Spatial Distribution of Fluoride and Cadmium in Ground Water of EPPAWELA Area

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INTRODUCTION

Ground water is the major source of fresh water on the earth. Water containing dissolved ions beyond the permissible limit is harmful and not suitable for domestic use. Although Fluoride (F) has both beneficial and detrimental effects on human health, Cadmium (Cd) causes extremely adverse effect on health.

F concentration around 1mg/L prevents effectively dental caries without harmful effect on health and strengthens bones, thus preventing bone fractures in older people. F at higher levels can cause severe skeletal and dental fluorosis (WHO, 1987). Further, even at lower concentrations of F, exposure a long period of time can cause for kidney failures (Dissanayake, 1991). High F in ground waters are found in many parts of the developing world and many millions of people rely on ground water with concentration above WHO guideline value of 1.5 mg/L. Worst affected areas are arid parts of Northern China, India, Sri Lanka, West Africa etc. Around 200 million people from 25 nations have health risks because of high F in ground water (Gupta *et al.* 2006).

In Sri Lanka, F related health problems are common in dry zone especially in *Eppawala* area where rock phosphate deposit is located. F occurs naturally in water due to weathering of rocks that contain F rich minerals such as Hornblende, Biotite, Apatite and Fluorite (Hewawasam and Dahanayake, 1999). F can also leach into ground water sources with the anthropogenic actions such as usage of phosphate fertilizers.

In addition to F, Cd is also a toxic element that causes many health problems in the humans. Use of phosphate fertilizers in agriculture and the geochemical weathering of phosphate rock in the *Eppawela* area are the major sources for Cd and F and certainly contribute to the contamination of agricultural soils and ground water with them. Therefore, F and Cd related health problems are common in dry zone especially in *Eppawala* area where rock phosphate deposit is located.

Though the several studies conducted to find the ground water F contamination level, information on the spatial distribution of F and Cd in *Eppawala* area is very limited (Nandasena *et al*, 2005). Therefore the scope of this study was to investigate spatial distribution of F and Cd in ground water with the distance of the rock phosphate deposit and generating a data base of F and Cd levels in dug wells in *Eppawala* area.

Materials and Methods

The study area covers three Grama Niladari Divisions viz. *Elliyadulwewa, Palugaswewa* and *Ihala siyabalawa* situated on the left bank of the *Jaya Ganga* with the geographical coordinates 8° 9' 0" North, 80° 24' 0" East in North Central Province, Sri Lanka. *Eppawela* rock phosphate deposit is located in the right bank of the *Jaya Ganga*. This area is typically influenced by the tropical climate with a low mean annual rain fall (<1500mm) and average annual evaporation of 1400mm. Its average annual temperature is 33^{0}C (IWMI, 2001).

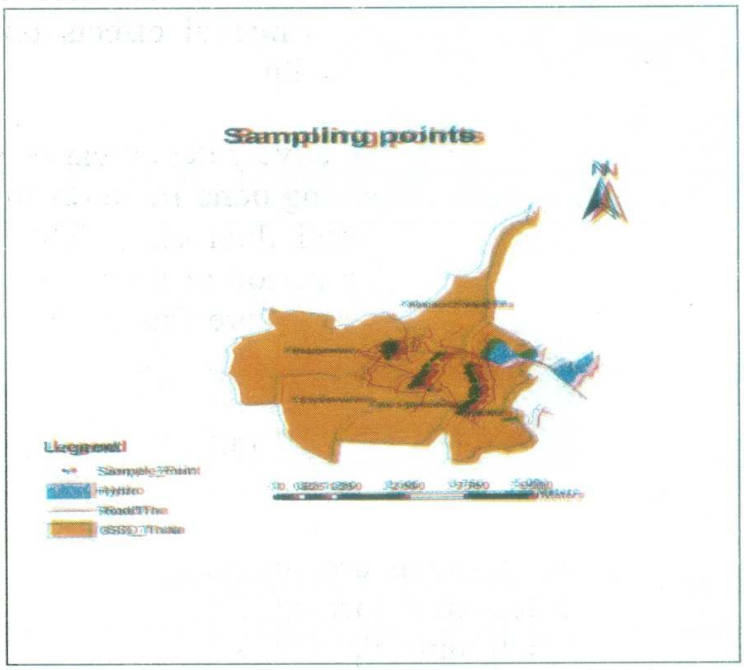

Figure 1: Location of the study area

Water samples were collected from 86 dug wells located in three Grama Niladari Divisions viz. *Elliyadulwewa, Palugaswewa* and *Ihala siyabalawa* situated on the left bank of the *Jaya Ganga*. Villagers in this area use shallow dug wells mainly for drinking and irrigation purposes. Water samples were collected in clean plastic bottles and pH and Electrical conductivity (EC) were measured in situ using portable pH and EC meters at the time of sampling. Samples collected were brought to the Soil Chemistry laboratory of Department of Soil science, University of Peradeniya for chemical analysis. All the reagents used in this work were of analytical grade. F in water samples was measured

colorimetrically using SPANDS method, and Cd, Calcium (Ca) and Magnesium (Mg) were measured using Atomic absorption spectrophotometer. Potassium (K) was measured using Flame emission spectrophotometer. Total Hardness of the well water was also calculated using Ca and Mg concentrations (Total hardness = Ca mg/L × 2.5 + Mg mg/L × 4.2). Data were analyzed using SAS software package.

Results and Discussion

The study was conducted to investigate the F and Cd contamination of the water sources of the *Eppawela* area due to the possible influence of *Eppawela* phosphate rock. There is a strong possibility that the influence of the geochemical process of weathering of nearby phosphate rock may directly or indirectly contribute to the water quality of the area. Some wells in this area were identified only for drinking and most of villages tend to use water from common well in the area.

Table 1. Chemical Properties of Well Water.

The minimum, maximum and mean value of the parameters analyzed for all 86 wells (n=86).

Parameter	Minimum	Maximum	Mean	SD
Fluoride (mg/L)	0.96	2.81	1.65	0.45
Calcium (mg/L)	19.11	996.53	359.13	201.02
Magnesium (mg/L)	0.32	157.59	55.47	32.58
Cadmium (mg/L)	0.03	0.60	0.31	0.16
EC (ds/m)	0.03	2.80	1.10	0.67

The F concentration of the well water analyzed the study area varied between 0.96 and 2.81mg/L (Table 1). Fig 1 shows the spatial distribution of F in three Grama Niladari Divisions of *Eppawela* area. Even within a small area F showed a considerable variation. According to WHO and Sri Lankan standards, if the concentration of F below the 0.5 and above 1.5 mg/L, the water is not suitable for drinking purposes and can be harmful to human health (WHO,1987). Therefore the desirable range of F for drinking is 0.5 to 1.5 mg/L.

According to the results, 36 wells out of 86 wells studied were within the desirable range thus fit for drinking purpose. No well water was observed with the F concentration below 0.5 mg/L. The F concentration below 0.5 mg/L promotes dental

caries. Waters of 50 wells showed high F contents over the desirable range and are also not suitable for drinking due to dental and skeletal fluorosis. According to Dissanayaka (1991) the value for F should be around 0.7 mg/L for Sri Lanka in view of the fact being in hot, humid climate, people who work under sun light consume more water. Average daily water intake is about 5L /day under heavy sunlight. If they use water with minimum amount of F, at the end of the day a considerable amount of F has been ingested through water and it's obvious that it is detrimental to health. Therefore the acceptable levels depend on climate, volume of water intake and intake of F from other sources.

Our study clearly indicates that the significant number of wells which is 56 % of total wells studied in the three Grama Niladari Divisions of the area(*Elliyadulwewa*19% wells, *Palugaswewa* 50% wells and *Ihala siyabalawa* 20% wells) are not suitable for drinking purposes as the F content was too high. Therefore, it is advisable not to use water in these well for drinking. The increasing level of F in the water in these wells of the area is undoubtedly due to the influence of the geochemical process of weathering of nearby phosphate rock which contains about 2-4% of F (Hewawasam and Dahanayake, 1999).

Permissible level of Cd concentration in drinking water is less than 0.01 mg/L according to WHO standards. All the wells tested for Cd were above the permissible level and it ranged from 0.03- 0.60 mg/L in *Ihala Siyabalawa* , 0.05-0.59 mg/L in *Elliyadulwewa* and 0.06- 0.58 mg/L in *Palugaswewa* areas respectively (Tables 1 and 2). The spatial distribution of Cd in well water of three divisions is shown in Fig 2. There is a strong possibility that the contamination of water with the Cd may be due to the influence of the geochemical process of weathering of nearby phosphate rock which contains Cd. (Chandrajith and Dissanayake, 2009).

Further, phosphate fertilizers produced from phosphate rock deposits contain significant concentrations of potentially toxic heavy metals such as Cd, Chromium (Cr), Vanadium (V) and Zinc (Zn). One study reported that phosphate fertilizers contained 4 – 7 mg/Kg of Cd (Brigden *et al*, 2002). It was reported that *Eppawela* phosphate contains 1.2 mg/Kg of Cd. Typically average concentration of Cd in soils is 0.01 – 1.0 mg/Kg (Alloway, 1990). Addition of phosphate fertilizer to the fields combined with the weathering of rock phosphate possibly contributes to the elevated Cd concentration in the soils and the ground water of the area.

Table 2: Mean F and Cd and Hardness of the well water in three Grama Niladari Divisions

Ihala siyabalawa				*Elliya dul wewa*				*Palugaswewa*			
Well No	F (mg/L)	Cd (mg/L)	Hardness (g/L)	Well No	F (mg/L)	Cd (mg/L)	Hardness (g/L)	Well No	F (mg/L)	Cd (mg/L)	Hardness (g/L)
1	2.5	0.18	1.879	1	1.36	0.12	1.074	1	1.26	0.47	1.124
2	1.89	0.31	1.252	2	1.84	0.17	0.185	2	1.64	0.55	2.975
3	2.14	0.39	1.160	3	1.29	0.30	0.236	3	1.57	0.44	0.974
4	2.08	0.47	2.329	4	1.28	0.45	0.753	4	1.23	0.25	1.304
5	1.71	0.47	1.982	5	1.03	0.51	0.877	5	1.55	0.10	1.064
6	2.22	0.23	1.630	6	0.98	0.58	1.206	6	1.13	0.13	0.785
7	1.40	0.08	1.931	7	1.55	0.33	1.411	7	1.12	0.27	0.547
8	2.43	0.08	2.041	8	1.52	0.08	1.418	8	1.34	0.42	1.733
9	2.09	0.26	1.689	9	1.17	0.18	1.656	9	1.42	0.51	1.615
10	2.24	0.37	1.425	10	1.60	0.31	0.992	10	0.97	0.55	0.465
11	2.29	0.46	0.227	11	1.12	0.42	0.933	11	1.55	0.48	1.241
12	1.92	0.53	0.810	12	1.38	0.52	1.096	12	1.60	0.28	1.327
13	2.55	0.41	0.585	13	1.26	0.56	1.120.	13	1.65	0.10	3.011
14	2.42	0.16	0.320	14	1.25	0.59	1.147	14	1.85	0.07	1.444
15	2.37	0.03	0.489	15	1.18	0.38	1.477	15	2.15	0.25	1.248
16	1.80	0.11	0.169	16	1.46	0.17	1.790	16	2.21	0.35	1.412
17	1.60	0.21	0.353	17	0.96	0.08	2.348	17	1.60	0.46	2.531
18	1.22	0.34	0.576	18	1.18	0.27	0.806	18	1.31	0.52	1.367
19	2.36	0.39	0.466	19	1.23	0.34	0.678	19	1.20	0.58	1.286
20	2.81	0.15	0.699	20	1.26	0.47	0.608	20	1.60	0.56	1.007
21	1.84	0.15	0.553	21	1.68	0.09	1.674	21	1.48	0.35	1.683
22	2.16	0.31	0.478	22	1.11	0.05	0.648	22	1.07	0.18	0.975
23	1.79	0.36	0.842	23	1.36	0.12	1.074	23	1.39	0.19	2.048
24	2.36	0.45	1.076					24	1.15	0.08	0.760
25	1.74	0.55	0.492					25	1.54	0.06	0.929
26	1.09	0.53	0.825					26	1.97	0.25	0.614
27	1.25	0.34	1.294								
28	1.31	0.11	0.049								
29	1.46	0.08	0.714								
30	2.21	0.25	0.267								
31	1.71	0.37	0.524								
32	2.24	0.46	0.995								
33	1.78	0.51	1.310								
34	1.38	0.60	1.131								
35	1.71	0.41	1.301								
36	2.20	0.19	1.735								
37	2.14	0.05	0.654								

- Means of three replicates.

The presence of elevated concentration of Cd in soil and water is greatest concern as a result of the toxicity of Cd and its ability to accumulate in soils, and bio-accumulate in biosphere. Cd has no biochemical or nutritional function and it is highly toxic to both plants and animals. In human and animals exposure to Cd can result in a wide range of health impacts with the kidney as a main target organ. In addition Cd and certain Cd compounds are listed by the International Agency for Research on Cancer as carcinogenic (IARC, 1973). Cd is readily available for uptake especially crops like grains, rice and vegetables. High concentration of Cd in soil therefore can result in increased concentration of Cd in crops. High concentration of Cd in water may cause health hazard and lead to develop chronic renal failure problems in people living in the area. Therefore, the well waters of the study area are not suitable for drinking purposes.

Ca and Mg concentrations of the all the well water ranged from 19.11 to 996.53 mg/L and 0.32 to 157.59 mg/L respectively (Tables 1 and 2). The distribution pattern of Ca and Mg are also shown in figures 4 and 4 respectively.

Total hardness (Total hardness = Ca mg/L × 2.5 + Mg mg/L × 4.2) of the water is reflected by the concentrations of Ca and Mg ions present in the water. Hard water which contains high Ca and Mg ions is generally not harmful to some one's health but some studies have shown a weak inverse relationship between water hardness and cardiovascular disease in men and can pose serious problems in industrial settings. According to the WHO standard, hardness of water is classified into four groups namely; soft (0-60mg/L), moderately hard (61-120 mg/L), hard (121-180 mg/L) and very hard (>180 mg/L) water. Total water hardness of the well water was also calculated (Table 2). According to our study all the well waters were in the category of very hard water (> 180 mg/L) except one well which contained soft water (WHO, 1987). Even though the hard water is not harmful to the health, it may adversely affect to the industry where boilers are used extensively with this water e.g. parboiling of rice.

Conclusion

High concentrations of F and Cd were recorded in the well waters of the three Grama Niladari Divisions of the area. About 56%wells (49 Wells) had F concentration above the desirable level. (1.5 mg/L). It is important to note that none of ground water samples were below the prescribed concentration (0.5 mg/L). The use of ground water for drinking purpose from these wells has to be restricted. Similarly all the wells tested for Cd were above permissible levels which are not suitable for drinking purposes. Weathering of F and Cd bearing minerals associated with *Eppawala* rock phosphate and

subsequent leaching and anthropogenic activities such as adding phosphate fertilizers may be the major reasons which contribute to elevated concentration of F and Cd in ground water

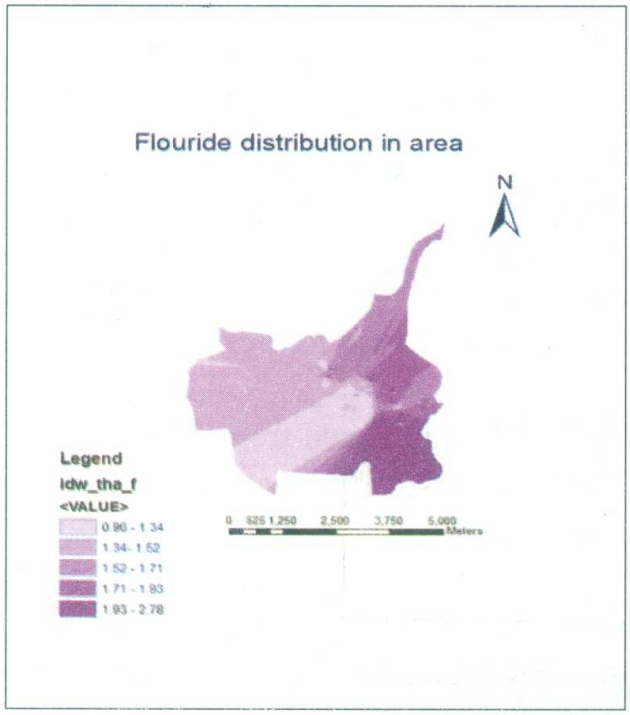

Figure 2: Spatial distribution of F in *Eppawala*

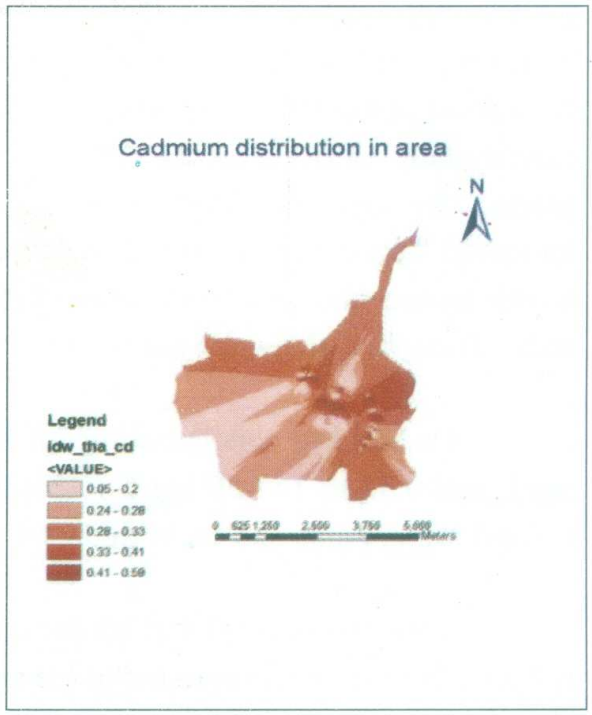

Figure 3: Spatial distribution of Cd *Eppawala*

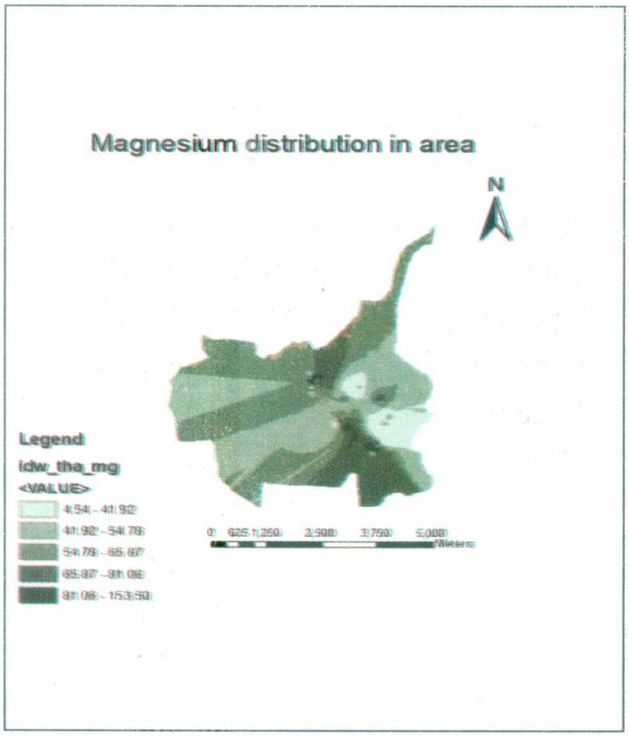

Figure 4: Spatial distribution of Mg in *Eppawala*

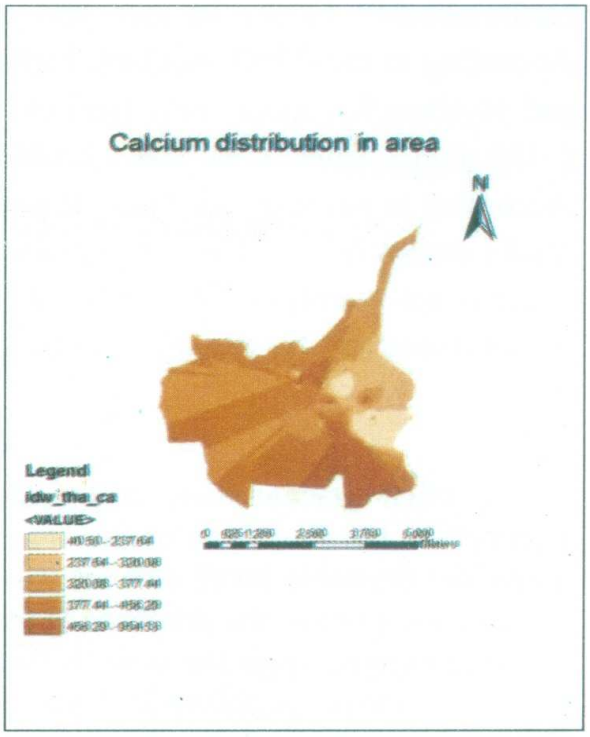

Figure 5: Spatial distribution of Ca *Eppawala*

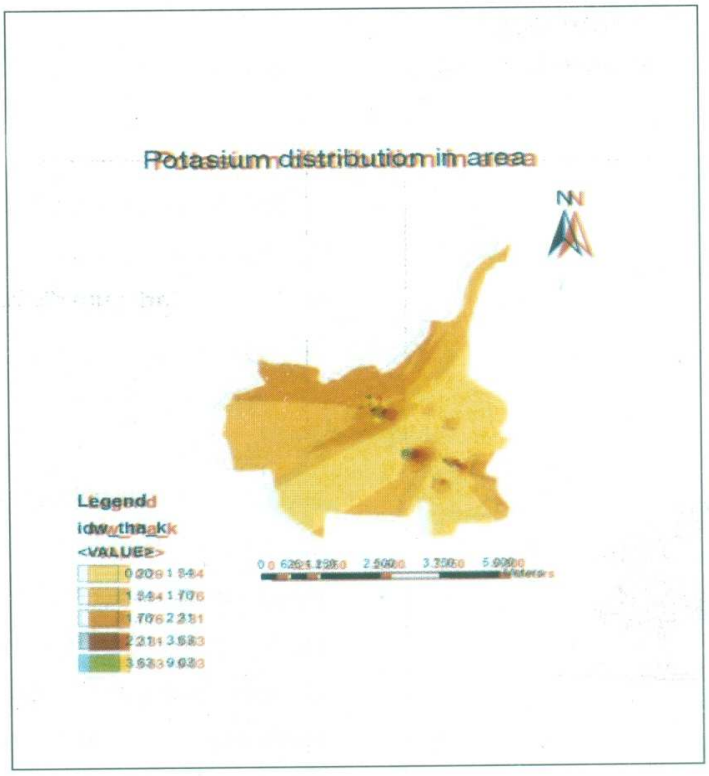

Figure 6: Spatial distribution of K *Eppawala*

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