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Evaluation of wastewater reclamation technologies based on in vitro and in vivo bioassays

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ABSTRACT

When municipal secondary effluent is used as the main supplementation water source for surface water bodies, its potential adverse ecological effects should not be neglected. The objective of this work was to investigate the effectiveness of several technologies, i.e. combination of coagulation and sand filtration (CSF), ultraviolet (UV) irradiation, chlorination, ozonation, ultrafiltration (UF) and reverse osmosis filtration (RO), on the removal of acute ecotoxicity, genotoxicity and retinoic acid receptor (RAR) agonist activity from the municipal secondary effluent. The effects of treated effluents on the development of Japanese medaka (*Oryzias latipes*) embryos were also evaluated. The secondary effluent exhibited a mutagenic effect on *Salmonella typhimurium* strain TA 1535/pSK1002, acute invertebrate toxicity to *Daphnia magna*, and weak RAR α activity. RO and ozonation demonstrated remarkable removals of the genotoxic effect, acute toxicity and RAR activity from secondary effluent, while chlorination could elevate both genotoxicity and acute toxicity. CSF, UV, UF, chlorination as well as RO could decrease the 4-day mortality of medaka embryos and accordingly increase the hatching success rate, comparing with the secondary effluent. Ozonation at 4 mg/l and higher doses, however, elicited significantly higher 4-day mortality, leading to the reduction of the hatching success rate.

1. Introduction

With its rapid economical development, China has experienced growing water crisis during the last two decades, both in terms of water scarcity and quality deterioration. Effluent from municipal sewage treatment plants (STPs) has recently been focused as a novel water resource because of its relatively stable quality and quantity properties. In some northern cities in China, which are in serious shortage of surface water, the use of reclaimed municipal wastewater as a major supplementation water source for rivers and lakes is considered to be an important countermeasure to the increasing water crisis. However, the secondary effluent has been found to cause some adverse aqua-ecological effects. Aguayo et al. (2004) found that the effluent from 7 investigated STPs all showed toxic effects to *Daphnia magna*, while some samples showed estrogenicity and teratogenicity. Dizer et al. (2002) reported that samples taken from a river accepting the secondary effluent caused genotoxic

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responses in the umu assay. The secondary effluent was also reported to induce significant reduction of hatching rates and increase of embryo lesions of exposed Japanese medaka (*Oryzias latipes*) embryo (Zha and Wang, 2005). One of the possible causative substance group is retinoids, which possess a chemical structure or functional properties similar to vitamin A, act as signaling molecules, and regulate many processes critical to early embryonic development (Sucov and Evans, 1995). Degitz et al. (2000) reported that 6.25 μg/l all trans retinoic acid could elicit higher teratological rate and mortality of exposed *Xenopus laevis*. Methoprene acid, a metabolic degradation product of methoprene, a pesticide, and organochlorine pesticides have been shown to bind to members of the retinoic acid receptors (RAR) (Harmon et al., 1995; Lemaire et al., 2005). Although up to now, it is not clear whether the reported increase of teratological rates of Japanese medaka embryos were related to retinoids in the secondary effluent, the above adverse ecological effects should be considered when the secondary effluent from the STPs is used as the main supplementation water source for surface water bodies.

Generally, almost all reclamation schemes have adopted some add-on technologies, among which the combination of coagulation and sand filtration (CSF) is most often introduced to the existing conventional secondary treatment, to upgrade the quality of reclaimed water. To reduce the pathogenetic risk, disinfection using chlorine is generally performed. However, the adverse effects of chlorination have caused concerns over the formation of hazardous disinfection byproducts (DBPs), and ultraviolet (UV) irradiation has been focused as a substitute for chlorination disinfection (Jolis et al., 2001). With the rapid development of membrane technologies, reclamation of municipal wastewater using ultrafiltation (UF)and reverse osmosis (RO) have become increasingly attractive (Bourgeous et al., 2001; Qin et al., 2005). UF has been known for its high efficiency in the removal of particles and some colloidal organic compounds (Bian et al., 1999; Abdessemed et al., 2000). RO is a very promising technique because it removes the majority of compounds, both organic and inorganic, with a high efficiency (Qin et al., 2005). Ozone with its strong oxidation potential is effective in disinfection, decoloration, and decomposition of organic compounds. Takanashi et al. (2002) found that ozone treatment was effective for the removal of mutagen precursors from wastewater. Petala et al. (2006) have compared the performances of different coagulants on the removal of ecotoxic and mutagenic effects from the reclaimed secondary effluent. However, systematic comparison of the existing add-on treatment technologies has not yet been carried out with respect to their respective performance in the reduction of various ecological toxicities.

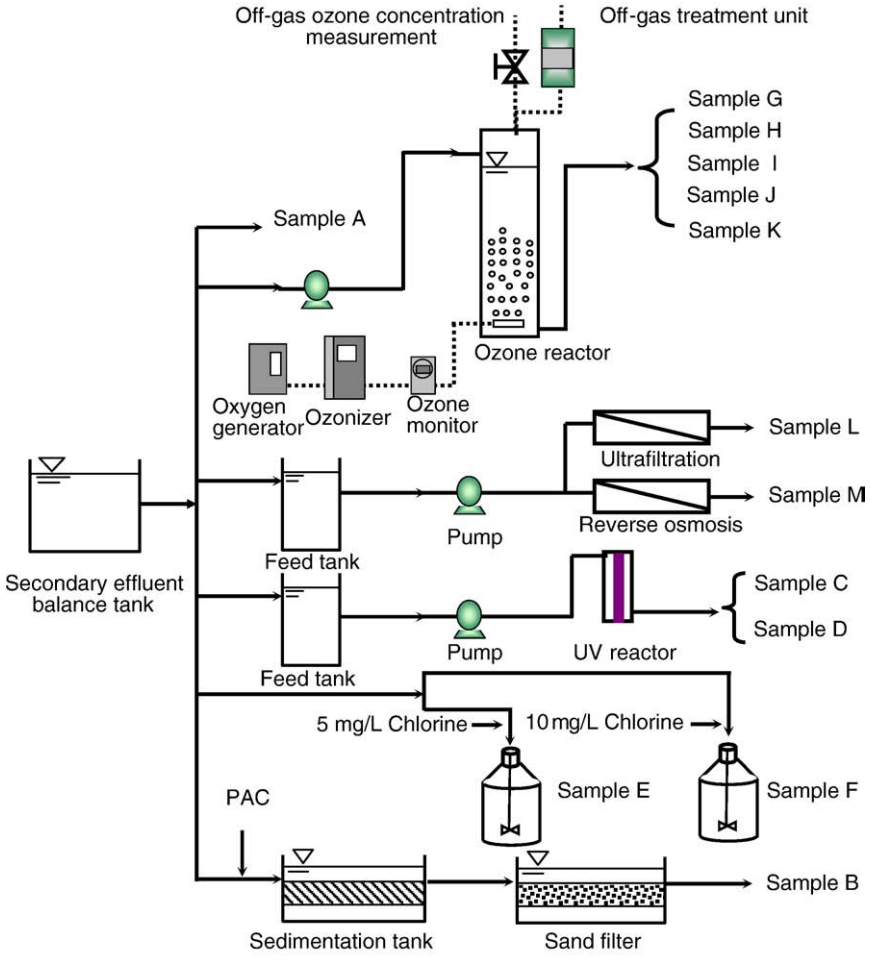

Fig. 1 – Schematic diagram of reclamation treatment process and sampling.