Accordingly the biofilm is essentially autotrophic (inorganic nutrient consuming) in nature and not able to retain or enmesh the algae passing over it.

> Algae can be a nuisance in oxidation ponds, and a drawback to their wider use. But, by trapping them on a trickling filter, they can be used to put a final polish on the effluent.

Switching the bacterial population on the biofilm from autotrophic to heterotrophic (biological carbon dependent) will result in the successful enmeshment of the algae. This is done by bypassing some of the anaerobic pond effluent to the trickling filter to provide a layer of heterotrophs that could assist in trapping the algae. Instead of using the secondary processes for mere upgrading of conventional oxidation pond effluent, the oxidation ponds must be designated as an 'understanding and amicable' pretreatment facility, and operated so as to enhance the performance of the traditional unit processes which they precede by ensuring a heterotrophic environment.

Advantageous use of algae

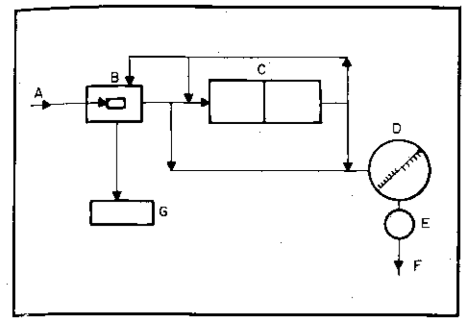
A most striking aspect is the surprising role played by algae if retained on a heterotrophic biofilm. Being immobilized and embodied in the biofilm in the dark in an aerobic liquid environment enriched with a nutritious substrate, at least some species of the algae present such as Cyanophyta, Bacillariophyta, Euglenophyta and Chlorophyta are able to perform also as heterotrophs (Miller and Allen 1972, Kessler 1972, Abeliovich and Weissman 1978, Neilson and Lewin 1974, Meilson and Larsson 1980). In this way, they actually participate in a subservient role to enhance the overall purification process.

This is especially true for a trickling filter installation since it is known that extracellular metabolites excreted by algae have a distinct flocculating ability (Avnimelech and Troeger 1982) which renders, in this instance, a final effluent with a clarity that trickling filters seldom achieve.

Analysis of effluent from the pond system at KaNyamazane.

mg/l (or as indicated)	Raw sewage	Primary pond effluent*	Final pond effluent	Humus tank effluent
Suspended solids	300	74	48	8
Chemical oxygen demand	710	160	152	50
COD (filtered)	–	124	112	46
4-hr Oxygen Absorption	80	15	20	5
NH_3–N	40	15	13	2.6
TKN–N	70	18	15	3.8
NO_3–N	–	–	–	5.7
Chlorophyll a (μg/l)	0	330	1020	60
Phaeophytins (μg/l)	0	72	130	45
Alkalinity	150	137	112	37
pH	7.1	7.2	7.5	7.1

* Includes high-rate recirculated final pond effluent



Above: Flow diagram of KaNyamazane Petro process. A–inflow, B–Ae/An pond reactor with fermentation pit, C–oxidation ponds, D–trickling filter or activated sludge reactor, E–humus tank, F–effluent, G–sludge drying bed.

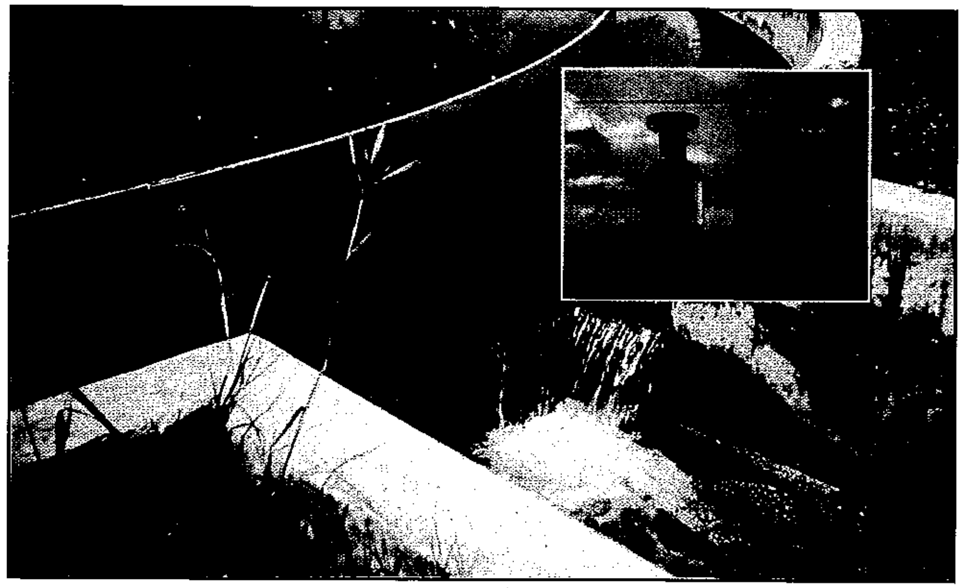
Markedly lower COD values are also obtained. In light of the above, the process is aptly called PETRO which is the acronym for Pond Enhanced TReatment and Operation. The process has been patented worldwide.

Overall plant performance

A typical analysis of the influent and effluent from a fully loaded 5 million litre/d integrated pond system at KaNyamazane, Transvaal using the Petro process is reflected in the Table (below left).

Functions performed by ponds

The following aspects of this integrated configuration and the underlying process highlight the many functions performed by the preceding pond system. This system, which is partly incorporated in a side loop is designed according to standard design criteria, ignoring the load exerted by the algae in the recycled pond water. For the design load on the trickling filters the same would probably apply, but until more feedback is available from existing installations, a nominal COD-load of 50mg/l is added to the outflow from the aerobic/anaerobic pond reactor directed onto the trickling filters. When designing the trickling filters the ammonia load may be the critical parameter and should be watched. The humus washed out of the trickling filters settles very readily and until more data are available current design criteria, as far as overflow rates are concerned, can be increased by 20%.



Above: One of four humus tanks at KaNyamazane. Insert compares the influent to trickling filters with that of the humus tank effluent.

- Most of the readily degradable carbonaceous matter when discharged into the oxidation ponds is biodegraded. As new algal cells are being synthesized, the overall COD is apparently not reduced in the ponds. However, COD exerted by the algae does not impose an equivalent load on the trickling filters. This stems from the fact that algae are surprisingly unmanageable on a trickling filter. This phenomenon calls for a more appropriate parameter to quantify effective loads present in an oxidation pond effluent and imposed on the trickling filter. The reason for this lies in the ostensible anomaly that the algae do not exert an equivalent organic load but in a way contribute to the purification process.
- The reduction of ammonia-nitrogen obtained in oxidation ponds is also very advantageous as it reduces the ammonia-nitrogen load to the trickling filters. It is often this load that constitutes the critical parameter in trickling filter design when using this process line-up.
- The oxidation ponds produce an algae laden effluent, part of which is recycled to the Ae/An pond reactor. Here it serves to ensure an aerobic overlay of this pond thereby alleviating a possible odour nuisance while promoting pronounced nitrification/denitrification in the Ae/An pond reactor.
- The ponds bring about a substantial reduction in the numbers of pathogenic bacteria and cysts in the water passing on to the trickling filters and renders a much more agreeable water to be given further treatment (Stander and Meiring 1962).
- The ponds serve to bring about a substantial attenuation of the hydraulic peaks that have to be accommodated in the downstream unit operations. This can be achieved by using the large pond surface area as a balancing facility.
- The production of sludge in the Ae/An pond reactor is relatively small and what sludge is produced is well-stabilized and dewaters readily.
- The extracellular metabolites exuded by the algae have a distinct flocculating ability which imparts a 'sparkle' on the filter underflow which trickling filters rarely exhibit.
- When sloughing of the attached biofilm occurs the detached humus is in the form of relatively large green clusters. In a humus tank these clusters settle rapidly.
- The humus sludge is pumped either to the Ae/An pond reactor where it is stabilized, or to a separate pond reactor to remove it from the system.
- Up to 85% nitrogen removal can be achieved.
- The operation is simple. There are two pumps for recycling effluent and two (or one) rotary distributors for the trickling filters. *Cont. over*

Full scale plants

In South Africa a number of integrated pond systems using the Petro process are operational whilst others are under construction. A feature of these plants is their cost-effectiveness, reliability and simplicity of operation. The original 5 million litre/d plant designed as a prototype and built in 1988 is now being extended to double its present capacity.

Cost-wise, a substantial saving is achieved by the omission of primary sedimention tanks, sludge digesters, thickeners, and large sludge drying beds. In addition the biological trickling filters can serve more than twice the number of people they do in a conventional facility; with primary sedimentation tanks, the amount of biosolids produced is substantially less and the operational and maintenance requirements are simple. Energy consumption is a fraction of that associated with an activated sludge plant.

Climate does play a role but not as pronounced as people may think. It is ironical that there are today many times more pond applications in both Germany and France than in South Africa. There is no reason why these facilities cannot be converted into integrated pond systems employing the Petro process.

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References

Abeliovich, A. and D. Weissman (1978) Role of heterotrophic nutrition in growth of alga *Scenedesmus obliquus* in high-rate oxidation ponds. *Appl. Environ. Microbiol.* 35, 1, 32-37.

Avnimelech, Y. and B. Troeger (1982) Mutual flocculation of algae and clay: evidence and implications. *Science*, 216, 2, 63-65.

Kessler, E. (1972) Physiologische und biochemische Beitrage zur Taxonomie der Gattung *Chlorella*. IV. Ververtung Organisch. Kohl. Verbind. Arch. Microbiol. 35, 1, 153.

Neilson, A.H. and R.A. Lewin (1974) The uptake and utilization of organic carbon by algae: essay in comparative biochemistry. *Phycologia*, 13, 3, 227-264.

Neilson, A.H., and T. Larsson (1980) The utilization of organic nitrogen for growth of algae: physiological aspects. *Physiol. Plant*, 48, 542-553.

Meiring, P.G.J. (1993) Integrating oxidaton ponds and biological trickling filters. Third WISA Conference, Durban, May.

Miller, J. and M. Allen (1972) Carbon utilization patterns in the heterotrophic algae *Chlorogloea fritschii*. Arch. Microbiol. 86, 1-12.

Stander, G. J. and P.G.J. Meiring (1962) Health Aspects of Maturation of Stabilization Ponds. 20th Annual Health Congress. SA Inst. Public Health, East London.

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