Contamination of Underground Water by Heavy Metals: A Case Study of Boreholes around Sony Sugar Factory, Awendo

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Abstract: ***Water is very essential and always gets contaminated when the industrial effluents are released into the environment untreated. The concentration levels of heavy metals in underground water in residential areas around Sony Sugar factory was determine. Water from different boreholes around the company were collected twice a month and tested for heavy metals (Zn, Cr, Cu, Cd, Pb, Co and Ni). The tests were carried out in the University of Eldoret chemistry laboratories using AAS. The concentration of Pb was the highest among the metals studied ranging between 3.843mg/L - 4.098mg/L. This range exceeds the World health organisation recommended limits for humanitarian and general life habitat. Fe concentrations from the samples were ranging from 2.066 - 2.843mg/L. This concentration is lying within the desirable limits as recommended by WHO, thus does not cause any health risks to the environment. Zn and Cu concentration were all within the recommended concentration levels. With the exception of Pb which had high concentration levels. The concentration of other heavy metals around the company's underground water were found to be within the tolerable limits and does not impose any health risk to the environment. To reduce the concentration of lead, the company should implement the use of unleaded fuel to reduce environmental pollution. Health screening should be carried out regularly on the workers and farmers around the company to check for some symptoms and effect of heavy metals particularly lead.***

Keywords: Heavy metals, boreholes, underground water, remediation, Sony Sugar

1. Introduction

The current pattern of industrial activity alters the natural flow of materials and introduces novel chemicals into the environment. The rates at which effluents are discharged into the environment have been on the increase as a result of urbanization and industrialization. Human, industrial, mining and military activities as well as farming and waste practices have contaminated large areas with high concentrations of organic and inorganic pollutants. In addition to their negative effects on ecosystems and other natural resources, these sites pose a great danger to public health, because pollutants can enter food through agricultural products or leach into drinking water (Qing - Hong *et al*., 2012). The heavy metals are also transported into receiving waters through industrial effluents, sewage and storm water from major cities and agricultural farms.

Some elements such as Iron, Copper, Zinc, Manganese, Cobalt, Chromium, Nickel and Silicon are believed to be essential for plant and animal life. But heavy metals, such as Mercury, Lead, Cadmium, and Arsenic, although useful in industrial and agricultural technology, can be highly toxic to human life and have been found to be associated with a variety of diseases in man (Shankar *et al*., 2014). Lead affects blood cells resulting to low haemoglobin levels and hence causes anaemia, (WHO 2011) and it inhibits enzymes. Cadmium disrupts the normal functioning of enzymes through inhibition, and in human beings cadmium accumulates in ovaries, kidneys and liver hence result to kidney and liver damage. Methyl mercury and its derivatives are very toxic to living organisms. They damage all tissues, including the brain. Mercury is used to clean vats in paper mills and then washed into neighbouring bodies of water, thermometer, fungicides and in small scale gold mining operations. In Nyanza Province of western Kenya mercury is used to amalgamate gold at Macalder (Davies *et al*., 2009**)**. Inorganic mercury compounds are methylated by bacteria in aquatic environments and thereby their toxicity and biomagnification is increased, (Alghobar and Suresha 2017). Despite the relatively low concentrations of the trace metals, their ability to bioaccumulate through the food chain is emphasized.

1.1 Remediation of heavy metals

Metals are among the most representative inorganic pollutants in the environment in general and in soil in particular. The fate and transport of a metal in soil and groundwater depend extensively on the chemical form and speciation of the metal (Ali *et al*., 2016; Aschale *et al.*, 2016). A particular contaminated site may require a combination of procedures to allow the optimum remediation for the prevailing conditions. Biological, physical, and chemical technologies may be used in conjunction with one another to reduce the contamination to a safe and acceptable level. Conventional methods to remediate metal - contaminated soils can be used at highly contaminated sites but are not applicable to large areas. A variety of reactions may take place affecting the metals speciation and mobility, including acid/base, oxidation/reduction, precipitation/dissolution, sorption, or ion exchange. Precipitation, sorption, and ion exchange reactions can delay the migration of metals in groundwater. The rate and extent of these reactions will depend on factors such as pH, complexation with other dissolved constituents, sorption and ion exchange capacity of the geological materials, and organic matter content (Khan, 2004). According to Gavrilescu (2009) established and emerging technologies for mobilization, followed by treatment, or immobilization of metals are followed as:

1) Soil washing: Established technology for the ex situ separation of fine grained soils.
2) Soil flushing: Developing technology for treating metals in situ by flushing contaminated soils with solutions designed to recover the contaminants.
3) Solidification and stabilization: Mature technologies for ex situ immobilization of contaminated soil.
4) Electrokinetics: Developing emerging technologies in which an electric field is applied to soil either to stabilize the contaminants in situ or to mobilize them for extraction near the electrodes.
5) In situ redox process: A developing method for treating metals at depths at which digging the trenches required for barrier technologies is impractical The technology involves injection of chemical reductants into the ground to create reducing conditions that lead to immobilization of certain metals and radionuclides.
6) Vitrification: Developing technology for immobilizing metal contaminants in the subsurface and using electricity to melt the waste and surrounding soil in place, then cooling it to formglass.
7) Land filling: These remediation methods require high energy input and expensive machinery (Schmidt, 2003). At the same time they destroy soil structure and decrease soil productivity. Conventional methods used for reclamation of metal contaminated soils, are costly to install and operate. Typically, the enormous costs of remediation using these technologies are a significant obstacle to corrective action. Termed as "phytoremediation", this technique engages plants to cleanse the nature, as plants can absorb, accumulate and detoxify contaminants of their substrates (soil, water and air) through physical, chemical or biological processes (Jabeen *et al*., 2009). The looming expenses of conventional technologies is one reason, phytoremediation has gained increased consideration as a possible alternative, or at least a complement, to standard engineering - based methods for site restoration.

1.2 Phytoremediation,

Also called green remediation, botanoremediation, agro remediation, or vegetative remediation, the *in situ* remediation strategy that uses vegetation and associated microbiota, soil amendments, and agronomic techniques to remove, contain, or render environmental contaminants harmless (Chen *et al*., 2013). Phytoremediation is energy efficient, aesthetically pleasing method of remediating sites with low to - moderate levels of contamination, and it can be used in conjunction with other more traditional remedial methods as a finishing step to the remedial process. Plants have shown the capacity to withstand relatively high concentration of contaminants without toxic effects. It utilizes inherent agronomic traits of plants like high biomass, extensive root systems, and stress tolerance.

1.3 Rhizofiltration

This technique relies on the ability of plant roots to take up and sequester metal contaminants or excess nutrients from the aqueous growth substrates (waste - water streams, nutrient–recycling systems). It remediates metals like Pb, Cd, Ni, Cu, Cr, V and radionucliides (U, Cs, Sr). The ideal plants should produce significant amounts of root biomass or root surface area, be able to accumulate and tolerate significant amounts of target metals, involve easy handling and a low maintenance cost, and has a minimum of secondary waste that requires disposal.

1.4 Phytostabilization

In this technique, plants are used to transform toxic soil metals to less toxic forms, which are not removed from the soil. Phytostabilization stabilizes wastes, prevents exposure pathways via wind and water erosion, provides a hydraulic control that suppresses vertical migration of contaminants into ground water and immobilizes the contaminants physically and chemically by root sorption and chemical fixation with various soil amendments. It requires plants that are able to grow in contaminated soil with their roots growing into the contamination zone, and alter the biological, chemical or physical conditions in the soil that convert the toxic forms of metal to less toxic ones (Nagajyoti *et al*., 2010).

1.5 Phytovolatization:

This is the use of plants to absorb heavy metal contaminants and convert them to volatile, less toxic chemical species through. Some metals, like As, Hg and Se, may exist as gaseous species in the environment. Some plants growing in high Se media, for example, *Arabidopsis thaliana* and *Brassica juncea*, produce volatile Se in the form of dimethylselenide and dimethyldiselenide.

1.6 Phytodegradatio (Phytotransformation)

In this method, plants degrade organic pollutants by metabolic processes and using the rhizospheric associations between plants and soil microorganisms. Plant enzymes that metabolize contaminants may be released into the rhizosphere, where they may play active role in transformation of contaminants. Enzymes, like dehalogenase, nitroreductase, peroxidase, laccase and nitrilase, have been discovered in plant sediments and soils. Organic compounds such as munitions, chlorinated solvents, herbicides and insecticides and the inorganic nutrients can be degraded by this technology.

2. Materials and Methods

2.1 Collection of Samples

The water samples were collected thrice from seven different locations within the factory surrounding. These include the bore holes around the residential area and a sample from River Kuja, which flows by the factory. Sample from River Kuja was taken 5 metres from the factories effluent point. The samples were collected into 2 litre bottles and transported to university of Eldoret University chemistry laboratory for analysis.

2.2 Analysis of Heavy Metals

Once samples reached the laboratory, they were preserved with solution of concentrated nitric acid. The samples were then digested with concentrated $3HNO_3$: HCl.

Atomic absorption spectrophotometer (AAS) was used for the determination of the heavy metals. Data analysis included statistical summaries (mean and standard error values at each sampling site.

3. Results and Discussion

Table 3.1: Heavy metal concentrations in underground water around Sony Sugar Company

Sample	Cu	Pb	Mn	Fe	Zn
S1	0.090	4.098	0.314	2.843	0.542
S2	0.092	3.843	0.305	2.066	0.378
S3	0.093	3.901	0.316	2.314	0.417
S4	0.094	3.910	0.317	2.004	0.398
S5	0.092	4.090	0.320	2.411	0.422
S6	0.096	4.106	0.322	2.252	0.415

The table above gives heavy metal concentrations in underground water around Sony Sugar Company from six sampling points.

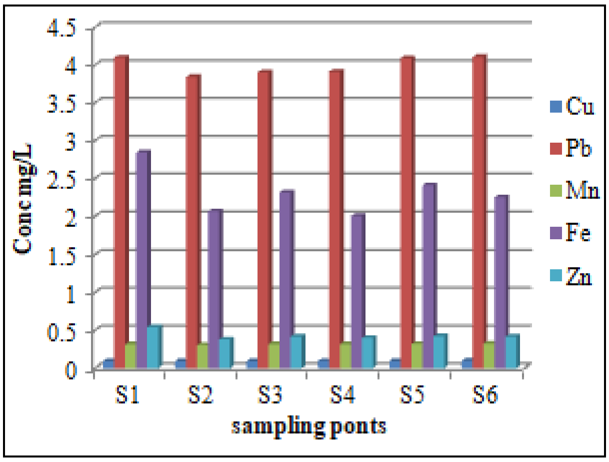

Figure 3.1: Heavy metal concentrations in underground water around Sony Sugar Company

Zn concentration was ranging from 0.378 mg/L to 0.542 mg/L. This range is within the required world health organisation maximum level. According to world health Organisation, tolerable concentration range is 1.0mg/L to 3.0mg/L. This implies it does not impose any health hazard to the environment. In comparison to Zn levels reported by Leung *et al.* (2006), the concentrations recorded for this study were lower because of the differences in the sampling sites and the activities carried around. Sample S1 contained the highest level of Zn among the samples studied. High levels of Zn can also influence the activity of microorganisms and earthworms thereby retarding the breakdown of organic matter.

Iron was found to have a concentration of between 2.066mg/L - 2.843mg/L across all samples S1 to S6. This concentration was within the required limit of world health organisation ranging from 1.0 to 3.0mg/L. The concentration of iron was slightly high. Manganese concentration was 0.305 - 0.322mg/L, copper concentration was 0.090mg/L - 0.096mg/L. All were within tolerable limits. The outstanding concentration was that of lead with a concentration of 3.843 - 4.098. This is above the tolerable limit and poses a health hazard to the environment. This high concentration could be due to the high number of automobiles around the factory using leaded petrol. The Pb concentrations recorded from this study were generally higher than the Pb concentrations reported by Leung *et al.*, (2006). This could also be due to the differences in the electronic product part recycled, the intensive nature of the activities and the method used.

4. Conclusion and Recommendation

4.1. Conclusion

The study established the quality and potability of underground waters for human consumption around the company. The concentrations of heavy metals around the company's underground waters were found to be desirable and do not impose any health hazard to the environment. However, the increased levels of lead (Pb) could potentially become toxic to microorganisms. It can lead to decreased litter decomposition and nitrogen fixation, less efficient nutrient cycling and impaired enzyme synthesis.

4.2. Recommendation

To reduce the concentration of lead, the company should implement the use of unleaded fuel to reduce environmental pollution. Health screening should be carried out regularly on the workers and farmers around the company to check for some symptoms and effect of heavy metals. There is also need to establish functional waste disposal mechanisms in the area with sanitation inspectors recruited with enactment of sanitary bye - laws. The factory should set up effluents treatment plants and should remain effectively operational.

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