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Research Progress on Toxicity of Typical Trace Pollutants in Reclaimed Water

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Abstract: With the continuous development of human society, reclaimed water plays an increasingly important role in human production and life. Although the current sewage treatment process has basically removed a large number of harmful pollutants, some trace pollutants usually exist in the reclaimed water environment at a low concentration (ng/L~ug/L), and may still affect human health through migration and transformation. In recent years, the research on single trace toxic pollutants in reclaimed water has gradually increased, but the combined toxic effects of mixed trace pollutants in reclaimed water are less studied.

Keywords: Mixture, Combined toxicity, Concentration addition.

1. Research Background and Significance

There are many kinds of pollutants in the natural environment, most of which coexist in the form of mixtures. The addition and synergy of some typical pollutants produced by mixing have great potential environmental and health risks, and the toxicity risks caused by the mixing and interaction of typical pollutants in the water environment are more prominent [1-6]. In recent years, research on the technological level of urban sewage treatment and regeneration has been continuously deepened, and the technological level has also been continuously improved. The treated sewage is usually used to replace tap water for industrial water, agricultural water, landscape water, etc., to alleviate the current situation of insufficient water resources. At present, many countries have incorporated urban sewage regeneration into national strategic planning, and recycled water has become a new form of water source application and all aspects of production and life. As the second water source needed for urban development, its application space and development potential are huge, and it has a broad market prospect. Increasing the recycling of sewage has become the main way to alleviate water shortage at present. The waste water produced by human production and life can usually be directly reused for agriculture, industry, landscaping and municipal utility after treatment by sewage treatment plants and recycled water plants. Nowadays, most countries are studying new technologies to treat wastewater. All domestic sewage and most urban sewage in Israel are treated back for production and life, and the utilization rate of sewage reuse is very high. Although Japan is not a water-scarce country, the Japanese sewage recycling project has been in operation for a long time, creating a system of intermediate waterways and replenishing the country's water-scarce or depleted rivers through the reuse of reclaimed water in the 1990s. By treating reclaimed water to recharge groundwater, California not only helps with water shortages, but also alleviates the current situation of land subsidence. In recent years, China has gradually paid attention to the reuse of sewage, the use of recycled water has gradually increased, the use of sewage treatment plant effluent has become more and more extensive, the use of more landscape water, greening and agricultural irrigation, fire water, domestic flushing water and industrial water cooling water. At present, public buildings such as schools and hotels with a certain building area are equipped with sewage treatment systems [7]. However, the reclaimed water treatment process is usually only for further treatment of conventional pollutants, and lacks the Disinfection By-Products (DBPs), endocrine DisruptingChemicals (End°Crine DisruptingChemicals, end °Crine disruptingchemicals, end °Crine disruptingchemicals. EDCs, Pharmaceuticals and Personal Care Products (PPCPs) and other trace amounts of toxic and harmful pollutants targeted removal. The reuse process will bring some trace pollutants into human production and life, thus affecting water ecology and human health. For example, when reclaimed water is used to create landscape water such as fountains or flows into rivers, humans may inhale small particles of water or come into contact with this part of water, or be consumed by humans after being absorbed by crops through agricultural irrigation [8]. Therefore, it is of great practical significance to conduct toxicity tests on trace pollutants in reclaimed water and assess their toxic interactions in reclaimed water, so as to provide basic data for the research on risk assessment of these trace pollutants on reclaimed water ecology and human health [9-26].

2. Research Progress on Toxicity Evaluation Methods of Mixed Pollutants

With the development of China's economic construction, a wide variety of chemicals have gradually entered people's lives, and with the increase of chemical production and use year by year, the types and contents of chemical pollutants in the water environment have also gradually increased. While expanding the range of production and living varieties, people are also under the threat of various pollutants. The problem of trace pollutants in recycled water treatment has been paid attention by scientists at home and abroad, and the basic research on the type analysis and toxicity analysis of recycled water pollutants has been gradually established. Among them, the evaluation methods of toxic interaction of pollutant mixtures in reclaimed water include equivalent map, effect addition method, toxicity index method, combination index, concentration addition (CA), independent effect (IA), and model deviation ratio (MDR). Among them, equivalent map, effect summation method and toxicity index method are the first evaluation methods. At present, the two most frequently used reference models for mixture toxicity assessment and prediction are CA and IA models, in which CA model is suitable for mixture systems with similar modes of action, while IA model is suitable for mixture systems with different modes of action. The equivalent map is qualitatively evaluated by graph, and the effect addition method, toxicity index method and combination index method are qualitatively evaluated by numerical comparison. CA and IA can be used for qualitative assessment of mixture toxicity, while the model deviation ratio (MDR) can be used for quantitative assessment of mixture toxicity. MDR is the ratio of the effect concentration predicted by CA or IA to the quasi-experimental concentration, which is a relatively intuitive evaluation system. MDR = 1, >1, and <1 are generally considered to represent additive, synergistic, and antagonistic actions, respectively. However, due to experimental errors and other factors, this criterion may lead to wrong conclusions. For example, MDR = 1.1(or 0.9) does not guarantee that the mixture will have a synergistic effect (antagonism). Therefore, on this basis, it is more reasonable to use the confidence interval (OCI) of experimental observations to characterize the uncertainty of toxicity experimental data.

3. DBPs

Disinfection plays an important role in dealing with microbial risks and is an indispensable and critical part of the recycled water reuse process. In recent years, the more common disinfection technologies used in sewage treatment are ozone (O3) disinfection, ultraviolet (UV) disinfection, chlorine disinfection, chlorine dioxide (ClO2) disinfection and chloramine disinfection. However, no matter what kind of disinfection technology will produce a certain amount of disinfection byproducts, such as ClO2 molecules as oxidants in the ClO2 disinfection process to oxidize microbial cells containing sulfur-based enzymes, resulting in microbial death, but in the process will decompose chlorite ions and chlorate ions and other toxic disinfection byproducts. In the process of chloramine disinfection, the production of nitrogen-containing disinfection byproducts (N-DBPs, including nitrosamines (NMs), halogenated nitromethane (HNM), haloacetonitrile (HANs), etc.) will be relatively high, and these products have strong carcinogenicity. At present, ozone disinfection is the most commonly used disinfection process in the sewage treatment process, which will produce bromate and carboxylic acid byproducts, and increase the formation of disinfection byproducts in the secondary disinfection. Recent studies have found many "newly identified or previously unrecognized" or unregulated emerging disinfection by-products. These emerging by-products have stronger toxicological effects and have more practical research significance in practical studies [27].

Research on DBPs toxicity has gradually attracted people's attention in recent years. Studies have shown that most DBPs have different degrees of carcinogenicity and reproductive toxicity on human and animal bodies. At present, most countries have conducted studies on the toxic effects of DBPs, and all countries have set standards for the concentration of disinfection byproducts. However, there are still few studies on the toxic effects of DBPs in our country, and it has only been a few decades since we started to study this field. At the same time, recent studies only focus on DBPs in drinking water, but the presence of a large number of DBPs can still be often detected in the effluent after sewage treatment, and DBPs generated during sewage disinfection has gradually attracted human attention. Zhang Yajing et al. [28] used juvenile zebrafish as the test organism to study the effects of secondary effluent from municipal sewage treatment plant and secondary effluent disinfection with sodium hypochlorite (NaClO) on catalase (CAT) activity, malondialdehyde (MDA) content and acetylcholinesterase (Ach) activity in zebrafish. Lu et al. [29] took HepG2 as a model organism and tested the growth of HepG2 cells, DNA damage and intracellular reactive oxygen species (ROS) level under the exposure of five HANs(single and combined) compounds. The HANs mixture induces co-toxicity in HepG2 cells. HAcAms are a class of nitrogenous DBPs. Plewa et al. [30] systematically analyzed the toxicology of 13 HAcAms using Chinese hamster ovarian cells (CHO) as the model organism.

Since the substances contained in sewage treatment are more complex than those in tap water, the types of DBPs contained in reclaimed water after disinfection are much more complex than those in tap water after disinfection. In recent years, the research on new DBPs only focuses on its detection and characterization methods, especially the toxicity studies on new DBPs are still few.

4. EDCs

In 1998, the United States Environmental Protection Agency (USEPA) announced that 67 endocrine disruptors had been detected from 86,000 chemicals and commercial products that could seriously affect animal or human health. At the same time, Japan also carried out a survey on endocrine disruptor species in the domestic water environment, and after a year of investigation, about 75 endocrine disruptors were identified in the Japanese water environment. There are many kinds of endocrine disruptors, and there are many ways for human production and life to discharge endocrine disruptors, such as endocrine disruptors in the wastewater produced by many chemical plants and daily necessities factories [31]. Many substances in environmental chemical pollutants belong to endocrine disruptors, and one of their common characteristics is that they have estrogen activity, but there is no formal statistical result in the world [32]. Endocrine disruptors are often discharged directly into the water body without restriction, resulting in water pollution. Purdom et al. [32] conducted a survey on six rivers and their tributaries in the UK, and the results showed that more than half of the rivers were polluted by endocrine disruptors [33].

The types of EDCs detected in reclaimed water are basically similar to those in other water environments. Deng Hongmei et al. [34] analyzed the distribution and content of bisphenol A (BPA), the EDCs with a high detection rate in water environment, and analyzed the toxic effects of BPA on various microorganisms and fish based on the concentrations detected in the actual environment. Li Rui et al. [35] studied the toxic effect of BPA on Cy clotella caspia. The results showed that the growth of algal cells was inhibited when the mass concentration of BPA was 4, 6, 8, 10 and 12 mg/ L, respectively. It was found that the content of chlorophyll a in algal cells decreased with the increase of BPA concentration.

KASHIWADA et al. found that the semi-lethal mass concentration (LC50) of BPA on male and female Medaka fish was 6.8 mg/L and 8.3 mg/L, respectively. The LC50 was 5.1 mg/L for killifish embryos and 9.0 mg/L for fish eggs during incubation. When male fish were exposed to water containing BPA(>10μg/ L) for up to 5 weeks, male fish were found to also behave as females, and female proteins were found in their cells.

In recent years, the detection of BPA has become a global problem, especially in relatively developed places, the detection rate is higher. Moreover, the detected concentrations have been increasing in recent years. However, due to the development of human economic society and industrial level, BPA plays a very important role in industrial production, and in recent years, it has been shown that further increase in production is needed to supply. In China, research on this classic endocrine disruptor (BPA) is just beginning, and more tests and toxicity tests are needed. At present, there are no national emission standards and toxicity thresholds for BPA in the water environment. Because it and DDT pose a great threat to human health and ecosystem safety, environmental monitoring of BPA and toxicity data of BPA concentration in the actual environment should be strengthened as soon as possible, and emissions should be controlled from the source.

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