Trace Metals' Contamination of Stream Water and Irrigated Crop at Naraguta-Jos, Nigeria

Ahmed, S. I.[1]; Sabo. A.[2]; and Maleka, D. D.[2]
[1]Chemical Engineering Programme, and [2]Environmental Management Technology Programme, Abubakar Tafawa Balewa University, ATBU, Bauchi, Nigeria.
*Corresponding Author: alsaeedng@yahoo.com Tel:+2347039106868

Abstract

The concentrations of trace elements Chromium (Cr), Cadmium (Cd), and Lead (Pb) in stream water and irrigated crop Carrots (*Daucus carota sativa)* in Naraguta area of Jos were determined. The stream water was sampled at three different sites A, B and C which were about 200m apart along the stream. The *Daucus carota sativa* were sampled from a farm at the bank of the stream around Site C. The trace metals were analysed with Atomic Absorption Spectrophotometer (Buck Scientific 200A model). The mean concentrations of Cr, Cd and Pb in the stream water were between 0.008mg/l – 0.440mg/L, 0.002mg/L – 0.138mg/L and 0.000mg/L – 0.404mg/L for sites A, B, C. respectively. The concentrations of these metals in *Daucus carota sativa* collected at site C were Cr = 0.02mg/kg, Cd = 0.042mg/kg and Pb = 0.404mg/kg. The concentrations of the heavy metals in water and *Daucus carota sativa* in some of the sites were beyond threshold limits set by the Federal Environmental Protection Agency (FEPA) and the World Health Organization (WHO). Therefore, water and *Daucus Carota sativa* obtained from these sites were unsafe for human consumption as they pose serious health risks due to contamination with the metals. For environmental sustainability the management strategies suggested includes proper treatment of effluents discharged into the stream and adoption of good farming practices by farmers through proper soil amendment and selection of crop varieties with lower metal absorbability

Key words: Heavy metals, Water, Carrots, Limit, Naraguta

Introduction

Water pollution is defined as the direct alteration of the physical, thermal and biological properties of water in such a way as to create a hazard or potential hazard to health, safety and welfare of any living species (Pickering & Owen, 1996). Water pollution leads to deterioration of water quality which is also defined by temperature, amount and character of mineral particle, dissolved substance and organic matter content of a body of water in relation to its intended use (Skinner & Porter, 1987).

Water pollutants of concern include heavy metals which occur in low concentration in natural aquatic ecosystems. In recent times, however, the occurrence of such metals in excess of natural background level has become a problem of increasing public concern. The present situation has arisen as a result of anthropogenic sources' including mining activities, industrial and domestic effluents, urban storm-water run-offs, leaching of metals from garbage and solid wastes dump, among others (Sabo *et al*, 2008).

The danger of heavy metals is aggravated by their almost indefinite persistence in the environment. Due to their immutable nature and in contrast to many organic pollutants, which are biodegradable, heavy metals can remain in the environment for a long time (Garbisu and Alkota, 2001; Wade *et al*, 2004).

Trace metal contamination has profound negative consequences on the sustainability of environment. Water is one of the elements of natural environment and a vital resource to man without which the existence of man is impossible. When this resource is polluted it prevents it from performing its vital functions which include provision of drinking and bathing water, irrigation, food, fuel and energy. When polluted water is used for irrigation, the farm land and hence the produce is likely to be contaminated. Trace metal accumulation in the soil have high tendency of disrupting the delicate balance of the physico-chemical and biological processes, which are the basis of soil fertility (Amiya, *et al*. 2002). Pollution of soils by these metals may also inhibit microbial activities and decrease species diversity and population of soil living organisms (Pandeya and Singh, 2001). Due to these reasons therefore, polluted environment must be effectively managed to ensure environmental sustainability.

Sources of heavy metals include effluent from tanning industries. Every tanning process, with the exception of the crust finishing operation produces effluents. These effluents when discharged into neighbouring surface water could deteriorate the physical, chemical and biological properties of the receiving body (ISI 1977). Chemicals and toxic residues from tanneries can render the receiving water body unsafe for any domestic use and can cause groundwater pollution from land pollution due to high salt content and toxic components (WHO 1992). The most common tanning process nowadays is a combination of chrome salt (Chrome tanning) and usable vegetable extract (vegetable tanning). Chromium makes the hide resistant to bacteria. Some of the most problematic parameters in tanning effluent are the heavy metals especially chromium. A research conducted in Pakistan shows that effluent run-off from tanneries contain up to 0.30 mg/L of copper, 0.15mg/L of cadmium, 7.0 mg/L of zinc, 1.14 mg/L of nickel and 1.8mg/L of lead. Most of these levels were above the suggested standard for toxic substance concentrations in effluent (Kasmi, 1995).

The aim of this study was to assess the trace metal contamination of stream water and a vegetable crop, *Daucus carrota sativa* (Carrot) at Naraguta-Jos, Nigeria. The causes, effects and management strategies were also proffered as ways of ensuring environmental sustainability.

Materials Method

Study Area

Naraguta stream originates from Naraguta village at the outsketch of Jos city in North Central Nigeria. It is one of the tributaries of River Dilimi in Jos North Local Government Area of Plateau State. The plateau State is located between latitude $8^{o}30'$ and $10^{o}30'$N and longitude $8^{o}20'$ and $9^{o}30'$E, with a surface area of about 9,400 km^2. It has an average elevation of about 1,250 meters above sea level and stands at a height of about 600 meters above the surrounding plains (Eswaran *et al*, 1997). Naraguta stream receives among other pollutants, run-off and refuse from Naraguta village and also effluent discharged from a nearby tannery. The stream serves as a source of water for a variety of domestic activities in the area.

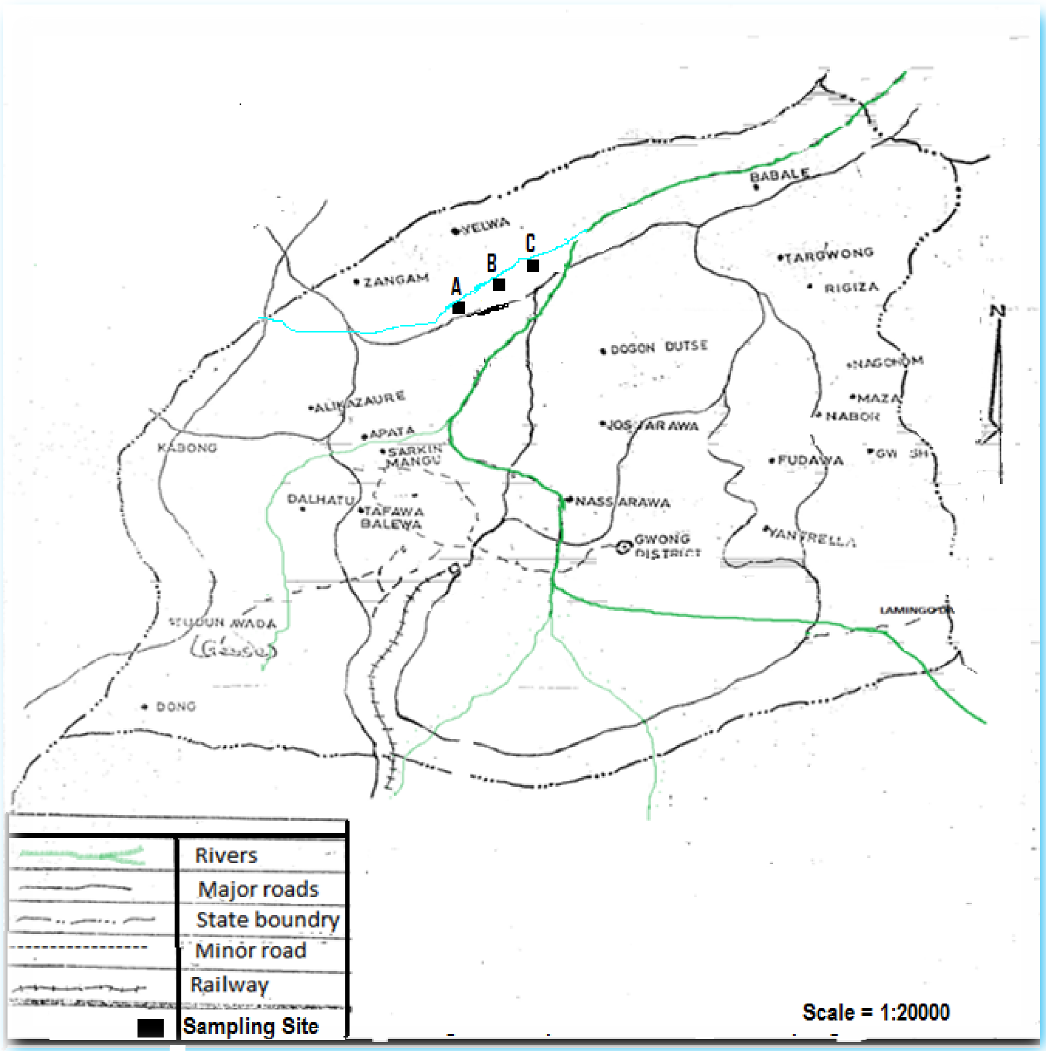

Figure 1. Map of Jos showing the study site.

Sample Collection

Samples of stream water and *Daucus carota sativa* from a nearby farm were collected in the month of November 2008 at Naraguta, Jos North Local Government Area of Plateau State. Water samples were collected from three (3) sampling sites designated as Sites A, B and C along the stream at about 200m apart. Site A is upstream; B is midstream and C downstream in relation to the effluent discharge point from the tannery. That is, sampling site B is the point where effluent from the tannery joins the stream. Five (5) samples of stream water were collected at each of the sampling sites mentioned above at 30cm below the surface using 1L Plastic bottles with screw caps, preserved appropriately. Five (5) samples of the *Daucus carota sativa* were randomly collected from a farmland in plastic bags previously cleaned with detergent and treated with 10% nitric acid. The farm is located at the downstream of the tannery, that is, around the sampling site C. All the specimens were taken in polythene bags and stored in deep freezer at 10^{o}C in the laboratory prior to analysis (Obasohan *et al*, 2007).

Laboratory Analysis

The *Daucus carota sativa* samples were allowed to defrost, grounded and then dried to constant weight in an oven at 105^oC. Water samples were not subjected to any further treatment and were sent directly for analysis using a Buck Scientific model 200A, Atomic Absorption Spectrophotometer (AAS) and the values obtained expressed in milligram per litre (mg/L) (Obasohan *et al*, 2007). 0.2g, each of the carrot samples were digested using 0.02M HNO_3 and HCl in the ratio 1:3 (aqua - regia) in a fume cupboard at 80^oC. AAS was used to analyze the digested carrot samples for heavy metals and the results expressed in mg/kg.

Results

Heavy metals in water

Table 1 shows the results of water analysis sampled from the stream at the three (3) sampling sites along Naraguta stream. The mean values of Cr and Cd recorded were highest (Cr = 0.44 mg/l and Cd = 0.138 mg/l) at sampling Site C, and lowest (Cr = 0.0.008 mg/l and Cd = 0.002 mg/l) at Site A. Also, Pb had its highest level at site B (1.566mg/L) and lowest value (0.00mg/L) at site A.

Table 1. The mean concentration of trace metals in water samples (n = 5)

	Heavy metal (mg/L)		
	Cr	Cd	Pb
SITE			
Site A			
Mean	0.008	0.002	ND
Standard Deviation.	*(0.008)*	*(0.004)*	*(ND)*
Site B			
Mean	0.040	0.022	1.566
Standard Deviation.	*(0.007)*	*(0.030)*	*(0.056)*
Site C			
Mean	0.440	0.138	0.404
Standard Deviation.	*(0.055)*	*(0.037)*	*(0.005)*
FEPA Limits (mg/l)	**0.050**	**0.003**	**0.010**

ND = Not Detected

Trace elements in carrot

Figure 1 shows a Bar Chart displaying the mean concentrations of the trace elements in carrot obtained at Site 3 (downstream to the effluent discharge point) and the threshold (standard) level approved by WHO. The mean concentration of Pb (0.404mg/kg) was the highest followed by Cd (0.042mg/kg) and the least was Cr with mean value of 0.02mg/kg.

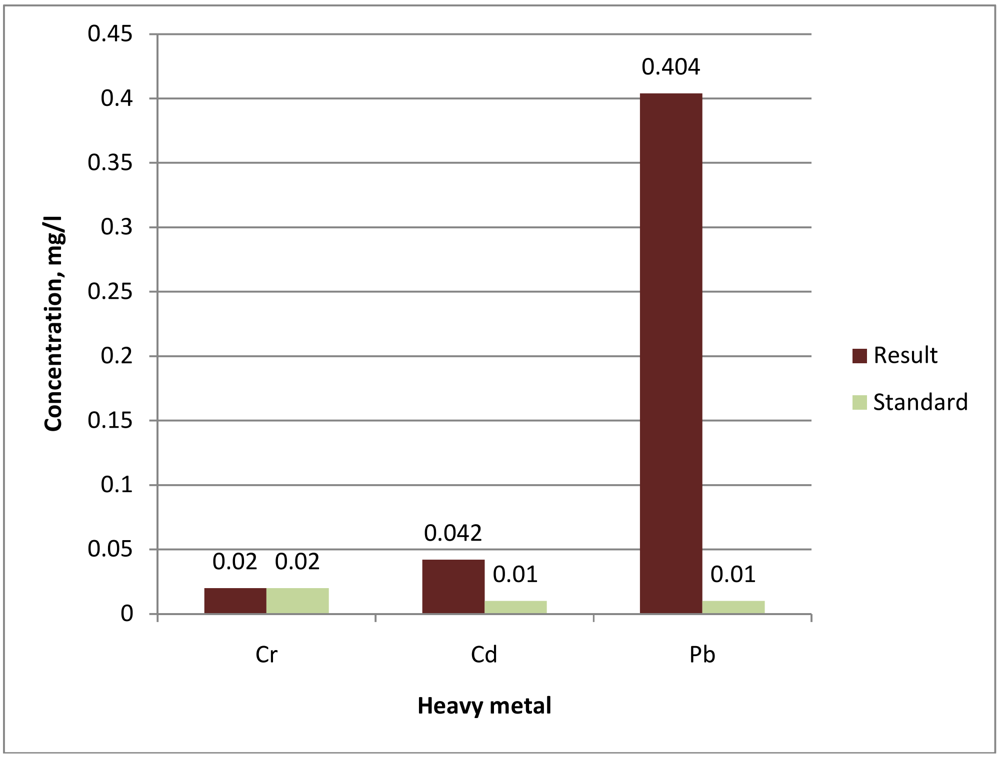

Figure 2. The mean trace metal concentrations in Carrots (mg/kg) obtained from Site C compared with WHO Standard (n = 5).

Discussion

All the trace elements (Cr, Cd and Pb) analyzed in this study were detected in the stream water and *Daucus carota sativa* from a farm irrigated with the stream water at Naraguta.
The study revealed that the mean concentration of Cr in water collected at all the sampling sites were within the threshold limit by Federal Environmental Protection Agency (FEPA, 1999) except for Site C where the mean value was 0.44 mg/L compared to FEPA limit of 0.05 mg/L. was recorded. The mean Cd concentrations at Sites B and C were 0.022 mg/L and 0.138 mg/l respectively which were all above FEPA limit (0.003 mg/L). The mean Cd concentration, at Site A is however, within the limit. In the same vein, Pb mean concentrations at Sites B, and C were 1.566 mg/L and 0.404 mg/L respectively which were all above FEPA limit (0.010 mg/L). This is in contrast to the situation at site A in which the Pb concentration is below detection limit (no value was recorded).

Figure 1, revealed that Cr concentration (0.02mg/kg) was within the WHO limit. However, Cd and Pb concentrations were above the limit. Cd mean concentration was 0.042 mg/kg against the WHO limit of 0.01 mg/kg while Pb mean concentration was 0.404 mg/kg against WHO limit of 0.01 mg/kg. The off-limit values for Cd and Pb are expected since the carrot farm was irrigated with the stream water found to contain high levels of the same trace metals.

Causes and Effects of the Contamination

The contamination of the stream is likely due to effluent discharge from a tannery

industry and uncontrolled solid waste and run-off discharged into the stream.
Research conducted on several tannery industries in Pakistan show that their effluents contain heavy metals such as cadmium, Cd, lead Pb, nickel Ni etc. which were above safe limit (Kasmi, 1995). The discharge of such effluents into water bodies could therefore be a source of trace metal contamination.

Solid waste and run-off that are discharged into the stream indiscriminately are also sources of contamination with such metals. Municipal solid waste contains a variety of materials which contain trace metals. An investigation on municipal waste site in Yola, Nigeria showed that the soil of the dump site was contaminated with trace metals, Pb and Co (Saddiq *et al,* 2007). Run-offs also carry solid and liquid wastes such as lubricating oil, and used oil from automobile repair workshop which contain trace elements

The usage of the stream water at the polluted sites-B and C and the consumption of the carrots could be detrimental to human health in many ways. It has effects on the central nervous system, hematological system, renal and neuromuscular system which can lead to diseases such as cancer, lead colic disease and palsy disease, anemia, basophilic stippling (damaging of red blood cells), insomnia, decline fertility of men through sperm damage and increase in high blood pressure. Other possible effects include kidney damage, miscarriages and subtle abortions, diminished learning abilities in children and some behavioral disruptions such as aggression, impulsive behavior and hyperactivity. High concentration of the metal pollutants could also bring about the death of different species of aquatic plants which are good sources of oxygen and food for other aquatic animals. Thus there could be a general disruption of the ecological balance of nature within the ecosystem. It can in addition affect the functioning of the nearby irrigated soil, and in consequence the general food chain (OECD, 1990, W.H.O, 1992 and Yuse *et al*, 1983).

The usage of the contaminated water at site C for irrigation is responsible for the contamination of the carrots. The crop accumulated the trace metals in their tissues from the soil/water. The contamination of the stream is an indication that the industrial activities in the area are not necessarily being carried out in a sustainable manner. If such trend continues the good relationship existing between the industry and the host community may be eroded leading to animosity which may result into conflict. The regulatory authorities may also impose sanctions on the industry which may lead to its closure. This may create unemployment and ultimately increase in social vices in the community.

Management Strategies

In order to have a sustainable environment, management of the contaminated sites is vital. This can be achieved by (1) the participation of the government through Plateau State Environmental Protection Agency (PEPA) and other similar regulatory bodies and (2) making sure that all effluents that originate from nearby industries are subjected to effective treatments before they are discharged into the stream.

The PEPA and other relevant authorities can help the situation first by sensitizing the inhabitants on the importance of proper environmental practices. This will discourage them from dumping their waste into the stream. The authorities should also help in proper solid waste disposal methods by providing the communities with facilities such as incinerators and sanitary landfills. This will help in improving the aesthetic value of the environment and eliminate or reduce volume of waste being discharged into the stream which was identified among possible sources of pollution. The authority should also ensure that the industries around the area abides by the “Guidelines and Standards for Environmental Pollution Control” set by the Federal Ministry of Environment. This will curb the pollution caused by the effluent discharged into the stream. The government can also help by encouraging the farmers to adopt good agricultural practices in which the soil will be amended with certain materials (eg application of manure) so that even if soil contains high concentration of such trace metals, very little will be available for uptake by the crops.

On the other hand, for a sustainable industrial activity, the tannery industry must operate in an environmental friendly manner. To achieve a high level of environmental protection that could encourage industrial innovation and increased competitiveness, the following are suggested:

- the use of the 3Rs of environmental management, that is, Reduction, Reuse and Recycling of materials in the manufacturing process (Pauli, 1998)
- the final effluent should be treated effectively.
- the trace metals can also be treated by adsorption process using activated clay.

When these are done effectively, a more sustainable environment can be achieved

Conclusion and Recommendations

The data obtained from this study revealed that the water samples obtained from Naraguta Stream, Jos from Sites B and C (representing midstream and downstream respectively in relation to effluent discharge) were contaminated with hazardous metals (Cr, Cd and Pb). It also revealed that the *Daucus carota sativa* obtained from the farm around Site C is contaminated with Cd and Pb, as values were found to be above safe limits set by FEPA and WHO. It is important to note that the carrots have accumulated the contaminants from the stream water used for irrigating the carrot farm. This is similar to the findings of Sabo *et al* (2008) in which the muscle of *C.gariepinus* (Mudfish) accumulated hazardous heavy metals from the water of River Gongola. This has health and socio-economic effects which are caused mainly by indiscriminate discharge of tannery effluent and solid wastes into the stream water. For a environmental sustainability therefore, it was suggested that (1) the tannery industry should reduce level of effluent discharged into the stream by adopting more environment friendly approaches to waste management and (2) the government, through its institutions such as PEPA should monitor discharges into the stream, encourage the inhabitants of Naraguta and its environs on good environmental practices and to remediate the polluted carrot farm.

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