An Assessment of Some Heavy Metal Levels in Drinking Water and Social Characteristics in Buruli Ulcer Endemic and Non-Endemic Communities in the Amansie West District

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Abstract

Buruli ulcer (BU) is a skin disease caused by Mycobacterium ulcerans (MU). It is often associated with slow-flowing or stagnant water and increase in incidence of the disease is also associated with ecological transformation. Several risk factors have been identified, and a number of transmission mechanisms suggested. However, the exact mechanism of transmission and development of BU through water-related human activities is unknown. A study was carried out to compare concentrations of cadmium, lead and aluminum in drinking water samples and some social characteristics from endemic and non-endemic communities in the Amansie West District in Ghana. Sixty-six drinking water sources were sampled from boreholes and hand-dug wells in the study area. The analysis of the samples showed that the average concentration of cadmium was significantly higher ($p < 0.05$) in endemic communities than in non-endemic communities even though all the values were below the WHO guideline values of 0.003mg/L. The average concentrations of lead and aluminum were lower in endemic communities than in non-endemic communities, but the differences between the average concentrations were not statistically significant ($p > 0.95$ for lead, $p > 0.30$ for aluminum). Aluminum concentrations in all the samples were however lower than the WHO recommended guideline value of 0.1mg/L, whilst the concentration of lead was higher than the recommended guideline value in several communities. It was therefore concluded that cadmium, lead and aluminum may not contribute to the occurrence and transmission of BU. In relation to the social characteristics, the educational level was generally poorer in endemic areas than in the non-endemic areas. The endemic communities used poorer source of water which include streams and hand-dug wells, unlike non-endemic communities which had better sources of water - boreholes and pipe-borne water only. Field observation showed that people in the endemic communities walked barefooted, whilst those in the non-endemic communities had footwear. In this District therefore, attitudinal behaviour/social characteristics may play a role in the occurrence of the disease. Other heavy metals like arsenic should be investigated into, as well as the water usage patterns of the people in the community (to determine whether the disease is water-washed, water-borne or water-based). The organism may be present in the water and/or soil, and it is recommended that more research be carried out to isolate it in the environment.

Keywords: Buruli ulcer, Drinking-water, Amansie West, Heavy metals

1. Introduction

1.1 Background

Buruli ulcer (BU) is a skin disease which often occurs as a disfiguring skin ulceration which is difficult to treat. It is caused by Mycobacterium ulcerans (MU) (Duker et al, 2004; Phillips et al, 2005; Wansbrough-Jones and Phillips, 2006). In its advanced stage the disease does not respond to drugs and requires surgery, often limb amputation, and may sometimes results in death. BU is not a localised disease, but occurs internationally. It is widespread in tropical and sub-tropical areas in more than 30 countries in Africa, Asia, Latin America, Western pacific and Australia. Studies have shown that West Africa is worst affected (Phillips et al, 2005).

Several risk factors have been identified and mechanisms of transmission suggested. Even though the causative organism has been identified, the mode of transmission is not fully understood, as well as the mechanism of development through water-related human activities. The disease is apparently connected to slow moving water bodies and may be transmitted by fish and some aquatic insects (Duker et al, 2004; Eddyani et al, 2004; Portaels et al, 1999). Some research has also linked the occurrence of BU to the presence of heavy metals such as arsenic in surface water (Duker et al, 2004).

This study seeks to investigate the relationship between BU occurrence and heavy metals in drinking water by comparing concentrations of cadmium, lead and aluminum in endemic and non-endemic areas, and contribute to the body of research on factors affecting transmission of BU.

1.2 Buruli Ulcer in Ghana

In Ghana, the first BU case was reported in 1971 from the Amansie West District (AWD), and between 1991 and 1997 more than 2000 cases were reported nationwide (Duker et al, 2004). All ten regions and at least 90 of the 110 administrative districts have been affected (Amofah et al, 2002; WHO, 2005). However, Ashanti Region is the worst affected, with the Amansie West District having the highest number of cases. Buruli Ulcer is the second most prevalent mycobacterial disease after tuberculosis (Amofah et al. 2002) but the disease has not received as much attention as Tuberculosis. A national search for cases of Buruli ulcer in Ghana identified 5,619 patients, with 6,332 clinical lesions at various stages. The overall crude national prevalence rate of active lesions was 20.7 per 100,000, but the rate was 150.8 per 100,000 in the most disease-endemic district (Amofah et al, 2002).

1.3 Heavy Metals

Heavy metals are trace metals with a density at least five times that of water. As such they are stable elements which cannot be metabolized by the body. Therefore, they pass up the food chain to humans and hence they tend to bio-accumulate. Some of them are necessary in minute quantities for the proper functioning of the body, but above a certain threshold level they become toxic (WHO, 2011). They get into the body by inhalation, through food, drinking water, through the skin from several chemicals invented by technology. According to Järup (2003) the main threats to human health from heavy metals are associated with exposure to arsenic, mercury, lead, aluminum and cadmium. For example, Duker et al (2004) identified significant spatial relationships between arsenic-enriched surface water and the occurrence of BU.

Heavy metals can directly influence behavior by impairing mental and neurological function leading to effects on human health such as: energy loss, respiratory problems, skin problems, increased risk of liver, lung and skin cancer, osteoporosis, learning disabilities, cardiovascular disease, amongst others (Järup, 2003).

1.3.1 Effects of cadmium

Cadmium is relatively rare and occurs with zinc ores and is used largely in batteries. Cadmium is non-essential for plants and animals. It is extremely toxic in humans, accumulating in the kidneys and liver. (ATSDR, 2012) Prolonged intake at low levels sometimes leads to dysfunction of the kidney and lung injury. Other effects of exposure to cadmium through inhalation or ingestion include abdominal pain, nausea, vomiting, muscle cramps, vertigo, shock, loss of consciousness and convulsions. (Tchounou, 2012) The effects of extensive cadmium exposure is not known, but are thought to include heart and kidney disease, high blood pressure, and cancer (ATSDR, 2012).

1.3.2 Effects of lead

The average abundance of lead in the earth's crust is 13ppm; in soils it ranges from 2.6 to 25ppm; in streams it is 3µg/L, and in groundwater it is generally less than 0.1mg/L. Lead may be found in the air from burning fuel or solid wastes and lead smelters. Exposure to lead may be through ingestion of food or water contaminated with lead, soil contaminated with lead, or inhalation of dust or cigarette smoke. Lead is nonessential for plants and animals. It is toxic by ingestion and is a cumulative poison, targeting the nervous system. The known acute health effects include nausea, abdominal pain, vomiting, muscle weakness, excessive bleeding memory loss, impotence, brain and kidney damage, coma, convulsions and death. (ATSDR, 2007)

1.3.3 Effects of aluminum

Aluminum is the most abundant metal in the Earth's crust, contained in a percentage from 7.5% to 8.1%. Aluminum is very rare in its free form. Humans are exposed to aluminum primarily through food, water and contaminants in the air. (Shaw et al, 2014; Yokel, 2000). High concentrations of aluminum may be found in acidified lakes and air, but also in the groundwater of acidified soils. Studies have suggested that aluminum is toxic and excess aluminum may cause gastroenteritis, kidney damage, liver dysfunction, loss of appetite, loss of balance, muscle pain, shortness of breath and weakness. (Shaw et al, 2014; ATSDR, 2008; Yokel, 2000) No health-based guideline values have been developed yet.

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2. Materials and methods

2.1 Description of the Study Area

mansie West is one of the 30 districts in the Ashanti Region located in the south-western part of the Region. It lies between Longitude 6.05oW and 6.35oW and Latitude 1o40'N and 2o05'N, covering an area of about 1,230 square kilometers. The district capital, Manso Nkwanta, is about 40 Km south of Kumasi (Figure 1).

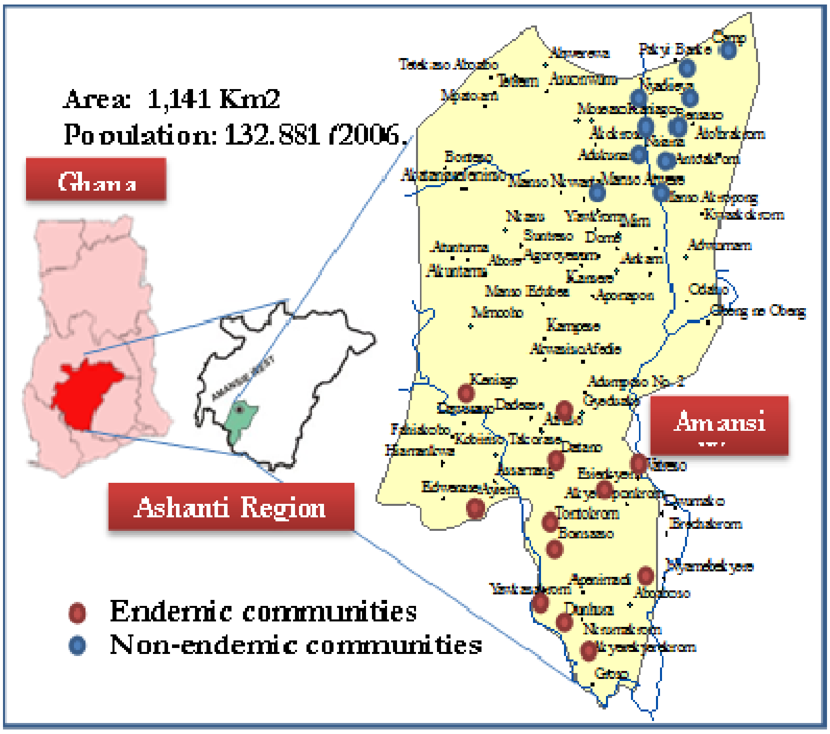

Figure 1. Map of Amansie West District (Source: Millennium Villages Project, Bonsaaso, 2006)

It is bordered on the northern part by the Atwima and Bosomtwe-Atwima Kwanwoma Districts, in the west by the Atwima Mponuah and Atwima Nwabiagya Districts and in the east by the Bekwai Municipal, Amansie Central and Obuasi Municipal Districts. A regional boundary separates it from Western Region on its southern part. The district has an area of 1,141 Km2 and a population of 134,331 (Ghana Statistical Service, 2012). The major soil types in the district are ferric fluvisols.

Diseases of public health importance are: Malaria, Tuberculosis, Diabetics, Hypertension, HIV/AIDS, and Buruli ulcer. In a national survey in 1999 conducted by Amofah et al (2002), the Amansie West District (study area) had the highest rate with a prevalence of 150.8 per 100,000. High incidence of BU occurs in settlements close to the Offin River.

The Amansie West District Health Administration (AWDHA) provided data on the number of Buruli ulcer cases in each sub-district for the year 2007 as follows: Agroyesum had three cases, Antoakrom had two, Edubiarecorded nine, Essuowin have one, Tontokrom had six while Keniago and Manso Nkwanta had four each. The number of cases outside the districts were 81, giving a total of 110 cases.

The number of cases recorded in the District spanning the period 2005 to 2008 was also obtained from the District Health Administration. The endemic communities selected for the study were randomly drawn from communities which had consistently reported cases over the last 3-4 years. The non-endemic communities were also selected randomly.

2.2 Field Visits, Surveys, Focus Group Discussions and Structured Interviews

A reconnaissance survey and transect walk were carried out in the communities selected for the study. The functioning water sources and activities carried out in the communities were observed during the transect walk.

In each of the communities visited ten questionnaires were administered. A total of 220 questionnaires were administered in the 12 endemic and 10 non-endemic communities. Structured interviews and focus group discussions were also carried out. The aim was to assess community understanding of the disease, sources and treatment of drinking water, and activities carried out close to drinking water sources. Four focus group discussions were conducted. One involved the chief and elders of Bonsaaso, another involved some women in the community at Tontokrom. The third and fourth focus group discussions involved the community members at Manso Atwere and Asarekrom respectively. Those interviewed in the communities included the the Assembly man, Unit Committee chairman or members, the health extension workers, and in some cases the agriculture extension officer.

2.3 Sample Collection and Analysis

For each of the communities selected for the research, all the functioning water points identified were sampled. A total of 66 water points in 22 communities were sampled using 0.5 litre acid-rinsed plastic containers. The temperature, potential of Hydrogen (pH) and conductivity of the samples were measured after collection. Each sample was filtered using 0.45 um cellulose filters to remove suspended solids. They were then acidified with 1.5 ml of concentrated nitric acid and stored in ice.

Heavy metal analysis was carried out by Flame Atomic Absorption Spectroscopy using a Perkin Elmer AAnalyst 200 setup at the International Institute for Water and Environmental Engineering, Ouagadougou, Burkina Faso. The metals tested for are cadmium, lead, and aluminum. The concentrations present in endemic areas were compared with those in non-endemic areas.

3. Results

3.1 Sources of drinking water

Observations made during the reconnaissance survey and field visits show that the sources of drinking water in the endemic communities are boreholes, streams and hand-dug wells (Table 1). Most of the communities had at least one borehole, whilst a few others had a hand-dug well or stream in addition. In the non-endemic communities, boreholes and pipe-borne water were the only sources of drinking water.

Table 1. Communities in AWD selected for the study and their water sources

Endemic Communities	Bore-hole	Stream	Hand-Dug Well	Non-Endemic Communities	Bore-hole	Pipe-Borne Water
Keniago	8	1	-	Bensaaso	1	
Ayiem	1	-	-	Besease	1	
Essienkyem	5	-	-	Mpranease	2	
Datano	6	2	-	Nanhin	3	
Watreso	3	1	-	Nyadieya	2	
Akyerekyerekrom	4	-	-	Asarekrom	3	
Dunhura	2	-	2	Nsiana	4	
Yawkasakrom	2	-	2	Antoakrom	3	
Bonsaso	2	2	-	Akropong	2	
Tontokrom	3	1	-	Manso Atwere	1	1
Afraso	3	-	-			
Adagya No. 1	2	-	-			
Total	41	7	4	Total	22	1

3.2 Physical parameters

The drinking water sources in both endemic and non-endemic communities were acidic with a pH range of 4.8 to 6.4 with no significant difference in values. Conductivity measurements showed low dissolved solids with values ranging from 117 to 319 µS. Temperature values were all in the mesophillic range 27.6 to 29.8 oC. (Tables 2 and 3). The field measurements are summarized in Table 4.

Table 2. Summary of field measurements for endemic communities

	Community	pH	Conductivity (µS)	Temperature (°C)	TDS (ppm)
1	Keniago	5.7	162	29.8	80.9
2	Ayiem	5.1	151	27.6	75.2
3	Esienkyem	5.0	319	29.9	159.0
4	Datano	5.2	154	28.1	77.1
5	Watreso	5.9	172	27.5	85.9
6	Akyerekyerekrom	5.8	237	27.6	118.5
7	Dunhura	4.9	276	27.7	138.5
8	Yawkasakrom	6.2	185	27.5	92.2
9	Bonsaaso	6.4	279	28.1	139.2
10	Tontokrom	5.8	145	27.8	72.3
11	Afraso	5.6	117	27.9	58.6
12	Adagya No. 1	5.9	171	27.6	85.7

Table 3. Summary of field measurements for non-endemic communities

	Community	pH	Conductivity (µS)	Temperature (°C)	TDS (ppm)
1	Bensaaso	6.3	244	27.7	122.0
2	Besease	5.8	134	27.7	67.1
3	Mpranease	4.8	314	27.8	157.4
4	Nanhin	6.2	243	27.7	121.7
5	Nyadieya	6.3	326	27.7	162.0
6	Asarekrom	6.2	276	27.8	137.7
7	Nsiana	5.6	161	27.8	80.5
8	Antoakrom	5.7	232	27.7	116.1
9	Akropong	6.2	264	27.9	131.5
10	M. Atwere	6.4	334	27.7	153.0

Table 4. Summary of Field Measurements

Value	pH		Conductivity (µS)		Temperature (°C)		TDS (ppm)	
	E	N-E	E	N-E	E	N-E	E	N-E
Minimum	4.89	4.82	117.30	134.3	27.53	27.7	58.63	67.1
Maximum	6.41	6.43	318.76	334.0	29.94	27.9	158.98	162.0
Average	5.63	5.94	197.28	252.8	28.09	27.7	98.60	124.9

TDS= Total Dissolved Solids; E=Endemic communities; N-E=Non-endemic communities

3.3 Heavy metal concentrations

In the endemic communities, the concentrations ranged from 0.7 to 2.3 µg/L for cadmium, 0 to 33.7 µg/L for lead and 0 to 1.3 µg/L for aluminum. The concentrations in the non-endemic communities ranged from 0 to 2.5 µg/L for cadmium, 0 to 35.5 µg/L for lead and 0 to 1. 5 µg/L for aluminum (Tables 5 and 6).

Table 5. Summary of heavy metal concentrations for endemic communities

Community	Water Point code	Concentration (µg/L)					
		Cd	SD	Pb	SD	Al	SD
Keniago	Kg	1.8	1.1	0.0	11.4	0.3	1.0
Ayiem	Ay1	1.0	1.6	0.0	9.0	0.0	0.1
Essienkyem	Es	2.0	1.3	1.2	7.7	0.4	0.7
Datano	Dt	1.0	1.2	19.3	15.2	0.3	1.4
Watreso	Wt	2.3	2.0	14.0	11.5	0.0	0.1
Akyerekyerekrom	Ak	1.2	1.2	24.0	9.1	0.8	1.1
Dunhura	Dh	1.5	0.6	0.0	10.6	0.5	0.2
Yawkasakrom	Y	1.7	1.1	33.7	5.7	0.3	1.0
Bonsaaso	Bn	1.7	1.9	0.0	9.0	1.3	0.1
Tontokrom	Tk	2.3	1.2	10.7	7.6	0.3	0.4
Afraso	Af	0.7	1.9	9.3	11.3	0.0	0.5
Adagya No. 1	Ad	1.5	1.5	25.0	0.5	0.0	1.5

SD = Standard Deviation

Table 6. Summary of heavy metal concentrations for non-endemic communities

Community	Water Point code	Concentration (µg/L)					
		Cd	SD	Pb	SD	Al	SD
Bensaaso	Bn1	0.0	1.4	19.0	14.2	0.0	0.2
Besease	Bs1	1.0	0.9	0.0	13.1	1.0	0.1
Mpranease	Mp	0.0	1.2	16.5	9.2	1.5	0.2
Nanhin	Nh	1.7	1.4	4.3	13.4	0.0	0.3
Nyadieya	Ny	0.5	1.0	35.5	3.8	0.5	3.1
Asarekrom	Ar	0.3	1.0	14.0	9.2	0.7	1.4
Nsiana	Ns	2.5	1.3	8.8	10.7	0.5	0.1
Antoakrom	An	2.0	1.5	0.7	26.9	0.0	0.1
Akropong	Ag	1.0	0.9	16.5	17.3	0.5	0.2
M. Atwere	MA	0	0.8	2	1.1	0.9	0.1

SD = Standard Deviation

When comparisons of concentrations of heavy metals were made in the Endemic and non-endemic Buruli Ulcer communities, it was realized that the concentrations of cadmium were significantly higher ($p < 0.05$) in Buruli Ulcer endemic communities than non Buruli Ulcer communities although the levels were below the WHO recommended values of 3 µg/L (Figures 2 and 5). There was no significant differences between endemic and non-endemic communities for lead and aluminum ($p = 0.95$ and 0.3 respectively). However, high levels of lead in some communities which were above the WHO (2006) recommended values need to be addressed (Figures 3, 4, 6 and 7).

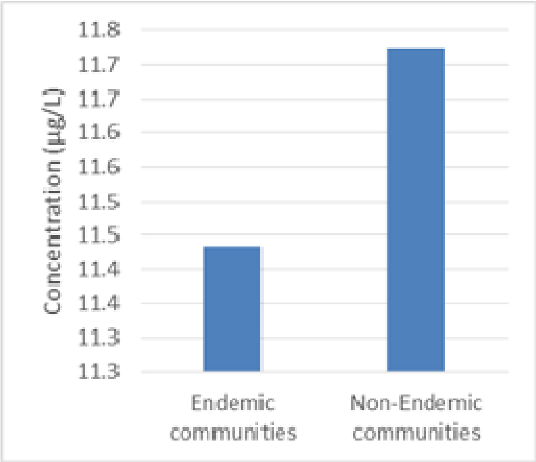

Figure 2. Average concentrations of cadmium in endemic and non-endemic communities

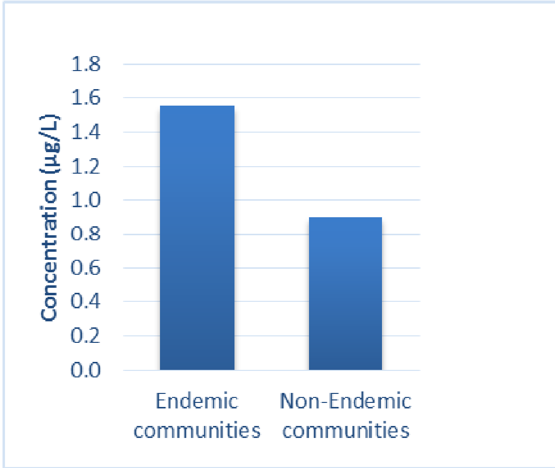

Figure 3. Average concentrations of lead in endemic and non-endemic communities

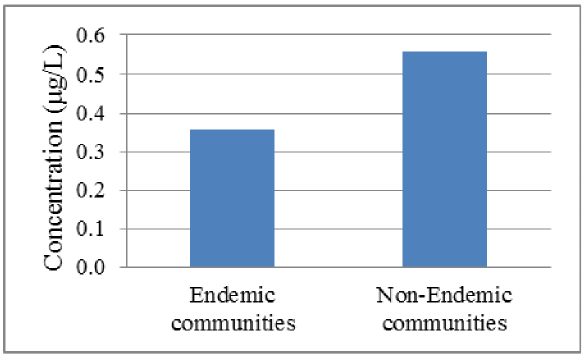

Figure 4. Average concentrations of aluminum in endemic and non-endemic communities

3.4 Social characteristics and focus group discussion

Most of the respondents for the survey were male in both endemic and non-endemic communities (Table 7) and they were mostly 20 years or older (Table 8). The level of education was higher in the non-endemic communities than in the endemic communities. In the endemic communities, 65.8% had education to secondary level as against 88% in the non-endemic communities, while 31.7% and 4% had no formal education in the endemic and non-endemic communities respectively. Both communities were mostly Akan and Christians. A large proportion of the respondents in both endemic and non-endemic communities were farmers.

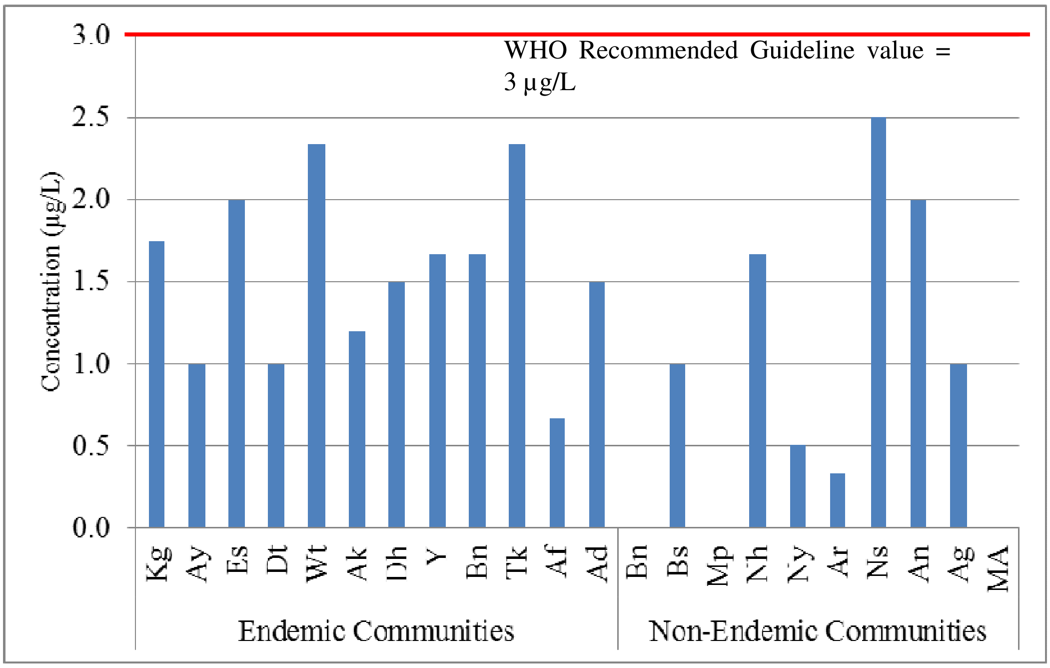

Figure 5: Cadmium concentrations in endemic and non-endemic communities

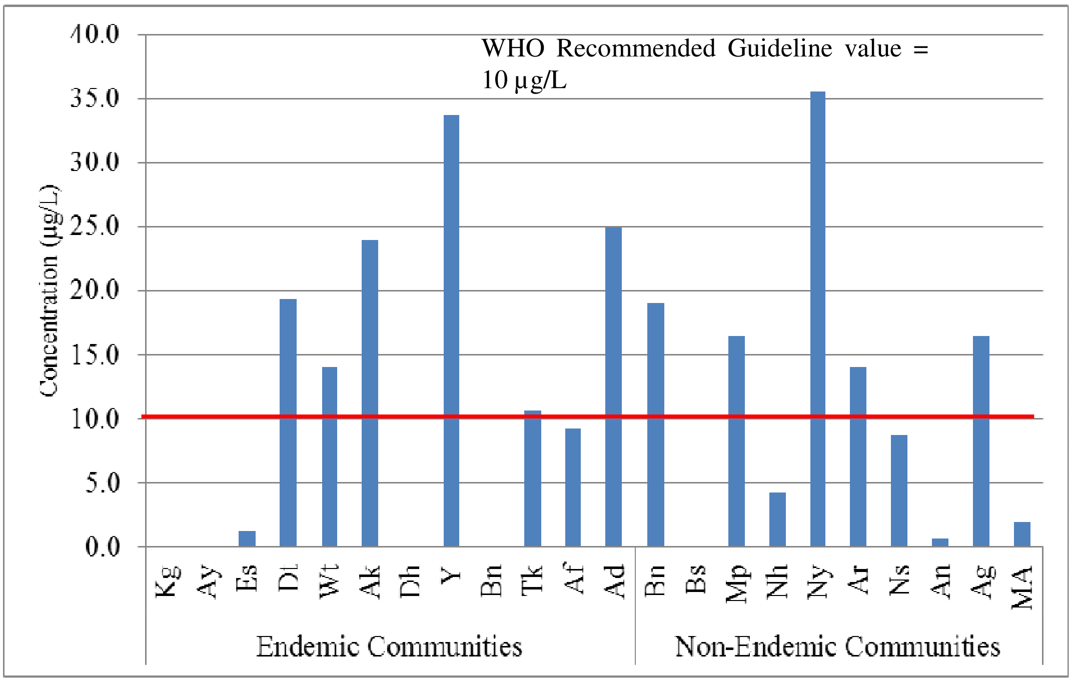

Figure 6. Lead concentrations in endemic and non-endemic communities

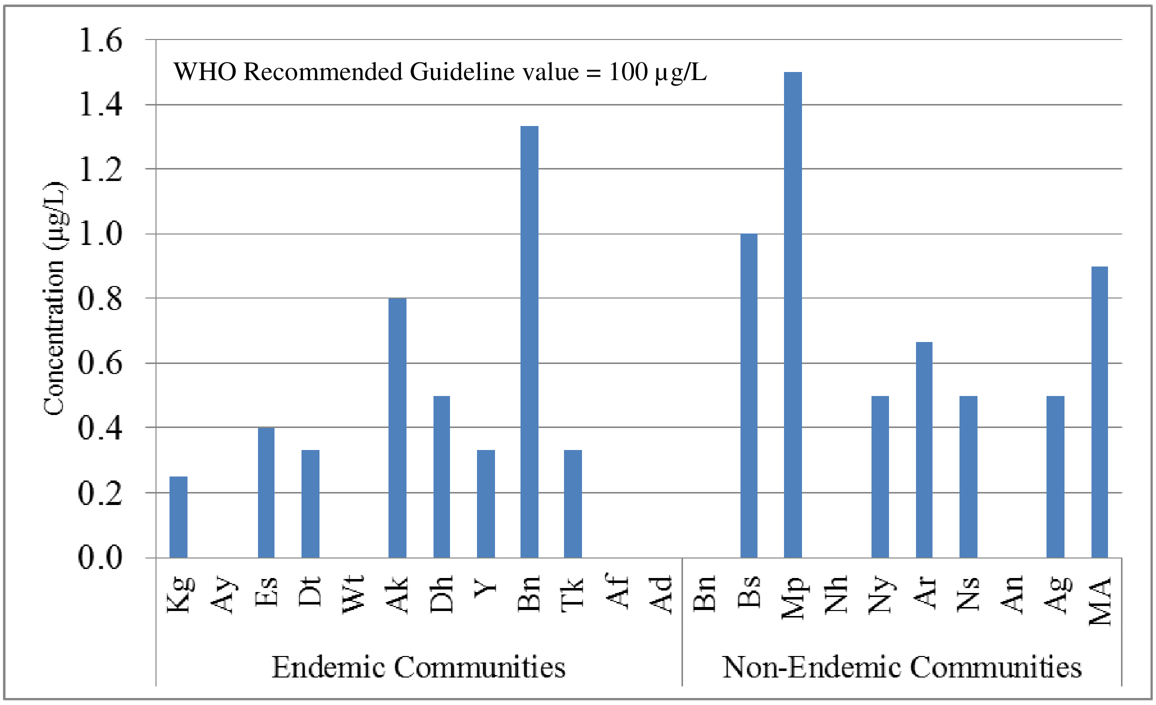

Figure 7. Aluminum Concentrations in Endemic and Non-endemic Communities

Table 7. Composition by gender of respondents

Gender	Endemic	Non-Endemic
Male	51.7%	55.0%
Female	48.3%	45.0%

Table 8. Age distribution of respondents

Age	Endemic	Non-Endemic
Below 10	0.0%	0.0%
10 to 20	14.2%	12.0%
20 to 40	55.8%	55.0%
Above 40	30.0%	33.0%

It was observed that most of the people in the Buruli Ulcer endemic communities walk bare footed. The non-Buruli Ulcer community members had footwear. Focus group discussions with community members showed that they were aware of the disease and believed that it was obtained through the drinking of stream water. They also believed that illegal mining or 'Galamsey' and private mining companies' activities might have introduced the disease since the disease was noticed after their activities had polluted their surface waters. It was also identified that community members carried water from the boreholes to use whilst working on their farms. They however had to resort to stream water when their supplies ran out whilst still in the farm.

In some of the endemic communities, especially Bonsaaso, Edwenase and Yawkasakrom, high concentrations of iron and manganese in the drinking water sources was evidenced by the reddish colour of water from the boreholes, stained concrete surfaces at the water points and previous analysis by the Millennium Villages Project. Mwacafe Filters have been installed for the removal of iron and manganese where the concentrations were extremely high (Bonsaaso and Yawkasakrom). In all the other communities however, borehole and well water are not treated before use.

4. Discussion

4.1 Sources of drinking water

The non-endemic communities generally have better sources of drinking water (boreholes and pipe-borne water) as compared to the endemic communities (boreholes, hand-dug wells and streams).

4.2 Physical parameters

There seems to be little or no correlation between the physical parameters measured and the TDS and heavy metal concentrations (Table 9). Even though the drinking water samples analyzed were acidic there was also no correlation between heavy metal concentrations and TDS.

Table 9. Correlation coefficients between physical parameters measured and heavy metal concentrations

	pH	Conductivity	Temperature	TDS
Cd	0.08	0.07	0.05	0.07
Pb	0.18	0.09	0.25	0.09
Al	0.11	0.44	0.01	0.44

The low levels of pH are caused by the presence of arsenopyrites (Duker et al, 2004). Such rocks are also low in cadmium and aluminum and even though the water is acidic the levels of these heavy metals were very low. Arsenic should have been measured to determine its role in the Buruli ulcer disease but due to logistics it could not be done. This should be pursued in future research.

4.3 Heavy metal concentrations

These low concentrations of cadmium in all the communities show that this heavy metal may not play a significant role in the transmission of Buruli ulcer disease. Similarly, the presence of lead and aluminum may also not play any role because of lack of significant differences between the Buruli Ulcer endemic and non-endemicnon-endemic communities. Instead it could be due to arsenic. Literature (Duker et al, 2004) seems to have some correlation of arsenic and Buruli ulcer and more studies should be done on arsenic levels. High lead levels identified in the communities should be examined to identify the source of contamination. High concentrations of lead may lead to adverse effects such as memory loss, impotence, brain and kidney damage.

4.4 Social Characteristics

Social behaviour has played a major role in the transmission of several diseases in the world. These include water use patterns (water washed diseases such eczema and yaws), walking bare footed (Ascaris, helminthiasis) wading and bathing in infested waters (schistosomiasis) and water borne diseases from drinking water that is contaminated (cholera, guinea worm and others). The endemic communities because of their educational background use good water to avoid water borne disease. This was deduced from focus group discussions. In addition, they had footwear and this would prevent some diseases that enter the body directly through poor sanitation. They also avoided swimming and wading in streams. These non-endemic communities have protected themselves from most of the possible routes of tropical parasitic diseases. Unlike the endemic communities which have availed themselves to all forms of transmissions. This attitudinal behaviour could be a major risk factor in the transmission of the disease. It must be noted here that several diseases could synergistically enhance the morbidity of the Buruli Ulcer disease. Extensive research work has not been done in relation to this and could be an interesting area for investigation. Illegal mining activities cause the soil disturbance which may release the bacteria which causes Buruli Ulcer. Thus the observation from the focus group discussion is a confirmation that mining activities could play a role in the proliferation of the disease.

5. Conclusion and recommendations

5.1 Conclusion

Based on the outcome of the results, the following conclusions were drawn: (1) The study revealed that the endemic communities had poorer sources of water which include streams and hand-dug wells, unlike non-endemic communities which had relatively better sources of water namely boreholes and pipe-borne water only. Though the quality of the sources of water varied, there were no significant differences between the recorded levels of heavy metals present in both communities. This indicates that the presence of cadmium, lead and aluminum in water may not be a contributory factor in the occurrence of Buruli Ulcer. (2) It was observed that the endemic communities engaged in social lifestyles which could be a contributory factor to the presence of Buruli Ulcer in the community. They engaged in unhygienic activities which included walking barefooted and wading in streams. Since the non-endemic communities practiced better social life style, it could be said that the prevalence of Buruli Ulcer may be due to social characteristics such as walking barefoot, wading through surface water and poor education. (3) Of all the communities that had detectable levels of lead, more than 50% had levels above the WHO recommended guideline value, with two of them being more than twice the recommended value. This could be due to a source of contamination, given that illegal mining takes place within the district and could pose a health risk to the community members.

5.2 Recommendations

The following recommendations are made: (i) The bacterium could be present in either the waters and/or soils around. An avenue for further research would be to determine the abundance of the bacterium in the environment of endemic communities and to identify the source. (ii) Further research should be done to study the behaviour of the bacterium in Arsenic environments. (iii) It is also recommended that the people in the study area be educated in order to raise awareness of the identified risk factors such as walking barefooted, and also improve upon their social behavior. (iv) In the case of the water sources with high levels of lead, the District Assembly should identify and eliminate the possible sources of contamination, or cap contaminated boreholes and provide alternative sources of potable water for the communities.

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