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FISH PRODUCTION IN WASTE STABILIZATION PONDS

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INTRODUCTION

Algal stabilization ponds are now being adopted as the main method of sewage treatment for water-borne sanitation in most tropical and subtropical countries wherever feasible. The adoption of ponds for treatment has been particularly marked over the past two decades - in Kenya, for example there were four systems in 1962, seventeen in 1972 and 52 in 1982. Algal ponds offer the possibilities for the intergration of aquaculture and sewage treatment. Reports of fish surviving in ponds, either occurring accidentally or deliberately introduced are numerous but the commercial exploitation of fish for human consumption grown in algal stabilization ponds, built on basic public health engineering designs for sewage purification, has never been exploited to any significant extent despite the fact that, albeit outside of Africa, sewage is recycled to fertilize fish ponds in many parts of the world - and has been since antiquity. The practice of building latrines over ponds or the addition of sewage-enriched flood waters to commercial fish ponds are cases in point.

Reports of fish surviving in maturation ponds are frequent in the literature. The majority of published papers, however, are reports of studies to assess the effect of introduced fish on water quality improvement (1) but some relevant fish production data is available - for example Sreenivasan et al (2) indicates possibilities of producing 9500 kg/ha/yr (Common Carp Cyprinus carpio and Tilapia sp.) in India from a maturation pond. More recently Edwards et al (3) have obtained extrapolated yields approaching 20 tons/ha/yr in fish ponds receiving the effluent from a high rate stabilization pond over a 3-month growing season. Both the last two studies were, however , carried out at institutional establishments; there is a dearth of information on survival of fish in facultative ponds, as distinct from maturation ponds, and in municipal ponds. Until such data becomes available public authorities will be unwilling to design works capable of combining fish culture and sewage purification. As part of a wider study on the evaluation of pond design criteria in Kenya - mainly carried out between 1977-80 - some observations on fish survival in ponds was also obtained. An outline of the data obtained is followed by a discussion.

MATERIAL AND METHODS

Ponds in Kenya are normally built in series with primary facultative ponds, which may or may not be preceeded by anaerobic treatment, designed to give a pond Biological Oxygen Demand at 25°C, inclusive of algae, never exceeding 75 mg/l, secondary facultative ponds give a pond B.O.D of 25 mg/l and followed by maturation ponds to produce an effluent with a faecal coliform count of less than 1000 per 100 ml.

At the town of Thika (1°03'S, 37°05'E) sewage is treated by anaerobic, primary facultative (dissolved O_2 range 0-20 mg/l), secondary facultative (O_2,1.2-26 mg/l) and maturation ponds. Further technical data is given elsewhere (4). Tilapia nilotica, which is an algal feeder, and a highly suitable fish for African aquaculture, were introduced into secondary facultative ponds as fingerlings. They were cultured in cages in order to ease sampling and to eliminate predation. Each cage, which had a metal framework, measured 90cmx90cmx100cm. Survival rate was over 95%. Figure 1 shows the results of growth rate at two stocking densities during 10 week growing season. At the lower stocking density growth data is available for up to 20 weeks.

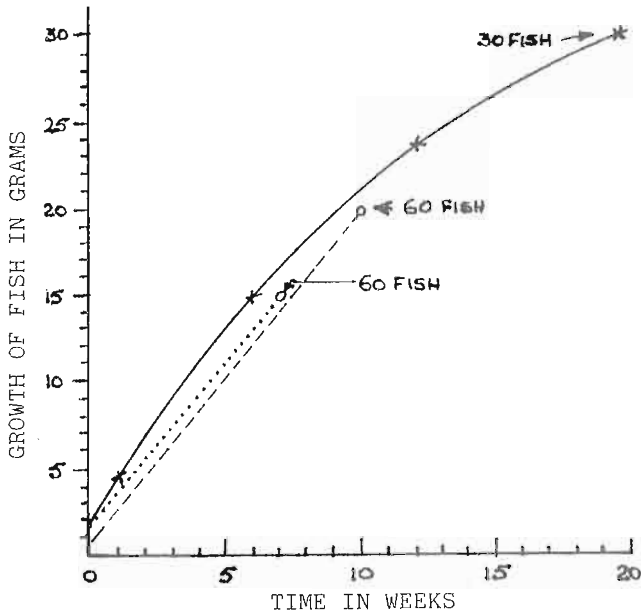

Figure 1: GROWTH RATE CURVE FOR TILAPIA NILOTICA IN SECONDARY FACULTATIVE POND

In addition to the Thika site fish were introduced also into the secondary facultative and maturation ponds at Kisumu (0°06'S34°45'E) At both sites fish were screened for chlorinated pesticides and heavy metal residues and compared with levels from natural waters.* Fish, particularly those from stabilization ponds contained D.D.T. and metabolites D.D.E. and D.D.D. Trace levels (max 0.011 mg/l) were found in fish tissues from natural sources, and at a fish hatchery (max.0.026 mg/l). In contrast, levels of D.D.T. in fish from Kisumu stabilization ponds were significantly higher (0.06-0.3 mg/l = 17-48 mg/l on fat basis). No significant levels of other pesticides were detected. Fish livers from ponds ranged from 39-199 mg/l Zn and 0.6-2.6 mg/l Cd. Lake Victoria sample also contained 45 mg/l Zn, 3.1 mg/l Cd and possibly Hg at 0.45 mg/l. No Cr, Pb or Hg was detected in samples from stabilization ponds. Liver-weight ratios from fish in Kisumu ponds averaged 0.9 (as % liver/total wt.) and 0.5 from Lake Victoria.

DISCUSSION OF RESULTS

Fish at Thika and Kisumu have grown satisfactorily and background levels of D.D.T., although elevated, are still within acceptable limits. The influent to both pond systems is predominantly domestic (currently 100% at the Kisumu ponds). The possible sources of D.D.T. which appears to have accumulated in fish from the ponds could arise from excreta, waste water washings from vegetables and fruit, and from laundry wash waters. A sample of maize meal purchased in Kisumu was found to contain 2 mg/l of D.D.T. and another sample collected at Nakuru (0°22'S, 36°05'E) 1 mg/l.

The liver/weight ratios do indicate that the fish growing in ponds are slightly more stressed than those in natural waters; this could be an effect of dissolved oxygen levels.

At Thika (Common Carp *Cyprinus carpio*) and *Tilapia sp.* were kept in continuous culture in the maturation ponds at Thika for over 7 years; there have been two fish fills involving up to 50% of the carp population but never *Tilapia*. *Tilapia* have similarly been stocked for a six year period in the secondary facultative and maturation ponds at Kisumu without any reported mortalities.

If *Tilapia* and especially *Tilapia nilotica* can be grown apparently successfully in ponds; what is holding up further development?

Allen and Hepher (5) in a global review listed the following restraints for wastewater fish culture: dissolved oxygen levels in ponds, toxic materials in wastewaters, tastes and odours in fish, fish parasites and diseases, public health problems, pond effluent standards and public acceptance.

In an African context and specifically for algal stabilization ponds, and particularly with current and planned municipal schemes in mind, the following will be important:-

Human disease transmission.
Poor operation and maintenance of sewerage systems.
Difficulties in obtaining good fish stocks.
Public acceptance.
Frustrations with existing pond designs.

Human disease transmission.

This is probably not a problem but to convince public health personnel that it is not will be difficult; it must rank as the main constraint.

Janssen(6) reviews a considerable amount of literature dealing with this subject. All the available evidence indicates that, unlike warm blooded animals, fish normally do not suffer from infections of *Salmonella*, *Shigella* or other *enterobacteriacea*. The problem, however, is the risk that pathogens may be carried passively by the fish and so serve as vectors. By allowing a depuration period the risk can be minimized; Buras (7), however, working in Israel, found that despite a 7-day depuration period there was no reduction in the faecal coliform concentration in the flesh of the fish grown in ponds fed with raw sewage although there was a significant reduction in blood and a slight reduction in organs. Nevertheless she was not able to identify any human enteric viruses in fish flesh. It is quite clear, however, that public health authorities in Africa will insist on data being carried out in their own region rather than rely on overseas work. At present there appears to be a complete absence of such information. A major constraint to obtaining it is the lack of laboratory facilities, especially for virus identification in many countries.

Standards based on faecal coliform levels have been suggested; for example Shuval (8) quotes a figure of 10 faecal coliforms/100ml for fish culture but for most countries in Africa such a standard cannot be enforced and without other background information, such as the existing health of the population, this standard becomes meaningless anyhow. Buras (7) found no correlation between faecal coliform bacteria, salmonella or human enteric viruses in raw sewage. Since most rivers in Africa are faecally polluted the risk of eating fish grown in treatment plants, where the water has already undergone settlement and, in the case of ponds, several days' retention, may perhaps be less than taking fish from rivers: although often unrecorded in statistics riverine fisheries are probably significant on the African continent.

The attitude of some donors has also been extremely conservative to wastewater reclamation.

*Analytical procedures and detailed results are available from the author.

To overcome the disease risk it has been suggested that fish from waste stabilization ponds should be used only as animal food, e.g. to chickens, or as a feed for "luxury" fish or crustacea.

Poor operation and maintenance of sewerage systems.
In the immediate future the economic situation for most African countries is bleak and the expense of maintaining, operating and augmenting existing water-borne sewerage systems may prove extremely difficult. In addition policies of governments, such as the desire to distribute industries outside of the capitals, is leading to a situation where few municipality works are now treating solely domestic sewage. Algal stabilization ponds are suitable for purely domestic sewage (4) but are proving far from ideal for industrial effluents and especially for industries, such as tannery and textile mill wastes, which are two types of industries being rapidly developed in Africa. In Kenya the number of tanneries and textile mills established in the country - and both industries produce a wide range of waste flows - has doubled in the past decade and most have been established in the smaller towns. In Kenya trade-effluent control within the sewerage system is the responsibility of the local authority albeit this is currently under review; few local authorities in Africa will be able to recruit the calibre of manpower needed to effectively control trade-effluent discharges. Most of the problems at present, are arising from pond overloading and the adverse effects of sulphides in the case of tanneries; as far as textile mill wastes are concerned the effects of dyes are serious. One case in Kenya showed that although the dye waste was less than 5% of the total flow this inhibited photosynthesis by over 70%; the dye waste was non-toxic but partially inhibited light penetration in the water columns. Non-point pollutant sources - detergents being the obvious ones - are generally not a problem in developing countries although in Israel they have mitigated against utilization of sewage effluents in some situations. *In the writer's view if fish culture could be successfully exploited, say by a co-operative or private organization, paying a rent to a local authority the incentive to maintain municipal sewerage systems in the future could be assured.*

Obtaining fish stocks.
Obtaining good stocks of fish is likely to be a problem in many African countries. Regretably, many Government fish farms do not supply healthy stocks of fish and cannot maintain hybrid or unisex stocks. Reliable commercial suppliers are, however, available in some countries.

Public acceptance.
This certainly does not appear to be a problem in fish-eating communities in Kenya, even amongst the well-educated strata of the population who are well aware of the source of the fish. At the experimental site at Thika and at a pond system in Kisumu, which is adjacent to Lake Victoria, it has been extremely difficult to stop local fishermen from seine-netting the ponds at night. Many African communities are, however, not yet adapted to a fish diet and it would probably not be wise to introduce sewage-grown fish at the outset.

Frustrations with existing pond designs.
The message of this paper is to utilize *existing* pond systems for fish culture and this does seem feasible.
It must, however, be recognized that to a fish farmer the existing designs are far from optimum for such a purpose.
Economic assessment will have to be undertaken to decide if additional construction costs are merited: this will include options for draining and providing fish collection basins in the centre of ponds and the provision of aerators with sensors to detect abnormal dissolved oxygen levels. Most fish culturalists would also like to see larger ponds than the present sanitary engineering designs allow.

CONCLUSIONS.
Preliminary studies indicate that the survival and growth rates of Tilapia nilotica in secondary facultative and maturation ponds now merits a detailed assessment of the possibility of combining fish food production and sewage purification.
The main constraint at present to any form of further development of utilizing sewage for fish culture is the lack of data on possible human disease transmission in an African context and until this is obtained public health personnel will not officially endorse the practice.
There is, in the author's opinion, a real and serious possibility that in the future local authorities will be unable to effectively maintain the many sewerage schemes which have been constructed during the past two decades or so. The possibility for collecting a substantial revenue from fish production could be the financial incentive to an improved operation and maintenance.

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Views expressed in the paper are those of the author.

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