ASSESSMENT OF EXPOSURE LEVELS OF DRINKING WATER CONTAMINANTS IN GROUNDWATER SOURCES IN HAMBANTOTA DISTRICT

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Abstract

This study was conducted to assess the exposure of drinking water contaminants (NO₃⁻, PO₄³⁻, F⁻, Hg and Mn) in groundwater at the selected areas of Tangalle, Beliatta, Angunukolapelassa and Balangoda (reference site). The water samples (n=6) were collected from groundwater sources where the owners were also kidney patients, during the dry period of September - October, 2013. Hg and Mn were analyzed using atomic absorption spectroscopy with the combination of cold vapor generator for Hg analysis and the accuracy of the method was determined using the value addition method. NO₃⁻, PO₄³⁻ and Fluoride concentrations were also measured by the standard methods. Questionnaire based field survey was conducted to identify the status of the hazard and to collect relevant data from the families to apply risk assessment models.

Hg was detected only in the groundwater of Tangalle and Angunukolapellassa areas and the mean concentrations were 0.0052±0.002 mg/L and 0.0015±0.001 mg/L respectively. Although the exposure of Hg in Tangalle and Angunukolapellassa areas were lower than the recommended exposure of 0.0003 mg/kg body weight/day, serious effects may occur with long term exposure. Mn was also detected only in above two areas and the mean concentrations were recorded as 0.649±0.2 mg/L and 0.18±0.2 mg/L. Mean concentration of Fluoride (1.48 mg/L) was relatively higher at Tangalle and Angunukolapellassa areas and the values are higher than the Sri Lankan standards. Mean values of NO₃⁻ and PO₄³⁻ concentrations were higher at the same locations but the levels recorded were lower than SL standards. The hazard quotient values for Fluoride and nitrate exposure exceeded the unity of the model in all four areas (1×10⁻⁶) and Mn exposure exceeded the unity of the model only at Tangalle and Angunukolapellassa areas which predicts potential health risk for noncarcinogenic effects.

Keywords: risk assessment, hazard quotient, Fluoride, groundwater

Introduction

The groundwater in Hambantota area has been recognized as the presence of separate pockets in the shallow regolith aquifer in the valley of cascade systems of small tanks (Panabokke and Perera, 2005). People who live in suburbs in Hambantota area are mostly affected by the non-availability of safe water for drinking and other domestic purposes. Therefore, only 33.4% of households use piped born water, 55.3% use water from dug wells and 6.2% use water from tube wells (Illangakoon, 2011). Chlorides, fluorides, manganese and iron are identified as the main constituents to influence groundwater quality in some districts of Sri Lanka including Hambantota. The excess use of superphosphate fertilizers has been identified as one of the sources groundwater contamination due to NO₃⁻, PO₄³⁻, cadmium and arsenic mainly in agricultural areas (Rail, 2014).

Exposure assessment for phosphates, chloride, sulphate, calcium, magnesium, potassium, nitrate, electrical conductivity, i.e. all the ions are important to evaluate the ionicity of the water (Dharmawardana, 2013). Apart from natural sources, a considerable amount of fluoride may be contributed due to use of Phosphatic fertilizers, which are extensively used in agriculture, often contain fluoride.
as an impurity. According to the personal communication with farmers in Hambantota area they use 5 to 10 times of the optimum requirement of fertilizer thinking that it would be a reason for getting better harvest. Jayasekara (2013) has said that some of the pesticides such as Carbaryl, Chlorpyryphos, Carbofuran, Propanil Glyphosate have been banned in Sri Lanka. But these chemicals are available in the market even after banning and Sri Lanka has ranked second for the presence of toxic heavy metals such as cadmium in the environment by comparing 12 Asian countries of the world.

The Chronic kidney disease (CKD) has already killed more than 20,000 people, mainly from poor farming families, over the past two decades. Mendis, (2013) has noticed that over 200,000 patients, including children as young as 10, suffer from the disease and at least 15 percent of the population in the 15–70 age groups in the two provinces of North Central and Uva has been affected. The mysterious kidney disease in the North Central Province (NCP) and adjacent areas may now be raising its head in the southern province as well and ground water is considered as the main carrier. The health effects from over-exposure of heavy metals and other chemical components in water are dependent on the amount of drinking water, chemical form, the age at exposure, an individual’s nutritional status and life style (U.S. Environmental Protection Agency, 2010). Therefore, the current study focuses the drinking water quality in some selected ground water sources in Hambantota. In addition we also determined the exposure level of drinking water contaminants using risk assessment models.

Materials and Methods

Site Description

Tangalle, Beliatta and Angunukolapalessa area were selected for this study based on the records taken from Tangalle and Hambantota hospitals. Balangoda area was selected as the reference site for this case study. Well water samples were collected from the selected households and the GPS locations of all wells were taken and mapped their respective locations (Fig 1).

Questionnaire based family survey

Questionnaire based family survey was conducted for 30 families at each area to collect details for risk assessment and to select the householders suffering from kidney disease (age, sex, occupation, body weight, drinking water source, water consumption, specific health conditions life style..etc).

Analysis of chemical parameters

Water samples were filtered via Nitrocellulose filter papers using hand hold filters and preserved in ice until do the analysis for NO₃⁻, PO₄³⁻ and F. Also, 100ml of the filtered water samples were preserved using conc. HNO₃ for the analysis of Hg and Mn using AAS (Varian 220). The accuracy of the method for each metal was determined following the value addition method. Table 1 gives the summary of the analytical methods according to APHA (1999).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate</td>
<td>Sodium Salicylate method: Absorbance of water samples was measured at the wave length of 420 nm (HACH DR2800, German, ± 3.0 Ext in Wavelength Range 340-900 nm)</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>Ammonium Molybdate method: Absorbance of water samples was measured at the wave length of 880 nm (HACH DR2800, German)</td>
</tr>
<tr>
<td>Flouride</td>
<td>2mL Spadns solution was added to 10 ml of the water sample and absorbance was measured at the wave length of 420 nm (HACH DR2800, German)</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>Titrimetric method: The titration was done using 0.01 M Na₂EDTA and Eriochrome Black T (EBT) as the Indicator</td>
</tr>
<tr>
<td>Hg</td>
<td>The cold vapor generator was used to evaporate the samples and 10% SnCl₂ was used as the reductant in the AAS (Varian 220) and the calibration series includes 0.0005 mg/L, 0.001 mg/L, 0.002 mg/L and 0.004 mg/L</td>
</tr>
<tr>
<td>Mn</td>
<td>C₂H₂ was used as the oxidant for the flame of AAS (Varian 220) and the calibration series includes 1 mg/L, 3 mg/L, 5 mg/L and 7 mg/L</td>
</tr>
</tbody>
</table>
Determination of Odd Ratio, Exposure and Hazard Quotient

Odd Ratio

Odds ratio values were calculated separately for occupation as farmers and non farmers and for exposure of Hg (0.002 ppm) and Mn (0.5 ppm) higher than the maximum permitted levels using the relationship between exposure and nonexposure. The measure of case-control study is called odd ratio, or relative odds, and calculated as follows (Joseph and Thomas, 1987).

\[
\text{Odd Ratio} = \frac{\text{Odd number for exposure}}{\text{Odd number for non-exposure}}
\]

Exposure

Exposure of the drinking water contaminants was calculated separately using the following equation and those values were used for Hazard Quotient calculations (Joseph and Thomas, 1987).

\[
\text{CDI} = \frac{\text{CW} \times \text{IR} \times \text{ED}}{\text{BW} \times \text{A}}
\]

Hazard Quotient

The Reference Doses of each contaminant are given in the Table 2 and there will be a potential non-carcinogenic effect if the HQ exceeds \(1 \times 10^{-6}\) (unity) (EPA criteria, 2010).

\[
\text{Hazard Quotient (HQ)} = \text{Reference Dose} \times \text{Exposure}
\]

Table 2: The Reference Dose of each contaminant in groundwater

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Reference Dose (mg/kg/day)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate</td>
<td>3.7</td>
<td>USEPA, (2010)</td>
</tr>
<tr>
<td>Phosphate</td>
<td>5</td>
<td>Nerrs.noaa.gov, (2014)</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.07</td>
<td>Pawelczyk, (2012)</td>
</tr>
<tr>
<td>Hg</td>
<td>0.0003</td>
<td>Epa.gov, (2014)</td>
</tr>
<tr>
<td>Mn</td>
<td>0.14</td>
<td>USEPA, (2010)</td>
</tr>
</tbody>
</table>
Fig 1: Sampling locations at the four studied areas
Statistical analysis

Descriptive data analysis (mean, standard deviation, standard error, maximum and minimum values) were carried out using Windows excel 2007 version. All statistical analysis was carried out using SPSS software programme (SPSS v 16.0). One way ANOVA was carried out to compare the mean heavy metal concentrations among the sampling sites further with the Post hoc comparison of means using Turkey’s multiple range tests at the significance level of 0.05.

Results & Discussion

Water quality in the selected wells

The mean values of water quality parameters for each area are given in Table 3 with the recommended levels for drinking water. NO$_3^-$, Ca$^{2+}$ & Mg$^{2+}$ and F$^-$ concentrations in well water samples varied significantly among the four study areas (p<0.005). The Post Hoc multiple comparison test explains that the significant difference of some parameters among the sampling areas and shows in Table 3 as small letters superscript. Hg and Mn did not detect in the well water samples from Beliatta and Balangoda areas. However, the mean Hg concentration in the selected wells in Tangalle and Angunukolapellassa areas reached the maximum permitted levels published by Board of Investment of Sri Lanka, (2011). Although, the NO$_3^-$ concentration was significantly different at Angunukolapella area the values did not exceed the recommended levels at each area. The NO$_3^-$ and Ca$^{2+}$ & Mg$^{2+}$ concentrations in groundwater in Jaffna area has been recorded as 20 mg/L and 862 mg/L respectively (Gunalan et al., 2014). Several eastern European countries has been reported high levels of nitrate contamination in a large proportion of private wells; in Romania, 20% of 2,000 wells had nitrate levels > 23 mg/L as nitrate-N (Mary H. Ward, 2005).

The exceeded Fluoride concentrations than the EPA guidelines have been observed in Moneragala district (Subashini et al., 2013). The Flouride range in the present study (1.53 mg/L to 0.13 mg/L) is similar to the range observed in groundwater of Moneragala district. The PO$_4^{3-}$ concentrations did not exceeded the recommended values but the concentration in Tangalle area corresponded to half of the recommended values.

Table 3: The mean values of water quality parameters at each area

<table>
<thead>
<tr>
<th>Area</th>
<th>Parameter (mg/L)</th>
<th>NO$_3^-$</th>
<th>PO$_4^{3-}$</th>
<th>Ca$^{2+}$ &amp; Mg$^{2+}$</th>
<th>F$^-$</th>
<th>Hg</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangalle (n=4)</td>
<td></td>
<td>0.568 ± 0.2</td>
<td>1.20 ± 1.3</td>
<td>0.2 ± 0.1</td>
<td>1.48</td>
<td>0.005 ± 0.002</td>
<td>0.65 ± 0.3</td>
</tr>
<tr>
<td>Angunukola (n=5)</td>
<td></td>
<td>2.391 ±1.8</td>
<td>0.677 ± 0.4</td>
<td>0.138 ± 0.06a</td>
<td>1.48</td>
<td>0.0015 ± 0.0011</td>
<td>0.181 ± 0.25</td>
</tr>
<tr>
<td>Beliatta (n=6)</td>
<td></td>
<td>0.168 ± 0.38</td>
<td>0.739 ± 0.32</td>
<td>0.27 ± 0.14b</td>
<td>1.37</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Balangoda (n=6)</td>
<td></td>
<td>0.444 ± 0.16</td>
<td>0.115 ± 0.16</td>
<td>0.0008 ± 0.0003</td>
<td>0.999</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Maximum permitted</td>
<td></td>
<td>45</td>
<td>2</td>
<td>600</td>
<td>1.5</td>
<td>0.001</td>
<td>0.5</td>
</tr>
<tr>
<td>levels (mg/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Board of Investment of Sri Lanka, 2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td></td>
<td>10</td>
<td>5</td>
<td>2 - 4</td>
<td>0.6</td>
<td>0.002</td>
<td>0.5</td>
</tr>
</tbody>
</table>
The calculated odd ratio values for different exposure factors are given in the Table 4. Occupation as farmers (male and female) and consumption of water with elevated Hg concentration than the maximum permitted level of 0.002 mg/L can be considered as exposure factors for noncarcinogen effect only in Angunukollapella area (A, OR >1). However, Mn exposure cannot be considered as an exposure factor for noncarcinogen effect due to the odd ratio was lowers than 1. Fluoride did not considered for OR calculation in this study because no concentrations exceeded the recommended value of 1.5 mg/L in the studied areas. However, Flouride has been identified as an exposure factor for dental flurosis in Moneragalla area (Subashini et al., 2013).

Table 4: Odd ratio values for the studied populations at the four areas

<table>
<thead>
<tr>
<th>Carcinogen effect</th>
<th>Non Carcinogen effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
</tr>
<tr>
<td>Number of female/farmers</td>
<td>1</td>
</tr>
<tr>
<td>Number of female/non farmers</td>
<td>0</td>
</tr>
<tr>
<td>Odds Ratio (OR)</td>
<td>T, OR = (1/15) (0/41)</td>
</tr>
<tr>
<td>Number of male/farmers</td>
<td>3</td>
</tr>
<tr>
<td>Number of male/ non farmers</td>
<td>0</td>
</tr>
<tr>
<td>Odds Ratio</td>
<td>T, OR = (3/31) (0/46)</td>
</tr>
<tr>
<td>Number of exposed people to Hg &gt;0.002mg/L</td>
<td>2</td>
</tr>
<tr>
<td>Number of non exposed people</td>
<td>1</td>
</tr>
<tr>
<td>Odds Ratio</td>
<td>T, OR = (2/21) (1/9)</td>
</tr>
<tr>
<td>Number of exposed people to Mn &gt; 0.5mg/L</td>
<td>1</td>
</tr>
<tr>
<td>Total non exposure</td>
<td>2</td>
</tr>
<tr>
<td>Odds Ratio</td>
<td>T, OR = (1/16) (2/14)</td>
</tr>
<tr>
<td></td>
<td>T, OR = 0.86</td>
</tr>
</tbody>
</table>
The calculated Hazard Quotient values for each water quality parameter are given in the Table 4 with the total Hazard Quotient for drinking of groundwater in the studied areas. The hazard quotient for Hg in drinking water is less than the recommended risk level of $1 \times 10^{-6}$ at the studied areas. However, the total hazard quotient for analysed contaminants in drinking water at the four areas exceeded the recommended risk level of $1 \times 10^{-6}$ for male, female and child. The highest HQ values were observed at Angunukolapellassa area due to the consumption of contaminated groundwater and it may be a reason for observation of more kidney failures at Angunukolapellassa area. The Hazard Quotient value has been recorded as $3.3 \times 10^{-3}$ for water consumption with the exceeded Flouride concentration than 0.6 mg/L in groundwater of Moneragalla district explained that there was a potential non carcinogenic effect in the considered population (Subashini et al., 2013). Similarly NO$_3$ and PO$_4^{3-}$ are considered as major exposure factors for non carcinogen effect in Tangalle and Anguncollapellassa areas due to exceeded HQ value than $1 \times 10^{-6}$. Health risk indicators such as chronic daily intake (CDI) and health risk index (HRI) has been recorded as less than 1, indicating no health risk to the local people in Pakhtunkhwa, Pakistan due to water consumption (Khan et al., 2013).

Table 4: Hazard Quotient values for human health due to drinking of groundwater at the studied areas

<table>
<thead>
<tr>
<th>Area</th>
<th>Parameter</th>
<th>Male</th>
<th>Female</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangalle</td>
<td>Nitrate</td>
<td>$224 \times 10^{-6}$</td>
<td>$165 \times 10^{-6}$</td>
<td>$4368 \times 10^{-5}$</td>
</tr>
<tr>
<td></td>
<td>Phosphate</td>
<td>$0.1 \times 10^{-6}$</td>
<td>$0.1 \times 10^{-6}$</td>
<td>$1.4 \times 10^{-5}$</td>
</tr>
<tr>
<td></td>
<td>Fluoride</td>
<td>$27 \times 10^{-6}$</td>
<td>$20 \times 10^{-6}$</td>
<td>$541 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Ca$^{2+}$ &amp; Mg$^{2+}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
<td>$0.0102 \times 10^{-6}$</td>
<td>$0.0075 \times 10^{-6}$</td>
<td>$0.203 \times 10^{-5}$</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>$602 \times 10^{-6}$</td>
<td>$448 \times 10^{-6}$</td>
<td>$11858 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>$853 \times 10^{-6}$</td>
<td>$633 \times 10^{-6}$</td>
<td>$16785 \times 10^{-6}$</td>
</tr>
<tr>
<td>Angunukola</td>
<td>Nitrate</td>
<td>$6275 \times 10^{-6}$</td>
<td>$9294 \times 10^{-6}$</td>
<td>$40670 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Phosphate</td>
<td>$0.06 \times 10^{-6}$</td>
<td>$0.088 \times 10^{-6}$</td>
<td>$0.39 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Fluoride</td>
<td>$18 \times 10^{-6}$</td>
<td>$27 \times 10^{-6}$</td>
<td>$119 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Ca$^{2+}$ &amp; Mg$^{2+}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
<td>$0.0021 \times 10^{-6}$</td>
<td>$0.003 \times 10^{-6}$</td>
<td>$0.013 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>$112 \times 10^{-6}$</td>
<td>$168 \times 10^{-6}$</td>
<td>$728 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>$6405 \times 10^{-6}$</td>
<td>$9489 \times 10^{-6}$</td>
<td>$41517 \times 10^{-6}$</td>
</tr>
<tr>
<td>Belliatta</td>
<td>Nitrate</td>
<td>$2249 \times 10^{-6}$</td>
<td>$2486 \times 10^{-6}$</td>
<td>$846 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Phosphate</td>
<td>$0.084 \times 10^{-6}$</td>
<td>$0.092 \times 10^{-6}$</td>
<td>$0.31 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Fluoride</td>
<td>$21 \times 10^{-6}$</td>
<td>$23 \times 10^{-6}$</td>
<td>$80 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Ca$^{2+}$ &amp; Mg$^{2+}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>$2270 \times 10^{-6}$</td>
<td>$2509 \times 10^{-6}$</td>
<td>$920 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>$2486 \times 10^{-6}$</td>
<td>$2509 \times 10^{-6}$</td>
<td>$920 \times 10^{-6}$</td>
</tr>
<tr>
<td>Balangoda</td>
<td>Nitrate</td>
<td>$171 \times 10^{-6}$</td>
<td>$236 \times 10^{-6}$</td>
<td>$1835 \times 10^{-5}$</td>
</tr>
<tr>
<td></td>
<td>Phosphate</td>
<td>$0.014 \times 10^{-6}$</td>
<td>$0.02 \times 10^{-6}$</td>
<td>$0.16 \times 10^{-5}$</td>
</tr>
<tr>
<td></td>
<td>Fluoride</td>
<td>$17 \times 10^{-6}$</td>
<td>$25 \times 10^{-6}$</td>
<td>$195 \times 10^{-6}$</td>
</tr>
<tr>
<td></td>
<td>Ca$^{2+}$ &amp; Mg$^{2+}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>$188 \times 10^{-6}$</td>
<td>$261 \times 10^{-6}$</td>
<td>$2040 \times 10^{-5}$</td>
</tr>
</tbody>
</table>
Conclusion

There was a potential health risk due to exposure of drinking water contaminants of fluoride and nitrate in Hambantota area. The long term exposure of Hg at the detected in the drinking water sources could be a serious health effect in future.

List of References


