JOURNAL OF ENVIRONMENTAL SCIENCES XX (2017) XXX–XXX

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/jes

JES JOURNAL OF ENVIRONMENTAL SCIENCES www.jesc.ac.cn

Study on the effects of organic matter characteristics on the residual aluminum and flocs in coagulation processes

Hui Xu[1,2], Dawei Zhang[3], Zhizhen Xu[4,5], Yanjing Liu[3], Ruyuan Jiao[1,2], Dongsheng Wang[1,2,*]

1. Key Laboratory of Drinking Water Science and Technology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China. E-mail: huixu@rcees.ac.cn
2. State Key Laboratory of Environmental Aquatic Chemistry, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China
3. School of Environmental and Municipal Engineering, Xi'an University of Architecture and Technology, Xi'an 710055, China
4. Key Laboratory of Occupational Safety and Health, Beijing Municipal Institute of Labor Protection, Beijing 100054, China
5. College of Life Science and Bio-engineering, Beijing University of Technology, Beijing 100124, China

ARTICLE INFO

Article history:
Received 21 August 2016
Revised 26 October 2016
Accepted 18 November 2016
Available online xxxx

Keywords:
Coagulation
Residual aluminum
Organic matter
Floc size
Fractal dimension

ABSTRACT

Characteristics of organic matter may affect the residual aluminum after the coagulation process. This study reported the results of a survey for one drinking water treatment plant and measured the concentration of residual aluminum species with different molecular weights. Survey results indicated that humic acid or organic matter whose molecular weight was smaller than 1500 Da had significant effects on residual aluminum. All the treatment processes were ineffective in removing dissolved organic matter whose molecular weight was smaller than 1500 Da. These results also indicated that the addition of sand or polyacrylamide in the coagulation process could greatly decrease the concentration of humic acid, and the concentration of residual aluminum also decreased. These results revealed that for all water samples after filtration, the majority of total residual aluminum existed in the form of total dissolved aluminum, accounting for 70%–90%. The concentration of residual aluminum produced in bovine serum albumin solutions indicated that when the DOC was larger than 4.0 mg/L, there were still significant differences when the solution pH value varied from 4.0 to 9.0.

Introduction

Coagulation is widely used in water treatment plants due to its low cost. Some factors may influence the aggregation of colloids, such as solution pH, turbidity, chemical composition of the water samples, coagulant dosage, water temperature, surface area of colloids, and mixing conditions (Hu et al., 2006; Xu et al., 2013; Wu et al., 2007; Jiao et al., 2015). Among all the coagulants, Al-based coagulants have been used most widely, and they can change surface charge properties to promote agglomeration and/or enmeshment of smaller particles into larger flocs (Xu et al., 2013; Wu et al., 2007; Yang et al., 2010a). Although Al-based coagulants can remove particles or organic matter in the coagulation process, the concentration of residual aluminum may sometimes be large (Yang et al., 2010a). Some studies have indicated that residual aluminum can be an important cause of Alzheimer's disease, and decreasing the concentration of residual aluminum is important to ensure

* Corresponding author. E-mail: wgds@rcees.ac.cn (Dongsheng Wang).

http://dx.doi.org/10.1016/j.jes.2016.11.020
1001-0742/

Please cite this article as: Xu, H., et al., Study on the effects of organic matter characteristics on the residual aluminum and flocs in coagulation processes, J. Environ. Sci. (2017), http://dx.doi.org/10.1016/j.jes.2016.11.020

water quality (H. Xu et al., 2014; W.Y. Xu et al., 2014; Wang et al., 2016). Researchers have studied the effects of solution pH, coagulant dosage, characteristics of coagulants, and water temperature on residual aluminum (Yang et al., 2011, 2010b).

Some studies have indicated that organic matter is an important component in the water treatment process, and organic matter is also a precursor in the formation of disinfection by-products (Chellam and Sari, 2016; Hussain et al., 2013; Hua et al., 2015; Wang et al., 2013). Different types of organic matter may have different functional groups (Kaiser and Ellerbrock, 2005), and the functional groups may affect the coagulation performance and the concentration of residual aluminum. Researchers have studied simulated water samples created by adding humic acid (HA) to kaolin suspensions, but the effects of different types of organic matter on the residual aluminum have not been well investigated. Natural organic matter (NOM) plays a dominant role as a complexing agent for trace metals in natural systems, and the majority of studies have focused on the extracted humic fraction of NOM (Hartland et al., 2012). Little is known about how different types of organic matter may interfere with Al-based coagulants in the coagulation process (Hoffmann et al., 2013). Organic matter in source water can be characterized for different components using three-dimensional excitation emission matrix (3D-EEM) (Chen et al., 2003; Namguk et al., 2003). Removal of HA in the treatment process was found to be important due to its role in the transport of inorganic and organic pollutants (Jiao et al., 2014; Michael et al., 1986; Papathanasiou et al., 2011; Ruben et al., 1997), and the effects of HA on residual aluminum have been well studied.

Ultrafiltration (UF) membranes with different pore sizes have been used to separate the residual aluminum fractions according to molecular weight (MW) (Kimura et al., 2013; Yoshihiko et al., 2013). Residual aluminum after the coagulation process exhibits a wide size range, and the concentration in a filtered solution will be highly dependent on the membrane pore size and the separation capability of the membrane. Generally, the concentration in water samples after membrane filtration was found to decrease when membranes with smaller pore sizes were used. In order to better understand the mechanism, the coagulation performance in different organic systems has been measured using the Mastersizer 2000 to determine the floc size and fractal dimension (Xu et al., 2011a, 2011b; Wei et al., 2009; Yu et al., 2009, 2010). The physical properties of flocs, such as floc size, strength and compactness, may significantly affect the efficiency of solid/liquid separation (Javis et al., 2005). In the coagulation process, flocs are inevitably broken. Thus investigation of the breakage and regrowth processes is important to ensure good coagulation performance. The strength factors and recovery factors have been used to evaluate the characteristics of flocs, and the former studies indicated that the strength of flocs depends on floc structure, floc formation mechanisms and the inter-particle bonds (Li et al., 2007). Although the breakage and regrowth processes in the coagulation process have been studied for many years, the effects of different types of organic matter on the characteristics of flocs have not been investigated well.

In this study, the coagulation performance in a water treatment plant in Beijing was studied, and different types of organic matters were used to investigate the effects of organic matter on the coagulation processes. The objectives of this study were: (1) to investigate the effects of characteristics of source water samples on the residual aluminum; (2) to investigate the effects of coagulation processes on the residual aluminum; (3) to investigate the effects of different components of organic matter on the residual aluminum; (4) to investigate the characteristics of flocs formed in different organic matter systems.

1. Methods and procedures

1.1. Sample acquisition and treatment process in water treatment plant

Water samples used in this study were taken once a week during the study period (four months), and the characteristics of source water were almost the same (low temperature and low turbidity). They were taken from the following stages of the treatment sequence: raw water, water after ozonation, water after coagulation, and water after filtration. There are three treatment processes in the water treatment plant. The source water for the III phase works-A (3A) and II phase works-A (2A) treatment processes was the same, but some amounts of sand and polyacrylamide (PAM) were added to the raw water in the II phase works-A (2A) treatment process. Because the turbidity of raw water in the experimental period was low, some amount of sand should be added to the raw water to provide a core for floc formation to improve the coagulation performance. The source water in the III phase works-A (3A) and III phase works-B (3B) treatment processes was taken from different reservoirs, so the coagulation processes may be different. Before the experiments, the characteristics of raw water were measured during the study period, and the results are summarized in Appendix A Table S1. The treatment process consists of pre-oxidation with O_3 and coagulant addition, flocculation and clarification with sedimentation, sand filtration, granular activated carbon filtration, and chlorine dioxide disinfection. The purpose of O_3 addition is mainly to control taste and odor problems, but also to disinfect the water. Chlorine gas is used in post-chlorination to yield a free chlorine residual of 0.3 mg/L in the purified water. At the time of sampling, the coagulant (polyaluminum chloride (PACl)) dosage was 14.0–16.0 mg/L. A DOC analyzer was used for DOC measurements after filtration by a 0.45 μm membrane. The organic matter in the water samples was characterized by high performance size exclusion chromatography (HPSEC) and 3D-EEM, and the results are summarized in Appendix A Tables S1 and S3.

1.2. Jar tests

In order to investigate the effects of different types of organic matter on the residual aluminum, coagulation experiments were conducted in 500 mL glass beakers using a conventional Jar-test apparatus at room temperature. A three-stage mixing process was conducted in this study, including rapid mixing (200 r/min for 1.5 min) after addition of coagulants followed by slow mixing (40 r/min for 10 min), after which the suspension was settled for 30 min. After sedimentation, the samples were withdrawn and measured by inductively coupled plasma mass

Please cite this article as: Xu, H., et al., Study on the effects of organic matter characteristics on the residual aluminum and flocs in coagulation processes, J. Environ. Sci. (2017), http://dx.doi.org/10.1016/j.jes.2016.11.020