Wastewater-Fed Aquaculture Systems: Status and Prospects

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PHOTOS BY PETER EDWARDS

Harvesting water spinach, a vegetable for human food raised in polluted surface water in the Bangkok suburbs.

Background

The term "wastewater" is used here in a generic sense to mean human excreta in the wide range of forms in which it is currently used in aquaculture: fresh excreta and 'nightsoil'; surface waters contaminated with fecal matter; sewage or waterborne transported fecal matter; and other partially treated forms such as septage.

Fish and other aquatic organisms, particular vegetables, raised in wastewater-fed systems provide an important source of food and employment for millions of people in developing countries, particularly in South, Southeast and East Asia. However, much wastewater reuse is traditional, often in systems which may pose threats to public health.

Current knowledge concerning wastewater-fed aquaculture systems has been reviewed in publications sponsored by international organizations such as ESCAP (Economic and Social Commission for Asia and the Pacific), United Nations Development Programme and the World Bank (Edwards and Pullin 1990; Edwards 1992). ICLARM and GTZ has published guidelines for wastewater reuse in aquaculture in a summary report of the Bellagio Conference on Environment and Aquaculture in Developing Countries (Pullin et al. 1992). Research continues on wastewater-fed systems in various countries but has had minimal impact to date on development. A re-examination of issues concerning the promotion of wastewater reuse in aquaculture is warranted to facilitate resolution of unfulfilled potential.

Issues

Global Increase in Population and Urbanization

The world population is estimated to reach almost 6 billion, and be more than 50% urban, by the year 2000, greatly increasing the need for integrated systems of wastewater treatment and reuse.

Wastewater Treatment or Fish Production?

Most traditional wastewater reuse systems were designed to produce fish from nutrients in wastewater. In contrast, conventional sewerage systems such as activated sludge, trickling filters and stabilization ponds are designed to treat wastewater and thereby remove nutrients. The World Health Organization recommended that wastewater reuse should always be considered in schemes to improve sanitation (WHO 1989). However, the dilemma of simultaneously optimizing wastewater treatment and fish production in a practical way has been resolved only recently following an Overseas Development Administration-sponsored mission to Calcutta (Mara et al. 1993).

It was proposed that wastewater be treated minimally in stabilization ponds (1-day anaerobic pond followed by a 5-day facultative pond) prior to discharge into a fishpond. According to WHO guidelines for the use of wastewater in aquaculture (WHO 1989), it is estimated that the fish would be microbiologically safe for human consumption with $<10^3$ fecal coliforms per 100 ml in their pond water.

Economic Aspects

Mechanical wastewater treatment systems such as activated sludge and trickling filters require much less land to treat sewage than ponds, especially if the latter incorporate aquaculture. As land has high value in suburban areas, mechanical systems are often promoted for financial reasons as well as the professional bias of sanitary engineers. The "financial benefits" of mechanical treatment are usually not realized because such plants rarely function in tropical developing countries. Their relative comparative advantage for wastewater-fed aquaculture systems may also be illusory if a broader economic analysis is conducted to include social and environmental factors.

Social Aspects

These are diverse. Wastewater-fed aquaculture systems create employment and provide relatively low-cost produce affordable to poor consumers in urban areas.

In societies in which there is a cultural aversion to consume produce reared directly in wastewater-fed systems, indirect reuse may be feasible; i.e., fish or duckweed raised in such systems may be used as high-protein animal feed (Edwards 1990) (Figs. 1 and 2).

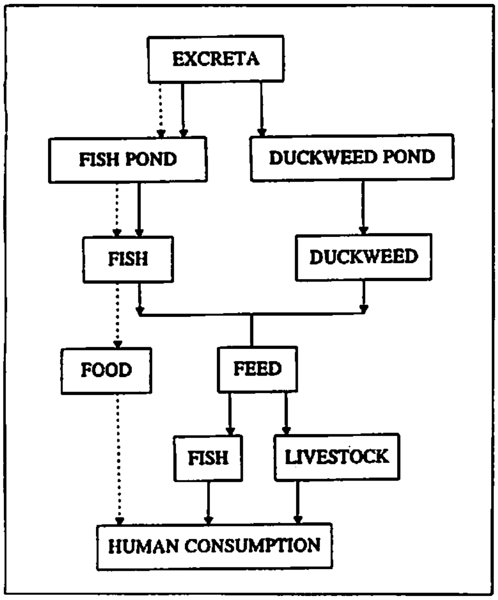


Fig. 1. Excreta-reuse strategies in aquaculture. Excreta may be used directly to produce food for human consumption (broken line) or indirectly through the production of animal feed for fish or livestock (solid line). High-protein feed may be either fish or duckweed, and it may be used to feed either fish or livestock.

Duckweed is raised in China for duck and fish feed. Research at the Asian Institute of Technology (AIT) demonstrated yields of tilapia of over 6 t/ha/year when fed septage-raised duckweed with a dry matter protein content of 26% (Edwards et al. 1990). Unfortunately, duckweed culture required twice the area than that needed to culture fish. PRISM, a nongovernment organization, recently set up such a system in Bangladesh which may be feasible as duckweed can be grown in shallow ditches and ricefields (Journey et al. 1991).

Public health aspects of both producers and consumers must be considered. Research at AIT has demonstrated rapid attenuation of both fecal coliforms and bacteriophages (viral indicators) in fertile septage-fed ponds: an initial reduction of 99% due to dilution followed by a further 99% reduction from 10^4 to 10^2 per 100 ml within only 30 hours (Fig. 3). Nevertheless, further research is required in this area.

Industrial pollution may pose a greater threat to public health than pathogens and parasites. Hundreds of factories discharge effluents into Calcutta's wastewaters, including highly toxic chromium from tanneries. One wastewater-fed fishpond system in Calcutta receives 70% industrial sewage. Hanoi sewage also contains about 30% industrial waste. Research is urgently required to assess this public health issue.

Environmental Aspects

Field observations have indicated high efficiency of wastewater treatment in wastewater-fed aquaculture systems, both in Calcutta and Hanoi. Wastewater-fed aquaculture systems provide healthy environments with high biodiversity, even in suburban areas. A large wastewater-fed system in Munich is a bird sanctuary and the Calcutta system has led IUCN to establish wastewater-fed fishponds as a special category of man-made wetlands because of their contribution to preserving nature (IUCN 1990).

Technical Aspects

Current practice can almost certainly be improved in terms of sewage treatment and aquaculture. Optimum nitrogen, biological oxygen demand and hydraulic loadings warrant study as do species composition and ratios, and stocking and harvesting strategies. Anticipated yields with better management may increase currently obtained yields in the Calcutta wastewater-fed fishpond system by two to three times (Mara et al. 1993).

Towards an Action Plan

It is proposed that a case study be conducted, in either India or Vietnam where major wastewater-fed aquaculture systems exist, to determine the social, environmental, technical and economic aspects of low-cost sewage treatment integrated with food production.

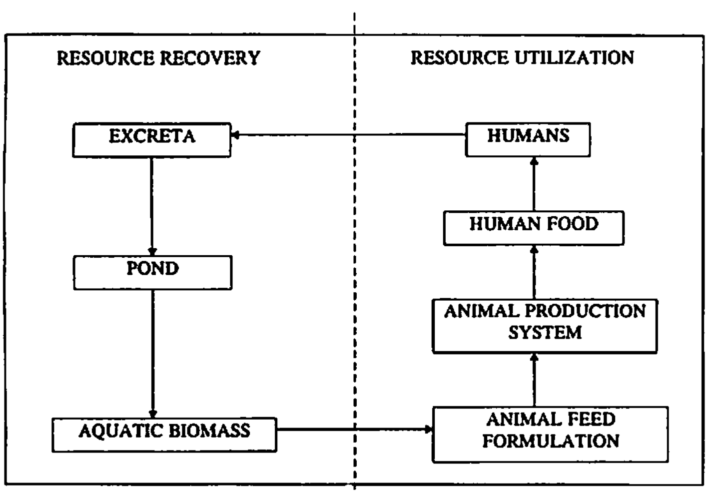


Fig. 2. Two distinct sequential processes are involved in the production of high-protein animal feed from excreta: resource recovery and resource utilization.

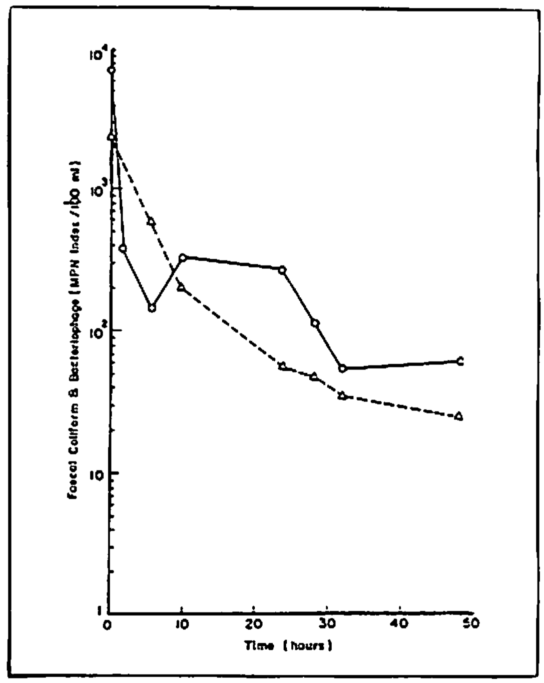
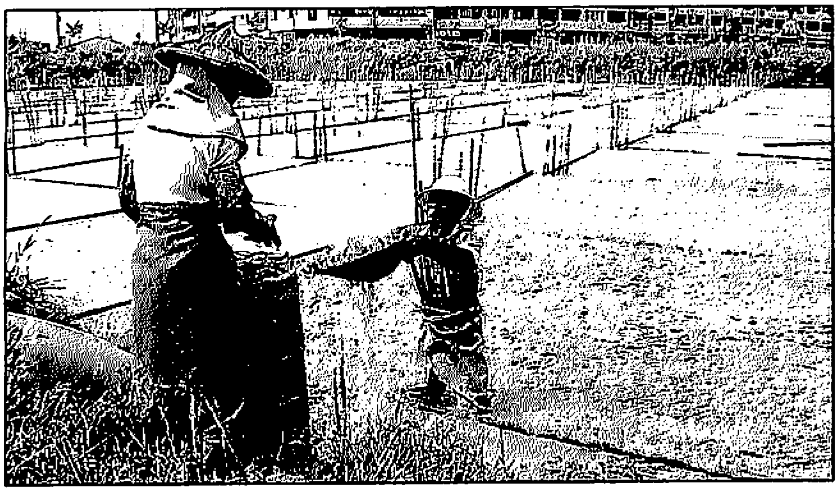


Fig. 3. Rates of fecal coliform (solid line) and bacteriophage (broken line) die-off in septage-loaded ponds.



Duckweed culture for feeding fish and ducks in Taiwan.

Harvesting fish from a wastewater-fed pond in Calcutta, India.

The project would investigate the following:

a) The importance and effectiveness of a wastewater-fed fishpond system in the treatment of sewage from a city.
b) The efficiency of a current wastewater-fed system in terms of sewage reuse.
c) Potential risks to public health from wastewater-fed fish culture and agriculture.
d) The degree to which such a system can continue to resist the pressures of urbanization and other alternative land uses.
e) The possibilities of technical improvement of the system in terms of more efficient sewage treatment.
f) The possibilities of technical improvements of the system in terms of wastewater reuse.
g) An economic and social analysis of the costs and benefits of this type of sewage disposal system, including distribution of benefits.

The project would require an interdisciplinary team of social and natural scientists, engineers and economists derived from the local national and international communities. All stakeholders, professional and lay, should be integrated into the study.

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