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Heavy Metals Contamination in Soils in and Around Some Selected Auto Mechanic Workshops in Ga East Municipal Assembly of Greater Accra Region, Ghana

John K. Senu

Chief Technologist, Nuclear Chemistry and Environmental Research Centre,
Ghana Atomic Energy Commission, Ghana

Michael Ackah

Ph.D. Candidate, Nuclear Chemistry and Environmental Research Centre,
Ghana Atomic Energy Commission

Moses A. Addo

Senior Research Scientist, Safety & Safeguards Centre, National Nuclear Research Institute,
Ghana Atomic Energy Commission, Ghana

Nafisatu Zakaria

Ph.D. Candidate, Nuclear Chemistry and Environmental Research Centre,
Ghana Atomic Energy Commission, Ghana

Ruby Torto

Senior Technologist, Nuclear Chemistry and Environmental Research Centre,
Ghana Atomic Energy Commission, Ghana

Hephzibah Konadu Agyeman

Principal Technologist, Radiation Protection Institute,
Ghana Atomic Energy Commission, Ghana

Clement Annor

Principal Technologist, Biotechnology and Nuclear Agriculture Research Institute,
Ghana Atomic Energy Commission, Ghana

Abstract:

Welder and auto mechanics face a number of occupational health hazards. In this study, distribution of nine heavy metals from soil samples collected from twelve auto mechanics and welders' workshops in Ga East Municipal Assembly of Greater Accra Region, Ghana at the depth of 0–30 cm for laboratory analysis. The samples were analysed for Fe, Mn, Cu, Zn, Cr, Ni, Pb, Co, and Cd using Atomic Absorption Spectrophotometric (AAS). The results of the analysis indicate that majority of metal concentrations (mg/kg) in the samples were above control (background) levels and threshold limits recommended in soil samples by some countries. The level of investigated metals in the soil samples generally decreased in this order; Fe > Mn > Cu > Zn > Pb > Ni > Cr > Cd > Co. The results of the analysis ranged from as high as 313 mg/kg for Fe to as low as 0.30 mg/kg for Co in the soil samples. Quantification of contamination was high for Cu, Fe, Cr, Zn, Co, Cd and Pb, moderate for Mn and low for Ni. The geo-accumulation index values for metals in auto-mechanic workshops showed that the environment is highly polluted with Cu, Fe and Cr, and to a lesser degree with Pb, Mn. and Ni. Zinc (Zn), Co and Cd showed moderate pollution status.

Keywords: Background Level, earth crust, geo- accumulation index, pollution, anthropogenic

1. Introduction

Soils may be contaminated by gradual accumulation of high metals waste and metalloids, spillage of leaded petrochemicals, run off from agriculture lands, sewage sludge, wastewater, animal manure, combustion residues and paints through the activities of expanding industrial areas (Aloysius et al., 2013, Adelenka et al., 2011). One of the major sources of increasing heavy metal concentration of the environment, in most developing countries is the activities of auto mechanics (Adewole and Uchegbu, 2010 as cited in Aloysius et al, 2013).

In Ghana, auto mechanic workshops are found in any available piece of land that is not developed in the vicinity of urban towns and cities where people reside. These auto Technicians are involved in the repair and maintenance of automobile, auto – electrical, welding and soldering, vehicle body spraying and other general services (Adams Sadick et al, 2015, Adelenka et al., 2011, Ipeaiyeda and Dawodu, 2008). In most of Nigeria states, a large track of land is allocated to a group of small scale auto mechanic technician and designated as “mechanic village” where most of the technicians come together along with the auto spare parts dealers to practice their trades (Adelenka et al, 2011, Nwachukwu et al., 2011,

Nwachukwu et al., 2010; Ipeaiyeda and Dawodu, 2008). This arrangement makes it very convenient for their customers to easily access their services (Emem et al., 2015). In spite of the existence of such designated areas, soil pollution problems associated with heavy metal concentration in the ecosystem have been widely reported (Adewole et al., 2010).

These anthropogenic activities, according to Emem et al., 2015 are not without job-related Health hazards. Some common practices which is detrimental to their health include washing of hands and vehicle parts with gasoline fuel, applying diesel to bruised parts of their bodies, eating and sleeping in poor sanitary environments (Ofonime et al., 2016, Udonwa et al., 2009, Oluwagbemi, 2007; Anetor et al., 2002). The health effects of dust from mechanic workshops can better be appreciated if one consider the fact that an active person typically inhales 10,000L to 20,000 L of air daily (Addo et al., 2012, Gbadebo et al., 2007). According to Drekert in 1996 toxic metals intake increases with vigorous exercise, during inhalation and exhalation, these metal pollutants can inflame, sensitize and even scar the lungs and tissue. It has also been reported that metal absorbed on ambient air suspended particulate produces tissue damage of the lungs and blood stream (Addo et al., 2012, Gbadebo et al., 2007, Drekert, et al., 1996

This makes reason to suggest that one of the major sources of increasing heavy metal concentration of the ecosystems could be linked to auto mechanic activities. The drive behind this anthropogenic activity includes urbanisation, over population and technological improvements (Nkwoada et al., 2018); what made the scenario worst in most of the developing countries including Ghana is the increase importation of home used or second hand vehicles into the country. In view of the increasing evidence of the adverse effects of heavy metals on human health and environment, not much data on soil contamination regarding auto-mechanics and welders' activities are available in Ghana. Also, Ghana has no specific standard level for both heavy and trace metals in the soil or sediment. It has therefore become imperative to monitor and evaluate the extent of soil pollution in these workshops. For the purpose of this research twelve automobile mechanic and welder's workshops scattered in Ga East Municipal Assembly in the greater Accra region of Ghana were selected for the study. The aim of this work was to assess the pollution risk, these heavy metals pose by activities of the auto technicians to human health and the environment. The data obtained would provide an adequate idea of the pollution levels of these heavy metals in the environment and also, serve as a proactive vehicle for selection and design of remediation.

2. Materials and Methods

2.1. Description of Research Area

Ga East Municipal Assembly is one of the ten districts in Greater Accra region of Ghana with Abokobi as its capital (Fig., 1). The area bounds between two bedrock formations in the Precambrian Guinea Shield of West Africa, namely the metamorphosed and folded Dahomean system and the Togo series ((Kesse 1985, as cited in Kortatsi et al. 2008; Fianko et al. 2009; Courage Egbi et al. 2017).

The municipality covers a total area of 166 sq. km. It is bordered to the west by the Ga West Municipal Assembly (GWMA), to the east by the Adenta Municipal Assembly (AdMA), to the south by Accra Metropolitan Assembly (AMA) and to the north by the Akwapim South District (GSS, 2010). The area has well-drained, red sandy clay loam to clay with abundant ironstone concretions and gravels. The Akwapim range rises steeply above the western end and lies generally at 375-420m north of Aburi and fall to 300m southward (GSS 2010).

Figure 1: Map Showing Sampling Sites in Ga East Municipal Assembly

The projected population for the Municipality is estimated at 259,668 at a growth rate of 2.3% which is highly due to migration influx (GSS, 2010). Rainfall pattern is bi-modal with the average annual temperature ranging between 25.1°C in August and 28.4°C in February whilst March, being the hottest months (Courage Egbi et al. 2017).

2.1. Sample Collection and Treatment

Soil samples were collected from twelve selected automobile workshops within the study area using soil auger, at the depth of 0-30cm representing the top soil as prescribed by (Krishna et al., 2007, Kakulu et al., 1993). At each location, the soil samples were taken from five different points, homogenised into a composite sample which weighed between 450 – 600g. Control samples were also collected about 100m away from each sampling point to avoid any influence from auto mechanics activities. These composite samples were collected into clean polyethylene bag with hermetic seals using plastic trowel (Dampare et al. 2005; IAEA Tec. Doc.20; TVA 2010; Bam et al. 2011a, b as cited in Courage Egbi et al. 2017); and transported to the Nuclear Chemistry and environmental Research Centre's laboratory of Ghana Atomic Energy Commission for analysis. In the laboratory, the soils sampled were subsequently air-dried to constant weight to avoid microbial degradation, homogenised by gently crushing repeatedly using an acid pre-washed mortar and pestle, and sieved using 250 µm mesh sieve prior to analysis.

2.2. Heavy metal analysis

One gram of the dried fine soil sample was weighed and transferred into an acid washed, 100 ml borosilicate beaker. 25ml of aqua regia was added to the sample in the ratio of 1ml conc. HCl to 3ml of conc. HNO₃ in the fume chamber. The mixture was placed on a hot plate and heated at 45°C for 3 hours. The mixture was allowed to cool to room temperature and then filtered using Whatman No.1 filter paper into a 50 ml volumetric flask and made up to the standard mark with deionized water after rinsing the reacting vessels, to recover any residual metal. The filtrate was then stored in pre-cleaned polyethylene storage bottles ready for analysis. The metal concentrations were determined using Fast Sequential Atomic Absorption Spectrophotometer (FSAAS 240) at the Nuclear Chemistry and Environmental Research Center (NCERC), Ghana Atomic Energy Commission (GAEC), Kwabenya. The Spectrophotometer was earlier calibrated with analytical grade standard solutions of the nine metals (Reference standards used are from FLUKA ANALYTICAL, Sigma-Aldrich Chemie GmbH, and product of Switzerland). A quality assurance programme was also put in place which involved analysis of blanks and duplicates and determination of percentage recovery (%) of the nine metals. Average percentage recoveries of nine determinations of each metal are, Fe (94.8 ± 5.4), Mn (93.5 ± 4.7), Co (96.32 ± 5.7), Zn (94.7 ± 4.9), Cu (91.7 ± 6.7), Pb (92.5 ± 5.7 %), Ni (98 ± 2.9 %), Cr (93.8 ± 7.8) and Cd (94.6 ± 4.8). This shows that the method employed for the determination of the metals in this study is good. The means of the concentrations of nine metals in twelve auto mechanics, welders, electrician, sprayers etc., were compared using analysis of variance (ANOVA – single factor) from Microsoft excel (2013 version).

2.3. Contamination Assessment Methods of the Soil Samples

The assessment of soil enrichment can be carried out in numerous ways. The most common ones are the index of geo-accumulation and enrichment factors (Ayodele et al., 2007 as cited in Addo et al. 2012). In this study, the index of geo-accumulation (Igeo) and quantification of contamination have been applied to assess heavy metals (Fe, Cr, Cu, Mn, Ni, Pb, Co, Cd, Zn) distribution and contamination in the soil samples from various Auto-workshops in Ga East Municipal Assembly. The index of geo-accumulation (I-geo) enables the assessments of contamination by comparing current and pre-industrial concentrations. Igeo is computed using the following equation:

$$I_{geo} = \log_2 (C_n / 1.5B_n)$$

Where C_n is the concentration of the metals in the enriched sample and B is the concentration of the metals in unpolluted or controls samples. The factor 1.5 is introduced to minimize the effect of the possible variations in the background or control values, which may be attributed to lithogenic variations in the soil (Mmolawa et al., 2011). Lu et al, 2009 as cited in Addo et al., 2012 gave the following interpretation for the geo accumulation index: Igeo < 0 = practically unpolluted; 0 < Igeo < 1 = unpolluted to moderated polluted; 1 < Igeo < 2 = moderately polluted, 2 < Igeo < 3 = moderately to strongly polluted; 3 < Igeo < 4 = strongly polluted; 4 < Igeo < 5 = strongly to extremely polluted; and Igeo > 5 = extremely polluted.

Quantification of soil contamination: Quantification of the anthropogenic input of heavy metals in the soil is as presented in Table 2. The quantification of heavy metals obtained from various Auto- mechanic and welders sites is presented below:

Cu > Fe > Cr > Zn > Co > Cd > Pb > Mn > Ni.

3. Results and Discussion

3.1. Heavy Metals in the Soil Samples

Many studies have shown that urban soils receive loads of contaminants that are usually greater than in the surrounding sub-urban or rural areas due to the higher anthropogenic activities of urban settlement; this research confirmed that accession. It is important to know that there are no soil quality guidelines for heavy metals in soils in Ghana. All the metals under the current study were found present in all the samples collected for analysis. To have a fair idea about the levels of contamination, data obtained from this research was compared with those from the control samples (background) collected approximately 100m from the studied sites. The background value of an element is the maximum level of the element in an environment beyond which the environment is said to be polluted by the element

(Nwachukwu, et al, 2011). The average level of these metals in the soil, around twelve auto-mechanic and welder sites indicate that they were not derived from the natural geology of the area as evident from the low level of metals in control sample. The heavy metals showed a hierarchical variation in the order $\text{Co} < \text{Cd} < \text{Cr} < \text{Ni} < \text{Pb} < \text{Cu} < \text{Zn} < \text{Mn} < \text{Fe}$. There are high levels of variation in the investigated soils with large standard deviations shown by Fe, Mn and Zn. Cu, Pb and Ni had moderate variability while Cr, Cd and Co displayed the least variability.

The increase in iron (Fe) content in all the auto-mechanic workshops investigated in this work could be due to dumping of iron scrap, unused body parts of vehicles, solvents, hydraulic fluid, spent lubricants, tin can, at these workshops. The high level of iron concentration had also been reported by Oluyiwola Olajumoke Abidemi in 2011 for Automobile workshops in Osun state in Nigeria. In most mechanic workshops visited during sampling, left over corroding vehicles and other metals are common and these may also be the major cause of Fe increase in the soil samples. Also, iron is a major component of steel alloy which is the material used in manufacturing vehicles body parts.

Copper was present in all the twelve auto-mechanic sites investigated. The mean concentrations were higher than those from various control sites (0.16 mg/kg). The distribution of Cu in all the sampling sites in this study could be due to welding and soldering, waste electrical and electronic parts, such as copper wires, electrodes and copper pipes and alloys from scrap vehicles which littered the workshops for a long time leaching into the soil.

There is wide range of distribution of Cu concentration from 1.45 mg/kg to 19.30 mg/kg. This value is above the maximum allowable limit (0.1 mg/kg) in Australia, Canada, Poland and Great Britain. Japan (0.125mg/kg), and Germany (0.05 mg/kg) and that of (Adams Sadick et al., 2015, Lu X et al., 2009, Yahiya et al., 2010)], but higher than 7.21 mg/kg reported by (Akoto et al., 2008)

Manganese (Mn) is one of the abundant elements found in the earth's crusts and is widely distributed in soils, sediments, rocks and water [Aloysius et al., 2013, Udebuani et al., 2010]. The mean range of Mn analysed gave values from 17.61 to 81.61 mg/kg. Even though, the levels of Mn found were above the control level which could be due to wear and tear of car body parts, there was no soil quality criteria established in Ghana for Mn level. However, judging by other reports (*ibid*) and mean concentrations observed in this study, it would appear that the levels of Mn in the soils investigated is building up substantially, especially auto-mechanic workshops at Dome- Kwabenya, Hatsoo, Atomic Junction and Ashley Botwe areas and need to be constantly monitored before it reaches alarming levels.

Nickel concentration in the soil samples investigated indicate a mean distribution of 1.7 mg/kg in the studied sites and 0.53mg/kg for the control sites. The results obtained from the analyses are relatively higher than values of 0.033 mg/kg reported in 2013 by Aloysius and below 11.5 mg/kg by Ipeaiyeda, 2001, in similar studies. Like the other metals the distribution of Ni in this study could be attributed to the disposal of spent automobile batteries from the auto-battery chargers and various paint wastes which have contributed to the contamination of the soils samples (Aloysius et al., 2013, Yahiya et al., 2010,). In all cases, however, the concentration of Ni was below the maximum allowable limits for heavy metals in soils regulated by various countries, which suggests that, for now, there is little anthropogenic contribution.

Zinc content in all the soil sampled and analysed had a mean value which ranges from 1.36 to 14.80 mg/kg. These values were higher than that of the background level suggesting that, there is anthropogenic contribution. The primary source of Zn could be attributed to waste lubrication oils in which Zn is found as part of many additives as Zincdithiophates and vehicle rubber tire, additive of lubrication oil since no industry exists in the vicinities of all the sampling areas. However, the concentration of Zn in this study is small compared with many other studies (Oluyiwola Olajumoke Abidemi, 2011, Nwachukwu et al., 2010, Lu X et al., 2009, Akoto et al., 2008,) and conform to acceptable limit of 0.05mg/kg.

Chromium content ranges from 0.03 to 0.9mg/kg. These values saw a significant elevation from the background level of 0.03 mg/kg suggesting that, there is anthropogenic contribution thus littering and spreading of used engine oils and spent fluid all over.

Lead: The mean concentration of Pb obtained in this study was 3.72 mg/kg. This value was higher than the control level of 1.12 mg/kg. The value of Pb obtained in this study is lower than the 26.66 mg/kg reported by Akoto et al., 2008 in abundant railway servicing workshop in Kumasi, 22.89 mg/kg reported by Addo et al., 2012 in road deposited dust in Ketu North District of Volta Region- Ghana. It is possible that high concentration of Pb in the study area could be due to the content of expired car batteries that were indiscriminately dumped by battery chargers and auto mechanics in the surrounding areas. This was observed during the fieldwork campaign that large amount of waste oil and expired car batteries were seen at the auto mechanic and auto electrician workshops especially at Atomic Junction which recorded the highest concentration of 6.18 mg/kg.

Cobalt: had its highest concentration value of 0.21mg/kg with the least concentration of 0.03 mg/kg in the study area. This value could be due abundant waste electrical materials and auto-painting unit which gradually leached into the soil. The information on cobalt content of soil in auto-mechanic workshop is sparse in literature

The mean Cd concentration in the study area was 0.19 mg/kg. The main source of environmental Cd pollution is believed to come from the ferrous-steel industry (Adam et al., 2015; Onder et al., 2007); the accumulation of Cd in the areas investigated is likely to come from lubricating oils, vehicle wheels and metal alloys used for hardening of engine parts (Dabkowska - Naskret, 2004).

Class	Values	Soil Quality
0	< 0	Practically unpolluted
1	$0 < I\text{-}geo < 1$	Unpolluted to moderately polluted
2	$1 < I\text{-}geo < 2$	Moderately polluted
3	$2 < I\text{-}geo < 3$	Moderately polluted to strongly polluted
4	$3 < I\text{-}geo < 4$	Strongly polluted
5	$4 < I\text{-}geo < 5$	Very strongly polluted
6	$I\text{-}geo > 5$	Extremely polluted

Table 1: The Degree of Metal Pollution Assessed In Terms Of Seven Contaminations Classes in Order of Increasing Numerical Value of the Index Laurent Et Al., 2011; Lu Et El., 2009

Metals	I-geo	Quantification of contamination	Background Concentration (BC)
Fe	2.12	89.36	16.20
Mn	0.55	53.77	12.90
Cu	6.87	95.28	0.16
Zn	1.30	75.05	1.11
Cr	3.99	81.85	0.03
Ni	0.60	49.87	0.53
Pb	0.67	64.62	1.12
Co	1.02	67.87	0.03
Cd	1.20	67.49	0.02

Table 2: Geo-Accumulation Index (I-Geo), Quantification of Contamination and Background Concentration (BC) of Heavy Metals in the Soil of Auto-Mechanic Shop in the Ga East Municipal Assembly

Results obtained from the calculation of geo-accumulation index (*I-geo*) for the soils are presented in **Table 2**. The pollution status of the metals in the environment expressed in terms of the geo-accumulation indices showed that the environment is highly polluted with Cu, Fe and Cr, and to a lesser degree with Pb, Mn, and Ni. Zinc (Zn), Co and Cd showing moderate pollution status.

Figure 2: Anthropogenic Contribution of Heavy Metals from the Entire Auto-Mechanic Workshops

3.2. Quantification of Soil Contamination

The quantification of anthropogenic input of heavy metals in the soil is as presented in **Table 2**. The quantification of heavy metals obtained for various Auto-Mechanic and welder sites is presented below:

$Cu > Fe > Cr > Zn > Co > Cd > Pb > Mn > Ni$. This could simply be an indication that the anthropogenic sources of the metals in the soils surrounding these auto mechanic workshops are of similar

4. Conclusion

The soil samples investigated in this study indicated that auto-mechanic workshops were indeed polluted with anthropogenic activities as all the indices of contamination considered indicate significant to considerable degree of contamination. The evidence of contamination was obvious when the investigated metals were compared with the control sites, with Cu, Fe and Cr representing the highest Igeo and QoC as shown by the following order of abundance $Cu > Fe > Cr$

> Zn > Co > Cd > Pb > Mn > Ni. This is an indication that there is a gradual accumulation of these metals at the auto-mechanic workshops.

Environmental Protection Agency should make sure that Code of practice and specific regulations guiding the establishment and the operation of mechanic workshops must be in place and accordingly enforced, areas such as auto-workshop (mechanic, electrician, sprayers. Welding and soldering, re-changing of car batteries etc.) should be well monitored to ensure that those working in these areas conform to environmentally friendly behaviours, indiscriminate spillage of petroleum products or lubricating oil into the surroundings should be avoided and also comprehensive waste management plan for auto -mechanic workshops need to be established. Examination of levels of heavy metals in the crops grown around these auto workshops is recommended.

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