Journal of Scientific Research & Reports
2(2): 513-521, 2013; Article no. JSRR.2013.003

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Determination of Heavy Metals in Soil Samples of Selected Sawmills in Ekiti State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ASS designed the study, read and approved the final manuscript, author OGI manage the literature search, wrote the protocol, author AOS wrote the first draft of the manuscript, perform the statistical analysis. Author AKE collect the sample, managed the experimental process and analyses of the study performed the spectroscopy analysis. All authors read and approved the final manuscript.

Research Article

Received 24th March 2013
Accepted 17th July 2013
Published 1st August 2013

ABSTRACT

The study investigated the impact of sawmill activities in the accumulation of heavy metals in soil around some selected sawmill industries in Ekiti State. Soil samples were collected at 5cm and 20cm depth; at interval of 10m, 20m, 30m, and 40m away from the site. The results obtained showed that the concentration of most of the metals at the different sites were almost similar, depicting that these metals are probably of natural origin with mild contribution from anthropogenic source, since the concentration of the metals decreased with distance from the various site. All metals monitored were detected in the soil samples and the values obtained were within the acceptable International Standards for soil/sediment.

Keywords: Heavy metals; soil; sawmill.

1. INTRODUCTION

The demand for wood products all over the world for industrial and domestic purposes has necessitated the establishment of sawmill industries (both small and large scale) in some

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strategic locations, most especially in the tropic areas. Since the production of wood requires relatively little energy for forestry and wood processing, it can be defined as low energy building materials. Ekiti state is located between latitudes 7º25^{I} and 80º5^{I}N and between longitudes 4º45^{I} and 5º46^{I}E. The state is endowed with abundant natural resources, with its forest holding valuable wood species such as iroko, opepe, mahogany, aphara (black and white), obeche, araba, and teak. Although the sawmill industry in Ekiti State has provided employment for large portion of her work force (both skilled and unskilled labourers) and has also contributed greatly to the internal generated revenue, a large portion of the forest has not been exploited on account of its remoteness. In developing countries like Nigeria, improved road accessibility enhances transportation of logs to sawmill for further processes. Fungicides and insecticides may be used in land-based log storage area if the logs will be stored for a long time until further processing. The major chemicals used in the wood processing industry are creosote, copper, chromium, arsenic (CCA) and pentachlorophenol (PCP). Soil contamination problem with one or more of these chemicals can often be expected at wood preservation site, particularly at old sites [1]. Infact, the chemicals used for wood preservation are chosen for several reasons, one being that they are toxic to micro-organisms and fungi which degrade the wood. Meanwhile, the toxicity is not specific for these organisms, thus these chemicals can cause serious problems when spread or release to the environment. Jang et al. [2] reported that during risk assessment, three different routes of exposure are typically considered: direct human exposure (ingestion, inhalation and dermal absorption), leaching to ground water, and ecological risk. All the three exposure routes can be relevant in relation to wood preservation sites. At wood preservation sites, extremely high concentration of Cu, Cr and As can be found, concentrations as high as 20mg/kg soil were reported from impregnation plant [3]. In agricultural soils, the anthropogenic input of trace metals can be enhanced by chemical applications such as fertilizers, herbicides and pesticides as well as applications of animal manure and sewage [4,5]. Machines and other auxiliary equipment used by sawmill operators in Ekiti State are powered by diesel or gasoline generator due to constant power outage. These activities send heavy metals into the air and are subsequently deposited into nearby soils which are absorbed by plants [6]. Heavy metals frequently reported in literature with regards to potential hazards and occurrences in contaminated soils are Cd, Cr, Pb, Zn, Fe and Cu [6,7]. Emission from heavy traffic was reported to contain Lead, Cadmium, Zinc and Nickel which are present in fuel as anti-knock agent [8,9]. The objective of this study is to evaluate the levels of some selected heavy metals in the soil samples around some selected sawmill industries in Ekiti State in order to assess the influence of sawmill activities on agricultural soils.

2. MATERIALS AND METHODS

2.1 Sampling and Sample Preservation

Representative soil samples were collected at sawmill sites from five different sawmills within Ekiti State. The sawmill sites were selected across the three senatorial districts in Ekiti State. Two of the sawmill sites Ifelodun and Falex are located away from the major road while Lannydot, Eyeloja and Fiyinfoluwa sawmill are located along major road. The samples were collected at intervals of 10m, 20m, 30m, and 40m away from the center of the sites at soil depth of 5cm and 20cm respectively. All the samples collected were sundried, sieved and stored in labeled polythene bags for analysis.

2.2 Sample Analysis

0.5g of dried homogenized powdered soil samples was weighed and digested in a Teflon beaker with a mixture of HNO_3, $HClO_4$ and HF in the ratio 4:1:4 respectively [10]. The mixture was placed on a hot plate for three hours at 85ºC, the digest was filtered into 100ml standard flask and made up to mark with deionized water. The resultant solution was analysed for the interested heavy metals using atomic absorption spectrophotometer (AAS, Buck Scientific Model 210). All the data were replicate of three reading.

3. RESULTS AND DISCUSSION

The average concentration of heavy metals in soil samples collected at selected sawmills sites are presented in Tables 1-5. All the metals investigated were found to be present in the soil samples. Coefficient of variation values for most examined metals revealed no significant difference among sampling points. This might be due to the fact that the waste generated by the sawmill industries are almost the same in composition. The levels (mg/kg) of Co, Cr, Mn, Pb, Cd, Cu, Fe, Ni and Zn at various sampling points from all the sites ranged from 0.40-1.69, 0.68-3.34, 0.24-1.74, 0.28-7.32, 0.07-0.47, 0.76-3.54, 5.58-18.67, 0.06-0.30, 9.19-3.58 respectively. With the exception of elevated levels of Fe at Eyeloja (8.87-18.67mg/kg), Fiyinfoluwa (13.24-16.18mg/kg), and Pb (1.31-7.32mg/kg) at Fiyinfoluwa sites, the concentrations of the other metals were almost similar regardless the nature of the activities taking place in each sawmill, thus suggesting that the metals with similar trend were probably of natural origin with mild contribution from anthropogenic source. Metals such as Cd, Cu, Pb and Zn have been reported with high tendency to binding tenaciously to organic matter contained in the soil. Hence, the organic matter of soil is known to play a major role in determining the bioavailability of heavy metals [11,12].

The elevated concentration level of lead (Pb), in Fiyinfoluwa Sawmill (Table 5) might be attributed to the traffic volume and its proximity to highway, that is, deposition from the automobile exhaust fumes since it has been reported that Nigeria gasoline is usually leaded[10] ,similar observation was reported by Ene et al. [13] on soil sample in Romania. Also, there is other small furniture making industries located close to the mill. They all depend on generator for operation. All this put together contributed to the elevated level of (Pb). This metal is undesirable to humans because of its hazardous nature. It is one of the most significant pollutants of heavy metals absorbed through ingestion of food, water and inhalation [14]. A notable serious effect of lead toxicity is its tetratogenic effect. Lead poisoning also causes inhibition of the synthesis of haemoglobin, dysfunctions in kidney, joints and damage to the central nervous system (CNS), most especially the organic form of Pb [14,15,16,17]. Its absorption in the body is mostly enhanced by Ca and Zn deficiencies. The values of Pb observed in Fiyinfoluwa (1.31-7.32mg/kg) were lower compared to average Pb level of 63.69±27.31mg/kg reported for Osogbo [18], 15.28-76.92µg/g for Kaduna [19] 58.56 – 342.67 µg/g for Maiduguri [20], 11.00 – 32.00mg/kg for Owerri [21] in Nigeria and other place outside Nigeria like 167±330 mg/kg in Tyne-side, Uk [22]. The value Obtained for Pb in this study was in the range (1.59-12.10 µg/g) reported for major streets in Jos [23], 0.25-4.24µg/g for Lagos-Badagry express way [24] while it was higher than 0.02-0.23 for Lagos [25] and 0.04-0.21µg/g for Botswana [26].

The consistently high load of iron recorded in all the sites is not surprising considering the fact that iron is one of the constituents (alloy) of the saws used in sawmill operations or wood processing. The wear and tears of the saws and other metal equipment used might have contributed to the concentration of this metal when compared with other metals in this research work. Moreover, it had been earlier stated by a good number of researchers that iron occurs in high proportion in Nigeria soil, implying that the concentration is contributed from both anthropogenic and crustal origin. The presence of iron in soils and plants is desirable [27] since it is one of the metals that are essential to human biochemical processes, for example haemoglobin in the human blood system contains iron which aids blood formation [28].

Similar observation was recorded for iron and lead concentrations in soil samples from sawmill sites in Sapele [29]. The Value of Zn (9.19-3.58mg/kg) obtained is higher than all other metals investigated except Fe, but lower than 25.68± 4.67mg/kg reported for 10m for road side soil in Osogbo [18]. The mean concentration of Zn is within the recommended limit in daily dietary allowance [30].The magnitude of mean concentration of Pb, Zn, and Cu are in agreement with values obtained in the street dust of Istanbul [31]. The concentration of copper in all the examined sites was moderately high when compared with some of the investigated metals. The Cu contents in this study are within the normal range given in literature for soil in Europe [32]. The value of Cu (0.76-3.54mg/kg) obtained is similar to 2.44 and 4.21mg/kg reported for fertilizer blending companies by Haramaiet al., [33] in their study of heavy metal levels in industrial estate of Bauchi, Nigeria. The concentration of this metal might be connected to the deposition of the chemicals used in the wood preservation on the receiving soil. The value of Cd (0.07-0.47mg/kg) obtained could be compared with 0.45±0.12mg/kg reported for soil samples from high traffic area [18] and 0.35mg/kg reported for roadside topsoil in Artic catchments, Northern Europe [34] however Cd was non essential element of human health with high biological toxicity which mainly accumulate in surface soil [35] (its concentration should be monitored. The concentration of Co and Ni content were low when compared with mean values reported by Peris et al., [36] in their study.

The apparent diminishing of heavy metals concentration away from the sawmill site operational point almost certainly suggests possible inputs from the sawmill operation to the metal content in the investigated environment, thereby, confirming the dust waste as metal sink and potential source of soil contamination. Also observed was increased metal load at the 5 cm depth compared to the concentration at the 20cm depth. This implies that all the metals are moderately leached underground by probably contribution from soil erosion. This is supported by the fact that under anthropogenic enrichment the maximum content of pollution is observed in the surface layer of the soil [37]. However, the levels of all the metals were within the permissible limits for metals in soil/sediment [38,39]. The level of Pb and Cd contents in Fiyinfoluwa Sawmill shows that the soil around this mill is moderately polluted. The level of the metals presents no significant exposure risk but, preventive measures are necessary to decrease the risk of heavy metal contamination of plants which are consumed by human beings and animals. Recommendations for agricultural policy on polluted lands are of great importance. Appropriate plants selection is one of the most promising methods of minimizing heavy metal transfer from soil to plants. In this case, non-edible crops and those relatively tolerant (cabbage, tomato) to the influence of heavy metals are preferred. In a moderately polluted land (Fiyinfoluwa Sawmill), it is advisable to restrict farming to species which are more resistant to pollutants, where uptake of pollutants by plant would not produce any risk for consumers' health. Sea foods and fish have also been found to have high levels of cadmium, organic mercury and arsenic [10]. For those eating significant amount of fish, the level can be monitored by direct food testing or stool test for current exposure levels. Air emissions control should be given priority in sawmills because of their contribution to a number of global and local environmental effects, such as global warming, acid rain, ozone layer depletion and photochemical smog.

Table 1. Mean metal concentration (mg/kg) in soil samples: Lanny dot sawmill (Ado-Ekiti)

Sample code	Co	Ni	Cu	Zn	Pb	Mn	Cd	Fe	Cr
A_{11}	1.19	0.12	1.46	5.33	1.65	1.03	0.28	9.67	1.30
A_{12}*	0.85	0.10	1.30	4.93	1.47	0.89	0.24	9.34	1.16
A_{21}	1.06	0.10	1.21	5.08	1.37	0.94	0.25	8.32	1.08
A_{22}*	0.77	0.08	1.03	4.16	1.16	0.81	0.22	8.16	0.92
A_{31}	0.83	0.08	1.01	4.54	1.14	0.75	0.20	8.14	0.90
A_{32}*	0.50	0.08	0.98	3.94	1.10	0.49	0.13	7.36	0.87
A_{41}	0.63	0.07	0.89	4.11	0.94	0.70	0.19	7.24	0.79
A_{42}*	0.40	0.06	0.76	3.91	0.86	0.57	0.15	6.58	0.68
Mean	0.78	0.09	1.08	4.50	1.21	0.77	0.21	8.10	0.96
S.D	0.25	0.02	0.21	0.52	0.25	0.17	0.05	0.98	0.23
C.V	32.00	25.00	20.00	12.00	21.00	22.00	23.00	12.00	24.00

*S.D. = Standard Deviation, C.V = Coefficient of Variation, * = soil samples at 20cm depth*
A_{11}, A_{21}, A_{31}, A_{41} = soil samples at 5cm depth

Table 2. Mean metal concentration (mg/kg) in soil samples: Falex sawmill (Ido-Ekiti)

Sample code	Co	Ni	Cu	Zn	Pb	Mn	Cd	Fe	Cr
B_{11}	1.18	0.16	1.96	6.47	2.22	1.10	0.30	10.66	1.75
B_{12}*	1.14	0.14	1.79	6.14	2.02	1.03	0.28	9.88	1.59
B_{21}	1.08	0.13	1.61	5.92	1.82	1.05	0.29	10.70	1.44
B_{22}*	0.87	0.12	1.51	5.03	1.71	0.87	0.24	9.79	1.35
B_{31}	0.81	0.11	1.41	4.85	1.32	0.81	0.22	8.23	1.26
B_{32}*	0.77	0.08	1.01	4.06	1.14	0.74	0.20	7.91	0.90
B_{41}	0.76	0.09	1.09	3.76	1.23	0.65	0.18	7.28	0.97
B_{42}*	0.62	0.06	0.79	3.58	0.89	0.42	0.11	5.58	0.70
Mean	0.90	0.11	1.40	4.98	1.54	0.83	0.23	8.77	1.25
S.D	0.19	0.03	0.38	1.05	0.44	0.22	0.06	1.70	0.34
C.V	21.00	28.00	27.00	21.00	28.00	26.00	27.00	19.00	27.00

*S.D. = Standard Deviation, C.V = Coefficient of Variation, * = Soil samples at 20cm depth*
B_{11}, B_{21}, B_{31}, B_{41} = soil samples at 5cm depth

Table 3. Mean metal concentration (mg/kg) in soil samples: Ifelodun sawmill (Ikole-Ekiti)

Sample code	Co	Ni	Cu	Zn	Pb	Mn	Cd	Fe	Cr
C_{11}	0.80	0.17	2.11	6.30	2.38	0.93	0.25	12.30	1.88
C_{12}*	0.60	0.15	1.89	5.97	2.14	0.85	0.23	11.99	1.69
C_{21}	0.58	0.16	2.02	5.52	2.05	0.81	0.22	11.15	1.80
C_{22}*	0.52	0.14	1.72	5.06	1.95	0.80	0.22	10.57	1.54
C_{31}	0.57	0.13	1.58	5.03	1.78	0.67	0.18	10.46	1.41
C_{32}*	0.41	0.11	1.36	4.82	1.54	0.53	0.14	9.67	1.22
C_{41}	0.55	0.10	1.29	4.90	1.46	0.49	0.12	9.00	1.16
C_{42}*	0.39	0.07	0.88	4.45	0.99	0.45	0.12	8.17	0.79
Mean	0.55	0.13	1.61	5.26	1.79	0.69	0.19	10.41	1.44
S.D	0.12	0.03	0.39	0.58	0.42	0.17	0.04	1.33	0.34
C.V	21.00	25.00	24.00	11.00	23.00	25.00	23.00	13.00	24.00

*S.D. = Standard Deviation, C.V = Coefficient of Variation, * = Soil Samples at 20cm depth*
C_{11}, C_{21}, C_{31}, C_{41} = soil samples at 5cm depth

Table 4. Mean metal concentration (mg/kg) in soil samples: Eyeloja sawmill (Ijero-Ekiti)

Sample code	Co	Ni	Cu	Zn	Pb	Mn	Cd	Fe	Cr
D_{11}	1.22	0.21	2.61	6.78	2.41	1.15	0.28	18.67	2.33
D_{12}*	1.18	0.17	2.11	6.85	2.38	1.00	0.27	13.17	1.88
D_{21}	1.33	0.18	2.27	6.73	2.56	0.94	0.25	12.29	2.02
D_{22}*	1.31	0.15	1.89	6.66	2.14	0.93	0.25	11.89	1.69
D_{31}	1.31	0.18	2.22	6.47	2.51	0.93	0.25	11.36	1.98
D_{32}*	1.02	0.16	1.97	5.76	2.23	0.75	0.20	10.71	1.76
D_{41}	1.08	0.16	1.96	6.24	2.22	0.51	0.14	9.50	1.75
D_{42}*	0.99	0.14	1.71	5.92	1.94	0.24	0.07	8.87	1.53
Mean	1.18	0.17	2.09	6.43	2.30	0.81	0.21	12.06	1.87
S.D	0.13	0.02	0.26	0.39	0.19	0.39	0.07	2.83	0.23
C.V	11.00	11.00	12.00	6.00	8.00	49.00	32.00	24.00	12.00

*S.D. = Standard Deviation, C.V = Coefficient of Variation, * = Soil Samples at 20cm depth*
D_{11}, D_{21}, D_{31}, D_{41} = soil samples at 5cm depth

Table 5. Mean metal concentration (mg/kg) in soil samples: Fiyinfoluwa sawmill (Ikere-Ekiti)

Sample code	Co	Ni	Cu	Zn	Pb	Mn	Cd	Fe	Cr
E_{11}	1.69	0.16	2.06	9.19	7.32	1.74	0.47	14.70	1.84
E_{12}*	1.50	0.28	3.54	8.89	6.00	1.39	0.38	13.47	3.16
E_{21}	1.34	0.25	3.08	8.48	6.48	1.14	0.31	14.93	2.75
E_{22}*	1.33	0.27	3.35	8.36	4.78	1.00	0.27	13.91	2.99
E_{31}	1.31	0.30	3.75	7.89	5.23	0.97	0.26	14.26	3.34
E_{32}*	1.28	0.19	2.41	7.82	2.72	0.87	0.24	13.24	2.15
E_{41}	1.31	0.19	2.36	8.27	2.67	0.75	0.20	16.18	2.11
E_{42}*	0.99	0.09	1.16	7.72	1.31	0.50	0.13	15.09	1.04
Mean	1.35	0.22	2.71	8.33	4.56	1.05	0.28	14.47	2.42
S.D	0.19	0.07	0.80	0.49	1.98	0.36	0.10	0.91	0.72
C.V	14.00	31.00	29.00	6.00	43.00	34.00	34.00	6.00	31.00

*S.D. = Standard Deviation, C.V = Coefficient of Variation, * = Soil samples at 20cm depth*
E_{11}, E_{21}, E_{31}, E_{41} = soil samples at 5cm depth

4. CONCLUSION

Assessment of soil metals (Co, Ni, Cu, Zn, Pb, Mn, Cd, Fe and Cr) from selected sawmill sites in Ekiti State was made in comparison with other previous study of heavy metals in soil. The relatively low average content of the metals investigated in this study present insignificant exposure risks. This does not ruled out the possibility of increase in concentration of this metals with time, since, the extent of heavy metal pollution varies with age. The concentration of the heavy metal levels in the soil suggests that these metals are of natural origin with contribution from anthropogenic influences. The level of Pb and Cd contents in Fiyinfoluwa Sawmill shows that the soil around this sawmill is moderately polluted. Hence, the cumulative effect through bio-accumulation might be of concern in future, thus calling for urgent attention on regular monitoring of the sawmill activities and its influence on the surrounding environment. Government, both state and local should design emission standards to regulate emission of particulate matters in form of wood dust and volatile organic compounds. This will provide environmental requirements that apply to sawmill industry. Sawmills should be located at least 500 feet from any "sensitive receptors" which include neighbours, place, this include businesses, residences, schools, recreation centres. Environmental protection agencies should help local governments in sharing information; conducting publicity and education on the danger of heavy metal pollution in sawmill industry.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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