

## Wastewater garden—a system to treat wastewater with environmental benefits to community

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### ABSTRACT

Many communities and villages around the world face serious problems with lack of sanitation especially in disposing of the wastewater—black water and grey water from the houses, or wash outs from animal rearing sheds. Across the world diverting wastewater to the surroundings or to the public spaces are not uncommon. This is responsible for contaminating drinking water sources causing health risks and environmental degradation as they become the breeding grounds of mosquitoes and pathogens. Lack of collection and treatment facilities or broken down sewage systems noticed throughout the developing world are associated with this situation.

Diverting the wastewater to trees and vegetable gardens was historically a common practice. However the modern world has an array of problems associated with such disposal such as generation of large quantity of wastewater, unavailability of space for onsite disposal or treatment and increase in population. This paper considers the wastewater garden as a means for wastewater treatment and to improve the vegetation and biodiversity of rural areas. This can also be implemented in urban areas in association with parks and open spaces. This also highlights environmental safety in relation to the nutrient, pathogen and heavy metal content of the wastewater. The possibilities of different types of integration and technology that can be adopted for wastewater gardens are also discussed.

**Key words** | community, hydroponics, reuse, sanitation, treatment, wastewater

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### INTRODUCTION

The demand for adequate waste treatment and management services is so severe that about 3 billion people around the world live without adequate sanitation (WHO 2006). Many communities and villages around the world have serious problems with lack of sanitation especially in disposing off the wastewater—black water and grey water from the houses, or wash outs from animal rearing sheds. This condition is directly proportional to the accelerated urban growth combined with increasing levels of poverty (Binns *et al.* 2003). Across the world it is very common that the wastewater run off from houses and animal sheds are disposed to the surroundings or to the public spaces. This is responsible for contaminating the drinking water sources causing environmental degradation. This causes

considerable health risks as they become the breeding grounds of mosquitoes which are responsible for epidemics such as malaria, dengue fever, chikun gunea and similar diseases. The main reasons for such disposal are lack of collection and treatment facilities or broken down sewage systems.

The guidelines for the safe disposal/reuse of wastewater by World Health Organization for developing countries are not as stringent as those for developed countries. This is to ensure that the developing countries be able to implement technologies that deliver good sanitation without compromising the health of people and the environment (Al Salem 1996). Reclaimed wastewater has been used for agriculture for centuries (Al Salem 1996; Asano & Levine 1996) whereas

in the arid developing/underdeveloped countries, the economic motivation to use wastewater was higher to farmers as freshwater was unaffordable or unavailable (Shuval 1991). Over the past 20 years, the increased water stress has seen led to a wider acceptance of water reuse in Europe (Ghermandi *et al.* 2007). Irrigation can be used as an advanced wastewater treatment to recycle nutrients to land. In countries like Israel, Jordan and Tunisia with severe water shortage, wastewater irrigation is very common as in Israel over 70% of its wastewater is reused in agriculture (Haruvy 1997). In the United States, California and Florida are in forefront in reusing effluent from wastewater treatment plants for irrigation purpose (Radcliffe 2006).

Open disposal of wastewater creates serious threat to the environment and health of living organisms in the region. Handling untreated wastewater without contaminating main waterways is a key step to manage the tragic condition of pollution and degrading the drinking water source of most communities. Diverting the wastewater (particularly grey water) to trees and vegetables was a very common practice in houses in the tropical countries in former days. Black water generation was minimal as flushing toilets were not common and solids went to a collection pit or septic tank which was degraded over time. The availability of space around the houses also facilitated that type of disposal. However the modern world has several problems associated with disposal such as generation of large quantity of wastewater due to modern lifestyles, less space available for onsite management, and increased population. Infrastructure and funding are not available to most places to cope with the demand for treatment. Vegetation and biodiversity in most villages and communities in the rural areas are affected due lack of water with trees and plants cut down for fodder/firewood or for new buildings and access roads. Incorporating wastewater treatment with vegetation and biodiversity in an area could be a sustainable option.

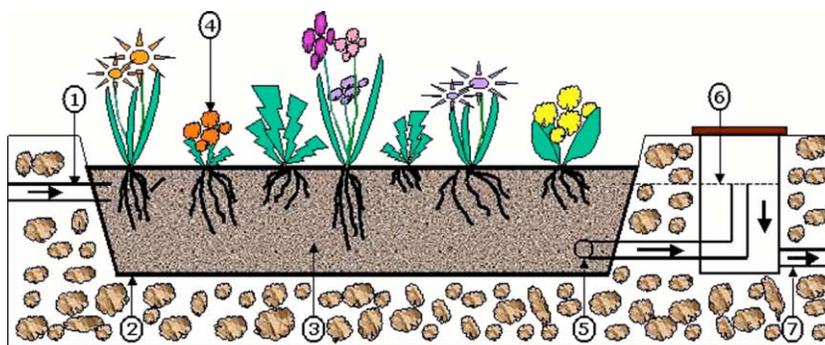
Systems or options for wastewater treatment are unheard of in many rural and urban areas of the world and is considered unachievable due to the capital and infrastructure cost involved, lack of technology, local skills and awareness on wastewater management. For effective implementation of a wastewater management system in

those regions, it is ideal to incline to the adoption of a natural process that requires very little external technology or skills. Domestic wastewater is abundant in nutrients required for plant growth along with pathogens and other components that are harmful to the environment and health. Plants and soil are the natural filters and converters of these organic pollutants, therefore constructing a wastewater garden to treat, filter and reuse the nutrients will be the most sustainable option for many such areas. This paper discusses wastewater treatment through plants as an option for onsite management for rural and urban regions worldwide.

### Wastewater garden

“Wastewater garden” is a laymans’ term used for systems that utilise wastewater for growing plants. Wastewater gardens normally support different kinds of trees and/or shrubs against the single species planting in constructed wetlands. It may be constructed in a single cell set up for small systems and more compartments in larger applications. More compartments provide better area for planting and therefore obtain better treatment of wastewater. A bedding of gravel can provide adequate surface area where organic compounds, suspended solids and excess nutrients are removed through chemical, biological and physical mechanisms and increase the residence time for the wastewater for better treatment. The roots of the plants will make the bedding medium porous and aerate the system although the main process is stripping off the nutrients to a green or colourful garden. The physical processes such as aeration, sedimentation, adsorption and decomposition combined with other chemical processes convert wastewater to a quality good enough for discharge or reuse. Figure 1 shows a simple model of a wastewater garden.

Stripping off nutrients from the wastewater and reusing it not only prevents environmental pollution but also helps conserve water for arid and water-scarce communities. The quality of effluent will depend on the filtration that had occurred in the system, the growth of plants and the size of the system. Normally the wastewater after passing through the plant growth system could be used for irrigating fruit trees or other landscape plants utilising maximum nutrients and water. There are several options for managing



1. Inlet pipe; 2. Sealing; 3. Gravel; 4. Plants; 5. Collecting pipe; 6. Control box 7. Outlet pipe

**Figure 1** | A simple model of wastewater garden (<http://www.carpathians.pl/gardens/budowa.html>).

the wastewater through this process depending on the quality and quantity of influent wastewater and the community needs such as swales and constructed wetlands.

### Swales

Swales are the simplest and the cheapest option for wastewater management and treatment. They are efficient in managing storm water and grey water around the property. Unlined swales can be used to prevent erosion and storm water runoff while lined ones are widely used to collect storm water and to divert water and wastewater from the source of generation, away from direct exposure to human beings. However, they can be converted and modified to treat wastewater particularly grey water that has lesser BOD than black water when planted with local species of plants.

### Wetlands

Wetlands are the natural systems that naturally treat wastewater. Mangroves serve almost the same purpose by filtering the suspended materials, lock up nutrients and provide food and shelter to enormous species of aquatic and bird life. Nutrient removal is the focus of the wetland system and involves filtration, sedimentation, plant uptake and microbial degradation (Hosomi *et al.* 2002). The wetland plants pump air into their root systems and act as aerators of the system to maintain a population of aerobic microbes essential for the treatment process. Incorporating engineering technologies, wetlands are constructed to treat wastewater and the latest advancement of subsurface flow

constructed wetlands has shown to be highly efficient in reducing the environmental risk and achieving better treatment of wastewater.

The subsurface flow constructed wetland is often an engineered design to treat domestic and industrial wastewater, where the system is designed to maintain the water level below the surface, preventing odour and eliminating the risk of human contact with the sewage. When treating water with high suspended solid content, the system is often designed in two or three steps, with a filtering system or a septic tank, for biological breakdown of the waste, where solids settle out to the bottom of the tank, water then flows to the wetland system followed by aeration/holding tank before it is reused for other purposes. The Ecowaters project in USA has several designs to make use of wastewater as a nutrient resource for landscape development. Ideally the system used for wastewater treatment should make use of gravity for water flow to reduce the cost although in many indoor systems, pumping water is required to circulate water through the systems.

## WASTEWATER HYDROPONICS

Hydroponics is a method of growing plants in an artificial nutrient medium with controlled physical and chemical condition and is widely used in nursery and vegetable production. However when wastewater is used as the nutrient medium, the growth of plants may depend on the nutrient availability in wastewater and the level of treatment it has received prior to usage. Some technical

problems such as blockage of irrigation system may occur due to bacterial and algal slimes from increased levels of nutrients in the water especially with trickle irrigation. If uneven distribution of water and nutrients occur, it may result in uneven plant growth.

### Effluent treatment

The USEPA (2004) guidelines suggested that for reuse in agriculture for food crops that do not undergo commercial processing, the wastewater should have secondary treatment, to  $BOD \leq 10\text{mg/L}$ ,  $NTU \leq 2$ , no detectable faecal coliform/100mL and minimal residual chlorine should be  $1\text{mg/L}$ . If wastewater is reused for non food crops, treatment should ensure  $BOD \leq 30\text{mg/L}$ ,  $TSS \leq 30\text{mg/L}$ ,  $<200$  faecal coliform/100mL and minimal residual chlorine should be  $1\text{mg/L}$ . Wastewater gardens by Birdwood Downs treated BOD by 89–95%, 90–95% in suspended solids, 30–58% total phosphorus and 48–73% total nitrogen. The faecal coliform count was reported to have reduced by over 98% without any disinfection (Nelson & Tredwell 2002). Oyama *et al.* (2005) observed that the microbial quality of the wastewater after hydroponic usage was safe for disposal or for irrigation meeting the current regulatory guidelines. They observed that leafy vegetable, such as bok choy did not grow successfully in secondary treated effluent due low content of plant macronutrients. Cheng *et al.* (2004) found that it was possible to grow tomatoes as part of a swine wastewater treatment and nutrient recovery process.

In wastewater hydroponics, for tertiary treatment macrophytes are grown (Osem *et al.* 2007) which will produce a high quality effluent that can be used onsite. Norstrom *et al.* (2003) combined the conventional biological treatment with hydroponics and microalgae demonstrating that this type of treatment can be used to produce valuable plants while treating the wastewater.

Aquaponics can be a working model of sustainable food production where plant and fish culture are integrated, for recycling of nutrients and water filtration. This is an option for small scale fish farms ideally for indoor systems where wastewater from fish tanks can be used for growing plants. Rahman showed that when plants were grown in a hydroponics system using wastewater from fish tanks,

the effluent was treated successfully. Diver (2000) explained the system and its advantages as (1) conservation of water resources and plant nutrients, (2) intensive production of fish protein, and (3) reduced operating costs relative to either system in isolation.

### Selection of plants

Locally available plants adapted to wetland conditions or that can survive in a flooded and drained conditions can be selected to make a diverse and beautiful wastewater garden. This shows that a system can be designed with many plants (with a high biodiversity) suitable to local climatic conditions. It was noted that since shoot, leaves, fruits or flowers are not exposed to or in contact with wastewater they are free from bacterial contamination from the water, therefore can be considered hygienic and safe to use by humans, or as fodder, timber, fuel wood or wicker production, or for cut flowers.

The benefit of wastewater garden is that unlike the constructed wetlands where the plant species is very limited and widely known as ‘reedbeds’, this system can utilise any plants that has some value as fruits, biomass, flowers or as a general aesthetic appearance. The treated water that comes out of the wastewater garden should be at a quality for general irrigation purpose. Valliant *et al.* (2004), has successfully tested a combination of raw stormwater-sewage wastewater in a hydroponics system to grow woolly digitalis and foxglove to reduce the total organic load in the wastewaters. Williams *et al.* (2006) has demonstrated a production of a perennial rhizomatous grass, the giant reeds which can grow up to 8 meters tall of about 50 tonnes/hectare when irrigated with wastewater (Figure 2). The high yield of biomass of this species shows the



Figure 2 | Growth of giant reeds (a) and tomato plants (b) irrigated with wastewater (Oyama *et al.* 2006; Williams *et al.* 2006).

additional potential of using them as biofuels which will generate additional income for a small community simultaneous with the on-site treatment of the generated wastewater. Figure 2b shows the comparable growth of tomato plants against a commercial hydroponics medium grown in 42 litre tubs using secondary treated wastewater.

At the Birdwood Downs in Western Australia, wastewater gardens are used in Aboriginal communities, public buildings for water conservation, sanitation and greening (Tredwell & Nelson 2006). They have planted banana and fruit trees which provided shade, biodiversity and a microclimate in the area. The wastewater from dining room/kitchen and the gazebo areas are treated and reused through the leach drains that are planted with shallow root plants to prevent damage to the lining (Figure 3). According to Nelson *et al.* (1999), Nelson (1998) the leachate from the septic tank also could be treated in the leach drain followed by a wastewater garden. Pinto (1996) grew crops such as tobacco, tomato and celery from pig slurry. Ayaz (1996) used three types of macrophytes as a tertiary treatment system and observed that hydroponics can be used in very little space. They have recommended that as a good sanitary system for remote communities to treat wastewater while having plants of significance such as canna lilies, Heliconia (Bird of Paradise) and oleander flowers as well as supporting banana, coconut, elephant ear, papyrus and pandanus palm.

### Concerns related to recommending wastewater garden

Health Departments are particularly concerned with wastewater gardens due to several associated risks. Growing crops with reclaimed water should consider various factors



Figure 3 | Different plants in wastewater garden (Tredwell & Nelson 2006).

such as policies and risk management. Leaching and contamination of ground water is a major issue which should be managed by making the system water tight by lining with concrete, impermeable clay or geo-membrane to hold wastewater. Another main barrier to its wide use is the public acceptance related to pathogens, odour, heavy metal and other quality factors. Several studies have shown effective pathogen die off in such systems with minimum risk of contamination to the exposed parts of the plants making the system pathogen safe (Oyama *et al.* 2006). It has been shown that uptake and accumulation of heavy metals occur more in the root system with above ground crops accumulating within the guideline limits and therefore safe for use (Levitan & Nair 2007).

Odour and mosquito risk is another concern which can happen if the wastewater is exposed to the air. The risk is negligible for sub surface irrigation and if water level is maintained below the surface of the gravel as it prevents mosquito breeding and accidental contact with wastewater.

## CONCLUSION

### Significance of wastewater gardens for developing countries

- The system is most suited in tropical areas where plant growth is all year round
- The availability of cheap labour and less operating cost
- The aesthetic approach to waste and wastewater is advantageous for such a project
- Most places lack drainage or proper wastewater collection and treatment options
- Solution to health problems related to disposal of wastewater
- Can be a community project
- Help in greening the community and increasing biodiversity
- Facility can be used for growing plants needed for the community
- System can be designed for individual houses to a cluster scale housing to a community scale.

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