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Trace Metal Dispersion in Soil from Auto-Mechanic Village to Urban Residential Areas in Owerri, Nigeria

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Abstract

Due to poor waste management in mechanic villages (MVs), average metal concentration (mgkg^{-1}) is Pb 1162±572; Mn 864±531; Cu 385±202; Fe 49259±4770; Cd 20±13; Zn 824±190; and Ni 40±35, causing ecological and public health risks in parts of Nigeria. Average metal dispersion (mgkg-1/m) from MVs to residential areas was estimated at 9.2 for Pb; 6.7 for Mn; 6.1 for Zn; 1.5 for Cu; 197 for Fe; 0.3 for Ni; and 0.04 for Cd. This represents a mobility order of Fe>Pb>Mn>Zn>Cu>Ni>Cd, and a pollution order of Pb>Ni>Mn>Zn>Fe>Cu>Cd. MV advantages as a capacity building, and in poverty alleviation notwithstanding, its practice must be environmentally friendly.

Keywords: metal to depth and distance ratios; dispersion rate; soil pollution; sustainability of mechanic villages.

1. Introduction

A mechanic village (MV) may be several hectares of land allocated to automobile mechanics, strictly for motor vehicle services within urban vicinity. This paper assesses the depth and distance dispersion of selected trace metals namely: Pb, Mn, Fe, Cu, Cd, Zn, and Ni within the near surface soil profiles of the Nekede and Orji mechanic villages (MVs) within Owerri metropolis in the Imo River basin Nigeria (Figure 1). It discusses the impacts of these metals on the immediate environments, and the needs for mechanic villages to be environmentally friendly. A secondary objective was to find out a safe control distance of farming that can be applicable to mechanic villages sited on sandy soil. It is essential to alert citizens on the present and future impacts of these contaminated sites to the immediate environments about the possible toxicity of farm products, and pollution of water. Nwachukwu [1] stated that poor living environment in many developing countries are connected with lack of awareness and environmental education.

This might cause significant ecological impacts depending on the degree, depth and distance of distribution of metal contaminants in soil. Liu et al. [2] observed that heavy metal concentration in soils is usually high near the

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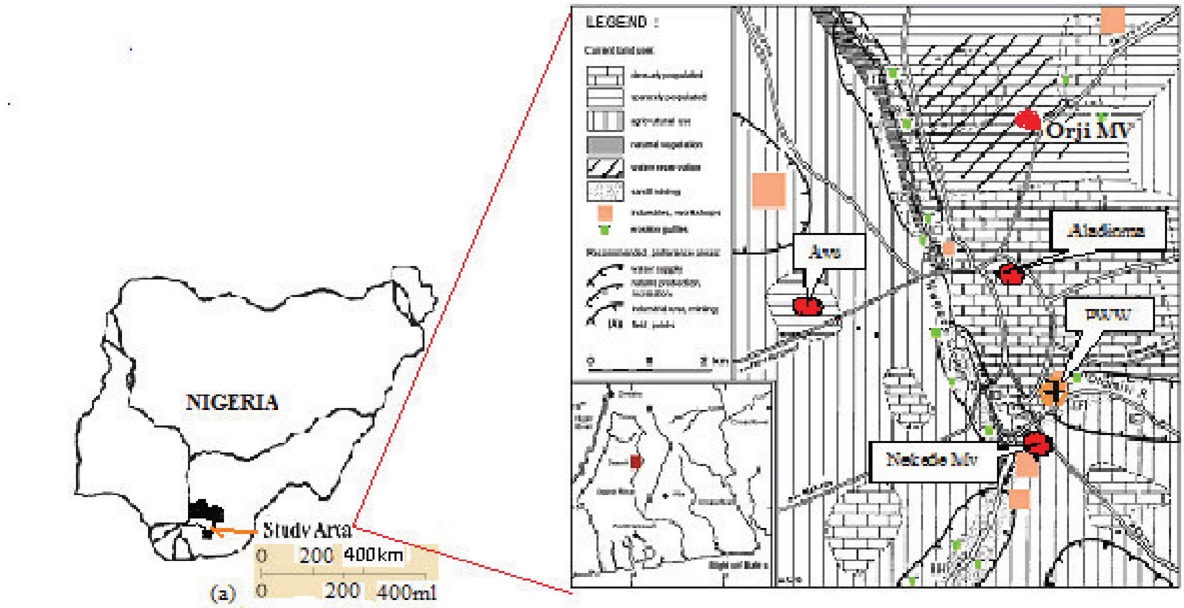
sources, and decline with both distance and depth due to physical dilution and increasing limits in mobility.



1a **1b**

Figure 1: 1a. Map of Nigeria showing Imo River basin. 1b: Land use map of the Owerri urban showing the three contaminated sites, the public water works (PWW), and traces of erosion sites amended after [3].

Depth of dispersion accounts for the tendency to groundwater pollution. Though the threat posed by trace metals to human health and the environment is dependent on their speciation in the soil solution rather than the total concentration [4]. High concentrations of trace metals in soil, soil microbial community composition and microbial growth are recognized under both field and laboratory conditions [5]. Soil plays a significant role in waste disposal such as disposal of sewage and solid wastes on soil. Irrigation, application of sewage sludge and fertilizers designed to counter failure of soil may end up contaminating the soil. Odukoya and Bamgbose [6], [7, 8, 9, 10] have all discussed cases of metal contamination of soil due to poor automobile waste management in different parts of Nigeria. These studies concentrated on single automobile workshops; abandoned or reclaimed auto workshops, and auto-waste dumps in mechanic villages. These are isolated cases, and the results will be significantly different from that of a mechanic village with hundreds of auto-workshops practicing for over 25 years such as the Nekede and the Orji MV. Heavy metals toxicity arises from the fact that the metal contaminants are not decomposable into nontoxic substances, and plants and animals have great difficulties in getting rid of the metals when exposed to their body. In a tropical rain forest belt of the study area consisting of coastal plain sandy soil, gully erosion near MVs is common phenomenon as shown in figure 2, which increases the mobility of trace metals in soil profiles. Gullies are steep-sided ravines that cut susceptible shallow slope materials by the surface water from heavy rain falls. Once started, they offer avenues for easy down slope movement of water and particles (including metallic ions) from later storms. Surface runoffs and soil solution erodes sides and floor of each gully, making it wider and deeper, causing short resident time, greater depth and distance dispersion of metal contaminants in the affected soil profile. Landslides, slumps, and related activities on the gully walls also contribute to move slope materials (Figure 2). Igbokwe et al [11] estimated soil loss due to gully erosion in the area as 9.23-9.93 tons/ha/y based on the analysis of satellite imagery. The head of the gully advances upslope, enlarging the gully system. Unchecked progress of the gullies results in bad land topography and destroying the ecology, land use and economy of the affected areas [12].

2. Materials and methods of assessments

Owerri urban is in the lower part of the Imo River basin (Figure 1a) lying fairly central to the eastern region of

Nigeria. It has a relatively limited land mass (about 11,420 km^2) with high population growth rate and density (about 230 – 1400 person km^{-2}), and home of about eleven million people based on the 2005 Nigeria census. The basin consists mainly of Imo and Abia states population. The basin is partly low-lying towards the Niger Delta (southern flank), moderately high plain to the north, and has arable land. Geographically, the basin is a 140 km north-south sedimentary syncline. The Nekede mechanic village (MV) is about 130 acres, and the Orji MV is about 101 acres, both located at interval at interval less than 3km in the sandy Benin Formation. The two MV soil is said to be under moderate to excessive pollution by trace metals, and shows evidence of poor land use [13]. The Nekede and Orji MVs are close to the city residential areas, at great slope and high elevation relative to the surroundings as shown in the satellite imagery [14], (Figure 3). Both Avu and the Aladinma waste dumps are located at relatively low elevations with respect to the MVs and at far distances to one other. The isolated locations of these sites as shown in the satellite imagery (Figure 3) confirm the absence of contaminants transport and interactions across the sites or effluents between sites.

Figure 2: Typical gully type in the Imo River basin

Figure 3: Satellite imagery of Owerri urban, showing the proximity of Nekede MV, the Avu, and the Aladinma MSWDs to the urban center and residential areas. Google Earth image © 2010, Coordinates: 5°28’27.32’’N 7°1’26.54’’E, Elevation 69 m

There are also no industrial or significant anthropogenic activities near the MV sites to contribute to the heavy metal concentration measurable in soil within and around the MV. The high elevation differentials of the MVs with the surrounding is most responsible for dispersion of trace metals from the MVs, but does not allow transport and loading of metal contaminants from any surrounding source. A possible source of additional metal contaminants to the MV soil may be the two nearby highways: the Aba Road passing the front of the Nekede MV and the Okigwe Road passing the front of the Orji MV (Figure 3). It is therefore certified that the trace metal enrichment of soil within and around the two MVs are due to automobile wastes or as a result of the poor management of occupational wastes of mechanics in the MVs. The Nekede MV is dangerously sited at the left bank of the Otamiri River. The Otamiri River is the primary source of domestic water to the city of Owerri. An element of safety is the city waterworks located at about 1km in the upstream section of the river from the MV (Figure 3). The downstream portion of the river from the MV towards Nekede and Ihiagwa is probably polluted with trace metals. Heavy metal analysis of water and sediment samples from this segment of the river will be the target of future research. Ibe and Njemanze [15], and Ibe and Njoku [3], wrote on the non-metallic pollutants in the Otamiri River. They charged the pollution to poor land use and unguided human activities. The proliferation of shallow private and commercial wells (120-220 ft) around the MVs is of great concern to public health.

Soil samples were collected with respect to distance and depth, following the direction of natural drainage. Samples were taken at 0-15cm depth for the top layer, 15-30cm depth for the second layer, 30-45cm depth for the third layer, and longitudinal distances of 10, 50, 100 and 200m away from each site. All the soil samples were stored in clean brown polyethylene bags. Sampling procedure is as shown in figure 4. The composite samples, each derived from the three replicate samples were digested following the US Environmental Protection Agency (EPA) method 3050B.

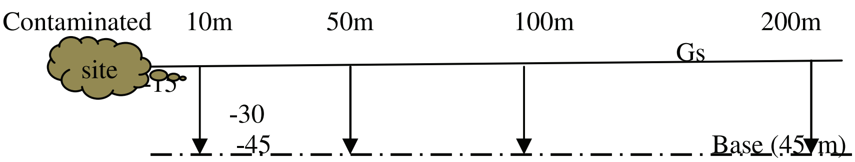


Figure 4: Soil sampling field procedure

The analysis was on a SOLAAR UNICAM 969 Atomic Absorption Spectrometer (AAS), at precision and accuracy better than 10% [16] and [17]). Trace metals dispersion and enrichment in soil profiles can be assessed by various methods, based on the available data, and interest of the study. Researchers usually consider concentration of the respective trace metals, infiltration rate or convective flux, moisture content, pH, and time. In a linear case, the flow equation affecting trace metal dispersion [18], equation 1 is:

$$Vc = V * 1/(1+R) \qquad (1)$$

where $\boldsymbol{vc}$ = convective flux; $\boldsymbol{v}$ = effective water flow velocity. $\boldsymbol{R} = q/\epsilon wc$, where $\boldsymbol{q} = kc$ *and* k = adsorption coefficient; ϵw = moisture content and c = metal concentration. One may consider the convective flux as the dominant component of the total flux [19].

2.1 Applicable statistical relations

In this study, metal depth ratio (MDR) equation 2, and metal distance ratio MDsR) equation 3, are used to assess the rate of metal dispersion. Metal dispersion rate (equation 4) was used to assess the degree of metal enrichment (DME), as a composite parameter to measure soil pollution in the three sites. Pollution factor was determined as a complementary parameter shown in equation 5. These are shown in equations 5-7, as follows:

$$\text{Metal-Depth Ratio (MDR)} = \frac{Mi}{Depth}\ \text{mgkg}^{-1}\text{cm}^{-1} \qquad (2)$$

$$\text{Metal-Distance Ratio (MDsR)} = \frac{Mi}{Distance}\ \text{mgkg}^{-1}\text{m}^{-1} \qquad (3)$$

Metal Dispersion Rate = $\frac{\frac{\Sigma(Mi)}{n} - B}{D(ave)}$ $\frac{\frac{\Sigma(Mi)}{n} - B}{D(ave)}$ mgkg-1/m (4)

Metal pollution factor = $\frac{Mi - B}{B}$ (5)

Where max and min are maximum and minimum values, *Mi* represents the concentration of the i^{th} metal pollutant in the MV, B is the background value, n represents the number of tests, while D(ave) is the average of measurement distance (90m).

2.2 Geophysical application

It was necessary to show safe distance to farming around a MV. Cultivation of crops and vegetables within and around MVs became a serious public health issue because of toxicity. To save cost and time, or for a preliminary survey of safe farming distance, electrical resistivity and elevation profiling was conducted across Orji MV towards drainage. The Orji MV was specifically considered due to availability of adequate traverse (line of measurements). The traverse used was free of obstacle, free of metallic objects, vehicles or traffic more than 20m from the line of traverse. All necessary precautions for electrical resistivity and GPS elevation mapping were duly considered. Without any other anthropogenic source of metal contaminants to the traverse, the team accepted the result of the resistivity profile as only influenced by metal dispersion from the MV, because of the poor occupational waste management. The low resistivity zone, which implied high conductive zone was mapped out, and discriminated from the entire profile as the most dreaded distance for safety of farm products. Apparent resistivity was obtained as shown in equation 8:

Apparent Resistivity (ρa) = $2\pi aR$ [20] (9)

Where a = Distance of electrode spacing, and **R** is the field resistance

3. Results and discussions

3.1 Analytical results

Analytical results of the soil samples (Table 1) show dispersion and collection of trace metals about the two sites. The order of relative abundance for the six metals (Fe exclusive) is as follows: Pb> Mn> Zn> Cu> Ni> Cd. This order of abundance is accordingly supported by the values of MDR and MDsR. The result further shows wide distribution of the metals in the three profile layers. The order of abundance varied with layer depth with Mn> Zn> Pb> Cu>>Ni in the surface layer (0-15 cm); Pb> Zn> Mn> Cu>>Ni in the middle layer (15-30 cm); Pb = Zn> Mn> Cu>>Ni in the last layer (30-45 cm). Generally there is no specific order of abundance with both depth and distance, but the metals show distribution with relative abundance that appears to be changing with distances.

Metals dispersion chart (Figure 5) shows Pb and Mn as having the greatest abundance, and widest dispersion. Pb has shown increasing abundance with depth, while Mn has fluctuating abundance with depth. With respect to distance, Mn shows increasing abundance with distance, while Pb has no specific order of abundance. Generally there is spatial abundance of all metals investigated, but Cu, Cd, Zn and Ni do not have specific order with depth and distance, yet Cd concentration is of serious environmental concerns. Both MDR and MDsR reveal that metal dispersion in soil from a point source may decrease or increase with both distance and depth in a discontinuous manner before the background level is reached. The chart (Figure 5) explains the spatial distribution of trace metals follow a similar trend with respect to depth and distance. The chart shows a continuous similar trend of loading in the two dimensions. The dispersion has not shown any significant decrease within the 200m distance and the 45cm depth studied. This implies that metal enrichment of soil does not immediately decrease with depth and distance from a point source, in a coastal plain sand environments of a tropical rain forest belt. The point of significant decrease in dispersion and storage varies with metal and locations because of many factors. These include rainfall intensity, drainage and slope, infiltration rates and local terrain features.

Table 1: Average metal concentration in soil (mg/kg) between the Nekede and the Orji mechanic villages

Distance (m)	**Depth (cm)**	**Pb**	**Mn**	**Cu**	**Fe**	**Cd**	**Zn**	**Ni**
10	0-15	250	607.15	323.35	50000	11.16	445.7	10.5
10	15-30	1108.35	1996.45	255.1	47500	22.5	967.15	16.86
10	30-45	516.65	412.5	583.5	47875	51.5	424.3	60.5
50	0-15	1550	694.65	236.65	56250	20.11	915.0	19.45
50	15-30	1433.35	410.7	326.65	60000	10.6	795.7	98.78
50	30-45	1341.64	505.35	373.35	46250	14.45	852.15	12.41
100	0-15	1933.35	1026.8	418.35	52500	39.6	981.45	36.0
100	15-30	1908.35	669.65	228.35	47500	21.0	877.15	14.625
100	30-45	1666.65	753.55	945.0	48675	10.43	944.3	84.125
200	0-15	641.65	708.95	368.35	46250	12.4	836.45	12.3
200	15-30	1066.65	1891	240.0	45000	20.0	962.85	14.6
200	30-45	525	692.85	325.0	43750	11.0	889.3	96.4
Computation of mean values								
90m	30cm	Pb	Mn	Cu	Fe	Cd	Zn	Ni
Mi (mg kg-1)		1162±572	864±531	385±202	49295±4770	20±13	824±190	40±35
MDR (mgkg^{-1}/ cm)		39	29	13	1643	0.7	27.5	1.3
MDsR (mgkg-1/m)		13	10	4.3	547	0.23	9.2	0.4
B (mg kg-1)		309	261	248	31582	17.2	274	11
Dispersion Rate (mg kg-1/m)		9.2	6.7	1.5	197	0.04	6.1	0.3
Pollution factor (Pf)		2.8	2.3	0.5	0.6	0.2	2.2	2.6

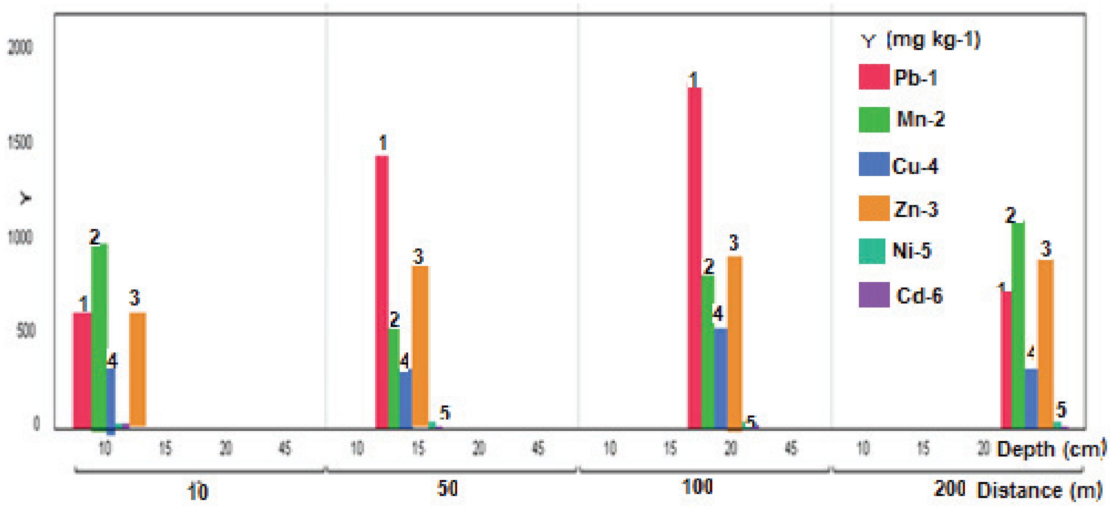


Figure 5: Sample chart illustrating the degree of metal dispersion with respect to distance and depth as average of metal enrichment (Mc-Bc) between Orji and Nekede mechanic villages. Y is the metal concentration.

Regression analysis also shows strong correlation (R^2 = 1.0) at 0.01 level, for both linear and quadratic curves, and 0.838 for the logarithmic. Considering MDR as independent variable, and MDsR as dependent variable, implies that trace metals dispersion or pollution distance of metals in soil will depend on the depth distribution. For example, infiltration rate of soil is high in the coastal plain sand of the study area, and terrain features and slope do not support rapid transport of contaminants on barren land, by the first few inch of rain. Then metal enrichment will tend to the order of depth than distance. On the other hand, if slope and terrain features are supportive of rapid transport of metal contaminants, the order of metal enrichment tends to distance than depth. Similarly, in a silty-clay soil environment with poor rate of infiltration, metal enrichment will tend to the order of distance. The regression linear fit equation of MDR and MDsR between the two sites is depth based, and represented in equation 9:

$$MDR = 0.0660937 + 2.9653498 * MDsR \quad RSquare\ 0.9994. \qquad (10)$$

This implies that trace metal dispersion or its enrichment in a sandy soil can be estimated at any point within the source and 200m away from source. This is applicable given some reference values such as metal concentration, slope, and drainage and rainfall intensity. Contour plots of metal concentration with depth and distance have been used to explain the dispersion trends of the four most abundant metal environmental pollutants (Pb, Mn, Cu, and Zn) discharged from mechanic villages.

Beside metal background values of the study area, the metal enrichment values were compared with average values of crustal metals as contained in [21], and [22] in Table 2. The result show that dispersion and storage levels for four metals were in excess. Average metal dispersion rate (mg kg-1/m) from the MVs was estimated at 9.2 for Pb, 6.7 for Mn, 6.1 for Zn, 1.5 for Cu, 197 for Fe, 0.3 for Ni, and 0.04 for Cd. The rate of dispersion varies with metals, and other dispersion factors are erosion, terrain features, soil characteristics and workshop density. The very high dispersion rate for Fe is anticipated because of its preferred use in building automobile chassis, and as the second most common crustal metal after Al. Fe is not considered risky to health, for its role in oxygen transport in blood, and for oxygen storage in the muscle, according to [23].

Table 2: Mean concentration of trace metals (ppm) compared with average crustal values

Trace Element	**Orji and Nekede MVs**	**Gao et al [21] 1999**	**EPA 6200 [22] (2008)**
Pb	1162 *	20	20
Mn	864 *	600	550
Cu	385 *	25	25
Zn	824 *	71	60
Cd	20	98	100
Ni	40*	20	19
Fe	49295 *	35000	26000

*Above crustal values

The contour plots suggest that metal dispersion from a contaminated point source varies with depth and distance. Šimunek et al [24], Carsel and Parrish [25] and Schaap et al. [26], have studied dispersion of trace metals in soil. They saw that during this process, trace metals undergo certain transformation among pools (solution phase, adsorbed phase, mineral phase, and organic phase) and constants that define solute transport. The applicable constants are the dissolution-precipitation rates, mineralization rate, the linear distribution coefficient between the solution phase and adsorbed phase, longitudinal dispersivity, and the molecular diffusion coefficient. These constants depend on the continuity of loading, and soil properties such as the soil bulk density and the hydraulic characteristics, all favorable at the study area.

3.2 Analysis of analytical results

Contour plots produced using the JMP 9.0 statistical software explains the distribution of Pb (Figure 6a) showing gradually increasing concentration 0-175m and depth of 0-35cm, then, followed by a gradual drop to the background. Figures 6b shows wide dispersion of Mn, largely retained within 0-50m and 150-200m distances, and within 15-30 cm depth. Figure 6c explains the spread and retention of Cu in the surface soil. It shows a continuous increase of Cu concentration from distance 0-100m and depth 0-45cm, followed by a decreasing trend to the background. Figures 6d show distribution of Zn, having increasing concentration with distance and at depths of 0-25cm. Lower depths 25-45cm shows a decreasing trend. Result of this study shows that concentrations of trace metals usually were greater in the middle (15-30cm) and the lower surface soil layers (30-45cm) than the surface 0-15cm layer. This may be caused by gradual leaching of metal ions to the soil lower layers due to high infiltration rate (18-23cm/h). It may also be caused by the high acidity (mean 5.8) and moisture (mean content 40%) around the sites, and heavy tropical rain (about 2400 mm/year) of the study area. The heavy rainfall put the metal ions in a continuous mobile state, and the resultant flooding will transport the ionic metals to greater distance away from the source. This movement is influenced by slope and terrain features. Noted terrain features include cavities, potholes and depressions forming storm water pools, and general surface roughness.

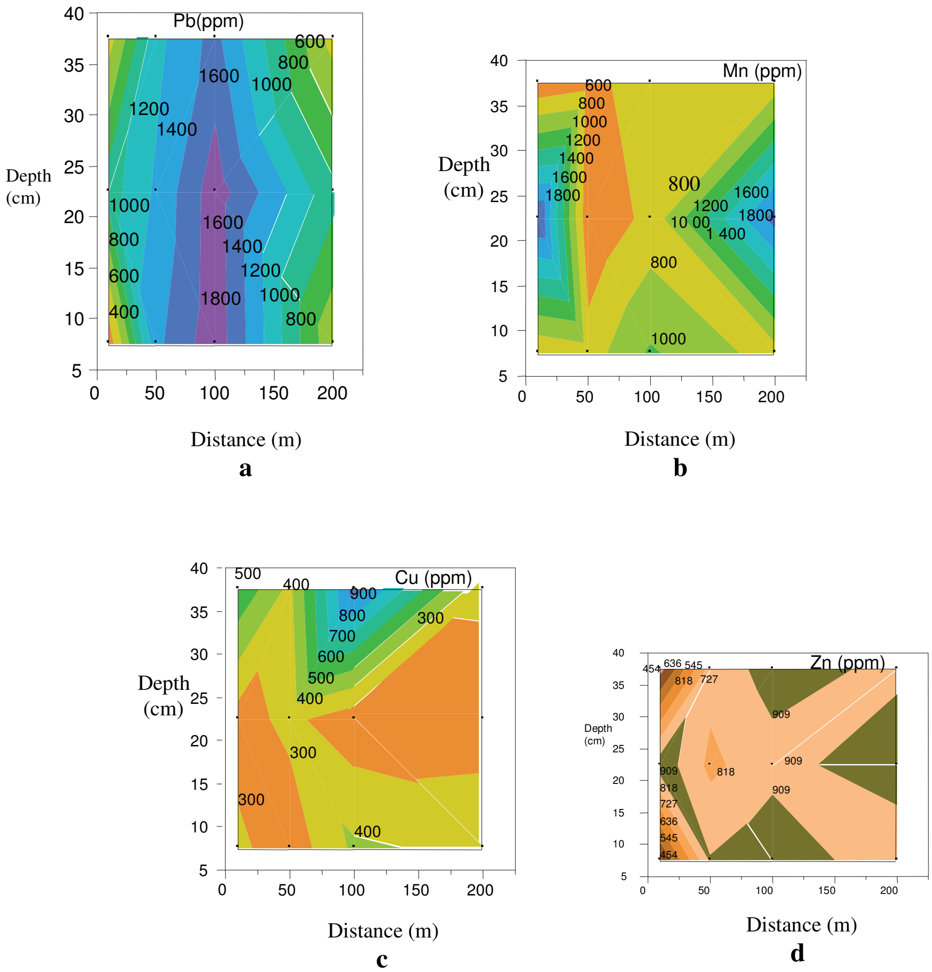


Figure 6a-d: Contour plots of Pb, Mn, Cu, and Zn dispersion from Orji and Nekede mechanic villages

Often sheet and gully erosion develop (Figure 2), resulting to greater transport of the metal contaminants to greater depths, shallow water wells, surface and groundwater respectively (Figure 7).The erosion profile (Figure 1b) runs southeast and southwest adjacent to the two MVs and the Otamiri River. The first few inches of rains may wash the surface soil layers of metallic ions, increasing dispersion, and reducing storage of the metal contaminants in the near surface. Gullies may range from few meters to hundreds of meters deep in the Imo River basin, enhancing dispersion to greater depths and distances. The most affected deposits are the poorly consolidated soil zones. The cleaner, more porous and weakly cemented sands are the most prone to gully advance, which increases directly with an increase in the proportion of grains, more than 1 mm in diameter [27]. The erosion menace now causing serious environmental concerns complicate the issue of soil metal pollution. This may account for the high concentration of Pb at lower layers (15-45cm) than at the surface layer in some of the measurement points.

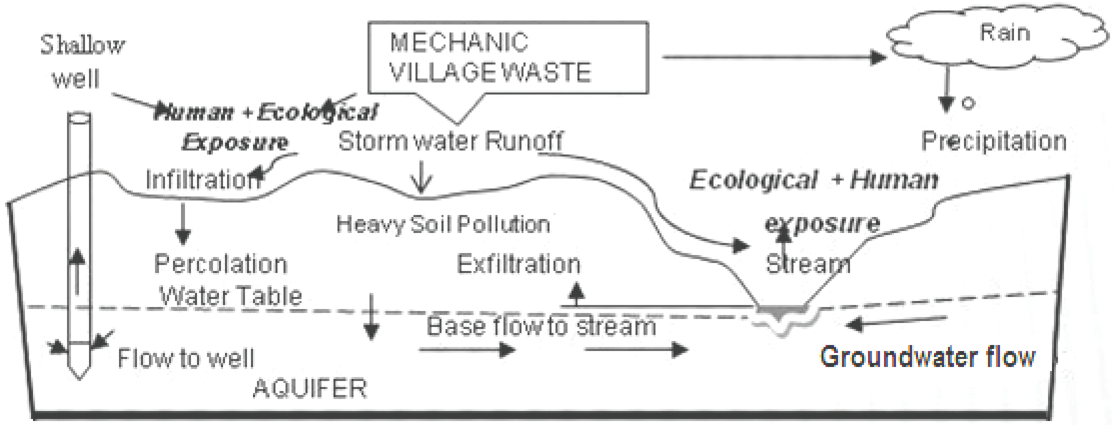


Figure 7: Metal Contaminants Fate and Transport in the MVs

Distance dispersion of Mn and Zn from the MVs also followed a similar trend by having greater concentrations at distances further away from the sites than close to the sites. Based on observations, the rate of metal enrichment of soil (loading rate) from a point source may not account for its concentration, because of variation in the resident time and storage. This variability among other causes may depend on the soil texture and grain size distribution. A declining order may be better defined only after a reference distance and depth to the background level is established. Particle size analysis of composite samples derived from three replicate samples collected from the two MVs show grain size ranging from 0.0625 mm – 2.0 mm. The most predominant range is 0.425 mm - 0.6 mm, with median (0.425mm) up to 27% of sample weight for depth 0-20 cm, and 17% of sample weight for depth 90-100 cm layer. An average clay-silt content of 20% was obtained of the soil, showing greater potentials for high infiltration rates.

Orji and Nekede communities are mainly farmers and they farm around the MVs respectively. Crops may store excess Pb and Mn in their tubers, fruits and vegetable since the farmers cultivate into the MVs and this may transfer to man on consumption (Figure 7). Figure 8a shows the result of electrical resistivity profiling across Orji MV, and Figure 8b is the elevation profile. Result of the resistivity show area of low resistivity as distinct from the resistivity responses within the MV. The low resistivity zone representing high conductivity corresponds to the low elevation zone shown in the elevation profile. It is expected that greater of the metal contaminants drained from the mechanic village accumulate in this zone, and represents the limit of significant dispersion. This interval was estimated as 350m from the MV, and established as a safe farming distance to Orji MV. This safe distance is applicable to Nekede MV and elsewhere, where drainage slope is 15-20% or increase with increased slope vice versa.

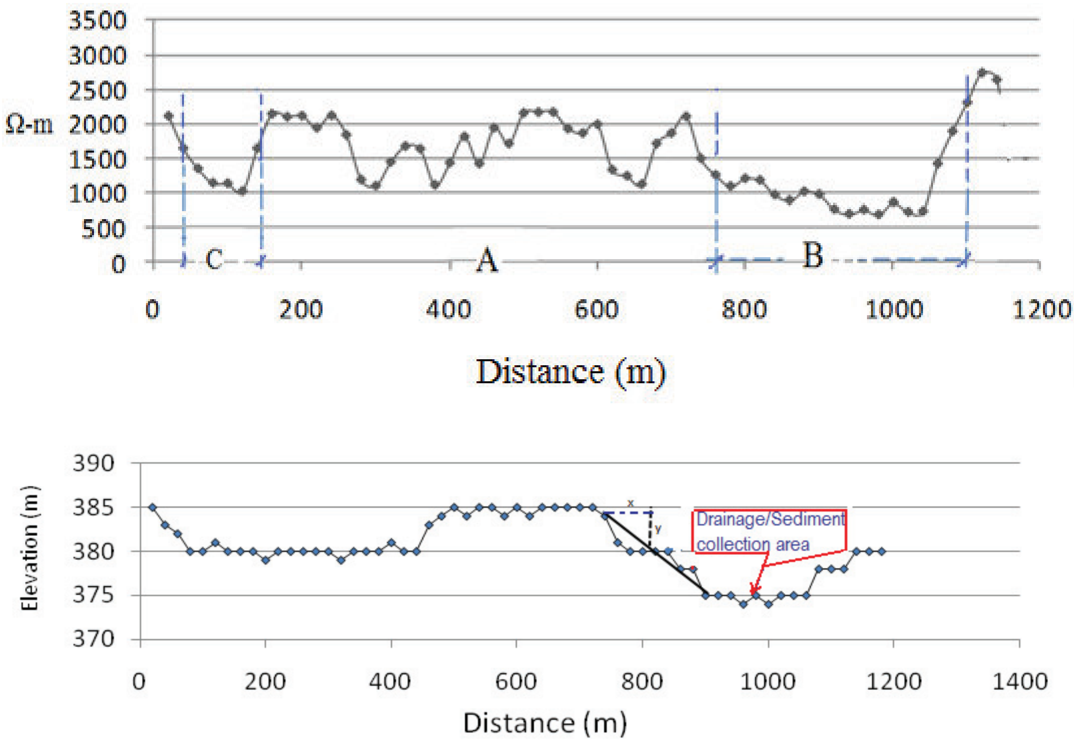


Figure 8: a. Orji mechanic village electrical resistivity profile. Distance B is the estimated safe distance (350m to the MV village operational area (A). Traverse in the direction of drainage (west-east); Coordinates: 5^{o} 31′ 15″ N, 7^{o} 02′ 22″ **b.** Elevation profile is in the same direction, and drainage collection area corresponds to the interval (B).

Excessive collection of Pb, Mn, Cu and Zn in the body poses health hazards. The result of the analysis shows that soil samples from the two MVs have high concentrations of Pb, Mn, Cu and Zn. Based on the [30], the maximum allowable limit (MAL) for Pb is 600 mg/kg, whereas the MVs have mean1162±572 for Pb. The Pb levels signify very serious ecological and public health risk. Result analysis confirms Pb with greater mobility and pollution factor around MVs. The MAL for Mn is 500mg/kg, and mean for Orji and Nekede MVs is 864±531. Result analysis confirms Mn with high mobility and high pollution factor in MV soil. There is high distribution of Cu in the MV soil, with average value of 385±202 mg/kg. This value exceeds the MAL 140 mg/kg of the [28]. This is attributed to automobile wastes containing electrical and electronic parts. Parts such as copper wires, electrodes and copper pipes and alloys from vehicles scraps littered for a long time gradually rust and leach into the soil, causing phytotoxicity. For example, [29], observed the toxicity of Cu to maize shoots as dependent on both labile Cu as well as free ionic Cu^{2+}. Crop vegetables planted around the MVs may become poisonous on consumption because of toxicity.

Result analysis indicates that Cu has less mobility and low pollution factor around mechanic villages. The high Fe concentration average (49295±4770 mg/kg), is anticipated. [30] have reported Fe concentration at range 10040-38600mg/kg in soil samples obtained from motor spare part market in Benin City, Nigeria. This market trade mainly on used spare parts which involve dismantling of parts from unserviceable vehicles with spillage and littering of the wastes. Heavy metal discharges from this market is expected to be less than that obtainable from a MV where continuous spillage of waste automobile fluids, and littering of automobile scrap metals occur. Research has shown that Fe however is not dangerous to health, because of its role in the transport of oxygen in the blood and in the mitochondria for heme synthesis [31], and [32]. The [28] standard for Fe in soil is 100mg/kg, which suggests that the MVs soil is already in excess Fe. Result analysis shows that Fe has high mobility, but with less pollution factor around MVs. The result further revealed that the MVs have dispersed Cd at mean (20±13 mg/kg), The [29] MAL for Cd is 3.00mg/kg, suggesting the MV soil to be enriched with severe to excessive Cd. Several studies however provided evidence of lung cancer and kidney disease due to exposure to Cd. Consuming farm products cultivated around MV sites may result in untold exposure to Cd. The high-level of Cd may be due to scrap metals, tire and tubes that litter. Uwagboe and Hymore [33] reported high Pb, Cd, Cu, and Zn concentrations in roadside soil, and attributed high Cd to the wear and tear of tire on the road, being also dependent on traffic density. However, Cd has low mobility and pollution factor in MVs. The MVs have high concentration of Zn, with a mean value of 824±190 mg/kg. The [28] MAL for Zn in soil is 300mg/kg, which implies that the MVs have dispersed excess Zn to its immediate environment that can cause high toxicity to farm products cultivated within and around the MV. Auto-spray and painting and other automobile wastes containing Zn may be responsible for the high Zn of the MV soil. Zn has intermediate mobility and pollution factor. Ni dispersion from the MVs was measured, and a mean value 40±35 mg/kg was obtained. The [28] MAL for nickel in soil is 75.00 mg/kg, which implies safe levels of Ni yet in the MV soil. Result of analysis suggests that Ni has low mobility but with high pollution factor.

4. Conclusions

Increasing the protection measures in the MV, and controlling waste discharges by the mechanics can reduce the environmental impacts of heavy metal dispersion from a MV. Greater dispersion rate does not necessarily imply greater pollution. Based on the estimated dispersion rates, the order of mobility for the seven metal is Fe>Pb>Mn>Zn>Cu>Ni>Cd, whereas pollution factor provides an order of Pb>Ni>Mn>Zn>Fe>Cu>Cd. Reducing the corrosion and erosion, and anthropogenic activities within and around the mechanic villages are equally essential. Erosion control around MVs is a priority to minimize dispersion of heavy metal contaminants to increasing the protection measures. It is necessary to restrict farming within and to MVs to a distance of 350m if slope is up to 15%, soil is sandy, and the prevailing high rainfall intensity. Generally, soil characteristics play major role in determining transport distance of contaminants, and safe farming distance. Rate of contaminant discharge as a function of workshop density and drainage slope are the major combination factors for safe farming distance. Regulating safe farming distance is necessary to minimize toxicity of farm products, yet this does not support sustainable land use, since the reserved portion of land could lie fallow or as waste to farmers. For a MV to be a sustainable urban infrastructure, its practice must be environmentally friendly. This study has shown the Nekede and the Orji MVs are not environmentally friendly. To be environmentally friendly, MVs must be sited off residential areas, off the local water ways, and off relatively high elevation and slope areas. MVs should be sited outside areas where water table is below 36.6m (120ft), or preferred in areas where topsoil is underlain by clay-shale bed. This study recommends relocation, soil remediation, and redevelopment of the two MVs. Future MVs must be selected based on proper site investigation, and defined in a 50-100 year urban development plan.

Environmentally friendly mechanic village (EFMV) idea most importantly integrates emission testing. It will provide the bases for the transfer of emission testing technology to developing countries; making the implementation and supervision easy for government. It integrates storm water treatment by the regular storm water best management practice or storm water BMPs [34]. EFMV integrates extended producer responsibility (EPR) for proper disposal or recycling of waste engine and transmission oil rather than spilling on the ground as now practiced. An understanding between the government owners of the MVs, the union of mechanics, and the major petroleum marketers (major gas stations) representing the producers may be reached. To simplify the EPR, major gas stations may be required to visit the mechanic villages probably monthly to collect the stored waste oil. In the same vein, the mechanics may be obliged to preserve to the last drop of their waste oil in government assigned waste oil containers in their respective workshops. EFMV should have deep domestic water wells or design protected shallow wells in its vicinity [35], to save citizens from exposure to heavy metals polluted water. In addition, groundwater quality monitoring wells must be provided within the vicinity for regular measurement of groundwater chemistry around MVs. EFMV should have toilet facilities, to protect shallow wells within and around MVs from coliform pollution [35]. They should be isolated from residential areas, and should have slope less than 1:10. EFMV should have tarred roads and drainage linked to storm water BMP. EFMV should have good health center and recreational facilities. It should have concrete floor workshops to prevent infiltration of accidental spills into the ground. It should also have fume or gas control roof chambers in specified workshops where spraying and painting and engine testing take place, to reduce air pollution in MVs. It is very necessary for EFMVs to integrate a continued education program for the mechanics [34]. This may include continuous skill development in fabrication of auto-parts, occupational health and safety, and waste management. As a capacity building, EFMV integrates poverty alleviation, being a large open skill acquisition center reachable to the ordinary school drop-out. EFMV will attract better investments, and more qualified and educated people into automobile maintenance, thereby improving the understanding of mechanics on the importance of proper management of their occupational wastes.

Future studies should find out the degree of heavy metal contamination of the Otamiri River based on the analysis of stream sediments downstream from the Nekede MV. There is need to investigate trace metal dispersion from MV 200-400m distance and 100- 400cm depth to confirm the 350m farm limit and the background by analytical method. There is need to investigate the level of air pollution in MVs. Study of local phyto remediation plants in the basin area sensitive to Pb, Mn, Cu, and Zn extraction is necessary. Toxicity of vegetables and tubers cultivated within and 500m from a mechanic village is a significant research. Design and cost estimates of a small, a medium, and a large model EFMV is also important, to facilitate local or foreign partnerships.

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