UNITED NATIONS
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**Water and Urban Initiative**
**Working Paper Series**
Number 01 — April 2015

# Urban Development and Water Sustainability

Chongrak Polprasert Thammasat University, Pathumthani, Thailand
Tatchai Pussayanavin Asian Institute of Technology, Pathumthani, Thailand
Thammarat Kottatep Asian Institute of Technology, Pathumthani, Thailand

**Water and Urban Initiative**
This working paper series shares findings produced as part of the research activities under the Water and Urban Initiative (WUI), a research project of the United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS). The WUI aims to contribute to sustainable development, focusing on developing countries in Asia, by providing policy tools and an information platform to assist planning and implementing policies for sustainable urban and water environment.

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## ABSTRACT

Due to limited access to safe drinking water and lack of adequate sanitation facilities in most developing counties, the rapid population growth and urbanization have caused serious water scarcity and water pollution problems. Another prevalent environmental problem is global warming caused by burning of fossil fuels which has negative impacts on the hydrological cycle and consequently unfavorable changes in water quality. The threats posed by global warming are an additional stressor to the environmental system and water sustainability. An ecological wastewater treatment management such as the "closed-loop systems" should be considered. The closed-loop concept, using wastewater cycles from "point-of-generation" to "point-of-production", could provide a better way for attaining high environmental quality and full utilization of wastewater resource. Subsequently, some innovative sanitation technologies recently developed such as solar septic tanks and hydrothermal carbonization for feacal sludge have been found to meet the closed-loop concept because they were able to inactivate the pathogens, remove the pollutants and producing valuable by-products such as biogas and hydrochar, respectively. These cost-effective technologies should be able to protect the public health, improve quality of the canals and rivers in the urban areas, all contributing to water sustainability.

*Keywords: urban development; water sustainability; resource recovery; environmental technology*

## 1. INTRODUCTION

The world population is growing rapidly over the last few decades. There are currently about 7 billion people with more than 50 % of them, mostly in developing countries, living in urban areas. Urbanization in many countries is generally due to economic growth in the past 40 years. The United Nations (2009) reported that more than 2.5 billion people of the world's population, especially in Asia and Africa, will add to the urban population, reaching up to 66% by 2050 (Figure 1). Sub-Sahara Africa and South Asia are expected to account for half of the world population in 2100 (United Nations Water, 2009).

Hinrichsen et al. (1998) estimated the demand for freshwater to be about 64 billion m3 per year, while the global fresh water resources is limited. A recent report of the United Nations (2009) found some areas of Asia and Africa to be already in water scarcity and the percentage of the world population affected by water-scarcity could increase up to 47% in a mere three decades. Because the main activity that contribute to poor water quality is wastewater generated from human activities (blackwater and greywater), lack of access basic sanitation facilities is one of the most important concerns of global water pollution. More than 80 percent of human waste in developing countries is discharged untreated to receiving water (WWAP, 2009). Water pollution problems are also increasing with more than 1,500 km3 of untreated wastewater being discharged to nearby canals and rivers (WWAP, 2003). The report of UNEP (2000) indicated that the amount of fecal bacteria indicators in Asia's rivers is about 50 times higher than the WHO (1989) guidelines.

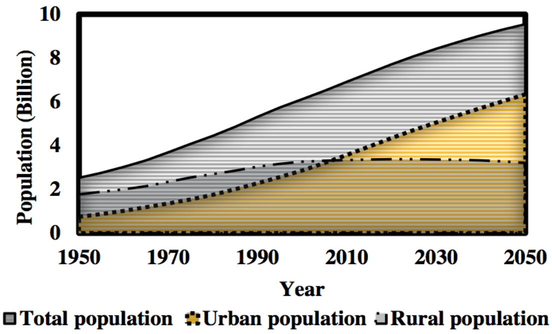


*Figure 1 (a): World, urban and rural population: (a) Population rural and urban (Modified from United Nations, 2014)*

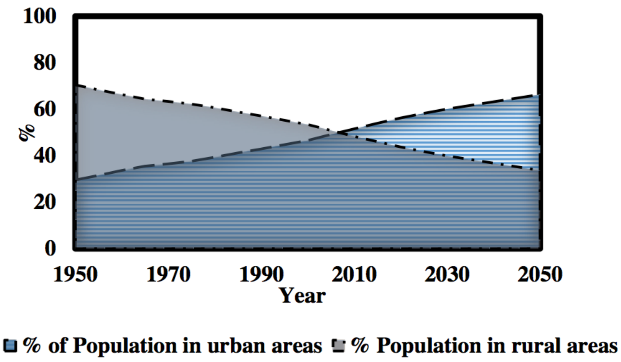


*Figure 1 (b): World, urban and rural population: percentage urban and rural (Modified from United Nations, 2014)*

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indicators in Asia's rivers is about 50 times higher than the WHO (1989) guidelines.

Another prevalent environmental problem is global warming caused by burning of fossil fuels which has negative impacts on the hydrological cycle and consequently unfavorable changes in water quality. For example, the effects of severe drought and increased precipitation rate caused by global warming could dramatically increase the risk of diarrheal diseases (WHO 2009; Confalonieri et al. 2007). The threats posed by global warming are an additional stressor to the environmental system and water sustainability.

## 2. Water sustainability concept

The above water problems especially in urban areas give rise to concern about appropriate wastewater management practices. In this respect, an ecological wastewater treatment management such as the "closed-loop systems" should be considered. The closed-loop concept, using wastewater cycles from "point-of-generation" to "point-of-production", could provide a better way for attaining high environmental quality and full utilization of wastewater resource (Jhansi and Mishra, 2013).

### 2.1 Ecological wastewater treatment

The development of ecological wastewater treatment systems will provide a better solution for the management of valuable wastewater resources and the reduction of pathogens in the receiving water. These systems employ the natural reactions of plants, microorganisms and sunlight to biodegrade organic wastes from the point-of-generation with the production of valuable products such as protein biomass for uses as animal feeds or human foods (point-of-production). Examples of these ecological wastewater treatment systems are described below.

#### High rate algae pond

Algae are diverse group of microorganisms that can perform photosynthesis. Solar energy is the primary source of energy for all life. This energy is utilized by phytoplankton during photosynthesis and synthesis of new cell occurs. With respect to algal mass culture in wastewater, efforts have been directed towards single cell protein production for potential human and animal consumption (Figure 2a). The desirable properties of algal single cell protein are high growth rate, resistance to environmental fluctuations, high nutritive value, high protein content and ability to grow in wastewater. Algal cells have high protein value, and subsequent harvesting of algae for human and animal consumption will be the financial incentive to wastewater treatment. The average production of algae is reported as 70 tons/(ha-yr) or 35 tons/(ha-yr) algal protein; comparing with the productivity of conventional crops, wheat 3.0 (360 kg protein), rice 5.0 (600 kg protein) and potato 40 (800 kg protein) tons/(ha-yr) (Becker, 1981). However, the existing technologies of algal harvesting are normally complex and expensive. Pathogen destruction occurs in algal ponds due to adverse environment such as: diurnal variation of pH due to photosynthesis, algal toxins excreted by algae cells, and most importantly, solar radiation (UV light). At present, the main attractiveness of algal mass cultures is that they have great versatility to be integrated into multi-use systems for simultaneously solving several environmental problems.

#### Aquaculture fish pond

The culture of phytoplankton-feeding (herbivorous) fish (Figure 2b) to graze on the algae is attractive in order to produce the fish protein biomass which is easily harvestable for animal (or human) feed. Waste treatment is the primary objective of any waste recycling scheme and the inclusion of fish production recovers nutrients in the waste, such as N, P and K. Addition of waste or its by-products such as biogas slurry and compost to fish ponds resulted in increased fish yields (Polprasert et al. 1982). Fish is a cold blooded animal and, unlike other farm animals such as cattle or poultry, does not have to spend a lot of energy for movement because friction is less in water. Thus fish have a better food conversion ratio than any other farm animals. Fish culture does not require highly skilled manpower for its operation (Polprasert, 2007). Fish production from wastes might have some limitations such as land requirement and existence of a waste collection system, availability of suitable fish fry, marketing and public acceptance

#### Aquatic weed

Using aquatic weeds in waste recovery and recycling will result in waste stabilization and nutrient removal, and conversion of the harvested weeds into productive uses. Aquatic weeds provide a medium for bacteria to be attached and grow at their roots and stems, to stabilize the waste (Figure 2c). The presence of weeds in the aquatic medium and subsequent harvesting enable the nutrient removal from the wastewater. Even though stabilization of waste is a slow process in aquatic systems, the removal efficiency is high and can produce an effluent superior or comparable to that of any other treatment systems (Polprasert, 2007). Aquatic weeds can be used, directly or after processing, as soil additives, mulch, fertilizer, green manure, pulp and fiber for paper making, animal feed, and human food, organic malts for biogas production and for composting.

#### Land treatment

Land treatment is defined as the controlled application of wastes on to the land surface to achieve a specified degree of treatment through natural physical, chemical and biological processes within the plant-soil-water matrix (Figure 2d). Land treatment systems are less energy intensive than such conventional systems as: activate sludge, trickling filters and aerated lagoons. However, energy is needed in land treatment for transportation and application of wastewater to the land. Since less mechanical equipments are needed for land treatment process when compared with other conventional treatment processes, the maintenance of the land treatment system is easy and less expensive.

## Constructed wetlands for wastewater treatment and recycling

Constructed wetlands are a wastewater treatment system consisting of shallow ponds or channels planted with emerging aquatic plants (Figure 2e). The processes by which wastewater is treated include a wide range of interacting biological, physical and chemical mechanisms. Constructed wetlands process are the symbiotic reactions between aquatic plants and bacteria similar to the algal photosynthesis. The aquatic plants perform photosynthesis under sunlight and the produced O2 is transferred from leaves to the root zones where bacteria will utilize it to decompose the organic matter (Polprasert, 2007). Other reactions occurring in a constructed wetland system such as adsorption and plant uptake will, respectively, result in better removal of SS and nutrients (such as N and P). BOD5 matter is degraded by the bacteria attached on the surface of the constructed wetland media and plant roots using O2 photosynthetically produced by the plant leaves that is transferred to the soil-water matrix. N and P are removed by plant uptake and sedimentation while, due to long retention time, most suspended solids would settle down in the constructed wetland beds and some could be removed by filtration and adsorption.

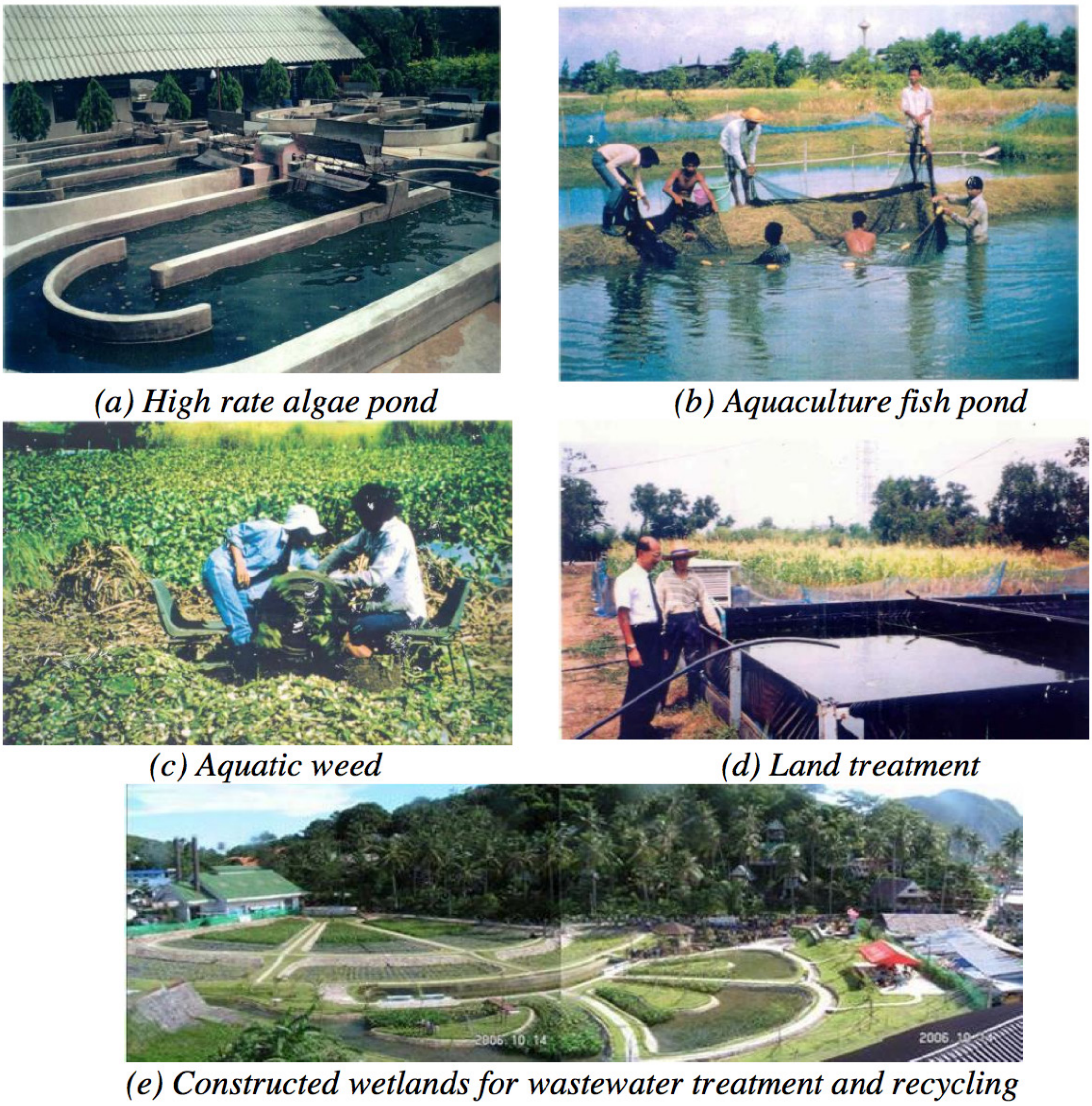


***Figure 2:*** *Ecological wastewater treatment systems (clockwise from upper left): High rate of algae pond; aquaculture fish pond; aquatic weed; land treatment; constructed wetlands for wastewater treatment and recycling*

## 2.2 Innovative sanitation technology

Some innovative sanitation technologies recently developed such as solar septic tanks and hydrothermal carbonization of feacal sludge (Figure 3) can meet the closed-loop concept because they effectively inactivate the pathogens, remove the pollutants and producing valuable by-products such as biogas and hydrochar, respectively. These technologies which are cost-effective should be able to protect the public health, improve quality of the canals and rivers in the urban areas, all contributing to water sustainability.

A modified conventional septic tank with solar-heated water is considered to be an effective on-site sanitation technology. Operating a septic tank at temperatures higher than ambient condition could enhance pathogen die-offs, increase biodegradation of organic matters and reducing sludge accumulation. Koottatep et al. (2013) reported the TCOD and BOD5 removal efficiencies of septic tanks operating at temperatures of 40-70 oC to be more than 80 %, while E.coli reduction was 4-6 logs. Rates of sludge accumulation and amount of $CH_4$ production in the solar septic tank operating at a temperature of 40 oC were found to be about 50 % lower and higher, respectively, than those in the conventional septic tank (Pussayanavin et al, 2014). Hydrothermal carbonization is an alternative technology that can be used to treat and convert feacal sludge into valuable solid product called hydrochar. The energy content and yield of the produced hydrochar were found to be about 20MJ/kg and 70%, respectively.

***Figure 3:*** *Innovative sanitation technology (top to bottom): Solar septic tank; hydrothermal carbonization of feacal sludge*

## 3. Common barriers and major concerns of water sustainability

Although awareness of water sustainability is increasing, due to globalization and industrialization, many developing countries still do not consider wastewater management as a priority. The common barriers for moving towards water sustainability consist of such issues as: government's priorities, legal status and regulation, national budgeting, availability of appropriate technology and technology transfer, and lack of awareness among local people. Moreover, restricted local budgets or funding can be one of barriers that decrease affordability for water sustainability approach, especially in many small and isolated villages.

## 4. Summary

Because of limited water resources, water pollution and global warming, many developing countries are facing water scarcity and water contamination. The application of the ecological wastewater treatments as presented in this paper are some of the technologies, which have proven effective in the pollution control and resource recovery. These systems are environmentally friendly and socially acceptable which should contribute to urban sustainability. The innovative sanitation technologies are new trends of on-site technologies which could be effective in wastewater treatment and sludge stabilization including the production of value-added products. Implementation of these technologies could create a platform towards global sustainability, but common barriers such as policies, regulatory procedures and budget planning need to be tackled concurrently.

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