1. INTRODUCTION

1.1 Municipal Wastewater Treatment Plants (MWTPs)

Municipal wastewater means the discharge of effluent from wastewater treatment plants which receive wastewater from households, commercial establishments, industries and combined sewer/separate storm overflows (European Environment Agency, http://www.eea.eu.int). Wastewater treatment plants are common worldwide and a necessary step to improve the quality of wastewater before it discharges to surface or groundwater and re-enters water supplies (Carey and Migliaccio, 2009).

The conventional municipal wastewater treatment plants (MWTPs) usually include two main treatment processes: primary treatment and secondary treatment. Figure 1-1 illustrates the main components of a conventional municipal wastewater treatment plant.

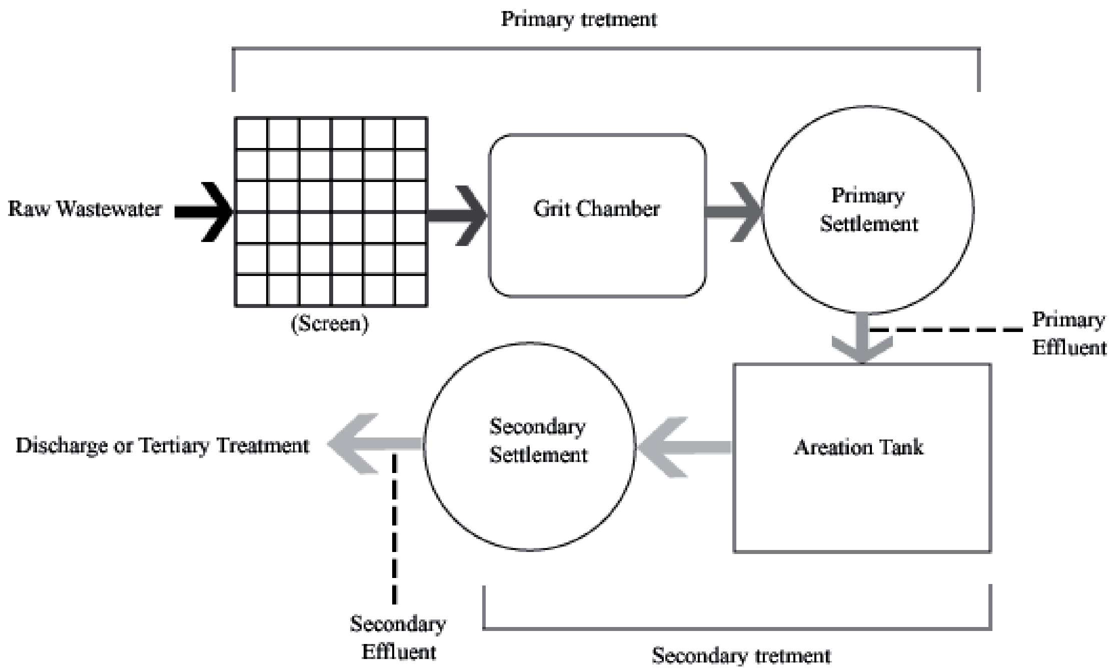

Figure 1-1. Simplified schematic review of a conventional municipal wastewater plant (Shi, 2005)

The primary treatment of municipal wastewater is designed to remove floating solids and suspended solids from raw sewage by physical and/or chemical process. It includes the processes of screening large floating objects by a “screen”, removing grit (cinders, sand and small stones) by a “grit chamber” and settling minute suspended solids by a "sedimentation tank" (primary settlement). The solids settled by the primary treatment are called raw primary biosolids and should be landfilled or incinerated. The water discharged after primary treatment is called primary effluent or primarily treated wastewater (USEPA, 1998).

After the primary treatment, the wastewater still contains high amount of organic matters and should be eliminated by secondary treatment. It is a process generally involving biological treatment, which employs microorganisms and a secondary settlement. After the sewage leaves the primary settlement tank in the primary treatment, it is pumped into an "aeration tank", where it is mixed with air and sludge loaded with bacteria and allowed to remain for several hours. During this time, the bacteria break down the organic matter into harmless degradation-products. From the aeration tank, the partially treated sewage flows to another sedimentation tank (secondary settlement) for removal of excess bacteria (USEPA, 1998).

However, neither the primary treatment nor the secondary treatment has sufficient ability to remove nitrogen and phosphorus from the wastewater. The secondary effluent still contains significant amounts of nitrogen and phosphorus.

1.2 MWTPs & Nitrogen and Phosphorus Pollution

1.2.1 Contribution of MWTPs Effluent to Nitrogen and Phosphorus

Researchers investigating nutrient pollution from nonpoint sources have discovered that nutrient loads were often more strongly influenced by wastewater treatment plants effluent than by nonpoint sources (Carey & Migliaccio, 2009).

European Environment Agency pointed out that most of the dissolved phosphorus loading of inland surface waters is attributable to discharges from point sources, especially municipal wastewater treatment plants and industrial effluent. In Europe, nutrient discharges from municipal wastewater treatment plants are in general higher than from any other point source. Results from large inland and marine catchments show that municipal wastewater constitutes about 75 % of the point source discharges of both nitrogen and phosphorus. Industrial sources constitute about 17 % and other point sources are relatively insignificant (EEA, 2005). In the United States, wastewater treatment plant effluent is also regarded as the anthropogenically nonpoint derived source of Nr (reactive form of nitrogen, such as ammonium and nitrate) (Driscoll et al., 2003).

1.2.2 Nitrogen and Phosphorus Pollution

1.2.2.1 Freshwater and Marine Eutrophication

Excessive nitrogen and phosphorus loading is a major ongoing threat to water quality and lead to increased rates of eutrophication nowadays. Large discharges of input from wastewater treatment plant may result in the permanent eutrophication of a water system. Eutrophication has been identified as a major environmental issue in both freshwater and marine waters in Europe's environment (EEA, 1999).

Phosphorus has been identified as a key grow-limiting nutrient for algae in lakes and reservoirs (Schindler, 1977). Issues associated with freshwater eutrophication include increased algal biomass, decreased water transparency, low dissolved oxygen (DO) levels, increased fish mortality and more frequent incidence of toxic phytoplankton. Therefore, eutrophication related water quality impairment could have very substantial negative economic effects, for example, higher treatment costs and health hazards due to algal toxins for drinking water (Smith, 2003).

In contrast with freshwater ecosystems, where eutrophication is caused largely by excess inputs of phosphorus, in coastal ecosystems, nitrogen is the most critical element (Ryther and Dunstan, 1971). Coastal eutrophication can cause excessive production of algal biomass, blooms of harmful or toxic algal species (red tides), loss of important estuarine habitat, massive fish and shrimp kills, change in marine biodiversity and species composition, increase in sedimentation of organic particles, and depletion of dissolved oxygen (Driscoll et al., 2003, Smith, 2003).

1.2.2.2 Other Pollutions

Acidification caused by the elevated inputs of reactive nitrogen has also been concerned as the adverse environmental pollution in freshwater ecosystems in the

Northeast of the USA, surface water acidification resulting from HNO_3 has been characterized as a seasonal and episodic phenomenon associated with high stream flows and is typically most severe during spring snowmelt. This causes pronounced decreases in pH, in addition, acidic episodes induced by NO_3^- also mobilize inorganic monomeric Al in the soil, which is toxic to fish (Driscoll et al., 2003).

Another environmental concern over nitrogen in aquatic system is the possible health risks associated with the consumption of drinking water containing high concentrations of nitrate. Nitrate itself does not pose a health threat; however, it is readily reduced to nitrite (NO_2^-) by nitrate reductase. Nitrite poses two distinct health risks, being potentially carcinogenic and causing methaemoglobinaemia (blue-baby syndrome) (McEldowney et al., 1993).

In addition, wastewater discharges to receiving waters characterized by alkaline pH values could exacerbate NH_3-N toxicity and threaten the viability of various fish species (Passell et al., 2007).

1.2.2.3 Phosphorus Crisis

Furthermore, at present, commercial phosphorous production is based almost exclusively on phosphate rock-primarily calcium phosphate in various forms (Morse et al, 1998). The remaining accessible reserves of clean phosphate rock might run out in 50 years, and the world would move from an oil-based to a phosphate-based economy (summarized by Gilbert, 2009). Anthropogenic impacts have intensified release of P such as discharges of urban and industry wastewater (Smil, 2000). Therefore, moving phosphorus towards sustainability is quite urgent. One of possible methods is to recycle the phosphorus from wastewater treatment discharge.

1.2.3 Regulations Concerning Nitrogen and Phosphorus Discharge from MWTP

It is true nowadays to recognize that nitrogen and phosphorus associated problems are one of the major concerns among different environmental issues in the society. Environmental laws are given general applicability and their enforcement has been increasingly stricter. This tendency will continue because of pressure from the public and various concerned bodies and agencies.

The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU, 2001) reported that a total of 10.5 billion m^3 of municipal wastewater were treated in the public wastewater treatment plants in 2001, among it, approximately 5% were treated only with mechanical and biological treatment without targeted nutrient removal. Thus, millions of tons of nitrogen and phosphorus have been discharged into the environment. The increasing world population and urbanization will lead to greater water demand of wastewater in the future. Therefore, more effective nitrogen and phosphorus management is important for the sustainability of water resources.

The German BMU (2004) sets up the limitation of nitrogen and phosphorus discharged from domestic wastewater treatment plants, which is 13-18 mg l^{-1} and 1-2 mg 1^{-1} respectively (Table 1-1). While, the European environment agency requires a higher standard (total nitrogen, 15 mg l^{-1}) for wastewater discharged in sensitive areas because such areas need more stringent treatment (EEA, 1991; Table 1-2). In developing countries, for instance in China, regulations (CEPA, 2002; Table 1-3) concerning nitrogen and phosphorus from municipal wastewater treatment plants are also becoming more and more stricter because frequently occurred eutrophication has strongly influenced human health and drinking water supply. For instance, over-exploration and over-utilization for Lake Taihu have caused degradation of the lake ecosystem and deterioration of water quality, hence affected the drinking water supply for several cities, such as Shanghai, Suzhou, Wuxi and Huzhou. From 1981 to 1998, total nitrogen, total phosphorus and COD_{Mn} increased by 2.6, 2.7 and 1.5 times, respectively. Municipal sewage accounts for **25% of the total nitrogen**, **70% of total phosphorus** and 27% of COD pollutant composition based on the data from 1998 (Qin et al., 2007).