CGIAR
RESEARCH PROGRAM ON Water, Land and Ecosystems
LED BY: IWMI International Water Management Institute

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USING RECYCLED WATER FOR AQUACULTURE

Harvesting fish from a nutrient-rich pond, using recycled water in Kumasi, Ghana. *Photo:* Mark Yeboah-Agyepong

A CHALLENGE AND OPPORTUNITY

Over the last decade, African governments and organizations have given high priority to tackling the region's food security and sanitation challenges. One of the tasks that urgently requires attention is enhancing the sustainability of wastewater management systems for health and environmental protection. Another is to provide growing urban populations, especially the urban poor, with better access to sufficient supplies of affordable, safe and nutritious food.

Recycled water has much potential for improving both food security and sanitation. This water can be put to good use in cities, including treatment for food production, with benefits for all. Wider use of recycled water can give rise to a more circular urban-rural economy by:

- Providing a reliable source of water and nutrients for food production, thus improving farm productivity and income
- Facilitating the production of nutritious, protein-rich food in and around cities, and improving urban food and nutrition security, especially in land-locked regions
- Generating income to facilitate the operation and maintenance of sanitation systems and to help combat environmental pollution.

SOUTH-SOUTH SOLUTION

One approach that could accomplish the above-mentioned purposes in Ghana and other African countries is the safe use of water and nutrients from urban effluents for urban and peri-urban aquaculture. The approach centers on a unique farming system that links water treatment and aquaculture – producing fish and/or aquatic plants (such as duckweed) in ponds fed with nutrient-rich recycled water.

Several Asian countries have a long tradition of using this practice. India's Calcutta Wetlands, for example, have the largest ponds of this type in the world, producing an estimated 18,000 tons of carp and tilapia annually for sale in nearby markets. Vietnamese farmers also widely use recycled water for aquaculture, with one site reported to produce 3,900 tons per year. In China, the practice has been

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documented at more than 30 sites, covering 8,000 hectares and producing 30,000 tons of fish annually. In Bangladesh, recycled water has been used to produce feed for fish grown in adjacent freshwater ponds. Fish sales cover all costs of the treatment plant.

RESULTS FROM A CASE IN GHANA

Waste stabilization ponds are widely considered to offer an appropriate low-cost sanitation solution for treating domestic wastewater in developing countries. In search of ways to recover operational and maintenance costs, the International Water Management Institute (IWMI) undertook a project in Kumasi, Ghana, in collaboration with Waste Enterprisers Ltd. and the urban authorities. Its purpose was to determine how to capture the economic value of nutrients from recycled water and thus help finance treatment facilities.

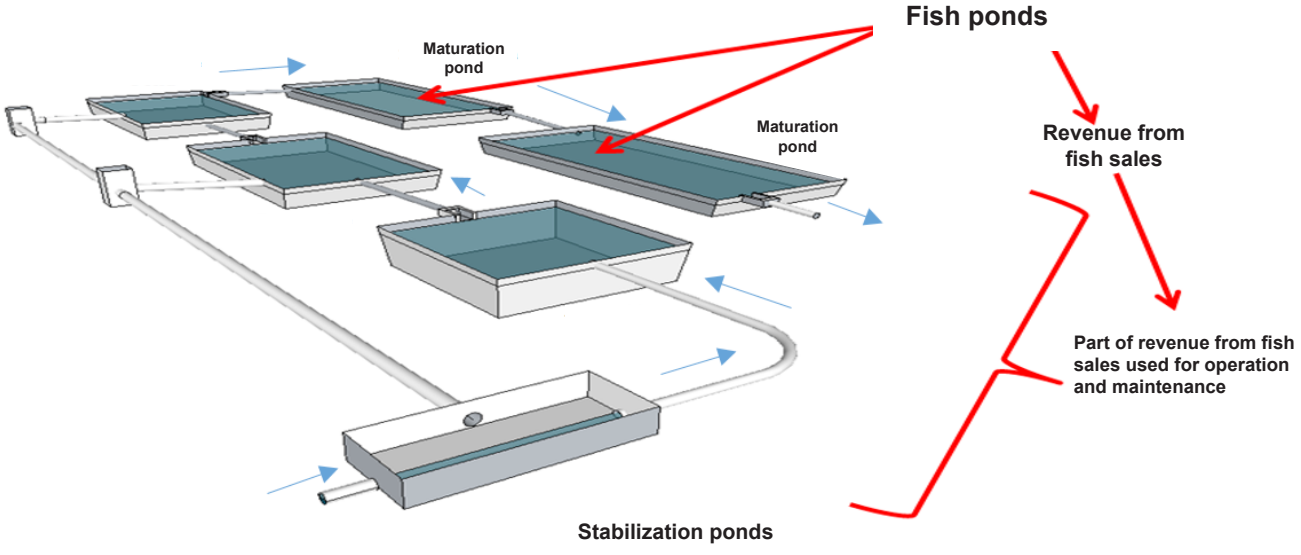
A new approach: Based on a market-oriented approach to sanitation called "Design for Reuse," the idea was to improve urban sanitation, while at the same time capturing economic and social value from recycled water and by-products of its use. This approach formally incorporates users into the finances, operation and maintenance of the treatment facility. New sources of revenue and labor help pay the operational and maintenance costs of wastewater treatment, thus easing the financial burden on households and institutions.

Pilot testing: The project tested this approach and its safety in a residential community, the Chirapatre Estate (with about 1,800 inhabitants). Household effluent is directed into a community-based waste stabilization pond system comprising five ponds. (see diagram below). Fish culture was established in the final two (maturation) ponds. The research included such activities as water and fish quality measurement, monitoring of fish growth, analysis of the suitability of the fish for human consumption, and assessment of market demand, risks and profitability. Laboratory results for pathogens, heavy metals and emerging contaminants were within safety ranges.

Production results: The results showed, after some initial problems, an 80 percent survival rate for catfish fingerlings, which were stocked at an average weight of 62 grams. This is consistent with rates reported elsewhere, thus confirming that it is crucial to grow fish to the right size before introducing them into the treated wastewater ponds. The estimated weight of harvested fish after 6 months ranged from 0.8 to 1.0 kilogram. (see figure at top right)

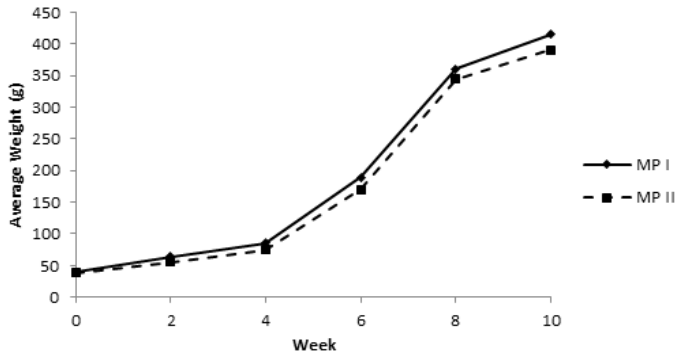
Financial results: While the ponds were provided by the city, the private partner invested in fingerlings and operational maintenance. The project compared different stocking densities (three versus two fingerlings per square meter) and the form in which the fish were sold (fresh versus smoked). Scenario 1A, with a stocking density of three fingerlings per square meter and the sale of smoked fish, proved to be the best, by far, generating profits (as shown in the figure at bottom right) from the second year onwards.

The internal rate of return for this scenario, at a 20 percent discount rate, was greater than the prevailing interest rate of 25 - 28 percent from commercial banks in Ghana. Moreover, with a profitability index of 2.1 and a benefit-cost ratio of 1.13, this scenario appeared most promising.

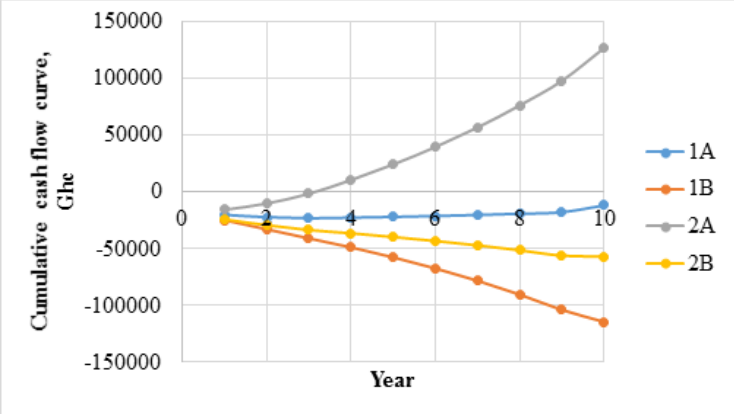


Blue arrows show the direction of water flow.

Designed by: Marc Sauchelli



Growth of catfish raised in two maturation ponds for 10 weeks



Cumulative cash flow curve for each scenario

RECOMMENDED PRACTICES

Entrepreneurs in many African countries – including Nigeria, Egypt, South Africa and Ghana – have tested the potential of aquaculture using recycled water. Listed below are some recommendations from IWMI research on the design-for-reuse approach in Ghana.

To ensure safety:

- In pond-based treatment systems, fish should be grown only in the last (maturation) ponds in the system, where water quality meets appropriate standards.
- Fish or poultry feed (like duckweed) can be safely produced in the treatment ponds, while fish are grown in subsequent ponds.
- Only ponds receiving domestic wastewater with no chemicals or relatively low levels – but NOT those receiving industrial wastewater – may be considered suitable for aquaculture.
- Allowing harvested fish to swim in and consume clean water for 2-3 days is important for fish depuration – that is, washing away contaminants to ensure safety. Smoking the fish also contributes to safety.
- Waste stabilization ponds require regular maintenance – to control fish predators like snakes, for example.

FOR BETTER BUSINESS

- The African catfish is a good candidate for aquaculture with recycled water because of its ability to withstand harsh conditions, like low oxygen levels in the water.
- Where pond water contains higher levels of dissolved oxygen (4 – 5 milligrams per liter), other types of fish, like Tilapia, may be more suitable.
- To boost the survival rate of catfish in recycled water, fingerlings must be grown to the required size of 40 grams living weight or more before stocking.
- To achieve profitability, it is important to maintain optimum stocking density (three to four fingerlings per square meter for catfish).
- In water with high oxygen levels, the stocking density may be increased to four fingerlings per square meter, since stocking at low oxygen levels reduces the survival rate of the fish.
- Production of fingerlings from brood stock cultured in treated wastewater could be another source of income. This is possible since thousands of fingerlings can be produced from a few catfish.
- To avoid potential health risks from catfish produced in treated wastewater, some of the fingerlings produced from the brood stock could be cultured in tanks using clean water. In this case, issues of customer perceptions about consuming fish reared in treated wastewater are avoided.
- Brood stock can also be sold directly to other farms, if needed. This means that there could be three different revenue streams.

THE WAY FORWARD

While showing some potential to generate enough revenue to pay the operational and maintenance costs of wastewater treatment, the use of recycled water for aquaculture also presents challenges, requiring appropriate monitoring.

Policies: Ghana's Ministry of Environment, Science, Technology and Innovation has taken an important step toward creating favorable policies for aquaculture with the use of recycled water by creating the Environmental Sanitation Policy, which supports safe resource recovery and reuse of waste.

Operational issues: Among the key challenges are to maintain good quality water for fish production; use appropriate stocking densities, and feeding and harvesting practices; and assure product quality. In line with the guidelines of the World Health Organization (WHO) for safe wastewater use in aquaculture, IWMI researchers have developed a training manual that helps producers address key issues through the preparation of an implementation plan.

Consumer health: As recommended by the WHO Sanitation Safety Planning manual, it is important to identify points at which risk is likely and then select options to mitigate the risk.

Consumer perceptions: Although consumers are generally more concerned about fish weight and price than its source, consumers' perceptions could change. Even low levels of contamination in fish produced in treated wastewater ponds could create negative perceptions of this product and reduce its acceptability, especially if strategies for reducing health risks are not in place. Product quality assurance from the Ghana Standards Authority may be required to address consumer safety concerns.

PROJECT PARTNERS

- Water Resources Commission (WRC)
- Kwame Nkrumah University of science and Technology (KNUST)
- Kumasi Metropolitan Assembly (AMA)
- Environmental Protection Agency (EPA)
- Ministry of Food and Agriculture (MoFA)
- Waste Enterprisers Ltd

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FURTHER INFORMATION

Philip Amoah, Researcher - Water Quality and Health, IWMI, Accra, Ghana (p.amoah@cgiar.org)

CGIAR RESEARCH PROGRAM ON WATER, LAND AND ECOSYSTEMS (WLE)

The CGIAR Research Program on Water, Land and Ecosystems (WLE) is a global research-for-development program connecting partners to deliver sustainable agriculture solutions that enhance our natural resources – and the lives of people that rely on them. WLE brings together 11 CGIAR centers, the Food and Agriculture Organization of the United Nations (FAO), the RUAF Foundation, and national, regional and international partners to deliver solutions that change agriculture from a driver of environmental degradation to part of the solution. WLE is led by the International Water Management Institute (IWMI) and partners as part of CGIAR, a global research partnership for a food-secure future.

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CGIAR Research Program on Water, Land and Ecosystems (WLE)
International Water Management Institute (IWMI)
127 Sunil Mawatha, Pelawatta, Battaramulla, Sri Lanka
Email: wle@cgiar.org
Website: wle.cgiar.org
Thrive Blog: wle.cgiar.org/thrive

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