Aquasanitation and Health

Introduction

Aquasanitation is a managed biological process combining cultivation of certain aquatic plants and sanitary treatment of human wastes in an aquaculture system. A highly effective aquasanitation system has been demonstrated in Bangladesh using aquatic plants of the *Lemnaceae* family, the common duckweeds to act as a "biological filter" whose rapid growth treats human feces in a pond and simultaneously provides an economically valuable crop in the form of feed for carp or tilapia.

However, using human wastes as the nutrient substrate to produce food for human consumption raises questions about potential pathogen transfer to consumers and deserves consideration. Bangladesh is the example selected to illustrate the major points:

Public Health Questions

Will pathogens be transferred by handling duckweed grown in sewage lagoons and in or on fish harvested from the fish ponds?

The issue has two elements. One is the risk of infection to workers who operate the system. The other involves the risk that pathogens will be delivered to the general population through the fish that are the end product of the aquasanitation production system. From the public health perspective, workers operating the system will greatly benefit the general population by reducing the prevalence of human excreta in the general environment.

However, the workers who harvest and transport the duckweed (and possibly the fish) almost certainly will be exposed to increased personal risk. The level of risk is comparable to the exposure of laborers in urban sanitation systems. A number of steps can be taken to minimize the risks. Workers should be isolated from physical contact with the pond and should follow a strict protocol for maintenance of good personal hygiene. This may include measures as simple as the provision of soap and supervised washing, such steps are only the beginning. Because these individuals are obviously at risk and the likely modes of transmission are equally obvious, better prophylaxis should be provided in the form of hygiene education, close monitoring, and treatment in those instances where infections occur. Workers should understand both the nature of the risks and the steps necessary to minimize them.

Public health and medical professionals routinely analyze and balance risks. The goal is to reduce broad or severe risks, provided that any risks accompanying the reduction are sufficiently narrow, limited or more manageable. The benefits of an aquasanitation system versus the exposure of workers to additional risk, therefore, is a classic example of public health analysis. As in many other occupations, a slightly increased level of risk to workers in the system is unavoidable, but the level of risk can be minimized and is manageable. Clearly, the slightly increased exposure to elevated risk of few informed individuals, risks that can be monitored and countered effectively, is balanced by greatly reduced exposure of the general population.

However, different elements come into play when considering the odds that pathogens might be transferred through fish to the general population. This concern is addressed by using an intermediate product, duckweed to feed the fish, and a two-pond system, so that fish never come into direct contact with feces. Fish can be raised directly in dilute wastewater, and indeed, are in a number of developing countries. Duckweed culture in a separate waste treatment pond, as an intermediate step, greatly reduces the type and number of viruses, bacteria, protozoa, helminths and other human pathogens coming into contact with the fish. Verification of these operating assumptions should be a routine part of any demonstration project. Based on experience with freshly harvested duckweed from sewage lagoons near Lima, Peru, and on published scientific literature, the following observations seem justified:

Viruses: The two viruses of most concern are Hepatitis A and *Rotavirus.* During the first stage of treatment wastewater is drained into a "primary" lagoon for sedimentation. Effluent moves from there into the "secondary" pond, where a considerable natural die-off of viruses occurs in the water column. The secondary stage is the beginning of the duckweed farm. Duckweed plants do not appear to ingest the viruses into their cells, but some can be expected to attach to the surface of the duckweed plants due to epiphytic attraction. Most epiphytic viruses are removed from the plant surface mechanically through the agitation of harvesting. When harvested plants are exposed to the sun and air, many more of the few remaining epiphytic viruses die. The small percentage of viruses surviving harvesting and air exposure will be deposited with the harvested duckweed into the fish pond, where most of those remaining will release from the plant into the water. The numbers of viruses will be again reduced through natural die-off in the water column, and the concentration of viruses will be reduced by a massive dilution factor. A few may be directly consumed by grass carp, but, because grass carp are not colonized by these particular viruses, most will be digested and killed in the fish gut. Some live viruses could be on the skin or in the gut of freshly harvested fish, but their low numbers are not likely to threaten the health of humans who handle or consume the fish.
Bacteria: Similar processes apply to most bacterial pathogens of humans introduced into the duckweed pond, including species of *Campylobacter E. coli, Salmonella, Shigella, Vibrio and Yersinia.* Carps species are inappropriate hosts to all these common enteric bacterial pathogens. *Aeromonas* species have been isolated from freshly-harvested duckweed grown in sewage lagoons in Peru. *Aeromonas* is not a commonly recognized human pathogen, although it is known to cause pediatric diarrhea. In poultry feeding trials in Peru using duckweed grown on wastewater, researchers were unable to isolate *Aeromonas* from chickens fed either fresh or dried duckweed.

Protozoa: Two common types are of concern, *Entamoeba histolytica* and *Giardia lamblia,* the cause of common amoebiasis and giardiasis respectively. Infection with both is common throughout Bangladesh, but the pathogenesis of such infections is debatable. Expert opinion holds that virtually universal, low-grade infections of *G. lamblia* and *E. histolytica* cause little real damage in a naturally immunized population typical of Bangladesh. The disease will flare up, and symptoms will be manifested only when the infected human host is severely weakened, or suffers from an immunological deficiency.

Amoebiasis: *E. histolytica* cysts, the common form of transmission among humans, sediment easily and can survive for seven to eight days in water between 21 and 22^{oC}. Fish are not considered viable vectors for transmission of *E. histolytica* cysts. We can conclude, therefore, that the transmission risk is negligible through the aquasanitation pathway represented as follows: human feces -> pond -> duckweed -> pond -> fish -> humans.

Giardiasis: *Giardia lamblia* cysts will sediment easily and survive longer at ambient temperatures than *E. histolytica* cysts. While the risk of transmission of *Giardia lamblia* through the aquasanitation cycle is extremely low, it is somewhat higher than that of *E. histolytica.* On the other hand, there is little evidence that *Giardia* causes serious disease (although it may be very uncomfortable) even in heavily infected human hosts.

Helminths: The most important helminthic infections in Bangladesh are *enterobiasis* (pin worm), *ascariasis* (round worm), *trichuriasis* (whip worm) and *ancylostomiasis* (hook worm). These are spread from person to person through fecal contamination of the soil surrounding village households. An aquasanitation system receiving the wastes of the village would eliminate this source of infection by greatly reducing the prevalence of feces in the environment. Helminth eggs introduced into the duckweed pond will be taken out of circulation through sedimentation. Even if some were to survive the harvesting cycle, these helminths would not survive because they do not colonize the fish gut.

Three helminthic diseases, *clonorchiasis* (Chinese liver fluke) *schistosomiasis*, and *diphyllobothriasis* (broad fish tape worm), which do rely on water, and fish or snails as temporary hosts during their life cycles, would be of potential concern if the three species were endemic in Bangladesh, which fortunately they do not. A final element in the barriers posed by an aquasanitation system against pathogen transfer is the culinary culture of Bangladesh. Though it is simple, it is important and effective: No uncooked fish is eaten in Bangladesh, nor is fish considered an item to be lightly cooked and served. Fish and most meat preparations tend to be overcooked when judged by western standards.

Will the settling tanks and the ponds used for growing duckweed contaminate the water table?

The primary pond receives raw wastewater and is the beginning of the treatment process. The wastewater will be detained for four to six days, where 90-95 percent of the settlable solids will be deposited. The *primary treated effluent* flows from the primary pond into the beginning of the secondary stage, which is also the beginning of the duckweed farm. Far from approximating a cesspool, the duckweed cover over the water surface will suppress odors and will not be unpleasant in appearance. While aesthetics is not the primary concern, the appearance of the duckweed culture pond will be pleasantly green and acceptable to villagers.

Most of Bangladesh is a delta where the water table is high. There is local interaction between groundwater and ponds. The exchange between pond water and subsurface water is slow; the speed of flow is retarded by the fine, dense sediment of soil and organic matter coating the bottom of mature ponds. This interaction is usually in the direction of ground towards the pond. The reason is a higher rate of evapotranspiration from the surface of the pond than from the surrounding earth-covered groundwater. The piezometric head of the groundwater is almost always higher than that of the pond. The drawdown point is lowest at the pond.

During times of heavy rain this relationship may be reversed when runoff from the land increases the volume of water in the pond to a level higher than the surrounding water table. Monsoon conditions might be expected to generate some flow from the pond into the water table. However, the water table is essentially at the surface during the monsoon season when these conditions prevail and tends to release into bodies of water such as rivers and flooded areas which eventually flow to the Bay of Bengal.

There are areas in the northwest quadrant of Bangladesh where the water table may be drawn down as much as ten or twelve meters during the dry pre-monsoon season. In those areas ponds that still contain water do make a small net contribution to groundwater recharge during April and May. However, there is still little danger of a wastewater treatment pond contaminating village drinking water. There are several reasons: The passive structural filtering effect of the fine, dense sediment, combined with active filtration of the sediment's organic component ensures that no viable pathogen, viral, bacterial or otherwise, penetrates more than a few centimeters below the pond bottom. The slow rate of seepage also introduces a retention factor, further ensuring that no living pathogen escapes the immediate vicinity of the pond. These mechanisms have been demonstrated experimentally, and UNICEF, WHO and The World Bank have approved installation of pit latrines and water supply wells with handpumps within a few meters of one another in the fine alluvial soils of Bangladesh.

In rural Bangladesh the preferred site for defecation is near ponds and rivers because of the proximity of water, which is used universally for anal cleansing. Fecal material is introduced directly into open water in use by the community for a variety of domestic purposes. Aquasanitation technology localizes waste, limiting fecal contamination to identifiable waters where it is rapidly recycled and limiting access by the public to those bodies of water. Localization of the fecal material also means that contamination risks can be taken into account when locating bathing and toilet facilities and potable water supplies, themselves an integral part of the system and a profound improvement over traditional, frequently contaminated surface water sources.

Conclusions and Strategic Implications for the Sector

Any strategy for rural sanitation, including aquasanitation, should consider and account for all types of risks of pathogen transfer in the context of current circumstances in Bangladesh. The practice in rural Bangladesh of indiscriminate defecation, usually on the bank of a pond or river, results in a high prevalence of feces in the general environment and leads to a high probability of contamination of surface water and food, which is a major cause of disease.

Fecally-transmitted parasites and diseases caused by the full range of enteric pathogens have an enormous cumulative impact on the general health of the population. The International Center for Diarrheal Disease Research, Bangladesh, estimates that 80 - 85 percent of the incidence of disease in Bangladesh is associated with poor sanitation. Diarrheal diseases, for example, cause of most post-neonatal mortality among children, who are the group in the Bangladesh population with highest mortality rate. These afflictions can be traced to the high prevalence of human wastes in the environment and, ultimately, in food and water.

A national sanitation strategy based on aquasanitation would provide an economically productive method to remove human wastes from the environment, localizing them and then using natural biological processes for their sanitary treatment. Aquasanitation interrupts the transmission of human pathogens to the food chain by actively removing them from the food and water humans consume.

An aquasanitation strategy for Bangladesh would construct public hygiene facilities that provide bathing, toilet and laundry facilities, as well as taps for household water collection. The facilities would be professionally managed and would emphasize cleanliness and cater to concerns for privacy (especially important to adult females). The public hygiene facility should be conveniently located to serve a "para", or neighborhood, consisting of several hundred individuals. The facility would satisfy all water supply and personal hygiene needs of the population, and in doing so, will generate a steady supply of wastewater, which is the growth medium for the duckweed crop and ultimately the source of nutrition for the fish crop.

The overall effect of an aquasanitation strategy in Bangladesh and in countries with demographic, economic and environmental similarities would be to *monetize* human wastes, which is currently a latent resource in the environment and simultaneously the cause of important diseconomies. The recognition of the resource value of human wastes will create a vested interest on the part of owner/operators of aquasanitation production systems to acquire and treat them to take advantage of the extremely high productivity of the process. When this happens, the environmental sanitation development sector will have been linked to an economic engine which will provide direct benefits in terms of **food production**, **jobs**, and mobilization of **private sector investment** in the sector heretofore inaccessible to national development planning. Finally, profoundly important indirect benefits will accrue to the society in the form of drastically **reduced morbidity** and **mortality** from diarrheal diseases.