ORIGINAL ARTICLE

HEALTH RISK ASSOCIATED WITH ALUMINIUM EXPOSURE IN GROUNDWATER: A CROSS-SECTIONAL STUDY IN AN *ORANG ASLI* VILLAGE IN JENDERAM HILIR, SELANGOR, MALAYSIA

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ABSTRACT

The purpose of this study was to determine aluminium (Al) concentrations in groundwater used for drinking and cooking and its related health risk among population of 28th Mile Orang Asli village in Jenderam Hilir, Selangor, Malaysia. A total of 100 respondents were recruited, comprising 51 (51.0 %) male and 49 (49.0 %) female residents. Inductively coupled plasma mass spectrometry (ICP-MS) was used to determine Al concentration, while the LAMOTTE TRACER ORP PockeTester was used to measure pH levels. Statistical Package for Social Science (SPSS) was used to analyze the data. Results showed that Al concentration ranged from 0.041 - 0.136 mg/L with a mean of 0.136 ± SD 0.041 mg/L, hence the values obtained were below the standard value (0.2 mg/L). pH levels ranged from 3.82 to 5.84, with a mean of 4.163 + SD 0.411, which is acidic and below the range permitted by the health authorities. The acidic nature may have an impact on the Al concentration in the water. The Hazard Index (HI) was found to be less than 1, thus there was no health risk of Al exposure in drinking water for the respondents involved. The study area was considered safe from having health risk associated with Al exposure.

***Keywords**: Aluminium, pH, drinking water, groundwater, Hazard Index*

INTRODUCTION

Groundwater is one of the sources of water that can be consumed. A movement of water under the earth's surface in fracture soil and rocks is called groundwater flow. Each drop of rain that permeate into soils, move downward the water table, which is the water level in the groundwater reservoir. According to Malaysian Water Association (MWA), groundwater is well-established as a reliable source of water overseas, with high levels of exploitation in countries such as Denmark (99%), Austria (98%), Switzerland (83%) and Thailand (80%)[1]. Since groundwater is the only water source available at the 28th Mile *Orang Asli* village in Jenderam Hilir, Selangor, the community in that area consume water which has not undergone any treatment prior to consumption.

Naturally, aluminium (Al) levels in surface water is usually really low which is less than 0.1mg/L. Al is released to the environment mainly by natural processes. Acid mine drainage or acid rain can cause an increase in the dissolved Al content of the surrounding waters which will cause acid environments[2,3]. Mineral weathering is one of the factors which contributed of Al^{3+} in surface and groundwater. Since Al in not mobile in the most natural water's pH, Al can be mobilized in acidic waters (pH<4) by dissolution of gibbsite and the accelerated weathering of both clay minerals and rock-forming minerals. However, due to extreme low solubility of Al-bearing minerals, it said that the concentration of Al is at very low level. Concentrations in groundwater are strongly pH dependent[4].

Al have the potential to be a toxicant to the central nervous, skeletal and haematopoietic systems which has been shown in animal and human[5-10]. It has been suggested that low level long-term exposure to Al may be a contributing factor in Alzheimer's disease and related disorders. The results of some epidemiological studies of the association between drinking water contained Al and Alzheimer's disease are consistent with this hypothesis while some others are not[7,11,12]. Similarly, only some of the studies that determined Al in bulk brain, neurofibrillary tangles and senile plaques of victims of Alzheimer's disease and related disorders are consistent with this hypothesis[12].

Safe drinking water as defined by World Health Organization[13], does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Investment and sanitation to water supply can result in economic benefits as the adverse health impact can be prevented. According to UNICEF, the major cause of illness and mortality is lack of safe drinking water, as a result of exposure to infectious agents, chemical pollutants and poor hygiene. UNICEF also stated that source of economic disadvantage is inadequate access to water in the home. This indicator provides a proxy measure both of exposure, in terms of access to safe drinking water and the effectiveness of actions to improve access[14].

The *Orang Asli* (Indigenous People) is classified as one of the most vulnerable groups in Malaysia, with a disproportionately high incidence of poverty and hardcore poverty. Apart from being extremely poor, *Orang Asli* also categorized as a group which has low immunization amongst children and also has lower educational level. Groundwater via tube well does not cost much. Poverty is a risk factor for chronic diseases and it is prevalent among indigenous peoples worldwide[15]. Similarly in Malaysia, the *Orang Asli* has been identified as one of the poorest groups and with a higher incidence of poverty (50.9%) and hardcore poverty (15.4%) compared to the national figures of 7.5% and 1.4%, respectively[16].

METHODS

This study was a cross-sectional study which involved adult aged 18 years old and above. It was conducted from January to March of 2016. The inclusion criteria were male and female respondents, aged 18 years old at the time of study, had been stayed for more than five years at the study location and those who consumed water directly from the groundwater source. A total of 100 respondents were recruited. Ethical issues pertaining to this study was presented and subsequently approved by the Ethics Committee for Research involving Human Subjects (JKEUPM), Faculty of Medicine and Health Sciences, Universiti Putra Malaysia UPM/TNCPI/RMC/1.4.18.1 (JKEUPM)/F2. Permission to conduct the research at the study location was also obtained from the Department of *Orang Asli* Development (JAKOA) JAKOA/PP;30.032Jld33(32). Written consent was obtained from the respondents as well.

Questionnaires were used to collect data on basic information, water usage such as daily intake of drinking water and health status of respondents.
For calculation of Chronic Daily Intake (CDI), body weight of the respondents had been measured. The pre-cleaned HDPE bottles were used to store water samples. The respondents needed to recall back the amount of drinking water they consumed daily. This information also was needed to calculate Chronic Daily Intake (CDI).

Al concentration was analyzed using inductively coupled plasma mass spectrometry (ICP-MS). Referring to EPA Method 200.8[17], the ICP-MS was based on collision and reaction cell technologies. Since Al fall under National Secondary Drinking Water Regulations, the lowest value that could be read by ICP-MS is 0.000048 mg/L.

To determine the exposure of Al level in drinking water, Chronic Daily Intake should be calculated first by using this equation:

$$CDI=(C \times DI)/BW$$ [18]

Where CDI is chronic daily intake (mg/kg/day), C is the Al concentration in drinking water (mg/L), DI is average of rate daily intake of water (L/day) and BW is body weight of respondents (kg). Then Hazard Index (HI) was used to conclude the significant different exposure and overall potential of health effects posed by Al in drinking water using this equation:

$$HI=CDI/RfD$$ [19]

Where HI is hazard index, CDI is chronic daily intake (mg/kg/day) and RfD is reference dose (mg/kg/day). RfD value that is used in the equation is 1.0 mg/kg/day[19]. If the HI value is greater than 1 (HI>1), it shows that there is significant risk level of Al content in drinking water with diseases such as Alzheimer's disease.

RESULTS

In the study, there were 51 (51.0%) male and 49 (49.0%) female 49 respondents. Please refer to Table 1.

Table 2 showed the weight measurement that had been taken into account for all 100 respondents involved. It showed that the mean of the weight of the respondents was 58.08±9.067. The body weight measurement was needed in order to calculate the Chronic Daily Intake in the exposure assessment part.

Table 1 - Gender of respondents

Variables	N = 100	Percentage (%)
Gender		
Male	51	51.0
Female	49	49.0

Table 2 - Weight measurement of respondents

Variable	Weight (kg)	
Mean±SD	58.08±9.067	
Median	59.00	
IQR	14.00	
95% CI	**Lower** 56.28	**Upper** 59.88

There were two parameters of drinking water samples that had been analyzed; Al concentration and pH level. The mean of Al concentration was 0.136±0.041, whereas for pH level the mean obtained was 4.163±0.411. The results are summarized in Table 3.

Based on the study that had been conducted, Al concentration in the study location did not exceed the standard (0.2 mg/L) whereas pH was found to be acidic.

Referring to the National Standard for Drinking Water Quality Malaysia, Engineering Service Division, Ministry of Health Malaysia[20], Al concentration in drinking water must not exceed 0.2 mg/L. Besides, according to the United States Environmental Protection Agency (EPA), Al fall under secondary contaminant category as Al is not considered to present risk to human health at the secondary maximum contaminant level.

With regards to pH, the National Standard for Drinking Water Quality mentioned that the pH value for drinking water should be within the range of 6.5 to 9. Based on the results, it showed that the mean and range did not meet the standard (Table 3). The pH value obtained fell under acidic condition.

Table 3 – Al concentration and pH level in drinking water

Variable	Al concentration	pH level
Mean±SD	0.136±0.041	4.163±0.411
Median	0.147	4.01
IQR	0.065	0.13
Minimum	0.046	3.82
Maximum	0.19	5.84

Generally for groundwater system, a normal water pH level should be within 6 to 8.5. Water with pH of less than 7 is considered acidic while water with pH of more than 7 is considered basic. There were two possibilities which contributed to low pH level in drinking water. One was from natural occurrences which are caused by bedrock and surrounding soils. The other factor was acid rain.

Several metals were said to be found in groundwater that played important roles in the body provided their level remained within the specified range recommended by the World Health Organization[21]. Al concentration in groundwater that results in low concentration were connected with the transformations of aluminosilicates in the active water exchange zone, where a large amount of Al did not move in the structures of secondary minerals, and only small parts of the elements could get to the water[22]. The process of releasing Al from mineral as a result of hydrolysis and dissolution, the reactions of cation exchange, the transfer of retained Al from pore water to groundwater in the soluble form, and the reactions of Al with the other components of the solution had influenced the Al activation in the groundwater. The loss of essential elements and increase the concentrations of potentially toxic elements in drinking water might be led by acid precipitation[23]. Strong concentration of Al had being discharged at low pH level which was less than 4[24].

From Table 4, it shows the Chronic Daily Intake (CDI) value for all respondents which then is used to calculate the Hazard Index for health risk that the respondents would face.

Table 4 - Chronic Daily Intake (CDI)

Variable	CDI (mg/kg/day)
Mean±SD	0.004±0.002
Minimum	0.00
Maximum	0.01

Hazard Index (HI) was calculated in order to determine the health risk associated with the exposure to Al in drinking water. To calculate the HI, the value of CDI obtained was divided with the Reference Dose (RfD) recommended by USEPA[19], 1.0 mg/kg/day. From the calculation, it was found that all respondents (100, 100.0%) had HI of less than 1 (Table 5). The mean value of HI was low as it was related to the CDI value. Since the HI values were less than 1 for all respondents, it indicated that they were not at risk of exposure to Al in drinking water in the study area.

Table 5 - Health Risk Assessment Information (Hazard Index)

Variable	HI	<1	>1
Frequency		100	0
%		100	0

CONCLUSION

Al concentration in groundwater taken from 28th Mile *Orang Asli* village in Jenderam Hilir, Selangor was below the standard level (0.2 mg/L). pH of water samples were acidic. HI was less than 1 for all respondents, indicating that the respondents were not at risk of exposure to Al in drinking water at the time of study.

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CONFLICT OF INTEREST

The authors confirm that this article has not been published, part of or whole, in any other journals.

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