JOURNAL OF ENVIRONMENTAL SCIENCES XX (2017) XXX–XXX

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

The impact of iodinated X-ray contrast agents on formation and toxicity of disinfection by-products in drinking water

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ARTICLE INFO

Article history:
Received 31 January 2017
Revised 23 March 2017
Accepted 23 March 2017
Available online xxxx

Keywords:
Disinfection by-products
Iodo-DBPs
Iodinated X-ray contrast media

ABSTRACT

The presence of iodinated X-ray contrast media (ICM) in source waters is of high concern to public health because of their potential to generate highly toxic disinfection by-products (DBPs). The objective of this study was to determine the impact of ICM in source waters and the type of disinfectant on the overall toxicity of DBP mixtures and to determine which ICM and reaction conditions give rise to toxic by-products. Source waters collected from Akron, OH were treated with five different ICMs, including iopamidol, iopromide, iohexol, diatrizoate and iomeprol, with or without chlorine or chloramine disinfection. The reaction product mixtures were concentrated with XAD resins and the mammalian cell cytotoxicity and genotoxicity of the reaction mixture concentrates was measured. Water containing iopamidol generated an enhanced level of mammalian cell cytotoxicity and genotoxicity after disinfection. While chlorine disinfection with iopamidol resulted in the highest cytotoxicity overall, the relative iopamidol-mediated increase in toxicity was greater when chloramine was used as the disinfectant compared with chlorine. Four other ICMs (iopromide, iohexol, diatrizoate, and iomeprol) expressed some cytotoxicity over the control without any disinfection, and induced higher cytotoxicity when chlorinated. Only iohexol enhanced genotoxicity compared to the chlorinated source water.

Introduction

Disinfection by-products (DBPs) in drinking water are formed through the reaction between disinfectants, natural organic matter (NOM), bromide, and iodide. Among various factors influencing the spectrum of DBPs in finished water, the composition of the source water can play an important role, especially at point sources where large amounts of wastewater contaminants are being discharged. In general, iodinated DBPs (iodo-DBPs) are known to be more cytotoxic and genotoxic than their chlorinated or brominated analogues (Plewa et al., 2004; Richardson et al., 2007). Naturally occurring iodide in source waters was thought to be the only precursor in iodo-DBPs formation, and it was shown that increase in natural iodide leads to higher level of iodo-DBPs formed (Bichsel and von Gunten, 2000; Richardson et al., 2008). However, there is a new concern that iodine-containing pharmaceuticals could also serve as precursors to highly toxic iodo-DBPs in drinking water

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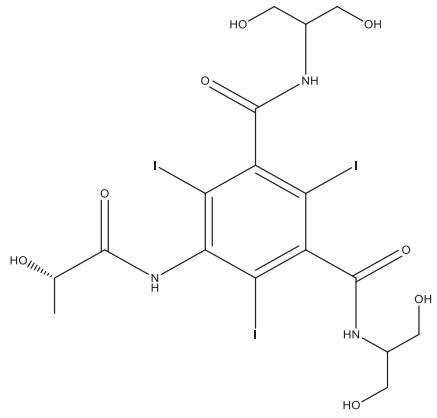
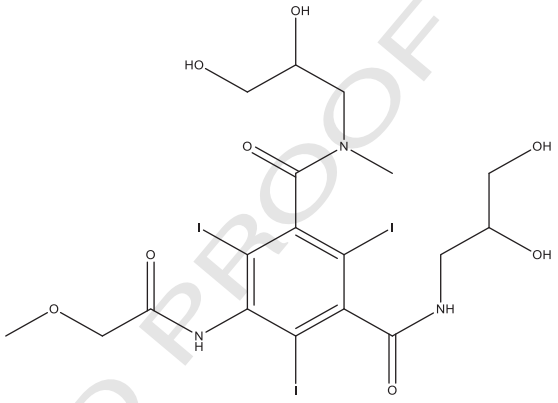
http://dx.doi.org/10.1016/j.jes.2017.03.032
1001-0742 © 2017 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V.

(Duirk et al., 2011; Kormos et al., 2011; Wendel et al., 2014; Yang et al., 2016).

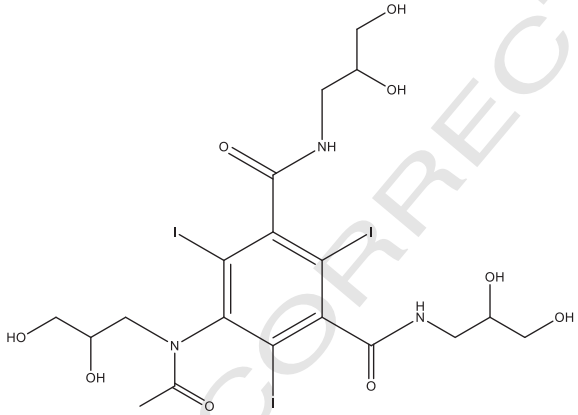
Iodinated X-ray contrast media (ICM) are widely used at hospitals and medical centers for tissue imaging, such as organs and blood vessels. The molecular structure of ICM consists of 2,4,6-triiodinated benzoic derivatives, with molecular weights varying between 600 and 900 Da, depending on the type of amide side chains (Fig. 1). The iodine atoms are responsible for the absorption of X-rays, and the compounds are designed to be persistent and polar so that they can be excreted within few hours after application. Typically, 95% of non-metabolized ICM are eliminated through urine and feces within 24 hr after application (Perez et al., 2006). ICM are not completely removed during the wastewater treatment, allowing them to enter source waters and serve as sources of iodine to form iodo-DBPs (Duirk et al., 2011; Richardson et al., 2008; Ternes and Hirsch, 2000; Wendel et al., 2014; Yang et al., 2016; Ye et al., 2014).



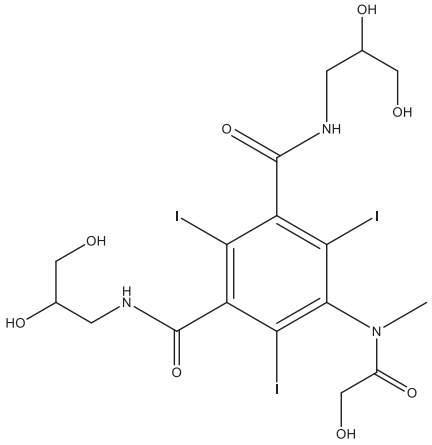
Iopamidol
CAS No. 62883-00-5
776.85 Da



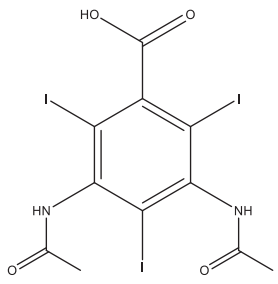
Iopromide
CAS No. 73334-07-3
790.87 Da



Iohexol
CAS No. 66108-95-0
820.88 Da



Iomeprol
CAS No. 78649-41-9
776.85 Da



Diatrizoate
CAS No. 737-31-5
613.77 Da

Fig. 1 – Chemical structures of five common iodinated X-ray contrast media.

Please cite this article as: Jeong, C.H., et al., The impact of iodinated X-ray contrast agents on formation and toxicity of disinfection by-products in drinking water, J. Environ. Sci. (2017), http://dx.doi.org/10.1016/j.jes.2017.03.032