

Aluminium in drinking water: An overview

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Abstract

Aluminium (Al) is one of the trace inorganic metals present in drinking water. In addition to the naturally occurring Al in raw waters, use of Al-based coagulants especially $Al_2(SO_4)_3$ (alum) often leads to an increase in treated water Al concentrations. A high (3.6 to 6 mg/l) concentration of Al may precipitate as aluminium hydroxide giving rise to consumer complaints. Al is also a suspected causative agent of neurological disorders such as Alzheimer's disease and presenile dementia. During conventional water treatment processes, Al undergoes various transformations (also called 'speciation' of Al) which are influenced by factors such as pH, turbidity, temperature of water source, and the organic and inorganic ligands present in water. Chemical precipitation, reverse osmosis, electrodialysis and cation exchange methods are efficient in Al removal from water. This paper gives an overview of the presence of Al in drinking water with reference to its speciation, removal (treatment methods), water supply and health problems, and the regulation of its levels in drinking water.

Introduction

Al-based coagulants such as aluminium sulphate ($Al_2(SO_4)_3$) (better known as alum) or polyaluminium chloride (PACl) are commonly used in drinking water treatment to enhance the removal of particulate, colloidal, and dissolved substances via coagulation processes. The treatment of surface water with aluminium sulphate has been in operation for over a hundred years all over the world. The use of alum as a coagulant for water treatment often leads to higher concentrations of aluminium in the treated water than in the raw water itself.

Typically, a portion of the alum added to the raw water is not removed during treatment and remains as residual aluminium in the treated water. The occurrence of aluminium in treated water has been considered for many years to be an undesirable aspect of treatment practice (Driscoll and Letterman, 1988; Van Benschoten and Edzwald, 1990). There is considerable concern throughout the world over the levels of aluminium found in drinking water sources (raw water) and treated drinking water. This has arisen mainly for two reasons. First, acid rain has caused the aluminium level in many freshwater sources to increase (Schecher and Driscoll, 1988). A high (3.6 to 6 mg/l) concentration of aluminium in treated water gives rise to turbidity, reduces disinfection efficiency, and may precipitate as $Al(OH)_3$ during the course of distribution (Rahman, 1992). Secondly, the possibility of an association between aluminium and neuropathological diseases including presenile dementia and Alzheimer's disease is frequently hypothesised (Schecher and Driscoll, 1988; Crapper and Boni, 1980; Davidson et al., 1982; Martyn et al., 1989; Gardner and Gunn, 1991; Jekel, 1991).

This paper reviews the presence of aluminium in drinking water with an emphasis on its speciation, removal, health problems, and regulation.

Aluminium speciation studies in drinking water

This section will focus on the methods available for the speciation of Al, including speciation terminology and the variables affect-

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ing speciation. Literature indicates that the use of any coagulant containing Al may either increase or decrease the Al concentration in the finished water depending on its speciation in the source water and conditions of treatment. However, for many water supplies (particularly where alum is used as coagulant), the total Al increases after treatment. The fate of Al during the water treatment process is not clearly understood since the majority of the water treatment plants measure either total or dissolved Al only. These data alone cannot explain the observed increase in Al levels, and there is a need to study the various transformations (speciation) of Al present in water to address this issue.

A review of the literature relating to Al speciation studies in drinking water indicates that there is no uniformity in defining the terms relating to various fractions of Al. However, there is general agreement on the following definitions to differentiate between the various Al fractions (Letterman and Driscoll, 1994). Total Al is the sum of suspended, colloidal and monomeric forms of Al. Particulate Al is the sum of suspended and colloidal Al. Monomeric Al can be divided into two forms: non-labile, and labile. Non-labile Al is Al associated with dissolved organic carbon. Labile Al includes aquo (Al^{3+}), and hydroxide, fluoride, and sulphate complexes of Al. Fig. 1 shows a block diagram of various forms of Al.

Three different approaches for fractionating Al in drinking water at ambient temperature have been described in the literature. Table 1 summarises these approaches and the Al species (or forms) they characterise. As can be seen from Table 1, the principal procedural differences among the methods are as follows:

- Organically bound Al was fractionated out separately by Van Benschoten and Edzwald (1990) and Driscoll and Letterman (1988) but not by Gardner and Gunn (1991).
- Gardner and Gunn (1991) measured reactivity and particle or molecule size, whereas Van Benschoten and Edzwald (1990) and Driscoll and Letterman (1988) attempted to determine chemical associations of Al present.
- Driscoll and Letterman (1988) did not include a filtering step to eliminate the problem of Al absorption on filters as their speciation method (acid digestion followed by oxine extraction) is sensitive only to dissolved Al.