Third edition of the Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture

Guidance note for Programme Managers and Engineers

KEY ISSUES IN THE SAFE USE OF WASTEWATER AND EXCRETA IN AQUACULTURE[1]

INTRODUCTION

Volume 3 of the third edition of the Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture is intended to provide a basis for the development and implementation of health risk assessment and management approaches (including standards and regulations) to address hazards associated with human waste-fed aquaculture. It provides a framework for informed national and local decision making. Aquaculture refers to the production of fish and non-molluscan shellfish and aquatic plants (filter-feeding molluscan shellfish are not considered in the Guidelines). Waste refers to domestic sewage that does not contain industrial effluents at levels that could pose threats to the functioning of the sewerage system, treatment plant, public health or the environment and excreta (faeces and urine or nightsoil, and faecal sludge and septage). The guidelines aim at maximizing overall public health benefits and at promoting the beneficial use of scarce resources.

The use of wastes in aquaculture can help communities to grow more food, increasing household food security and improving nutrition for poor households in rural and peri-urban communities. In the case of waste-fed aquaculture, the focus is on using precious nutrient resources. The international policy context for waste-fed aquaculture is provided by United Nations Millennium Development Goals 1: *Eliminate extreme poverty and hunger*, and 7: *Ensure environmental sustainability*. However, it should be practiced safely to maximize public health gains and environmental benefits.

Volume 3 of the Guidelines describes the present state of knowledge regarding the impact of waste-fed aquaculture on the health of product consumers, workers and their families and local communities. Health hazards are identified for each group at risk, and appropriate health protection measures to mitigate the risks are discussed. The information provided is applicable to intentional waste-fed aquacultural practices; and to the increasingly important unintentional use of faecally contaminated surface waters for aquaculture. An example of the growing importance of such unintentional use comes from China. In spite of the recent decline in waste-fed aquaculture in China, infections of clonorchiasis with *Clonorchis sinensis* tripled between 1995 and 2004, with an estimated 15 million people infected in 2004. This upward trend is probably associated with the recent rapid growth of aquaculture; using, unintentionally, waste contaminated water.

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The Guidelines review the current knowledgebase related to the transmission of infectious diseases associated with waste-fed aquaculture. In particular, the foodborne trematodes are covered with their complex lifecycles linked to fish and/or snails as intermediate hosts. Information on disease transmission and the effectiveness of different health protection measures are used to derive the guideline values and best practice procedures.

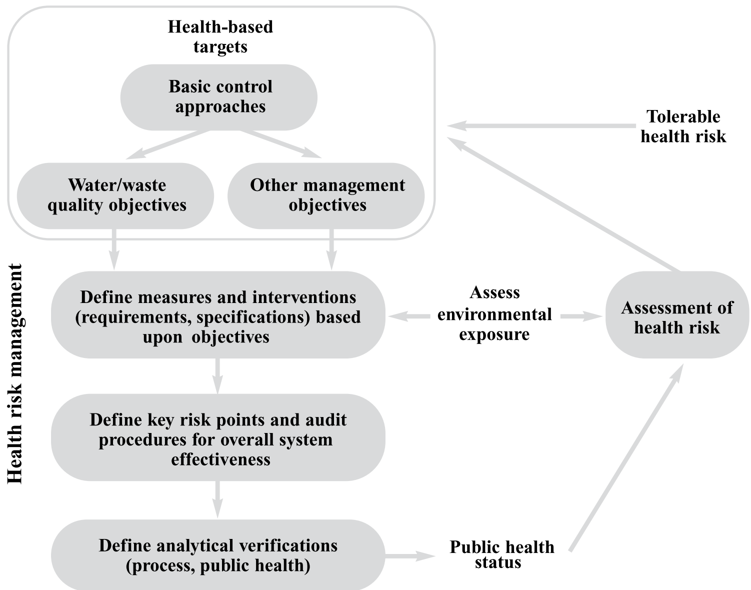
Volume 3 of the Guidelines:

- provides an integrated preventive management framework for safety, applied from the point of waste generation to the consumption of waste-fed aquaculture products
- describes realistic minimum requirements of good practice to protect the health of people using wastes, people living in local nearby communities and people consuming waste-grown products
- provides information on how to derive health-based targets.

The Guidelines follow the Stockholm Framework, an integrated approach that combines risk assessment and risk management and facilitates the management of infectious diseases in an holistic fashion (see figure 1). It allows consideration of local social, cultural, economic and environmental circumstances. It also allows comparison of waste-fed aquaculture-associated health risks with risks that may result from microbial exposures through other water and sanitation routes and additional exposures through food and hygienic practices.

The approach followed in the Guidelines is intended to support the establishment of national standards and regulations that can be readily implemented and enforced. The global guideline values proposed are not mandatory limits. The philosophy behind the Guidelines is that introducing overly strict standards may not be sustainable and, paradoxically, may lead to reduced health protection because they may be viewed as unachievable and thus be ignored. Rather, minimum good practices nor health-based targets should be based on local social, cultural, environmental and economic conditions and be progressively implemented over time depending on the existing reality and resources of each individual country or region, leading to steady public health improvements. The guidelines strive to maximize overall public health benefits and the beneficial use of scarce resources.

FIGURE 1: The Stockholm Framework for developing harmonized guidelines for the management of water-related infectious disease (adapted from Bartram, Fewtrell & Stenström, 2001)



HISTORICAL AND CURRENT WASTE-FED PRACTICE

Waste-fed aquaculture is centuries old in several countries in East, South and Southeast Asia, especially China. It has been developed mainly by farmers and local communities to use nutrients contained in wastes to produce aquatic food. Wastes and faecally polluted surface water are often used in aquaculture without any pretreatment. Systems primarily engineered to treat wastewater that incorporated aquaculture were developed in Germany from the end of the 19th century but only the Munich system remains, for tertiary wastewater treatment and as a bird sanctuary. Wastewater systems were also developed independently in India from the 1930s, in China from the 1950s and in Vietnam from the 1960s onwards but they were designed primarily for aquaculture, not to treat wastewater. Few engineered wastewater-fed aquaculture systems have been developed recently.

There is a great diversity in current waste-fed aquacultural practice involving fish and aquatic plants. Most waste-fed aquaculture involves the direct addition of waste with little or no prior treatment, or faecally contaminated surface waters to produce human food. Less common is indirect use to produce either fish seed or fish and aquatic plants to feed livestock or other fish. Fish species cultivated are mainly carps and tilapias. Aquatic plants are mainly lotus, water mimosa and water spinach. Fish may be cultured in ponds or cage and pen enclosures and aquatic plants in ponds or staked in faecally contaminated surface waters.

Most traditional waste-fed aquaculture has occurred in parts of Asia but is in decline due to rising value of peri-urban land, increasing industrial pollution of surface waters and demands of more affluent consumers for higher-value fish species.

HEALTH HAZARDS

Various hazards are associated with waste-fed aquaculture: excreta-related pathogens (bacteria, helminths, protozoans and viruses), skin irritants, vectors that transmit pathogens and toxic chemicals.

Fish and plants passively accumulate microbial contaminants on their surfaces but they rarely penetrate into edible fish flesh or muscle except for trematodes (parasitic tissue flukes). The relative risk of disease from bacteria e.g. *Salmonella*, protozoa e.g. *Giardia* and viruses e.g. hepatitis is low to medium. Some of these microbes may be present in the gut of fish. Cross-contamination of foods at the marketplace or in the kitchen is the greatest risk which is reduced by hygienic processing and cooking. Soil-transmitted helminths e.g. *Ascaris* present low to high risks for producers and consumers, which are lower from fish than plants. For foodborne trematodes e.g liver flukes, and schistosome trematodes (blood flukes) e.g. *Schistosoma* the risk ranges from nil to high as they have restricted geographical ranges. For the former the risk is where they are endemic and fish or plants are eaten raw; for the latter where they are endemic and transmitted through water contact. The transmission of trematode parasites is of particular concern in aquaculture as trematode-associated diseases are associated with high morbidity. Although seldom fatal, they are highly debilitating and complications may lead to death.

The risk from skin irritants causing contact dermatitis, possibly through microbes or chemicals, is from medium to high. The risk from vector-borne pathogens e.g. *Plasmodia* spp, causing malaria, is nil to medium, with no specific risk associated with aquaculture.

Regarding the risks from chemicals, the risk from antibiotics is nil to low as they are not usually used in waste-fed aquaculture. The risk from heavy metals is low; although they may accumulate in fish or aquatic plants. Concentrations of heavy metals from fish raised in waste-fed aquaculture do not usually exceed levels recommended by the *Codex Alimentarius* Commission. The risk from halogenated hydrocarbons is low as they are generally in low concentrations in wastewater and excreta and fish raised in wastewater usually show only low concentrations.

HEALTH-BASED TARGETS

Global health-based targets for waste-fed aquaculture are presented in the Guidelines for the major hazards:

- 10^{-6} DALY (the disability adjusted life year) for excreta related pathogens
- absence of infections for foodborne trematodes and schistosomes
- absence of vector-borne disease for vector-borne pathogens
- absence of skin disease for skin irritants
- *Codex Alimentarius* Commission tolerable daily intakes for chemicals

Microbial quality targets have been established that can be used to facilitate compliance with the health-based targets e.g., viable trematode eggs not detectable (number per 100 ml or per g total solids or ≤ 10^4 *E. coli* (arithmetic mean number per 100 ml or per g total solids) and ≤ 1 helminth egg (arithmetic mean number per litre or per g total solids) in pond water to protect consumers.

HEALTH PROTECTION MEASURES

A range of health protection measures in different combinations can be used to reduce health risks for product consumers, workers and their families, and local communities. Risk management strategies for waste-fed aquaculture involve constructing "multiple barriers" to prevent exposures to pathogens and toxic chemicals with combinations of various interventions.

Examples of hazard barriers to protect consumers include: waste treatment to remove pathogens; application of wastes to allow die-off periods; produce restriction; control of trematode intermediate hosts; prevention of cross-contamination; post-harvest processing; food hygiene; and cooking food. Examples of measures to protect workers and families include: waste treatment; personal protective equipment; access to safe drinking water and sanitation near the aquaculture facilities; control of vectors and intermediate hosts; and personal hygiene. And examples of measures to protect local communities include: waste treatment; access to safe drinking water and sanitation; restricting public access to aquaculture facilities; control of vectors and intermediate hosts; and vector barriers, repellants and prophylactics.

PRODUCE RESTRICTION

Most waste use involves production of fish or plants for direct human consumption, but waste may be used in aquacultural nurseries to produce seed or fingerlings which are then grown out to full-size table fish in separate systems without the use of wastes.

Waste may also be used to raise high-protein animal feed such as duckweed or small tilapia, to be subsequently used as feed for fish or livestock raised in separate systems without the use of wastes.

The benefits of produce restriction are: a reduced public health risk; and, lengthening the food chain which may increase social acceptability of waste use.

Cultivation of duckweed is a traditional Chinese practice to produce feed for grass carp fingerlings. Over the past three decades, research has been conducted on waste-fed duckweed. There are several positive attributes of waste-fed duckweed: high annual yields of 10-40 tonnes dry matter/ha; high crude protein content of 25-45% on a dry matter basis (although less true protein); effective wastewater treatment through shading the water column and nutrient uptake; readily harvested by net and pole; and readily consumed by fish and poultry. Unfortunately growth of duckweed is adversely affected by extreme (low and high) temperatures and high light intensity although the high temperatures and light intensity can be reduced by shading. Duckweed is occasionally infested with insects. It is difficult to dry so it needs to be fed fresh to animals; also because it decomposes rapidly. Furthermore, waste treatment and use through duckweed is land intensive. For that reason, recent pilots in Bangladesh are unlikely to be replicated elsewhere in the country.

Research has demonstrated the feasibility of the production and use of tilapia raised on septage as a high-protein fish food. Annual extrapolated yields of almost seven tonnes/ha of small tilapia have been produced by seining ponds stocked with a breeding population of tilapia. The septage-raised tilapia fed were as effective as marine trash fish when fed directly to carnivorous walking catfish and as fish meal in a formulated fish diet.

HEALTH PROTECTION MEASURES FOR TREMATODES

The geographical distribution of trematodes is limited, but they are given special consideration in the Guidelines because their transmission is associated with the consumption of fish and plants and may cause severe health outcomes. There are two types of trematodes of relevance in waste-fed aquaculture: food-borne trematodes (intestinal, liver and lung flukes); and schistosomes with infection by larvae penetrating skin of people entering water for domestic, occupational or recreational purposes. They have complex life cycles involving intermediate hosts, mainly fish (tissue flukes) or snails (schistosomes).

The global health burden is 40 million people infected with food-borne trematodes and 10% of the world population at risk. Some 200 million people are estimated to be infected with schistosomes, mostly in Africa south of the Sahara. There is limited direct waste-fed aquaculture in Africa, but there is risk from indirect waste-fed aquaculture; and there are pockets of disease in Asia.

Trematodes are difficult to control as domestic and wild animals may act as reservoirs; and molluscides adversely affect fish. Protection is achieved by combination of different health protection measures: removal of vegetation effectively controls intermediate host snail populations; and cooking fish thoroughly prior to consumption is a most most effective way to control food-borne trematodes, although traditional cultural practices of consuming raw/fermented fish or raw aquatic plants initially may be resistant to change. Chemotherapy is effective against trematode infections.

Monitoring trematodes is difficult because standardized methods for detecting trematode eggs have not been developed. In water, eggs develop rapidly into larvae, so the presence of trematodes may not be detected. It may be easier to identify the presence of the snail intermediate hosts and the encapsulated metacercariae in fish flesh or on aquatic plants in endemic areas.

SOCIOCULTURAL, ENVIRONMENTAL AND ECONOMIC ASPECTS

There is a reluctance or opposition to waste-fed aquaculture, and with improving social and economic status this now is even so in societies where it is traditional practice. Recently, there has been a dramatic decline in waste-fed aquaculture in China where it used to be widespread because of several factors: reduced availability of nightsoil as sanitation improves; increasing contamination of domestic wastewater with industrial sewage, rapid urban expansion with rising land prices, intensification of aquaculture with reduced demand for fish pond fertilizer, and increasing consumer demand for high-value fish rather than low-value fish from waste-fed ponds.

Waste use schemes, if properly planned and managed, can have a positive environmental impact. They reduce surface pollution which would otherwise occur. They also lead to conservation or more rational use of freshwater resources, especially in arid and semi-arid areas.

Waste-fed aquaculture may be considered a low-cost waste treatment system, with the cost of waste treatment offset by sale of fish or aquatic plants. A model to calculate the revenues for wastewater-fed aquaculture in tropical and subtropical areas has been developed in Lima, Peru.

POLICY, PLANNING AND IMPLEMENTATION

The safe management of waste-fed aquaculture is facilitated by appropriate policy, legislation, institutional frameworks and regulations at the international, national and local levels. Different country-level strategies are outlined to facilitate the development of appropriate frameworks at each level to help to encourage the safe use of wastes in aquaculture.

Planning and implementation of waste-fed aquaculture programmes require a comprehensive and progressive approach that responds to the greatest health priorities first. Key considerations that are required for implementation of waste-fed aquaculture programmes at the national level are discussed, including communication to and interaction with stakeholders.

POND DESIGN FOR WASTEWATER-FED FISH CULTURE

Fish culture using the effluents of conventional wastewater treatment plants, including wastewater stabilization ponds, would have limited yields because of the high degree of treatment prior to fish culture. A design procedure is presented in Annex 1 of the Guidelines based on the concept of **minimal** wastewater treatment in waste stabilization ponds for **maximal** production of microbially safe fish. The design takes into consideration the extremely rapid die-off of enteric bacteria and viruses in fertilized 'green water' fish ponds which function similarly to maturation ponds. Waste stabilization ponds are a low-cost (usually the lowest-cost) wastewater treatment option if land is available at reasonable cost. Incorporation of fish culture would provide benefits as well as offsetting the cost of wastewater treatment through sale of fish.

World Health Organization

IDRC CRDI

IWMI International Water Management Institute