

## Removal of Aluminium from Drinking Water (Penyingkiran Aluminium daripada Air Minum)

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### ABSTRACT

*Aluminium in drinking water comes from natural sources and the alum used as coagulant in the water treatment process. Exposure to aluminium has been implicated in dialysis dementia, Parkinson and Alzheimer's disease. Drinking water containing aluminium was considered to be one of the main sources of Al intake into human body. For this reason, the removal of aluminium from drinking water is vital to our health. In this study, removal of aluminium was carried out by using a chelating resin. To achieve the purpose, two chelating resin iontosorb oxin (IO) and polyhydroxamic acid (PHA) were used. The effects of concentration, pH, stirring time and resin amount was investigated. The concentration range varied between 10 and 500 ppb, pH range was between 2 and 12, stirring time between 5 and 60 minutes, and resin amount between 100 and 1500 mg. The optimum conditions of these resins were determined in a batch system. The results obtained showed that the optimum condition to remove aluminium for polyhydroxamic acid and iontosorb was pH 5-8 and pH 4-9; concentration range between 50-500 ppb, and 150-500 ppb, resin amount 200 mg and the stirring time was 20 minutes, respectively.*

*Keywords: Aluminium; drinking water; iontosorb oxin (IO); polyhydroxamic acid*

### ABSTRAK

*Aluminium di dalam air minum berpunca daripada sumber semula jadi dan alum yang digunakan sebagai pengental dalam proses rawatan air. Pendedahan kepada aluminium boleh mengakibatkan penyakit dialysis dementia, Parkinson dan Alzheimer. Air minuman yang mengandungi aluminium telah dikenalpasti sebagai salah satu sumber utama bagi pengambilan aluminium ke dalam tubuh manusia. Atas alasan ini, penyingkiran aluminium daripada air minum mestilah dilakukan untuk menjaga kesihatan kita. Dalam kajian ini, penyingkiran aluminium telah dilakukan dengan menggunakan resin pengkelat. Untuk itu, dua jenis resin pengkelat iaitu iontosorb oxin (IO) and asid polihidroksamik (PHA) telah digunakan. Kajian terhadap kesan kepekatan, pH, masa pengacauan dan jumlah resin telah dilakukan. Julat kepekatan yang digunakan diubah antara 10 hingga 500 ppb, julat pH antara 2 hingga 12, masa pengacauan antara 5 hingga 60 minit dan jumlah resin antara 100 hingga 1500 mg. Penentuan keadaan optimum bagi resin-resin ini telah ditentukan di dalam sistem batch. Keputusan yang diperolehi menunjukkan bahawa keadaan optimum untuk menyingkirkan aluminium untuk PHA dan IO adalah pH 5-8 dan pH 4-9; julat kepekatan antara 50-500 ppb bagi PHA, dan 150-500 ppb bagi IO, jumlah resin 200 mg dan masa pengacauan adalah 20 minit bagi setiap satunya.*

*Kata kunci: Air minum; aluminium; asid polihidroksamik*

### INTRODUCTION

Al-based coagulant such as aluminium sulphate ( $\text{Al}_2(\text{SO}_4)_3$ ) (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 (Srinivisan et al. 1999).

There is considerable concern throughout the world over the levels of aluminium found in drinking water sources (raw water) and treated water. This has risen mainly

for two reasons. First, acid rain has caused the aluminium level in many freshwater sources to increase (Schecher & 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  $\text{Al}(\text{OH})_3$  during the course of distribution (Rahman 1992). Secondly, the possibility of an association between aluminium and dementia, Parkinson and Alzheimer's disease is frequently hypothesised (Crapper & Boni 1980; Davidson et al. 1982; Gardner & Gunn 1991; Jekel 1991; Martyn et al. 1989; Schecher & Driscoll 1988).

Removal of aluminium can be carried out by several methods such as cation exchange resin, reverse osmosis and electro dialysis. Treatment methods namely aeration/

stripping, chemical oxidation/disinfection and anion exchange are ineffective for Al removal. Processes such as coagulation, sedimentation and filtration (combined) as well as lime softening are moderately effective in Al removal (Srinivisan et al. 1999). In the present work, preliminary removal of aluminium by chelating ion exchange resin namely Iontosorb (IO) and Polyhydroxamic acid (PHA) will be examined.

## EXPERIMENTAL

### INSTRUMENTS

An Inductively Couple Plasma-Optical Emission Spectroscopy (ICP-OES) Optima Perkin Elmer 4300 DV was used for Al analysis. A digital pH meter (Fisher Scientific Model AB 15) was used to determine the pH of test solutions. The buffer solutions at pH values of 4, 7 and 9 were used to standardized the pH meter used.

### REAGENTS

A standard 1000 ppm aluminium solution of BDH Laboratory Supplies was used as a stock solution for Al(III). The working solutions of lower concentrations were prepared by suitable dilutions. Iontosorb Oxin 200 (IO) 200 was supplied by the Oldrich Tokar, Republic of Czech. (2007), cellulose resins containing covalently bound 8-hydroxyquinoline functional group (Figure 1) with the capacity 0.20 mmol of active group per 1 g of dry resin, the water content 80% and maximal sorption capacity for Al is  $10.75 \pm 0.92$  mg/g (Polakovic 2003). Polyhydroxamic acid resin was prepared based on Vernon (1982), Wan Yunus and Ahmad (1988), and Lee and Hong (1994) methods, poly(ethyl acrylate-divinyl benzene) resins containing covalently bound hydroxamic acid functional group (Figure 2) with the capacity of 1.19 mmol/g of dry resin, the water content 30% and maximal sorption capacity for Al is  $9.15 \pm 0.65$  mg/g. All reagents used were of analytical reagent grade.

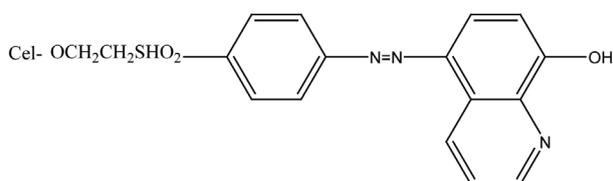


FIGURE 1. Functional group of 8-hydroxyquinoline covalently bound on cellulose resin Iontosorb Oxin

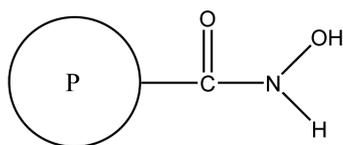


FIGURE 2. Functional group of hydroxamic acid covalently bound on poly(ethyl acrylate-divinyl benzene)

### GENERAL PROCEDURE

Aluminium solution (50 ml) was pipette into a 250 ml conical flask and a certain amount of resin was added. The solution was stirred with a magnetic stirrer at room temperature for a certain period. At appropriate intervals, stirring was stopped momentarily and after flash centrifugation an aliquot of the supernatant was removed and the concentration of Al was determined by ICP-OES. The concentration of the removed Al was calculated as the difference between the initial (before the sorption) and final (after the sorption) concentration of Al in the solution (Matus & Kubova 2005).

### RESULTS AND DISCUSSION

#### EFFECT OF pH ON THE RECOVERY OF ALUMINIUM

The studied pH range was between 2 and 12, amount of resin is used 200 mg and stirring time is 20 minutes. The effects of pH on metal uptake as determined in batch experiments are shown in Figure 3. The pH of the solution was adjusted in the range of 2-12 by nitric acid and ammonium hydroxide.

Figure 3 shows that the removal of Al is about 20% at pH 2 and it increased to about 100% at pH 4 and pH 5 for IO and PHA respectively. This percentage of removal was maintained until pH 8 for PHA and pH 9 for IO and after that it decreased. This pH range, especially pH range from 5.0 to 8.5 is very suitable for the water treatment (Delphos & Wesner 2005) and removal of Al from the drinking water.

The most important forms of dissolved aluminium are  $Al^{3+}$ ,  $[Al(OH)_2]^+$ , and  $[Al(OH)_4]^-$ . Each species predominates over a certain pH range. The cation  $Al^{3+}$  predominates when  $pH < 4$ . At pH values around 5-6,  $[Al(OH)_2]^+$  predominates. Around pH 6, aluminium solubility reaches a minimum, and  $Al(OH)_3$  will formed. Above neutral pH, the predominant dissolved form of aluminium is the complex anion  $[Al(OH)_4]^-$  (Bodek et al. 1988). From Figure 3, it is shown that the PHA and IO can remove all of this forms of aluminium ( $Al^{3+}$ ,  $[Al(OH)_2]^+$ ,  $[Al(OH)_4]^-$  and  $Al(OH)_3$ ) from the synthetic solution of water.

#### EFFECT OF CONCENTRATION ON THE REMOVAL OF Al

In this preliminary study, the method will be applied to the drinking water from Sungai Semenyih Treatment Plant, Putrajaya. The concentration of Al in the drinking water produced by this treatment plant is not more than 200 ppb. This level is in compliance with the acceptable level of Al in drinking water (200 ppb) as determined by the World Health Organization (WHO). Based on the concentration of Al at the treatment plant, the working range for the Al concentration in this study was chosen between 10 ppb to 500 ppb. The amount of resin is 200 mg and stirring time is 20 minutes.

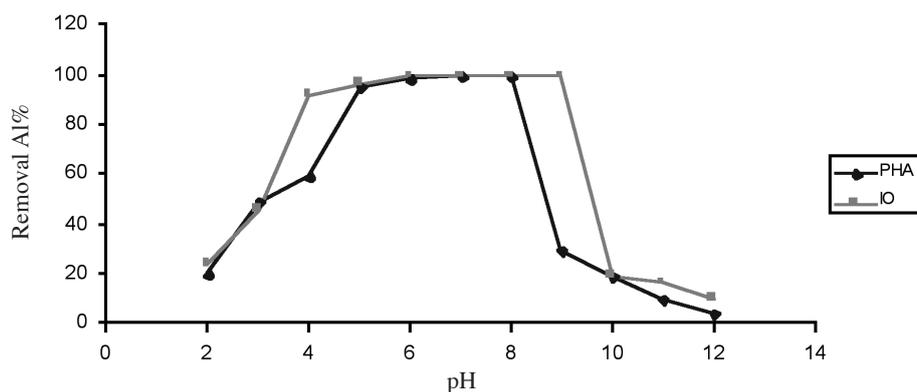


FIGURE 3. Effect of pH on the removal of Al (concentration of aluminium (III):50 ppb, sample volume: 50 ml, stirring time: 20 minutes and resin amount: 200 mg)

From Figure 4, we can see that the removal of Al at optimum pH for IO and PHA at 10 ppb was 89% and 96% respectively. The removal increased to about 100% at 50 ppb for PHA and 150 ppb for IO. After 150 ppb, the removal of Al by PHA and IO fluctuated between 95% to 100%.

Figure 5 shows that the optimum amount of resin for the removal of Al at the optimum condition (pH 6.5, stirring times 20 minutes and concentration of Al is 50 ppb) is 200 mg.

#### EFFECT OF RESIN AMOUNT ON THE REMOVAL OF Al

The influences of amounts of PHA resin on the removal of Al was also investigated in the range 100 – 1500 mg.

#### EFFECT OF STIRRING TIME ON THE REMOVAL OF Al

Stirring time range was between 5 and 60 minutes. The studied concentration is 50 ppb Al, pH 6.5 and resin amount 200 mg. The results are given in Figure 6. It is

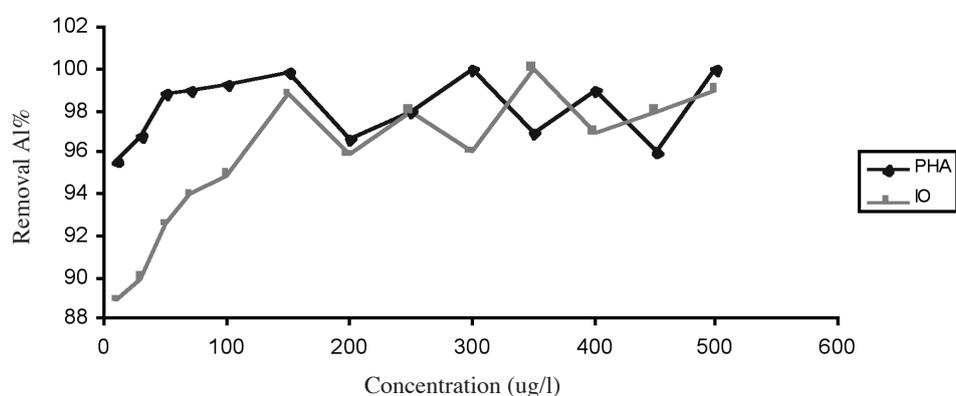


FIGURE 4. Effect of concentration on the removal of Al (pH 6.5, sample volume: 50 ml, stirring times: 20 minutes and resin amount: 200 mg)

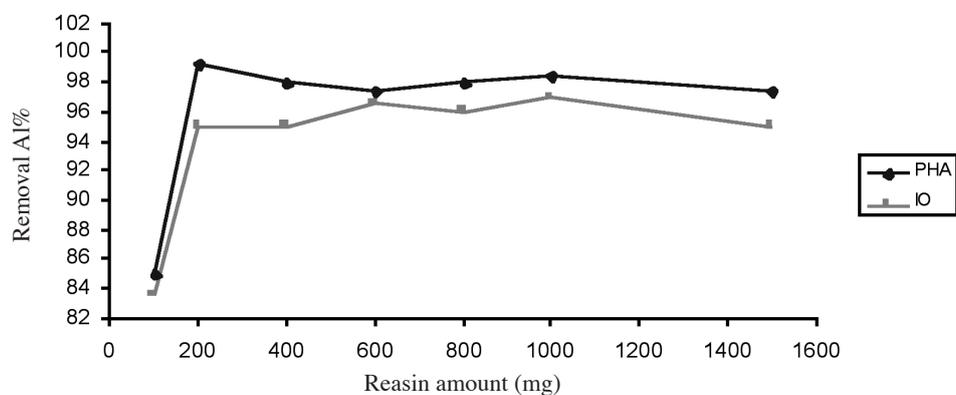


FIGURE 5. Effect of resin amount on the removal of Al (pH 6.5, concentration of Aluminium (III):50 ppb, stirring times: 20 minutes and sample volume: 50 ml)

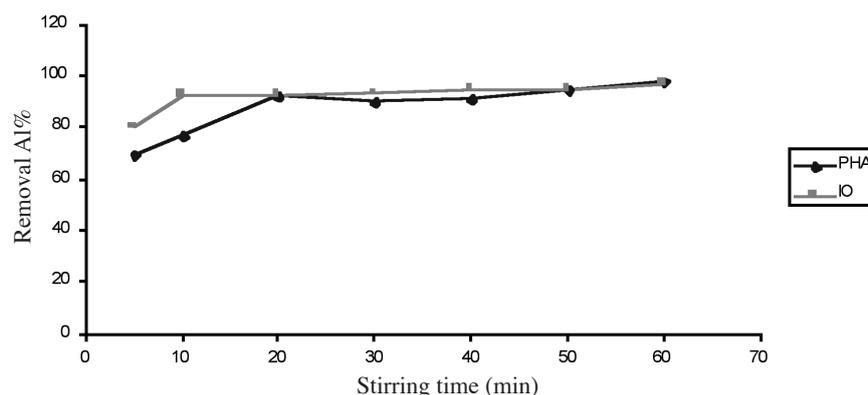


FIGURE 6. Effect of stirring time on the removal of Al (pH 6.5, concentration of Aluminium (III):50 ppb, sample volume: 50 ml, resin amount: 200 mg)

shown that 90% and 70% of the aluminium was taken up by IO and PHA in the first 5-10 minutes respectively. Both chelating resin achieved 93% and 98% of aluminium removal at 20 minutes and 60 minutes, respectively. The optimum stirring time of 20 minutes was chosen for both chelating resins because there was not much difference between removal Al value on resins after this period.

#### CONCLUSION

The removal of aluminium was carried out by using two chelating resin, Iontosorb Oxin (IO) and polyhydroxamic acid (PHA). The effects of concentration, pH, stirring time and resin amount were investigated. The optimum conditions of these resins were determined in a batch system. The results obtained showed that the optimum condition to remove aluminium for Iontosorb (IO) and polyhydroxamic acid (PHA) was pH 4-9 and pH 5-8; concentration range between 50-500 ppb and 150-500 ppb, resin amount 200 mg and the stirring time was 20 minutes respectively. Percentage removal of aluminium for both resins are more than 95% at the optimum condition. The pH range 4-9 for IO and 5-8 for PHA is very suitable for the removal of aluminium from the drinking water.

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