Wastewater reuse for agriculture and aquaculture – current and future perspectives for low-income countries

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Exploiting the nutrient and water value in wastewater through agriculture and aquaculture may also help limit uncontained pollution that results from unregulated disposal of wastewater in surface water bodies. Treatment processes form an important part of wastewater reuse strategies, alongside other measures to protect health, but a concerted effort to promote capacity at all levels is required to enable the benefits of wastewater reuse to be realized.

By 2015, cities will be home to half of the world's population. Every day, city dwellers consume substantial amounts of water for a wide variety of domestic, commercial and industrial activities, and each of these produces wastewater. On average, a city with a population of 10 million generates 0.7M m^3 of water per day (at a lower end consumption of 100 litres/capita/day). The total urban population in Africa, Asia and Latin America produces 204M m^3 of wastewater every day.

Even in the best-case scenario, it is estimated that only 35 per cent of this wastewater will be treated prior to disposal or reuse.[1] The cost of improvement is enormous – for example, even if New Delhi triples its present capacity for wastewater treatment, at an estimated cost of US$7.5 billion, this will be insufficient to meet the required capacity for safe disposal and reuse of wastewater.[2]

We can safely assume that for the foreseeable future, most wastewater will be discharged without treatment, causing widespread degradation of the quality of natural water resources. Making productive use of wastewater through planned management and disposal on agricultural land is one way of exploiting its water and nutrient values as well as regulating wastewater disposal and preventing uncontrolled pollution. In countries facing the limits of their natural water resources there are increasing demands from agriculture and industry to reuse wastewater. While industrial wastewater recycling requires effluents to be treated to a high degree before reuse, currently agricultural reuse utilizes waters of varying quality, from highly treated wastewater to partially treated and untreated wastewater.

Farmers in Faisalabad, Pakistan, block sewers to divert wastewater onto adjacent fields for irrigation

The treatments and precautions suggested here for agriculture, which is the main subject of this article, also apply in general terms to aquaculture.

Existing practices and guidelines

The productive use of wastewater in agriculture and aquaculture is a centuries-old practice, and it can be particularly beneficial to poor farming communities around cities. In countries where wastewater reuse is recognized, it is associated with formal schemes; but in the majority of countries it is associated with informal reuse. In cases of formal use, which is usually accompanied by treatment, the demand can be directly attributed to water scarcity. In Israel, treated wastewater currently supplies 10 per cent of the national demand for water and there are plans to capture and treat all of its wastewater by 2015. Australia aims to treat and reuse 3 per cent of its wastewater for agriculture and irrigation by 2020. In some of the water-scarce Mediterranean cities of Europe and in California USA, wastewater reuse after treatment is common. In the Middle East, most countries treat wastewater before use but, despite strict compliance requirements, some informal use does

Box 1. Treatment systems for municipal sewage effluents

- *Preliminary* – simple physical processes such as screening and grit removal to remove large particles and gross solids.
- *Primary* – sedimentation of settleable solid material in storage tanks.
- *Secondary* – aerobic or anaerobic biological processes to break down organic matter.
- *Tertiary* – processes for the removal of pathogens, nitrogen and phosphorus, or specific industrial pollutants.

occur because it is a viable alternative for the farmers (see McCornick's article in this issue).

The extent to which wastewater is treated before application in compliance with existing regulations varies with the income level of the country. In Pakistan, only 2 per cent of cities have any form of treatment facilities, and even in these cities less than 30 per cent of wastewater is treated. Local farmers block sewers so that the wastewater level rises to the surface and overflows onto the fields. Sometimes local authorities auction wastewater to farmers as a means of disposal. Stormwater retention ponds in Vietnam, designed for flood control, receive wastewater which is then pumped onto nearby fields. These ponds are often used for aquaculture as well.

In poor countries, wastewater is applied untreated and there is a burgeoning business of high-value vegetable production downstream of cities in urban and peri-urban locations. In Pakistan, it is estimated that 26 per cent of all vegetable production is grown using highly polluted water.[3] In Hanoi, Vietnam, up to 80 per cent of vegetable production is irrigated with wastewater.[4] In Hyderabad, India, up to 40 000 direct and indirect beneficiaries depend on wastewater as a source of livelihood. The African situation is no different, with Senegal, Kenya, Ghana and Mauritania producing high-value vegetables for urban consumption using wastewater.

The potentially serious health consequences for both those who work in agriculture and aquaculture and those who consume their produce are overlooked under the conditions of market demand for fresh produce grown in proximity to the cities. To date, guidelines have been developed to be universally appropriate – one size fits all – but there are considerable problems in implementing these same standards in poor countries. The success of these guidelines is relative to the conditions in a country. In rich countries, wastewater is treated to safe levels for the use intended, and WHO[5] and US-EPA guidelines[6] are two examples used to set standards in such instances. In poor countries, the application of standards has to fit into a holistic approach that integrates wastewater management with productive use.

Strategies for mitigating the health risks

It is evident that the answer to these complex problems does not lie in the centralized government agencies that set official standards for wastewater reuse – not unless the realities of the existing situation are taken into consideration in the formulation of national guidelines. It is also clear that conventional treatment processes are generally unaffordable and inappropriate for use in the locations where the demand for wastewater reuse is greatest – peri-urban areas and small towns where agriculture is near to a sufficiently large source of wastewater.[7]

Experience suggests that some form of treatment prior to reuse is necessary, but the most appropriate form of treatment will depend on the characteristics of the wastewater itself, local site conditions and desired performance requirements, which will be dictated by the reuse application. Industrial wastewater mixed with wastes from domestic sources can create a potential additional problem from the perspective of treatment and reuse for agriculture and aquaculture.

Because wastewater usually contains large amounts of dissolved and suspended organic matter that has the potential to clog soil pores and irrigation equipment, pre-treatment is a necessity for all forms of wastewater reuse. Preliminary treatment is a simple process involving screening and grit removal to remove the gross solid pollution and larger settleable solids.

It is generally advisable to include primary treatment, involving sedimentation of settleable particulate material in storage tanks. Typical removal efficiencies of suspended solids will be between 55–60 per cent after two hours detention in sedimentation tanks, and this will also result in a 35 per cent reduction in organic pollutant load (measured as biochemical oxygen demand). Sometimes wastewater will require treatment to remove oil and grease, and wastewater effluent that is applied through drip irrigation systems will typically require sand filtration to avoid problems with clogging.

Treatment systems may be effective at reducing pollutant concentrations in wastewater, but this is only part of the solution,[8] because they are generally not effective at removing pathogens.

A small-scale wastewater treatment plant in Colombia. Credit: WHO photo library

Wastewater is pumped onto farmers' fields from a drainage channel in Than Tri, peri-urban Hanoi, Vietnam

In this wastewater reuse facility run by PRISM in Mirzapur, Bangladesh, duckweed is grown in wastewater stabilization ponds and is then harvested to feed to fish

The other primary problem associated with using treated wastewater for agriculture and aquaculture is the inherent health risk from a wide range of pathogenic organisms – such as bacteria, viruses and helminths. Various treatment technologies such as waste stabilization ponds (see the Technical Brief in this issue) and reedbeds can be used for treating wastewater to reduce pathogen concentrations, but even these relatively simple technologies need to be managed properly for optimum benefit.

Perhaps a more pragmatic approach is to consider a combination of partial wastewater treatment in combination with one or more of the other measures to reduce the health risks of wastewater reuse (as described by Richard Carr in this issue of *Waterlines*). In the case of agriculture there are various strategies to reduce health risks to farm workers and consumers which include: restricting the range of crops grown, choosing appropriate methods to apply wastes, post-harvest handling of crops, human exposure control, and consumer awareness and protection measures. In particular, cooking vegetables and fish can go a long way towards protecting consumers' health.

How should the situation be improved?

The productive use of wastewater in developing countries has to be linked to flexibility in applying treatment guidelines. Applying current guidelines strictly would immediately limit reuse, resulting in either uncontrolled use or the pollution of water bodies, leading to unmitigated health risks. It is clear that an incremental approach to applying guidelines is required (see Carr's article in this issue). To enable this to be achieved effectively, a decentralized approach towards wastewater management is advocated that promotes decision making for sanitation and wastewater management down to the most appropriate level.

It is important that those who make the decisions are adequately equipped with the knowledge and skills to make the best decision. It is also necessary to consider the various constraints, other than cost, to the application of treatment and other forms of protection in developing countries, which may explain why these strategies are not widely applied in practice. These include:

- a lack of awareness of the dangers by producers, consumers and politicians
- unwillingness to comply with existing regulations
- an awareness of dangers, but lack of demand for improvements
- few alternatives for the poor farmer – linked to a lack of knowledge of cost-effective ways of reducing the risks
- a lack of financial incentives to implement solutions
- weak regulatory bodies – an ineffectiveness of institutions to regulate, monitor and enforce existing regulations.

To overcome these constraints, capacity building is required at the both the local level and higher levels in order to promote collaboration between sectors using a multi-stakeholder, multidimensional integrated approach. Wastewater reuse needs to be planned in conjunction with water resource management, water supply, wastewater production, management and disposal; and technical solutions have to be combined with a range of preventive measures to mitigate health risks.

Based upon international experience, it is clear that improvements in wastewater management practices are only feasible where there is political will. Advocacy at all levels is possibly the most important requirement – to get politicians and decision makers to understand the issues and to promote a pragmatic wastewater reuse strategy to their constituencies.

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References

1 As quoted in Scott, Christopher, Naser Faruqui and Liqa Raschid-Sally (eds) (forthcoming) *Wastewater use in irrigated agriculture: confronting the livelihood and environmental realities,* Commonwealth Agricultural Bureau International (CABI), Orient-Longman, and International Development Research Centre (IDRC), Ottawa, Canada.
2 Agarwal, A., and S. Narain (2002) 'Private sector cannot solve India's water and sanitation problems', *Water and Wastewater International* Vol. 17 No. 2.
3 Ensink, J.H J., T. Mahmood, W.Van der Hoek, L. Raschid-Sally, F.P. Amerasinghe (2004) 'A nation-wide assessment of wastewater use in Pakistan: an obscure activity or a vitally important one?'
4 Lai, Tran Van (2000) 'Perspectives of peri-urban vegetable production in Hanoi', background paper prepared for the Action Planning Workshop of the CGIAR Strategic Initiative for Urban and Peri-Urban Agriculture (SIUPA), Hanoi, Vietnam, 6–9 June, convened by the International Potato Center (CIP), Lima, Peru.
5 World Health Organization (WHO) (1989) 'Health guidelines for the use of wastewater in agriculture and aquaculture' *World Health Organ Tech Rep Ser*. 1989, 778: 1–74.
6 US Environmental Protection Agency (2004) *EPA Guideline for Water Reuse,* U.S. Environmental Protection Agency, Health Effects Research Laboratory. Cincinnati, Ohio.
7 Parkinson, Jonathan and Kevin Tayler (2003) 'Decentralized wastewater management in peri-urban areas in low-income countries' *Environment and Urbanization*, Vol. 15 No.1. International Institute for Environment and Development, (IIED), London.
8 Blumenthal, Ursula, Anne Peasey, Guillermo Ruiz-Palacio, and Duncan Mara (2000) 'Guidelines for wastewater reuse in agriculture and aquaculture: recommended revisions based on new research evidence', Report summary of WELL Task No. 68 (Part 1).