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Lead contamination of traditional hand-dug wells in parts of Kwale County, Kenya

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People's health, behavior and intellect to a certain extent are a function of their environment. One important component of this environment is water, a basic necessity that human beings cannot do without. The water available, however, is not always safe for human consumption due to contamination. Among the many water contaminants, lead (Pb) is one of the most dangerous due to its bio-accumulative nature and high toxicity. Children are most vulnerable to Pb toxicity as their main organs such as the brain and the nervous system are still developing. For them, exposure to even relatively low concentrations can result in reduced intelligence quotient (IQ), learning disabilities and attention deficit disorders, behavioral problems such as delinquency and drug abuse, and such conditions as impaired hearing and mental retardation. The main aim of the present study was to determine Pb concentration in water from hand-dug wells in Kwale County in the coastal region of Kenya. Kwale County hosts a number of schools for mentally disabled and hearing impaired persons, while the coastal region in general has among the lowest literacy levels in the country and the highest incidences of drug abuse. Thirty-seven water samples were randomly collected from selected villages and analyzed for Pb content using a flame atomic absorption spectrophotometer (FAAS). Also analyzed were the water pH and conductivity using portable digital meters. Pb concentration in the water samples ranged from below detection limit to 1.397 mg/L with a mean concentration of 0.330 mg/L. Over 62% of the samples had Pb levels above WHO recommended value of 0.01 mg/L. The pH ranged from 5.8 to 10.4 with a mean value of 9.2 while conductivity ranged from 85.3 to 6060 µs/cm with a mean value of 930.351 µs/cm.

Key words: Lead, well water, intelligence quotient (IQ), mental retardation, deafness, Kwale.

INTRODUCTION

Water is essential to life and without it, life as we know it would not be. However, as much as it is precious, it may be a source of diseases and disabilities amongst members of the public. This is because water naturally contains minerals and organisms which may be of a type and/or concentration that is not safe for human consumption. Of particular concern are heavy metals. Heavy metals are non-biodegradable chemical elements that are ubiquitous in the environment and are toxic at relatively low concentrations (Adelekan and Abegunde, 2011; Momodu and Anyakora, 2010; Ghanem et al., 2008). While trace amounts of some metals such as calcium (Ca), chromium (Cr), manganese (Mn), Iron (Fe), cobalt (Co), copper (Cu), zinc (Zn) and molybdenum (Mo) are essential for proper growth and development others such as Pb are non-essential to human beings with no

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known biological function in the human body (Silveira et al., 2003). Pb is a bio-accumulative and highly toxic element that can cause irreversible damage to body organs such as kidneys and the nervous and reproductive systems (Todd et al., 1996). Pb is particularly toxic to children as their main organs such as the brain and the nervous system are still developing. For them, exposure to even relatively low concentrations can result in such conditions as hearing impairment and mental retardation, reduced intelligence quotient (IQ), learning disabilities and attention deficit disorders, and behavioral problems such as delinquency and drug/substance abuse (Froutan et al., 2011; WHO, 2010; Park et al., 2010; Chen et al., 2007; Norman et al., 2007; Pruss-Ustun et al., 2004; Needleman et al., 2002; Dietrich et al., 2001; Osman et al., 1999; Mendelsohn et al., 1998; Sciarillo et al., 1992; Schwartz, 1992). Chronic exposure to Pb may cause neurological damage and neurobehavioral disorders in the long run (Pabello and Bolivar, 2005; Patrick, 2006). Drugs temporarily restore neurotransmitter functions that are abnormal, and substance abuse may often be crude self-medication in response to the effects of Pb toxicity (Masters, 1999). Pb poisoning can result to iron deficiency anemia, a condition whose prevalence among pregnant women and children in Kenya is very high (Makokha et al., 2008).

In view of the health, intellectual and behavioral impacts of Pb contamination, the present study was carried out in Kwale County in the coastal region of Kenya to determine Pb levels in drinking water from traditional hand-dug wells. Kwale County is home to Mlalani special unit for mentally handicapped children, Kwale School for the mentally handicapped, Kichakamkwaju deaf unit, and Kwale School for the deaf, while the coastal region in general has among the lowest literacy levels in the country and the highest incidences of drug abuse. The literacy level in the region was placed at 62.8% in 2000, the lowest in the country at the time (UNESCO, 2005). Due to continued dismal performance in national examinations, the coastal region was a subject of a documentary tagged *"The last to graduate"* aired in July 2012 on KTN, a local TV channel. In the documentary students as old as 13 years could not read comprehensibly in either English or Kiswahili, the national language in Kenya. The coastal region leads in the use of narcotics (NACADA, 2010) with *Bhangi* (cannabis sativa) being the drug of choice for most young people due to its low price range and relative ease of access (National Assembly Official Report, 2010).

Typical to the coastal region, Kwale County has rich albeit unexploited mineral resources that include rare earth elements such as niobium and titanium (Ministry of Environment and Natural Resources, 1985). Kwale County residents are however, poor village folks who depend mainly on small scale farming for subsistence. Probably due to low education standards, the villagers still ascribe to traditional practices such as witchcraft and more often than not, all sorts of misfortunes ranging from diseases, poor performance in school, poverty and even drought are attributed to sorcery and other supernatural powers (Tinga, 1998). The County generally lacks most basic amenities such as piped water and the residents rely mainly on groundwater from communal traditional hand-dug wells for drinking and other domestic purposes, water that they use without any form of treatment.

Four villages within Kwale County namely Kanana-Shimoni, Munje, Ramisi and Shirazi were chosen for the present study. In these villages, communal hand-dug wells serve as the sole source of drinking water. The wells are indiscriminately sunk without regulation or regard to water quality. The wells are typically shallow and usually no deeper than 20 m. A few of the wells are covered and fitted with a hand pump. Most of the wells however, are open and water is drawn using a tin tied to a rope.

MATERIALS AND METHODS

A total of 37 wells were sampled; 8 in Kanana -Shimoni, 9 in Munje, 13 in Ramisi and 7 in Shirazi. The sample size reflects the population density and thus the total number of wells in each village. Sampling was done during the dry season. 500 ml plastic bottles which had been pre-cleaned and rinsed off with dilute nitric acid, distilled water and sample water, in that order, were used. Water was drawn from the wells in the same way the local residents fetched their water: using a tin tied to a string in the case of open wells and hand pump in the case of closed wells. The samples were tested on site for pH and conductivity using portable digital meters before being transported to the laboratory where they were acidized using nitric acid to a pH<2 for preservation. They were then left to sit for at least 72 h before the commencement of Pb measurement.

The samples were prepared for Pb measurement using the EPA 200.2 digestion method. In this method, 100 ml of thoroughly mixed sample was poured into 150 ml beaker and 2 ml concentrated NO_3 and 1 ml concentrated HCl added. The solution was heated using an electrical burner at a solution temperature of 95 ± 5°C up until the volume was reduced to 20 ml. After cooling, the solute was topped up to 100 ml using distilled water and filtered to rid any particulate matter. The samples were then analyzed for Pb content using a calibrated GF-990 flame atomic absorption spectrophotometer (FAAS) at the School of Pure and Applied Sciences, Pwani University College, Kilifi, Kenya.

RESULTS AND DISCUSSION

Table 1 shows the overall results of the parameters analyzed while Table 2 gives the summary statics. The Pb levels in the water samples ranged from below detection limit (BDL) to 1.397 mg/L with a mean concentration of 0.33 mg/L. As a guideline for lead contamination in drinking water, the World Health Organization (WHO) has set up a reference level of 0.01 mg/L against which remediation measures are required (WHO, 1993). The mean concentration of Pb in the samples was above the WHO reference level, and so

Table 1. Overall results for water samples from Kwale County.

Sample	Type of well	Village	pH	EC (µs/cm)	Pb conc. (mg/L)
S01	Closed	Ramisi	10.1	85	BDL
S02	Closed	Ramisi	7.2	341	BDL
S03	Closed	Ramisi	9.4	394	BDL
S04	Closed	Ramisi	9.9	426	BDL
S05	Closed	Kanana-Shimoni	9.6	506	BDL
S06	Closed	Kanana-Shimoni	10.0	610	BDL
S07	Closed	Kanana-Shimoni	9.7	425	0.014
S08	Closed	Shirazi	9.7	392	0.041
S09	Closed	Shirazi	9.5	2960	0.492
S10	Closed	Shirazi	9.5	472	0.573
S11	Closed	Ramisi	5.8	207	0.743
S12	Closed	Shirazi	9.7	667	0.889
S13	Open	Munje	10.3	98	BDL
S14	Open	Munje	10.0	338	BDL
S15	Open	Ramisi	8.4	360	BDL
S16	Open	Ramisi	10.1	414	BDL
S17	Open	Ramisi	10.2	715	BDL
S18	Open	Ramisi	7.9	949	BDL
S19	Open	Munje	9.8	1106	BDL
S20	Open	Kanana-Shimoni	7.5	5770	BDL
S21	Open	Shirazi	9.5	506	0.015
S22	Open	Ramisi	9.2	2370	0.045
S23	Open	Kanana-Shimoni	9.9	604	0.136
S24	Open	Kanana-Shimoni	9.9	296	0.248
S25	Open	Kanana-Shimoni	10.0	477	0.254
S26	Open	Munje	8.7	576	0.336
S27	Open	Munje	8.3	336	0.365
S28	Open	Munje	8.2	6060	0.421
S29	Open	Kanana-Shimoni	10.4	1000	0.458
S30	Open	Munje	8.3	1078	0.489
S31	Open	Shirazi	10.0	471	0.714
S32	Open	Shirazi	10.1	361	0.777
S33	Open	Ramisi	9.5	721	0.844
S34	Open	Ramisi	9.9	414	0.893
S35	Open	Munje	6.0	659	0.922
S36	Open	Munje	7.5	928	1.146
S37	Open	Ramisi	10.0	331	1.397

were 62.16% of the samples. Pb contamination of groundwater supplies may arise from either anthropogenic sources such as pesticides, fertilizers, industries and mining activities, or from natural deposits in rock and soil. Pb contamination of the well water of Kwale County is most likely mainly due natural sources as there are no active large scale industries, major mining activities or extensive use of fertilizers and pesticides in the region. Moreover, Kwale County like the rest of the Kenyan coast has heavy mineral sand deposits that contain lead-zinc bearing ores (Kariuki, 2002; Njuguna, 2007). The sampling area is also within the Pleistocene coral limestone formations which may serve as a host rock for Pb deposits.

The pH of the water samples was between 5.8 and 10.4 with a mean value of 9.18. WHO has no health based guideline value for pH, but a range of 6.5 to 8.5 is usually recommended (Napacho and Manyele, 2010). 72.79% of the samples had pH values outside this range with 67.57% of them having pH levels above 8.5, an indication of high alkalinity of groundwater in the region. Electrical conductivity (EC) levels ranged between 85.3

Table 2. Summary statistics of the samples analyzed.

Parameter	pH	EC (µs/cm)	Pb conc. (mg/L)
Minimum value	5.8	85.3	BDL
Maximum value	10.4	6060	1.395
Mean	9.18	930.35	0.33
WHO reference value	-	-	0.1
Samples exceeding WHO reference level			62.16%

Table 3. Range mean and standard deviation values for Pb concentrations for each village.

Village	Range (mg/L)	Mean Pb conc. (mg/l)	STDEV (mg/L)
Kanana-Shimoni	BDL - 0.458	0.139	0.172
Munje	BDL - 1.146	0.409	0.406
Ramisi	BDL - 1.397	0.302	0.486
Shirazi	0.015 - 0.889	0.500	0.348

Table 4. Percentage of samples with Pb levels above WHO reference level.

Village	No. of samples	Samples above WHO ref. level	% above WHO ref. level
Kanana-Shimoni	8	5	62.50
Munje	9	6	66.67
Ramisi	13	5	38.46
Shirazi	7	7	100.00

and 6060 µs/cm with a mean value of 930.35 µs/cm. The high conductivity could be due to sea water intrusion bearing in mind the region's proximity to the Indian Ocean. Two of the wells with the highest conductivity (5770 and 6060 µs/cm) had extremely salty water and although the local residents did not use it for drinking, they used it for other domestic purposes like cleaning and cooking.

Out of the 37 wells studied, 12 were covered while 25 were open. The mean Pb concentration in the closed wells was 0.229 mg/L with a standard deviation of 0.342 mg/L while that of closed wells was 0.378 mg/L with a standard deviation of 0.417 mg/L. A bigger proportion of contamination was observed in the open wells (68%) as compared to the closed wells (50%). The higher concentration of Pb in the open wells may be due to siltation. Table 3 shows the range, mean and standard deviation values of Pb in samples from each village while Table 4 looks at the number of wells sampled per village and the percentage of sampled wells with Pb levels above the WHO reference level. Samples from Kanana-Shimoni Village had the lowest mean value of Pb at 0.1 mg/L while those from Shirazi Village had the highest at 0.5 mg/L. Munje and Ramisi Villages had wells with mean Pb concentrations of 0.409 and 0.302 mg/L respectively. Despite registering the lowest mean Pb value, 62.5% of the sampled wells in Kanana-Shimoni Village were Pb contaminated which implies that lead bearing soils are more or less distributed throughout the village. 66.67% of the sampled wells in Munje Village and all the sampled wells in Shirazi Village had Pb levels above WHO action value. Ramisi Village had the least proportion of contaminated sampled wells at 38.46%. Ramisi Village is a settlement center of sorts unlike the other villages which are farmlands in which dwellings and consequently water wells are relatively far between. From information gathered from the villagers, underground streams are alleged to flow in Ramisi Village and this may explain the low percentage of wells that are Pb-contaminated. No prior study is carried out a site before a well is dug and consequently not all wells coincide with points of good water. Again, being a settlement center, the human population in Ramisi Village is high and therefore there exists a likelihood of well contamination resulting from improper disposal of human waste as well as from minor activities such as paint jobs and bicycle repair works. This may explain the high levels of Pb in some of the wells in the village.

Conclusion

There is one question that lingers in the minds of many Kenyans familiar with the prevalent drought situation of

Kwale County: with such a high water table, why is it that the coastal villagers do not harvest the groundwater and use it for irrigation purposes but instead wait upon the almost always unreliable seasonal rainfall? Why the disabilities, the prevalent drug/substance abuse, the low education standards, the poverty, the superstitions? People's health, behavior and intellect to a certain extent are a function of their environment and water is an important aspect of that environment. 62% of the sampled wells in the part of Kwale County studied had Pb contamination levels that can adversely affect the health and life of human beings. In the natural order of things, there is a tendency for living organisms to react intuitively to thwart impending threats, and it is probably for this reason that the Kwale villagers have refrained from using groundwater for irrigation purposes, given its high toxicity evident from the current research. Coincidentally or otherwise, among the villages studied, human settlements were most concentrated in Ramisi Village, the village with the lowest proportion of Pb-contaminated wells.

RECOMMENDATION

As much as it may be of poor quality, water is essential to life and with no access to other sources, Kwale villagers turn to untreated groundwater for drinking, then to superstitions when calamities possibly brought about by the same water strike. Such calamities may be averted by providing quality water to the residents of Kwale County. There is also need for further research to identify and map the wells with good/poor quality water in terms of other chemical components. Such information would be vital in advising the villagers on which wells to use and to avoid as well as form a basis of mass education on the dangers of Pb and other heavy metal contaminants. For comparative analysis, further research on Pb levels in groundwater during the wet season is required.

REFERENCES

Adelekan BA, Abegunde KD (2011). Heavy metals contamination of soil and groundwater at automobile mechanic villages in Ibadan, Nigeria. Int. J. Phys. Sci. 6(5):1045-1058.

Chen A, Cai B, Dietrich KN, Radcliffe J, Rogan WJ (2007). Lead exposure, IQ, and behavior in urban 5-7 year olds: Does lead affect behavior only by lowering IQ? Pediatrics 119(3):650-658.

Dietrich KM, Ris MD, Succop PA, Berger OG, Bornschein RL (2001). Early exposure to lead and juvenile delinquency. Neurotoxicol. Teratol. 23:511-518.

Froutan H, Zadeh AK, Kalani M, Andrabi A (2011). Lead toxicity: a probable cause of abdominal pain in drug abusers. Med. J. Islamic Republic Iran. 25(1):16-20.

Ghanem A, El-Azab SM, Mandour RA, EL-Hamady MS (2008). Relationship between lead levels in drinking water and mothers' breast milk. Mansoura J. Forensic Med. Clin. Toxicol. 16(1):13-24.

Kariuki DK (2002). Natural resources-minerals: a report of the civil society review of the implementation of agenda 21 in Kenya Kenya NGO Earth Summit 2002 Forum.

Makokha AO, Mghweno LR, Magoha HS, Nakajugo A, Wekesa JM (2008). Environmental lead pollution and contamination in food around Lake Victoria, Kisumu, Kenya. Afr. J. Environ. Sci. Technol. 2(10):349-353.

Masters RG (1999). Poisoning the Well: Neurotoxic Metals, Water Treatment, and Human Behavior. Plenary Address to Annual Conference of the Association for Politics and the Life Sciences, Four Seasons Hotel, Atlanta, GA. Sept. 2, 1999.

Mendelsohn AL, Dreyer BP, Fierman AH, Rosen CM, Legano LA, Kruger HA, Lim SW, Courtlandt CD (1998). Low-Level Lead Exposure and Behavior in Early Childhood. Pediatrics. 101(3):10.

Ministry of Environment and Natural Resources (1985). Kwale district environmental assessment report. National Environment Secretariat, Ministry of Environment and Natural Resources, Kenya.

Momodu MA, Anyakora CA (2010). Heavy Metal Contamination of Ground Water: The Surulere Case Study. Res. J. Environ. Earth Sci. 2(1):39-43.

NACADA (2010). Report of Survey on Drug and Substance Abuse in Coast Province Kenya. Main Report. National Campaign Against Drug Abuse Authority, March 2010.

Napacho ZA, Manyele SV (2010). Quality assessment of drinking water in Temeke District (part II): Characterization of chemical parameters. Afr. J. Environ. Sci. Technol. 4(11):775-789.

National Assembly Official Report (2010). Threat of international narcotics trade to Kenya. Prime Ministerial Statement, Wednesday, 24th November, 2010(P).

Needleman HL, McFarland C, Ness RB, Fienberg SE, Tobin MJ (2002). Bone lead levels in adjudicated delinquents; A case control study, Neurotoxicol. Teratol. 24:711-717.

Njuguna FK (2007). Baseline study towards non-toxic environment in Africa. Country Report, Kenya, 08 August 2007.

Norman R, Mathee A, Barnes B, Merwe L, Bradshaw D (2007). Estimating the burden of disease attributable to lead exposure in South Africa in 2000. South Africa Med. 97:773-780.

Osman K, Pawlas K, Schütz A, Gazdzik M, Sokal JA, Vahter M (1999). Lead exposure and hearing effects in children in Katowice, Poland, Environ. Res. 80(1):1-8.

Pabello NG, Bolivar VJ (2005). Young Brains on Lead: Adult Neurological Consequences? Toxicol. Sci. 86(2):211-213.

Park SK, Elmarsafawy S, Mukherjee B, Spiro A, Vokonas PS, Nie H, Marc G, Weisskopf MG, Hu JSW (2010). Cumuative lead exposure and age-related hearing loss: The VA Normative Aging Study, Hearing Exposure. 1-2: 48-55.

Patrick L (2006). Lead Toxicity Part II: The Role of Free Radical Damage and the Use of Antioxidants in the Pathology and Treatment of Lead Toxicity. Altern. Med. Rev. 11(2):124-127.

Pruss-Ustun A, Fewtrell L, Landrigan PJ, Ayuso-Mateos JL (2004). Lead Exposure, pages 1495 – 1552 In: Ezzati, M., A.D. Lopez, A. Rodgers, and C.J.L. Murray. Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors. World Health Organization, Geneva.

Schwartz J (1992). Low-level lead exposure and children's IQ: meta-analysis and search for threshold. Environ. Res. 65:42-55.

Sciarillo WG, Alexander G, Farrell KP (1992). Lead exposure and child behavior. Am. J. Public Health 82(10):1356-60.

Silveira MLA, Alleoni LRF, Guilherme LR (2003). Biosolids and heavy metals in soils. Sci. Agric. 60(4):793-806.

Tinga KL (1998). Cultural practice of the Midzichenda at crossroads: Divination, healing, witchcraft and the statutory Law. APP. 55:173-184.

Todd AC, Wetmur JG, Moline JM, Godbold JH, Levin SM, Landrigan PJ (1996). Unraveling the chronic toxicity of lead: an essential priority for environmental health. Environ. Health Perspect. 104 Suppl 1:141-6.

UNESCO (2005). Policy Review Report: Early Childhood Care and Education in Kenya. UNESCO/OECD Early Childhood Policy Review Project. The Section for Early Childhood and Inclusive Education, Division of Basic Education, UNESCO Education Sector.

WHO (1993). Guidelines for drinking-water quality, second edition, volume 1 World Health Organization (WHO), 21993.

WHO (2010). Childhood lead poisoning. World Health Organization (WHO), 2010.