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Review

Bromine and water quality – Selected aspects and future perspectives

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A R T I C L E I N F O

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A B S T R A C T

Bromine is a microelement present in waters, both in inorganic and in a wide range of organic compounds, though at lower concentrations. Typically, concentrations of organobromine compounds in waters are several orders of magnitude lower than of bromides. Two issues are addressed in the paper: the influence of bromides on the quality of treated waters and organobromines as contaminants of natural waters. Bromide presence in treated water gives rise to formation of potentially mutagenic disinfection by-products (DBPs). Registered amounts of DBPs in potable waters, exceeding the admissible levels, and the published data on DBPs in waters used for leisure and recreation activities, clearly indicate the health risk. Major sources are identified and registered concentrations of EDB, DBCB, methyl bromide, bromacil and PBDEs in the aquatic environment are summarized. The effects of bromide on DBPs formation and numerous examples of organobromine contamination of the aquatic environment indicate that the presence of bromides and organobromine compounds in the aquatic environment will have to be given more consideration, for several reasons. Firstly, larger amounts of bromide are present in saline and contaminated waters and the proportion of such waters being handled is increasing. Similarly, the processes of water purification, treatment and disinfection are now playing a major role. Secondly, emissions from manufacturing of bromine-containing materials growing, due to, inter alia, intensive development of the electronic industry and the plastic manufacturing sector. Thirdly, bromine compounds are also used as medicine ingredients. There is now a growing awareness of the presence of pharmaceuticals in the aquatic environment. Fourth, low bromide concentrations in hypergene zones may be modified in the future, partly because of the climate changes, which may give rise to difficulties with water treatment systems.

Water quality standards having relevance to water used for consumption are based only on the best-known (most widespread) DBPs. However new more restrictive legal regulations relating to the use of bromine compounds have been put in place prohibiting the use of certain bromine-based substances or restricting their amount in finished products. In the light of current legislation, the monitoring of water contamination with potentially toxic, mutagenic and endocrine-disrupting organobromine compounds is still unsatisfactory because newly discovered compounds are not included and certain factors governing the exposure to those substances are still left out.

The effects of bromine (bromide and organobromine compounds) on water quality have been investigated by researchers from several fields of expertise. The water management authorities ought to make use of the available research data and identify the problems which need to be addressed directly and those which may emerge in the future.

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1. Introduction

Bromine (an element from the halogen group) is not present in nature in its free state. It may have various oxidation levels (−1, 1, 3, 5, 7) the most widespread being −1 (bromide). Bromine forms easily soluble compounds. The discovery of bromine as an element was first described in 1826, even though certain organobromine compounds were well-known and widely used much before. About 1500 BC, ancient Phoenicians used the 6,6'dibromoindigo dye, better known as the Tyrian purple, made from the sea slugs' secretion (Wisniak, 2002). The number of identified natural organobromine compounds went up from about 60 in 1973 to more than 1600 at the end of the 20th century. They are produced by marine and terrestrial plants and microorganisms: bacteria and fungi, higher sea animals and a few mammals, including humans (Gribble, 1999). Certain compounds present in marine organisms are manufactured and used in industry, for example bromophenols present in algae and polychaetes are also components of brominated flame retardants and fungicides (Hassenklöver et al., 2006).

The presence of bromide in the aquatic environment has received a great deal of research interest and three aspects seem to be of major importance: identification of water salination, presence of tracers to study water flows, and water treatment processes (Edmunds, 1996; Davis et al., 2004). Bromide has long been used in prospecting for hydrocarbon deposits and in studies of the aquatic environment in salinated water areas, of various origins (Rittenhouse, 1967; Sánchez-Martos et al., 2002). The chloride-bromide indicator allows a reliable distinction to be made between salination being the result of halite leaching and that caused by the presence of seawater (Winid and Witczak, 2004 Freeman, 2007; Alcala and Custodio, 2008; Dailey et al., 2014). It is particularly useful when investigating the areas where hydrocarbon deposits are located, in mining areas, in seawater transgression areas and when identifying the sources of water salination resulting from diverse anthropogenic factors (Edmunds, 1996; Davis et al., 1998; Vengosh and Pankratov, 1998; Panno et al., 2006; Whittemore, 2007; Hudak, 2010). Because of low bromide concentrations in most underground waters (below the detection levels), the flow analyses in the vadose and saturation zones typically use bromide salts as tracers (Poletika et al., 1995, Nielsen et al., 2011). During the treatment of bromide-containing waters, disinfection by-products (haloorganic compounds) emerge, and some of them are considered to be carcinogens (Von Gunten, 2003; Richardson et al., 2007). The occurrence of carcinogenic organobromine compounds in municipal water systems gives rise to major health considerations and growing concerns about the key issue - availability of drinking water. Alongside the three major issues, another reason for the growing research interest in the presence of bromine in the aquatic environment are organobromine compounds that permeate to the aquatic environment causing a threat to human health. In the context of technological advances, the applications of organobromine compounds are becoming more widespread, including brominated flame retardants, artificial plastic components used in the electric and electronics industry, in construction engineering and in furniture production.

The condition of the aquatic environment is changing with the level of industrialization whilst diagnostic and research efforts keep at pace with its deterioration rates. The aim of the present study is to review the presence of bromide and bromine forms as microcomponents of water and to investigate their complex role in water quality. Two issues were addressed: the effects of bromides on treated water quality and the presence of organobromine contaminants in natural waters. Inorganic and organic bromine forms in the aquatic ought to be treated as two separate issues. Nevertheless these two aspects are sometime inseparable because the bromides may be the product of disintegration of organic compounds and bromides may enter into reactions during the water treatment forming organobromine compounds, so in further sections references are made to both organic and inorganic compounds. The purpose of this study is to characterize the role of bromides in water treatment and summarise the effects of water contamination with organobromine compounds. In the future the role of bromine (in both inorganic and organic forms) as a water quality indicator in the aquatic environment will be further enhanced in the light of the technological, analytical and climatic factors. In the context of the increasing population numbers, deterioration of the natural environment and water deficiency, the