Chapter 3
Wastewater Treatment Plants Advantage to Combat Climate Change and Help Sustainable Water Management

Kapilkumar Nivrutti Ingle, Mulugeta Chanie Fenta, Koichi Harada, Akash Sopan Ingle, and Atsushi Ueda

Abstract Wastewater treatment plants (WWTP) can provide water and nutrients for plant growth for small scale agricultural farming. Cultivation is possible if the parameters in wastewater treatment plants are available within the usable range. The waste treatment plants use wastewater mainly originating from underground, which is less affected by climate change than surface water and can be used for several purposes even during climate change. This chapter aims to assess the characteristics of treated wastewater at waste treatment plants and discuss its possibility to use the water, surrounding space and nutrients for small scale agricultural purposes. We assessed systematically the worldwide open sources works and use selected four wastewater treatment plants data of Kumamoto city of Japan. The previous results

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K. N. Ingle (✉)
Department of Ecology, University of Szeged, Középfasor 52, 6726 Szeged, Hungary

K. N. Ingle · A. Ueda
Department of Preventive and Environmental Medicine, Graduate School of Medical Sciences, Kumamoto University, Kumamoto, Japan

M. C. Fenta
Doctoral School of Geosciences, Department of Mineralogy, Geochemistry and Petrology, University of Szeged, Szeged, Hungary

School of Earth Sciences, Bahir Dar University, Bahir Dar, Ethiopia

K. Harada
Department of Microbiology and Environmental Chemistry, School of Health Sciences, Kumamoto University, Kumamoto, Japan

Department of Medical Technology, Faculty of Health Science, Kumamoto Health Science University, Kumamoto, Japan

A. S. Ingle
Department of Civil Engineering, Zeal College of Engineering and Research, Pune, India

A. Ueda
Asian Health Promotion Network Center (AHP-Net), Kumamoto, Japan

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and our data analysis of the pollutant load per capita to the plant and pollutant discharge per capita from the plant showed that all plants are efficiently reduced the pollutants loads. Still, there are variations in nitrogen and phosphorous concentration in the final effluent discharge. On that basis, we found that the treated water is useful for agricultural purposes, and moreover, the nitrates and phosphate values released by all plants are adequate to cultivate microalgae.

Keywords Wastewater treatment plant · Pollutant discharge · Nutrients · Small scale agriculture · Climate variability

3.1 Introduction

The recent global air and ocean temperature increase is considered indisputable evidence of climate change. It has already started to have adverse consequences for water resources and will have severe implications in the upcoming decades. Some of the factors that increase these values are population growth, urbanization, land-use changes, increasing demands for water and energy, improving living standards, shifting agricultural works, growing industrial works and change of economic activities. All these are profoundly likely to harm water resources. These adverse effects due to climate change and its impact on natural resources along with mitigation strategies must be studied for sustainability (Alcamo et al. 2007).

Climate predictions and current observations suggest that the hydrological system, including river flows and regional water resources, are anticipated to have the most substantial impact on climate change. As an example, the quantity of great inland flood devastations per decade that occurred between 1996 and 2005 is twice as large as between 1950 and 1980 that resulting in increased economic losses by a factor of 5 (Kron and Berz 2007). The increase in flood risk is observed due to increased climate variability as a result of an increase in temperature (Kundzewicz et al. 2007). Around the world, many major river systems are fed by snowpack and melting glaciers and global warming is likely to have an effect on snowmelt and related runoff. Glaciers are affected by several hydrological variables including wind speed, precipitation, humidity and typically the temperature that makes them a good indicator of global warming. Rivers found at higher latitude and altitude may experience an increase in discharge due to melting of glaciers though there is a decline of precipitation (Dyurgerov 2003). Global warming is having a noticeable influence on glacier retreat on every continent (Milner et al. 2017). Warmer temperatures can also affect water quality in many ways such as reducing dissolved oxygen level, and reduction in stream and river flow as well as an increase in contaminant load to water, algal blooms and the possibility of coastal region invasion by saltwater intrusion. The release of sulfuric and nitrogen compounds to the atmosphere results in acid rain which degrades the water quality and changes the chemical content variations in streamflow and increases chemical loads to rivers. Thus a proper water management technique, including its reuse is essential to provide a better quality of water.

Water, once an abundant natural resource, is now becoming a more valuable commodity due to its overconsumption and draughts. Water resources management encompassing the action of planning, developing, distributing, managing the optimum use and strategic reuse of water resources is required. Such a management plan will consider all competing water demands and seek to allocate water on an equitable basis to satisfy all of its uses and requirements. Therefore, for such water management plan to be successful, sustainable and to reduce the overexploitation of fresh groundwater, it is crucial to reuse wastewater after its treatment. Wastewater treatment and its reuse has been evolved and advanced throughout human history. The untreated municipal wastewater has been reused for many centuries to divert human waste outside the urban settlements. Also, for centuries, land application of domestic wastewater is a common practice that has seen many stages of development that led to a better understanding of treatment technology. Therefore, it leads to having processing techniques for the eventual outcome of water quality standards of the treated wastewater. The increase in population growth and urbanization with time imposes challenges for sustaining water resources and disposing of wastewater. Nowadays, wastewater is usually transported to a centralized wastewater treatment plant (WWTP) through collection sewers at the lowermost height of the gathering system generally close to the point of discarding to the environment. The centralized WWTPs are mostly arranged to route wastewater to these remote locations for treatment. Water reuse in urban areas is often inhibited due to lack of dual distribution systems (Metcalf & Eddy et al. 2014). These make it highly essential to provide proper wastewater treatment facility and water reuse strategy along with its reclamation in quality.

Treatment procedures in wastewater reclamation are implemented either separately or together with domestic water quality to achieve reclaimed water quality aims. Water reclamation might develop and use several stage treatment processes, flow diagrams and operations to meet the water quality requirements of a particular reuse application. The vital task is to point out significant factors affecting water reclamation technology. The choice of water reclamation technology might be affected by several factors. The critical aspect for such purpose are the kind of water reuse application, the objectives of reclaimed water quality, the characteristics of sources water to the wastewater, suitability with the present environments, process flexibility, energy and chemical requirements, operating and maintenance requirements, personnel and staffing requirements, residual disposal options and environmental constraints (Esposito et al. 2012). Water recycling is a crucial process in water treatment plants that applies the reuse of treated wastewater for valuable purposes including small scale agriculture and landscape irrigation, industrial applications, toilet flushing and replacing groundwater systems (groundwater recharge) (Exall 2004). Water reuse consents the public to be less reliant on groundwater and surface water resources and helps to decrease the alteration of water from sensitive ecosystems. Furthermore, water reuse may reduce the nutrient loads from wastewater emancipations into waterways, thereby reducing and avoiding pollution (Kim et al. 2008).

The purpose of this chapter is to assess the characteristics of treated wastewater at wastewater treatment plants at selected sites in Japan. The chapter aims to evaluate the nutrient content of treated water and its suitability for small scale agriculture and other purposes. The relevance of treated water from the treatment plants is planned to be assessed mainly based on the two main indicator parameters; pollutant loads per capita (PLC) to the wastewater treatment plant and pollutant discharge per capita (PDC) from the wastewater treatment plant (Tsuzuki 2006). Each of this parameters is calculated from the biochemical concentrations parameters of the treated and untreated water. Therefore the chapter objectives to calculate those indicators from the biochemical concentrations of input and output water of four selected treatment plants in Japan. The fresh groundwater is less affected by climate change and supplies water for the cities and then wastewater to the treatment plants. The chapter also aims to discuss the possibilities of using the treated water, surrounding space and nutrients for small scale agricultural purposes even during climate change.

3.1.1 Selected Case Study Area

The case study area of our research is Kumamoto city, a capital city of Kumamoto Prefecture and a third populous city in Kyushu island of Japan, known as ‘city of water’ for its aquatic environment. The use of groundwater as one of the primary sources for domestic and societal purposes is a vital feature of Kumamoto city. The city public sewer started in 1948 as a part of post-war reconstruction of the city to serve a population of 48,000 residing in the city area of 278 hectares. The essential components of the wastewater treatment system are domestic wastewater sewerage, industrial non-hazardous wastewater sewerage, sanitary sewage pipes, pumping stations and treatment plants. Kumamoto city has four treatment plants which are managed by the city government and serve the city’s major population. The four treatment plants of Kumamoto city namely; Chubu, Tobu, Nanbu and Seibu sewage treatment plants are situated and responsible for the disposal and treatment of sewerage from the central, eastern, southern and western parts of Kumamoto city respectively (Fig. 3.1).

The central and eastern part of the city is generally residential and commercial zones respectively, served by two treatment plants (Chubu and Tobu). These plants have two separate lines as Chubu line A and B and Tobu line A and B, which treats the main part of the city wastewater (Fig. 3.2). The western part is a new settlement and not much crowded.

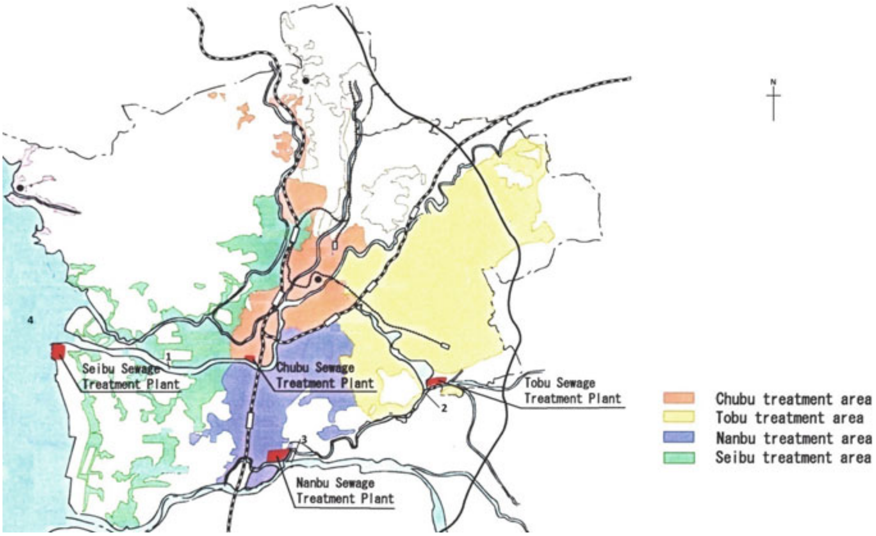

Fig. 3.1 Map of Kumamoto city with sewerage treatment plants' service areas in 2008. *Source* Booklet of central wastewater treatment plant-2007, Kumamoto city

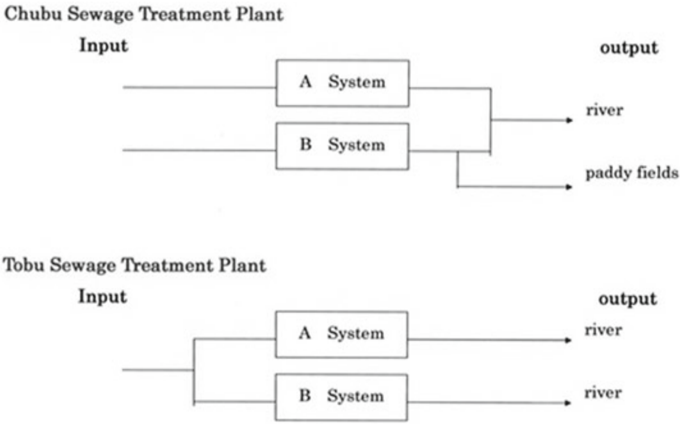

Fig. 3.2 Arrangement of two parallel treatment systems of two treatment plants

3.2 Material and Methods

The necessary data and other information for this investigation were gathered from the four treatment plants and the wastewater management system of Kumamoto city. The data collection was focused on specific parameters that play an essential role for algal growth used to produce biofuel, vegetables and fruits (such as cabbage, salad, carrot, potatoes, tomatoes, etc.) that can be cultivated in a small farming area

Fig. 3.3 Indicators selected for this study are based on a few water quality parameters

close to the treatment plants. These data focus on the environmental parameters used to calculate the indicators, PLC and PDC, which are used to know the number of nutrients that come to the four WWTP and discharge to the ambient water bodies from them as shown in Fig. 3.3. They are also useful to estimate whether the treated water is suitable to cultivate the biofuel producing microalgae, vegetables and fruits in small farmland. These data were collected from the treatment plant test results by the plant authorities, governmental officials, websites, annual reports, visiting to plant and taking questionary survey results of the city and treatment plant personals.

These indicators are comprised of seven environmental parameters namely; biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), suspended solids (SS), total nitrogen (TN), ammonium nitrogen (AN), organic nitrogen (ON) and total phosphorous (TP). The monthly data for the concentration of the seven environmental parameters were collected from April 2006 to March 2007 and the treated water agricultural sustainability parameters (PLC and PDC) were calculated using the monthly and yearly based formula (Tsuzuki 2006).

$$\mathrm{PLC} = \frac{\sum_i \mathrm{WQ}_{\mathrm{inf},i} \times \mathrm{FR}_i \times \mathrm{DAY}_i}{\mathrm{POP} \times 365} \qquad (3.1)$$

and,

$$\mathrm{PDC} = \frac{\sum_i \mathrm{WQ}_{\mathrm{eff},i} \times \mathrm{FR}_i \times \mathrm{DAY}_i}{\mathrm{POP} \times 365} \tag{3.2}$$

where PLC is pollutant load per capita, $\mathrm{WQ}_{\mathrm{inf},i}$ is water quality in influent in the month i (mg/l), PDC is pollutant discharge per capita, $\mathrm{WQ}_{\mathrm{eff},i}$ is water quality in the effluent in the month i (mg/l), FR_i is flow rate or treated wastewater volume in the month i (m^3/day), DAY_i is the number of days in a month i and POP is population served by the treatment plant.

The data from two treatment plants (Chubu and Tobu) were taken as the average data of the two lines and considered as the data of the entire plant for this work. In Japan, WWTPs can treat nontoxic industrial wastewater if toxic elements are already removed or treated by industrial effluent treatment plant (Ingle et al. 2011). Here we are not considering the impacts of rainwater if any. The PLC (g/person/day) indicates the characteristics of input wastewater from the community served by WWTPs (Benedetti et al. 2008) and PDC (g/person/day) shows (Tsuzuki 2006) the discharge of pollutants to ambient water bodies like the coastal sea, rivers, etc. Moreover, the calculated PLC values enable us to infer the social life of the people and seasonal changes in the routine awareness of the environment.

3.3 Results

3.3.1 Pollutant Loads to Wastewater Treatment Plant Per Capita (PLC)

A load of pollutants to the wastewater treatment plant is generally high if the plant is serving a large population of the city. The population size of Kumamoto city when this study was conducted was 556,806 who reside in a total area of 9313 hectors. Tobu WWTP plant served approximately 45% of people living in the area while Chubu plant served 14%, Nanbu plant 15% and Seibu plant 7% of the total population. The rest part of the city is served by two more plants managed by the prefectural government that we did not include in our case study. The large size of the site area of Seibu plant and Nanbu plant denotes future planning of urbanization in their regions. Chubu plant can use its total planned capacity to treat the wastewater amounting to 94,200 m^3/day, but average inflow recorded in 2006–2007 is 69,693 m^3/day. Nanbu plant has a planned ability to handle 73,500 m^3/day wastewater, with potential to treat 42,000 m^3/day; however, the recorded average inflow amount is 31,502 m^3/day. Seibu treatment plant is located near the coast and is developed for future prospects with a planned capacity of 54,900 m^3/day. However, the recorded average inflow of wastewater is 8355 m^3/day. Tobu plant has the potential to treat 141,000 m^3/day wastewater with a planned capacity of 204,000 m^3/day whereas its average inflow is 115,331 m^3/day.

The sources of sewage are generally domestic, included black water containing human faces with urine, greywater from kitchen sinks and bathrooms, outflows from washbasins and washing machines, etc. The average values of selected environmental parameters; BOD_5, COD, SS, TN, AN, ON and TP concentration to sewage treatment plants are given in Table 3.1.

The incoming loads to all pollutants present as influents, expressed in grams per capita per day, is higher for Chubu plant followed by Tobu, Nanbu and Seibu plant respectively, as shown in Fig. 3.4.

Although the treatment technologies of all WWTPs are similar, there are differences in the values of treated water quality parameters. These differences might be due to variations in the design of plants, the components of inflow water, operators skills, technical problems, local water consumption and the season of the year. The average daily inflow of wastewater per capita to Chubu plant is approximately

Table 3.1 Environmental parameters and water characteristics to and from treatment plants

Factors	Parameters	Chubu	Tobu	Nanbu	Seibu
Influents (water before treatment)	Water quantity treated (annual) (l)	25,437,984	42,095,740	11,498,410	3,049,541
	BOD (mg/l)	236.5833	213.9167	193.1667	104.4167
	COD (mg/l)	82.2083	93.8750	83.5833	58.1667
	SS (mg/l)	159.5417	195.8750	133.6667	83.1667
	TN (mg/l)	34.7208	54.3792	48.4917	27.1833
	A N (mg/l)	21.4208	32.6542	36.3750	17.0917
	ON (mg/l)	12.9625	21.6208	12.0000	10.0917
	TP (mg/l)	4.0333	7.2417	5.0583	2.4083
Effluents (Water after treatment)	Water quantity output (annual) (l)	23,651,230	37,020,322	11,183,427	2,944,236
	BOD (mg/l)	5.0000	7.3333	5.6667	1.2833
	COD (mg/l)	7.3875	9.1083	10.6667	6.5417
	SS (mg/l)	2.2208	3.3750	3.8333	1.6000
	TN (mg/l)	14.9833	21.3792	34.2167	18.2083
	A N (mg/l)	5.1875	13.0792	27.4250	6.4750
	ON (mg/l)	2.8542	3.2333	2.8000	1.7500
	TP (mg/l)	1.5833	2.5708	1.7833	0.1500
Population		79,646	249,953	85,727	41,442
Area searve(ha)		1358	3653	1455	785
Site area (m^3)		93,850	120,350	120,700	111,000
Reuse water (l)		1,775,621	5,056,164	309,542	104,308
Flow per day (l/day)		69,693	115,331	31,502	8355
Sludge per year (kg/year)		1,113,242	1,925,360	544,065	99,661

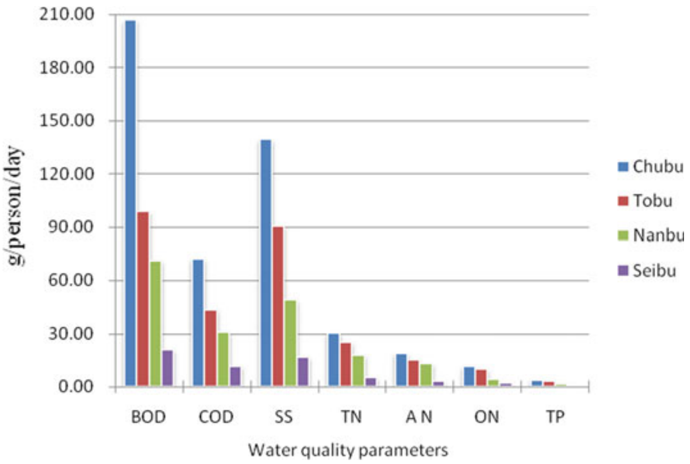

Fig. 3.4 Average of annual loads of pollutants from the community to the treatment plant in g/person/day

twofold the sum amount of inflow to Tobu and Seibu plants and 5.6 times more than Seibu plant.

3.3.2 Pollutant Discharge from Wastewater Treatment Plant Per Capita (PDC)

The amount of effluent discharged from a sewage system depends on the service area size, population and the amount of water used by the community. Figure 3.5 shows the pollutant discharges from all WWTPs. Chubu plants, with the exception of nitrogen, had a higher release of pollutants to the environment. Among all four WWTPs, Nanbu plant discharges a higher amount of nitrogen discharge per capita. BOD and SS are the most abundant constituents of WWTPs' outflow, which play an essential role to determine the environmental health of water bodies due to discharging treated wastewater. Chubu plant discharges effluents having BOD and SS concentration values of 5 and 2.2 milligrams per litre respectively and release a daily average of approximately 0.3 tonnes of BOD and 0.14 tonnes of SS into Shirakawa river. The discharge value of Tobu plant is less than half of Chubu plant, while more than twice the discharge value of Nanbu plant. Seibu plant discharges approximately 0.01 tonnes of BOD and SS per day. The National and City Government standards to release treated water into water bodies are less than 15 (mg/l) for BOD and 40 (mg/l) for SS, which are obeyed by all plants. Seibu plant, being the newest plant of all plants, releases the lowest PDC value compared to other plants. However, it discharges its effluent into ambient water bodies (the sea) results in a higher dilution capacity compared to other plants.

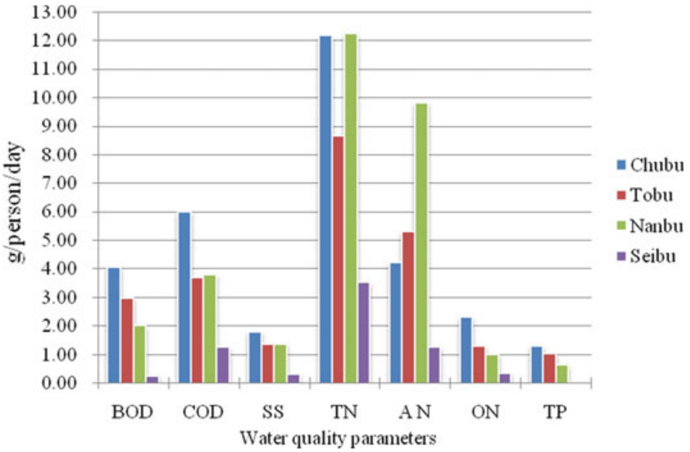

Fig. 3.5 Average of annual pollutants discharge to ambient water bodies from a treatment plant in g/person/day

In some cases, few amounts of treated water have been already reused in a paddy field. However, a significant quantity of treated water is discharging to ambient water bodies of rivers and finally, the sea. The Chubu plant is located to the side of Shirakawa river, the main river in the prefecture and removes the treated water into it. Tobu plant is situated close to Kiyama river, a tributary river to Khase river and discharges treated water into it. Nanbu plant located near to Khase river and releases treated water into it. In contrast, Seibu plant is situated at the mouth of the Shirakawa river and removes treated water into the Ariake sea, the place where all rivers end and recharge the sea.

3.4 Discussion

Although all WWTP efficiently treated the wastewater, the nitrogen level in terms of PDC of treated water was higher compared to other pollutants which can be considered as nutrients for further use. In the process of urbanization, population growth in the rest of Kumamoto city can become an important reason to increase the number of pollutants discharged, through the increase in the use of water quantity, changes in lifestyle and land development. Generally, the urban population in any country would be more prosperous and affluent compare to the rural people. The growth of population leads to a change in the lifestyle and living standards due to the need for an improved quality of life. These interns will have a possibility of more consumption of natural resources, including water. As an example, changes in the toilet system from old-style Japanese toilets to flush toilets, or changes in the bath system leads to showers or tub baths with the use of different types of soaps. The changes in food style also play an essential role in the characteristics of greywater. This can result in a rising amount of wastewater generated per person and pollutant discharge to ambient water bodies. The impacts of improperly treated water on aquatic environments principally depend on, amount of effluent discharged, the quality of the effluent, receiving aquatic environment characteristics, assimilative capacity of the receiving ambient water bodies, climate and season.

The presence of chemicals in the effluent, particularly from industrial areas, may have long-term environmental effects. However, in the case of Kumamoto WWTPs, there is no possibility of such adverse impact because the industrial area was minimal and industries have their system to treat their effluents. Besides, there is a ban on the use of many chemicals, even in industrial areas. Therefore, there is no possibility of mixing industrial water into city wastewater. Kumamoto city treated wastewater has the potential to be reused for many purposes, including the issue of tackling global climate change.

3.4.1 Treated Water and Climate Change

Most of the water supplies to urban cities come from groundwater and surface water. In comparison to surface water, groundwater is less affected by climate change, especially for the short term, seasonal factors. However, the associated structures and facilities are vulnerable to the adverse effects of climate change (Case 2008). The consummation of groundwater as freshwater is high and worldwide 3–5 billion people depend on groundwater as a drinking water source (Kundzewicz and Doll 2009). Population growth is pressure on water supply in addition to climate change and the overall factors lead to increase the need for reuse of water exceptionally diverse climate change (such as droughts) become more predominant (Major et al. 2011). In most places like Kumomanto city of Japan, where the sources of freshwater and the input to WWTP is groundwater, are expected to be less affected by climate change. It can form the basis of adaptation programs securing food through small scale agriculture. This is mainly because the groundwater systems create a buffer against more unpredictable rainfall (Kundzewicz and Doll 2009). Therefore, groundwater resources are more likely affected by increased demand for irrigation, domestic and industrials use than the changes to recharge due to climate change (Taylor et al. 2013). The global groundwater recharge is unlikely to be affected by more than 10% due to climate change (Kundzewicz and Doll 2009).

The treated water that is primarily used for household applications will have use in combating climate change for farmers who are mainly affected by extreme weather conditions including drought, severe heat, flooding and other shifting climatic trends. The small scale agriculture will help to combat climate change. If agricultural activities include cultivating crops like corn, wheat, rice in addition to vegetables and fruits, they will extract nitrogen from the air to use on their own and radically reduce the need for humanmade fertilizers. These kinds of agricultural works are an essential step towards a carbon zero future for agriculture. The large scale agricultural enlargements lead to having significant land that causes deforestation and diminishes draining of wait land. These agricultural works will later reduce the ability of the natural ecosystem to absorb and store carbon dioxide while small scale agriculture using the reuse of treated water can minimize the effect. Therefore, smalls scale agriculture using treated water will help to preserve the natural habitat and help to combat climate variation in turn.

The use of a large amount of fresh water for irrigation can broadly impact the world freshwater resources. As an example, the study by Döll et al. (2012) showed that in 2000, irrigation accounts for ~70% of global freshwater withdrawals and ~90% of consumptive water use. The same research indicated that globally, groundwater is the source of one-third of all freshwater withdrawals, supplying an estimated amount of 36%, 42% and 27% of the water used for domestic, agricultural and industrial purposes respectively. The use of groundwater for large scale agriculture will deplete the groundwater and it may fever future climate change and deficiency of food demand. The dependence on rainwater for agriculture similar to developing countries intern cannot combat climate change and even can trigger food demand shortage. The study and report by IPCC (2008) predicted that climate change over the next century would affect rainfall patterns, river flows and sea levels all over the world. According to the study by Jarvis et al. (2010), agriculture is one among which will be severely affected during the coming hundred years due to unprecedented rates of changes in the climate system. The use of recycled water (treated water) will, in turn, be intensified significantly for small scale agriculture and production of microalgae in a little farming land without affecting the ecosystems of the environment. The reuse of treated water can help to alleviate the shortage of water and food due to climate change.

Treated water is also used to circulate in the city as the climate change adaptation strategy. In various cities, rainwater on the surface circulates and flows in narrow channels that help to grow different green, attractive and ornamental plants (Fig. 3.6). The green plants help to increase the cities' beautification and combat climate change. Treated water can also help to reduce greenhouse gases (GHG) emissions from wastewater in the future due to the action of increasing wastewater collection and treatment. Moreover, as an increased scarcity of water resources, wastewater reuse will become more necessary as climate change accelerates. The value of treated water recuse is expected to increase in the coming decades due to intense climatic extremes associated with climate change which intern results in food scarcity. When the treated water sources recharge groundwater, the world's largest part of stored freshwater, it will play a significant role in sustaining ecosystems and enabling long-term human adaptation to climate variability and change.

3.4.2 *Treated Water and Agriculture*

The reuse of wastewater in agriculture involves further use in treated wastewater for crop irrigation (Claro 2008) which is an efficient means for water resources management. The reuse helps to minimize the requirement for planned water supply and compensate for water scarcities caused by seasonality and irregular availability of water resources for irrigation (Jaramillo and Restrepo 2017). Even though the reuse of wastewater is the earliest practice, it has not always been appropriately managed or met quality standards according to use. Consequently, the awareness about wastewater use has been progressed with the history of humankind. The Food and Agricultural Organization (FAO) of the United Nations has developed several guidelines relevant to the use of wastewater in agriculture. In 1987, the wastewater quality guidelines for agricultural use were issued that focused on the degree of restriction of water use to salinity, infiltration and toxicity parameters of specific ions (Ayers and Wescott 1985). The work by FAO in 1999 proposed guidelines for the agricultural reuse of treated waters and treatment requirements. The guidelines classified the types of agricultural water reuse depending on the kinds of irrigated crops (Pescod 1992).

The agricultural use of treated wastewater assist human wellbeing, the environment and the economy. It provides an alternative practice for diverse regions challenged with water deficiencies and increasing urban populations with growing water demands (Jaramillo and Restrepo 2017). It has crucial importance, particularly for areas affected by the decline of surface and groundwater resources instigated by climate variability and climate change. Wastewater sourced pollutions, which are not usually treated before reaching the surface channels and its associated aquifer pollution, affect the availability of freshwater resources (Jaramillo and Restrepo

Fig. 3.6 Circulation of the rainwater from Kumamoto city to combat the climate change issue

2017). On the other hand, the agricultural use of treated wastewater has a tremendous advantage by reducing the pressure on freshwater resources serving as a vital alternative irrigation water source. The benefit is significant as agriculture is the highest global water user who consumes 70% of available water resources. Furthermore, wastewater reuse increases agricultural production in regions suffering from water shortages, thus contributing to food security (Roy et al. 2011).

3.4.3 Possible Utilization of Treated Water for Microalgae Cultivation

The sustainability of biofuel is uncertain due to the requirement of various resources such as land, water, nutrients, etc. and environmental issues possibilities and processing technological uncertainty (Gerbens-Leenes et al. 2009). For example, the use of soybean, palm, sunflower and rapeseed have no technical restrictions but require land and water (Sensoz and Kaynar 2006). This can have inquiries about food security and can have a dispute with food versus fuel and environmental problems. However, microalgae can serve as feedstock for fuel by converting the carbon dioxide in sunlight into potential biofuels, including biodiesel (Banerjee et al. 2002), biohydrogen and methane (Spolaore et al. 2006). The possibility of converting both types of microalgae, prokaryotic and eukaryotic types, into various biofuels and byproducts attracted many companies to cultivation at the mass level for their lipid accumulation properties (Chisti 2007). However, the mass level production of microalgal biomass is not cost-effective due to maintenance expense requirements.

The vast land requirement for large scale cultivation is more challenging. The use of transparent polymer films such as polyethylene or polyurethane (Kim et al. 2016) can be an expensive way of farming. This type of cultivation may have few environmental issues due to poor management. The open-pond outdoor microalgae cultivation system is the most popular and economical method which is implemented by many companies. Its low operations accost and low energy input requirement makes it be more attractive farming system while there are contamination possibility issues. Concerning the water footprint, microalgae bioenergy is beneficial compare to other bioenergy sources. A study by Yang et al. (2011) recorded a microalga, *Chlorella Vulgaris*; biodiesel has a water footprint of 3726 kg-water/kg-biodiesel. The reuse of treated water can reduce this and simplify the cultivation system.

Considering our case study WWTP of Kumamoto city of Japan, the nitrates and phosphate values are discharged by all plants in sufficient quantities to cultivate the microalgae. The phosphorous and nitrogen concentrations in city wastewater vary from 30 to 40 mg/l and 5 to 10 mg/l, respectively. The total nitrogen (TN) and total phosphorus (TP) requirement for algal growth vary from 15–90 mg/L and 5–20 mg/L values respectively and the nitrogen to phosphorus ratio (N/P) is approximately 3.3. On the other hand, the Chlorella and Scenedesmus species of microalgae can grow in a wide range of wastewaters and can decompose nitrogen and phosphate in

10 days. The microalgae that can be cultivated for the biofuel showed a harvesting cycle of 1–10 days, which makes it possible to harvest numerous times in a short duration (Chisti 2007). The open-pond system is a simple method based on ground level ponds in which intermixing of water may be possible by the use of paddle wheels. This system requires low operating, capital cost and power than closed-loop photobioreactor systems (Benemann et al. 2012), which make it accessible in commercial algae producers (Lundquist et al. 2010).

3.4.4 Can Treat Water be Used for the Household Appliance?

Even after advanced treatment of the wastewater, there is no guarantee for continuous chemically and microbiologically indisputable drinking water quality. Thus, the substitution of drinking water with treated water may be possible for several purposes other than potable water, for instance, garden irrigation and toilet flushing. In addition to sludge arising after drinking water treatment, the addition of considerable amounts of chemicals can be minimized. The water reuse systems available from stormwater or greywater can be designed cost-effective with proper operation, presenting no hygienic risk or discomfort to the users (Nolde 1995). To use the treated water for household appliances, the treatment and the distribution of treated water should not demand more energy consumption and chemicals in comparison with conventional systems. The water from recycling systems should fulfil specific criteria such as hygiene, environmental tolerance, technical and economic feasibility (Nolde 2000) to be used for household appliances.

According to Delphi study, about 76% of surveyed international experts in “Water Technology, 2010” considered it as technically feasible to use treated wastewater in households by the year 2010 with no known risk. The “Guidelines for Water Reuse” published in 1992 by the US Environmental Protection Agency (EPA) describes the treatment stages, water quality requirements and monitoring tools (US EPA 1992). According to the report, reclaimed water used for toilet flushing must undergo final filtration and disinfection. The effluent should not have detectable faecal coliforms in 100 ml of the treated water, a BOD_5 of less than 10 mg/L and a residual Cl_2 of less than 1 mg/L and the resulting Cl_2 should be continuously monitored (US EPA 1992).

Treatment of wastewater for service use should follow a sedimentation stage, biological treatment, a clearing stage and final UV disinfection. According to the study, Funnel-shaped sedimentation tanks having automated sludge-removing devices proved to be most effective. Biological treatment can be followed in a plant itself with the provision of either a vertical-flow soil filter or a multiple-stage Rotary biological contactor (RBC) alternatively a trickling filter, coupled with a clearing tank to remove the existing biomass. The treated water should also be eventually disinfected by UV before storing in the service water tank. Distribution of service water is achieved with a booster pump for pumping to heights.

The quality requirements for non-potable, i.e. service water uses must be scientifically justified with a risk assessment analysis desirable in every case. As per sustainable water concepts, lower energy and chemical demand should be achieved in service water systems than conventional systems. Wastewater treatment for service use has proved to be technically feasible. There are enough positive examples to verify that the total water for toilet flushing (about 15 to 55 l/person/day) can be substituted with service water without a hygienic risk or discomfort. It should be possible soon to have a dual water system in households with two water qualities, the first one with high-quality drinking water originating primarily from natural freshwater resources and the second one with water quality for all other service uses. This should bring environmental and sustainable relief to both the water and energy sectors.

3.5 Conclusion

In this chapter, we reviewed the possibility of treated wastewater application in small scale agriculture, microalgae cultivations and household service water appliances which help to conserve water resources and combat climate change. A case study in Kumamoto city water treatment plant, Japan, water and treated water data has been taken and analyzed to find the BOD and COD values of the four treatment plants. We found that the city wastewater treatment plant is efficient to remove the solids in water, reducing the BOD and COD values and keeping the right amount of nutrients in the treated water which can be useful for small scale agriculture, microalgae cultivation. The clear treated water has the potential to penetrate the sunlight and create a better environment for microalgae. It is possible to make some arrangements in the treatment plant for use that treated water for cultivation of biofuel producing microalgae because a majority of requirements of such farming are already present in wastewater treatment plants. Moreover, it is identified that the treated water could also be applied in small scale farming land and possible also to use as a service household water for toilet flushing and gardening service water. In both cases, treated water can help to combat climate change by reducing vast farmlands that cause deforestation, minimizing the shortage of water for several applications during climate changes since most WWTPs are supplied water initially from groundwater.

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