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THE IMPACT OF OPEN SOLID WASTE DUMP SITES ON SOIL QUALITY: A CASE STUDY OF UGWUAJI IN ENUGU

OGBUENE, Emeka Bright[1];
IGWEBUIKE, Eze Hilary[1]
and
AGUSIEGBE, Udochi Mercy[1]

[1]Centre For Environmental Management And Control (Cemac)
University Of Nigeria, Enugu Campus, Nigeria

ABSTRACT

The study considered the impact of open solid waste dumped on soil quality of Ugwuaji environment. The study involved the collection and laboratory analyses of eight soil samples from different locations in the solid waste dump site. The result of the laboratory analyses, indicates that the soil is presently contaminated with arsenic, cadmium, iron, mercury and lead poisoning. Principal Components Analysis (PCA), Factor analysis and ANOVA were applied to determine the correlation matrix, factor loadings and locational differences of each detected element in the soil. It was discovered that the correlation matrix of the detected pollutant had strong positive significance in the study. ANOVA result disclosed high F value of 21.168 and 99.954 % Significance in the area. The implication is that the waste dump has deteriorated the soil quality in Ugwuaji Environs. The study observed that Ugwuaji is one of the major suppliers of farm products such as yam, cassava, fruits and vegetables to the Enugu urban city. These farm products are likely to be contaminated with the poisonous element detected in the area, thus creating arrays of health impact to the people. In that light, it became expedient to apply waste source reduction, waste sorting, recovery, recycling, waste treatment practice, encourage Environmental Management System (EMS), Environmental Impact Assessment (EIA) and Environmental Impact Auditing in Ugwuaji and the entire Enugu State.

Keywords: Solid Waste, Soil Pollutants And Environmental Quality.

1. INTRODUCTION

Among the arrays of environmental problems besieging urban centres, solid waste stands out as a serious hazard in Enugu metropolis. The rapid population explosion, industrialization and continuous change in consumption pattern have compounded solid waste challenges in the area. The components and constituents of urban waste are hazardous and devastating. The hazardous nature of the waste is a serious threat to soil quality, health, water and the entire ecosystem. Ozone destruction, climate change and biodiversity deterioration is on the increase due to pollution. A visit to the dump site will actually validate the thoughts

(Ogbuene 2010). Mabogunje (1988) observes that ineffective solid waste management is caused by the poor attention being paid to physical planning in Nigeria cities. As a consequence, the relic of pre-industrial urbanization in these cities such as narrow, irregular and unplanned lanes and alleys hamper the efficient collection and disposal of solid waste in the cities.

Agukonroye (2005), Agunwamba (1998) and Ogbuene (2010) opined that several factors like inadequate infrastructure, weak environmental administration lop-side planning structure, among others are responsible for ineffective waste management services in Nigeria urban areas. For instance, about 83 percent of population in Nigerian cities dump refuse illegally in their neighborhood due to inadequate street or compound waste bins, thereby creating unsanitary condition. Recently, the flood disaster all over the urban cities in Nigeria is traced to blockages of drainage channels by unlawful dumping of refuse. This result to series of environmental hazards, health related issues, loss of life and properties. Sule (1981) ascribes the main cause of poor environmental condition in Nigerian cities to the improper solid waste management and lack of seriousness in enforcing solid waste disposal code.

Urbinato (1994) maintained that Pollution is the introduction of contaminants into an environment that causes instability, disorder, harm or discomfort to the ecosystem i.e. physical systems or living organisms. Pollution can take the form of chemical substances or energy, such as solid waste, noise, heat, or light. Fleming and Knorr (2006), established that about 400 million metric tons of hazardous wastes are generated each year. The United States alone produces about 250 million metric tons. Americans constitute less than 5% of the world's population, but produce roughly 25% of the world's CO_2, and generate approximately 30% of world's waste. In 2007, China has overtaken the United States as the world's biggest producer of CO_2. This constitutes a serious threat to soil, health quality, biodiversity and the entire ecosystem. Okosun, (2011) opined that many of the Nigerian cities are now characterized by uncontrolled roadside dumping of waste, thus resulting in health hazards and degraded aesthetic quality of the living environment. In many Nigerian cities, the volume of solid waste has overwhelmed urban administrators' capacity to plan for their collection and disposal. Thus, it is not uncommon to find urban streets, drainage system and roads practically blocked by solid wastes.

Yet not much has been done on waste management thus, the environmental quality and health conditions of the people is highly affected. Presently, the high volume of waste in Enugu has out weighed management strategy available in the area. The highest concentration of metals from domestic and industrial waste is of serious concern, considering the toxic properties of some trace metals. Several researchers have disclosed that some trace metals are essential for plants and animal nutrition. They help in biological functions of the system. Consequently, copper (Cu), manganese (Mn), Selenium (Se), Cobalt (Co), zink (Zn) and molybdenum (Mo) are useful to both plants and animals. However, minutes trace of arsenic (As), Chromium (Cr), Nikel (Ni) and Tin (Sn) are essential for animals but not for plants. Mercury and silver have not yet been confirmed to be essential for both plants and animals. These elements have no biological functions in plants and animals (Dara, 2004). Recently, the highest concentration of these elements in our environment is becoming more worrisome. Lopex et al (2002) opined that trace metals have a density at least five times that of water and are not biodegradable in nature. The major serious threats of their persistence are biological amplification in food chains. The elements can be toxic and also have adverse health impacts following long term exposure. Clitamba (2007), clearly established that lead can be harmful to neuropsychological development, thereby causing behavioural problems in children. In their research findings, Cabejra et al (1996) argued that copper, chromium, manganese and zinc are toxic at high level exposure while cadmium can affect renal function. Dara (2004) opined that Hai-Hai disease of Japan is triggered by rice which is contaminated with cadmium. The research on the impact of Enugu State solid waste dump sit on health and soil quality is of paramount importance. Industrial, domestic, clinical and sewage waste is dumped together in an open space at an Ugwuaji dump site in Enugu State. This is disastrous, unethical and unhealthy practice, since nothing is done concerning management strategy. Agunwanba (2001) and (1998) maintained that waste management treatment hierarchy involved source reduction, recycling, treatment and waste disposal. Waste generation cannot be totally avoided; neither can waste recycling be achieved completely. There is the need and purpose for waste treatment. Consequently, the general purpose of waste treatment is cost-effective stabilization of waste and resultant residuals for minimizing of environmental and public health hazards.

(2000) and Ogbuene (2010) argued that some of the observable impact of solid waste is demonstrated through increased disease transmission, contamination of ground and surface water, damage to the ecosystem, emission of greenhouse gases and other air pollutants. Currently, the Enugu Waste Management Authority (ESWEMA) has just been involved in waste transportation from point sources to Ugwuaji dump site. They are yet to evolved waste management strategy, thus awaken the interest of this study. Ezerah (2006) noted that despite these efforts of ESWEMA, the authority leaves much to be desired. Illegal refuse dumps are still noticed at road junctions and in undeveloped land areas in Enugu. The impacts of solid waste on soil quality and biodiversity degradation among others need urgent management action and attention.

2. LITERATURE REVIEW

Amuno (2011) remarked that academic inquiry into the potential impact of dumpsites on soil quality is receiving global attention due to the growing awareness of environmental and epidemiological risks associated with municipal solid wastes disposal. Open dumpsites present a number of risks to soils due to its propensity to generate toxic chemicals, pathogens and alter the natural environment of the soil. The findings from his study indicates that soil from both dump sites can be classified as moderate to extremely contaminated with heavy metals such as lead and cadmium. It is also observed that the soil contamination ranges from low to high with Zinc, Copper, Arsenic and Molybdenum. The subject of soil contamination from dump sites has received substantial scholarly attention in recent years (Amuno, 2011 and Ogbuene et al 2012)

Municipal solid waste is a significant contributor to greenhouse gas emissions through processes of decomposition and life-cycle activities. Effective mitigation of greenhouse gas emission is important and could provide environmental benefits and sustainable development, as well as reduce adverse impacts on public health. The waste sector is a significant contributor to greenhouse gas emissions and account for approximately 5% of the global greenhouse budget (IPCC, 2006). This 5% consist of methane emission from anaerobic decomposition of solid waste and carbon dioxide from wastewater decomposition (IPCC, 2007). The greenhouse gas emissions related to land filling are mainly due to methane and carbon dioxide present in the biogas produced by anaerobic bacteria used as carbon source. The biodegradable carbon is contained in the waste (IPCC, 2005). In particular the disposal of waste in landfills generates methane that has high global warming potential.

Solid Waste was not considered as a big threat in the beginning. However, as cities grew exponentially, the absence of planned scientific landfill for municipal solid waste started showing high impact on soil quality and the health of the population living in close vicinity (NSWAI, 2009). Each year, billions of tonnes of solid wastes are generated which are in need of proper treatment. Improper management of solid wastes has direct adverse effect on soil and water quality (Dawei, 2012). Amuno (2011) opined that dumpsites are potential sources of soil contamination as a result of the migration and proliferation of leachate produced through the decomposition of municipal solid wastes (MSW). Schwarz (1997) argued that the landfill would worsen the soil quality and environmental damage. He further observed that soils are often damaged by untreated industrial and hospital waste. Production facilities that contaminated soil include metallurgic factories and petrochemical industries such as paints or pharmaceutics and petrol stations. Leachate from landfills and wastewater sludge are inclusive. Soil pollutants also include hydrocarbons such as benzene, toluene, polyaromatic hydrocarbons, chlorinated hydrocarbons, oil used for a variety of industrial purposes over several decades, and heavy metals from battery production.

Waste management is at the lowest ebb in most towns and communities. Most parts of the city centres do not benefit from public waste disposal services and therefore, have to bury or burn their waste or dispose it haphazardly (Agirtas et al 1999). In Nigeria, there are very few sanitary landfill sites for solid wastes. The dump sites are usually haphazardly located without careful consideration of environmental and public health. These sites are usually open, subjected to frequent incineration and soil contamination (Agunwamba, 1998, 2001).

Agirtas et al (1999) maintained that waste materials contaminated with heavy metals are disposed into landfills where they deteriorate the soil quality. He also emphasized that considerable amounts of toxic metals arising from human activities accumulate in soil. Ideriah et al (2010) opined that higher concentrations of lead are obtained in the vicinity of the waste dump sites and this contaminates the soil quality.

Heavy metals are found naturally in undisturbed soil. In fact, small amounts are required by plants to remain healthy. Metals found in waste dumps exist in various forms either as the pure metal or alloyed with various other metals. Heavy metals that impair the quality of our soil come from various sources that can be categorized into urban-industrial aerosols; liquid and solid wastes from animal and man; industrial and agricultural chemicals (Gerard, 1996).

The amounts of metals increased significantly with haphazard disposal of waste in soils. The analyzed species of heavy metals in the soils could reflect the variability of metal composition in the solid or liquid waste. This has a grave impact on the soil quality (Muhammad, 2011). Ideriah, et al (2010) maintained that the waste dumps contribute to the high copper levels in the soils. Copper in the vegetation growing around the waste dumpsites was compared statistically with that away from the dump site. It was found that the copper level in the plants within the dump site was significantly higher. Solid waste deposited on the surface adds metallic contaminants to the soil on which economic crops are cultivated. It is necessary to undertake regular environmental impact study to assess waste dump sites.

The higher concentration of copper in vegetation than in soils is attributed to direct contact rather than absorption from the soil. Ukpong and Agunwamba (2011), in their study "effect of solid waste dumps on the engineering and some chemical properties of the underlying soil for three different dump sites in Uyo". The results showed that there was an increase in specific gravity, plasticity index, maximum density and permeability, concentration of zinc, lead and iron in soil under the dump site when compared with soil away from the dump sites (control). On the other hand, there were reductions in the values of liquid limits, plastic limits and optimum moisture content. Solid waste dumps have some effect on the engineering and chemical properties of soil. Not only does it reduce the overall soil strength and consequently its usefulness as a foundation material, it also can result in pollution of ground water sources due to percolation of toxic and hazardous chemical. Although the extent of damage may not be quantified, it is recommended that careful study precede the setting of these dumps which are currently located in Nigeria haphazardly without public and environmental health concern.

Soil is a fundamental resource base for agricultural production systems. Besides being the main medium for crop growth, soil functions to sustain crop productivity, maintain environmental quality, and provide for plant, animal and human health. There is however a growing recognition that poor air or water quality has profound impact on the health and productivity of o given agro-system and on the ecosystems that interface with it (Mitchelli, 2001 and Ideriah 2005). Soil is a dynamic resource that supports plant life. It is made up of different sized mineral particles (sand, silt, and clay), organic matter, and numerous species of living organisms. Thus, soil has biological, chemical, and physical properties, some of which are dynamic and can change in response to how the soil is managed (David 1997 and Dara 2004). An assessment provides information about the current functional status or quality of the soil. The assessment must start with an understanding of the standard, baseline value, or reference value to be used for comparison. Assessments can be made to help identify areas where problems occur, to identify areas of special interest, or to compare fields under different management systems. Land managers can use this information, along with data from soil surveys, fertility tests, and other resource inventory and monitoring data, to make management decisions (Daniel 1999). Interest in evaluating the quality and health of our soil resources has been stimulated by increasing awareness that soil is a critically important component of the earth's biosphere, functioning not only in the production of food and raw material but also in the maintenance of local, regional, and global environmental quality (Glanz, 1995). Monitoring of soil quality indicators over time identifies changes or trends in the functional status or quality of the soil. Monitoring can be used to determine the success of management practices or the need for additional management changes or adjustments (Daniel 1999 and Dara 2004).

3. METHODS AND MATERIALS

The sources of data for this study included secondary and primary sources. The secondary sources are published materials such as books, journals and other categories of internet publications. Data generated from primary sources included soil samples collected from different locations within the dumpsite. This comprises of locations that are predominantly of asbestos, clinical, metal scraps, biodegradable and sludge wastes. For each location, control samples were also collected at considerable distances of 50 meters. The sampling depth was 150 mm. This enables the study investigate the pollution extent of the solid waste dumpsite on soil quality in the area. The study employed stratified random sampling in the processes of soil sample collection. The soil samples were analysed in the Project Development Agency (PRODA), Enugu Nigeria. In addition, direct observation and snapping of relevant photographs were carried out in the dumpsite. Principal Components Analysis (PCA), with varimax rotation was employed to determine total variance explained and Loading of each of the five detected heavy metals in the soil within the study area. Analysis of Variance (ANOVA) was also utilized the significant difference in among detected heavy metal within various study location. ANOVA is used as a validation test in this study. SPSS version 15.0 was utilized in the process of PCA and ANOVA statistical analysis.

4. RESULTS AND DISCUSSION OF FINDINGS

The result of laboratory analysis showed that the soil samples from the study area are contaminated with the following heavy metals: Arsenic (As), Cadmium (Cd), Iron (Fe), Mercury (Hg) and Lead (Pb). The rate at which solid waste contaminates the soil quality in the study area is great concern especially with the immense accumulation of these pollutants which are poisonous and hazardous in nature. The study therefore applied various appropriate statistical techniques to ascertain their various critical levels in the area.

The result of Principal Components Analysis (PCA) with varimax rotation of detected heavy metal is presented in table 1. Two factor loadings for these detected heavy metals were produced, namely factors 1 and 2. This shows the loading disposition of the results of heavy metals in different study locations. The total variance explained from heavy metals analyzed with PCA is 99.912. The information loss is 100 – 99.912 = 0.088. This implies that the soil quality is highly contaminated with heavy metals.

Table 1: Factor Loading of Percentage Concentration of Oxides of Heavy Metals Detected in the Study Locations

Soil samples	As	Cd	Fe	Hg	Pb	Factor 1	Factor 2
1	0.49	0.01	0.24	0	0.07	0.94**	0.99***
2	0.07	0.03	0.12	0.005	0.05	-0.99***	-0.38
3	0.5	0.02	0.25	0.01	0.08	0.79*	0.87**
4	0.08	0.04	0.13	0.006	0.04	-0.99***	-0.52*
5	0.17	0.002	0.24	0.001	0	0.94**	0.99***
6	0.13	0	0.16	0.001	0.05	-0.3	0.89**
7	0.18	0.003	0.25	0.002	0.001	0.79*	-0.99***
8	0.14	0.01	0.17	0.02	0.06	-0.45	0.76*

(Source: Authors SPSS PCA Analysis, 2012)

Note: The symbol (*) indicate those heavy metals that are of high factor loading. In ranking order, the high factor loadings are recorded in factor 1 in locations 4, 2, 1, 5, 3 and 7. Also factor 2 loads high in locations 7, 2, 6, 3 and 8. The rate of loading signifies those locations that are predominating with specific waste material. These include asbestos, clinical, metal scraps, biodegradable and sludge wastes.

The Eigenvalue – Components Number Screen Plot for the heavy metals was also shown in fig 1. This determined the optimal number of components extraction commonalities of heavy metal in the analysis.

Fig 1: Eigenvalue – Components Number Screen Plot for Heavy Metals in the Study Area (Source: Authors SPSS PCA Analysis, 2012)

The continuous increase in the concentration of heavy metal in the soil is worrisome. Solid waste dumping activities take place on daily bases in the study area. The soil and environmental quality are continually degraded and deteriorated. There is an urgent need to promote and implement waste management policy and strategies. This is in line with Dawei (2012) and Amuno (2011). Their studies remarked that solid waste contaminate the soil and need management techniques. However, their findings do not lay emphasis on the five heavy metals as detected in this study. In addition, the result of correlation matrix produced from PCA in table 2 disclosed the various levels of correlation and significance among the percentage oxide of heavy metals detected in the area.

Table 2: Correlation Matrix and Level of Significance of Detected Heavy Metals in the Study Locations

Correlation Matrix Variables	High Score	Moderate Score	Low Score	Significance Score	% Level of significance
Arsenic & Cadmium	nil	nil	-0.16	0.352	99.648
Arsenic & Iron	0.715	nil	nil	0.023	99.977
Arsenic & Lead	0.603	nil	nil	0.057	99.943
Arsenic & mercury	nil	nil	0.075	0.43	99.57
Cadmium & Iron	0.584	nil	nil	0.064	99.936
Cadmium & Lead	nil	nil	0.214	0.305	99.995
Cadmium& Mercury	nil	nil	0.223	0.298	99.702
Iron & Lead	nil	nil	0.043	0.46	99.54
Iron & Mercury	nil	nil	0.227	0.294	99.706
Lead & Mercury	nil	0.416	nil	0.153	99.847

Source: Authors' SPSS PCA Analysis, 2012

The correlations of Arsenic and iron; Arsenic and Lead as well as Cadmium and Iron are 0.715, 0.603 and -0.584 with 99.977, 99.943, and 99.936 % levels of significance respectively. It should be noted that % level of significance is calculated as 100 minus significant score value. This further proves that Arsenic, Iron, Lead and cadmium have high concentration, thus deteriorating and polluting the soil quality and microorganisms in the area. The study established that Mercury is slightly lower in the sample analysed with significant level of 99.7 %. This buttresses the work of Ideriah et al (2010), which investigated that plants grown on soil within dumpsite have higher significant level of copper pollutants than those away from dump sites. Though, his study did not assess the presence of other heavy metals such as Arsenic, Iron, Lead and Cadmium which deteriorate soil quality as established in this present work.

The graph of concentration of the detected heavy metals against sample locations (fig 2) disclosed the location variations in the levels of Arsenic, Cadmium, Iron, Lead and Mercury in the dumpsite. This result indicates that Arsenic varies highest at two different point locations among other detected heavy metals within the sampled locations. The value of Iron (Fe) fluctuates along 0.13 and 0.25 percent. Unfortunately, most of the reviewed work did not address the locational variation of individual soil chemical pollutants. This disclosed the novelty of this study and the ability stir up prompt policies in waste management approach by government and NGOs.

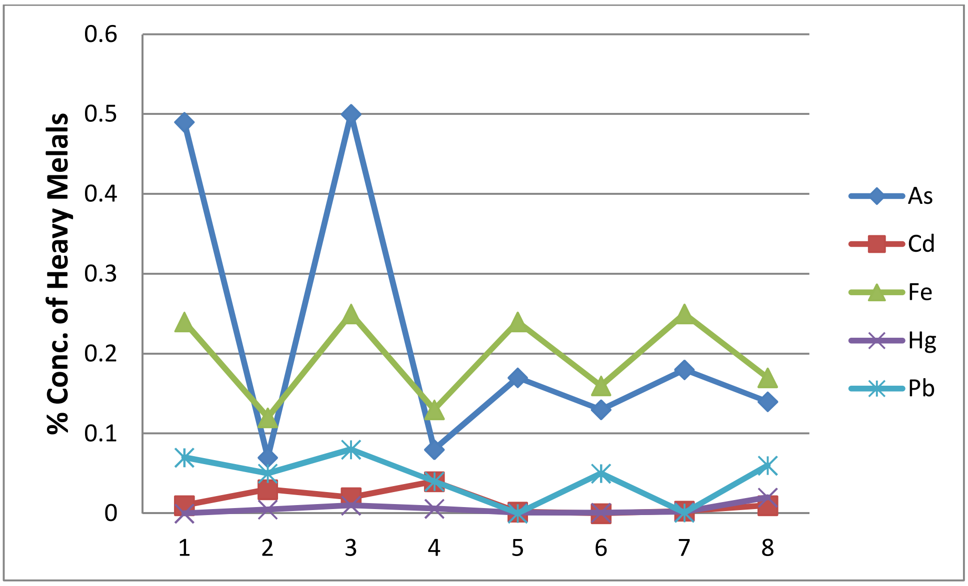

Fig 2: Graph of Concentration of Detected Heavy Metals Against Sample Locations (Source: Table 1)

The study also applied ANOVA (table 3) which is a validation test to assess the locational differences in the concentrations of the detected heavy metals in the area.

Table 3: ANOVA of Soil Sample Locations and Detected Heavy Metals

	Sum of squares	Df	Mean Square	*f*	Sig.
Regression	41.22	5	8.244	21.168	0.046(a)
Residual	0.779	2	0.39		
Total	42	7			

Source: Authors SPSS ANOVA, 2012

The following were observed from the ANOVA conducted:

Sum of squares = 41.221
Degree of freedom = 5
Mean square = 8.244
f value = 21.168
Level Significant = 0.046
% Level of Significance is calculated as (100 – 0.046 = 99.954)

The result of *f* value of 21.168 and 99.954 % level of significance difference shows that the soil is highly polluted with heavy metal across different locations in the dumpsite. Standing on the result, we conclude that there is a high level of significance difference between the sample locations and percentage oxides of heavy metals detected in the study locations. The implication is that the solid waste grossly deteriorated and polluted the soil quality haphazardly in Ugwuaji Environs. The study observed that Ugwuaji is one of the major suppliers of farm products such as yam, cassava, fruits and vegetables to Enugu urban. In the process of group field study, the researcher discovered a large number of pawpaw fruits and maize right inside and within the dumpsite. In a brief interview with the scavengers and farmers, it was discovered that they sale the pawpaw fruit and maize in Enugu urban markets. This also indicates that the crops are contaminated through bio-accumulation with some percentage oxides of Arsenic, Cadmium, Iron, Lead, and Mercury. Consequently, the health related impact will be severe and disastrous. In a similar view, Cabejra et al (1996) in their study carried out in Municipal dumpsite, established that soils within a 50 meter radius has been contaminated by trace metals of lead, Iron, Copper, Zinc, and phosphorus. Dara (2004) opined that direct dumping of untreated wastes in the soil and water bodies can result into bioaccumulation of toxic substances in the food chain through plants and animals. This is similar to the case of the Ugwuaji dump sites were established in the analysis. Clitamba (2007), in his study carried out at Kariba showed that soil sample taken from the vicinity of the dumpsite had a high level of concentration of Mercury (Hg), and lead (Pb). This is in alignment to the finding of the study and there is an urgent need for improvement in solid waste management policy and practice.

5. RECOMMENDATIONS AND CONCLUSION

The study on the impact of solid waste dump site in Ugwuaji Environs has been carried out. The results of the analysis indicate that Arsenic, Iron, Lead, Cadmium and Mercury have a serious impact, thus deteriorating and polluting the soil quality and microorganisms in the area. The study observed that waste management strategies are not practiced at all in the area.

The graph (fig 2) indicates that Arsenic varies highest at two different point locations among other detected element within the sample locations. This constitutes a serious pollution problem with the soil quality. Earlier attempts in the solution of this soil pollution problem did not focus on locational variations of individual soil chemical pollutants. This would have aided the advancement of solutions to soil pollution management. This study recognized Arsenic, Cadmium, Iron, Lead and Mercury as grave soil pollutants in the area. The pollution levels of these heavy metals vary significantly with the type of solid waste that predominates in the study locations within the dumpsite. These innumerable problems call for stringent adherence to the recommended management strategies. It also serves as a clarion call for the prompt implementation of policy on waste management as established by this study.

The study also established that the soil quality within the dumpsite has been severely contaminated with Arsenic, Cadmium, Iron, Lead and Mercury. These pollutants posed a serious danger on soil which is an indispensable natural resource on which human survival and entire ecosystem hinges upon. This calls for urgent, imperative and well articulated recommended strategies which will not only stem the problem in the study area but constitute a policy implementation material for solid waste management techniques. In light of this, the following solid management strategies are proffered.

- Encourage Environmental Management System (EMS), Environmental Impact Assessment (EIA) and Environmental Impact Auditing. This will help to assess the position of any industry on waste management strategies provisions.
- Waste source reduction should be encouraged by the government.
- Waste should be sorted from the point of generation. This will make way for prompt haulage of biodegradable waste to farmland as manure and livestock feed.
- Recovery and recycling of waste for wealth creation through private sector initiatives. This process will help reduce the volume of waste and add value to waste. Thus, move from waste to wealth creation.
- What is left after waste reduction, recovery and recycling are usually negligible. They must be treated so as to reduce the hazardous effect on the soil.
- Waste disposal must be done in an environmentally friendly manner. Some of the waste can serve as soil manure since the hazardous components have been treated.

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