Nigerian Defence Academy Shooting Zone: Soil Speciation of the Kwanar-Doya Military Shooting Range, Kachia, Kaduna State, Nigeria

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Abstract — The speciation of toxic metals of Co, Cr, Cu, Mn, Pb, Zn, Ni and As in Kwanar – Doya Shooting site of the Nigerian Army, Military Training, Base Camp, Kachia, Kaduna State, Nigeria was investigated. The soil physico-chemical parameters, total metal content and sequential extraction methods were determined in duplicates using standard methods. The pH ranged from 3.93–4.51, showing the high acidity of the soil and electro -conductivity gave a mean value of 0.11 ms / cm showing the poor nutrient value of the soil). While the mean total metals values were Zinc: 28.94 mg/kg, Nickel: 13.45mg/kg, Manganese: 78: 12 mg/kg, Lead: 40.6 mg/kg, Arsenic: 305 mg/kg, Chromium: 49.32 mg/kg, Cobalt: 162:50 mg/kg and copper: 7.3 mg/kg. All the metals were above the W.H.O permissible limit for toxic metals in soils except Zinc and Nickel. The sequential partitioning and distribution and variation of toxic metals in the various fractions of the Nigerian Defence Academy Shooting Range soil were in the following order: Cobalt: Residual > Bound to carbonate > Exchangeable > Organic > Fe – Mn Oxide Arsenic: Fe – Mn Oxide > Bound to carbonate > Residual > Organic > Chromium: Bound to carbonate > Exchangeable > Fe – Mn Oxide > Organic > Residual. Nickel: Fe – Mn Oxide > Exchangeable > Bound to carbonate > Residual > Organic. Manganese: Residual > Fe – Mn Oxide > Bound to carbonate > Organic > Exchangeable. Lead: Residual > Organic > Bound to carbonate > Exchangeable > Fe – Mn Oxide. Zinc: Fe – Mn Oxide > Residual > Organic > Bound to carbonate > Exchangeable. Copper: Residual > Fe – Mn Oxide > Exchangeable > Bound to carbonate > Organic. The Toxic metals speciation of the soil samples indicate that the toxic metals were predominately in the non-residual fractions suggestive of input by anthropogenic sources and human activities due to military exercise and are readily available for plant uptake. This could pose serious health risk to the military personnel using the training period. Thus phyto-remediation technique which is cheap and non-destructive is recommended to be applied to remedy the affected toxic metals in the soil for its continual use as a military training ground and also preserve the soil fertility for continued agricultural use of the area when there is no military operation.

Index term — Toxic Metals, Speciation, Total metal Content, Military Activities and Shooting Range.

I. INTRODUCTION

Heavy metals are present in the environment and most of them are essential for animals and plants. They are natural constituent of rocks, soil, and sediments [1]. There is always a natural background level of metals originating from the parent rocks and these metals can occur in high concentration but in an inert form which, however, can be converted to

mobile and dangerous forms due to changing environmental conditions or changes in soil properties and this could lead to a “chemical time bomb” [2]. Heavy metals such as copper, nickel, chromium, and zinc are used in all kinds of practical objects and building materials without the users understanding its harmful risk. An origin of heavy metals may come from natural or anthropogenic a source, that is why it is very important to distinguish the individual species of heavy metals because some are more mobile, and some have a longer retention time in the soil environment [3].

While metals such as Pb, Hg, Mn, Cr, Br, Li, etc. are toxic even in small concentrations; the issue of toxicity is usually merely a matter of quantity, with the range varying for each element [4]. A heavy metal is not toxic per se; it is only considered toxic when its concentration exceeds a certain threshold (it is the dose that makes the effect) [5].

Some anthropogenic sources of toxic metals such as Arsenic, Cadmium, Chromium, Lead, Mercury and Nickel include the burning of coal and industrial sewage sludge, pesticides, fertilizer impurities, emissions from mining and smelting operations, military activities, wastewater from dyeing and chemical industries, lubricants and metallurgical activities [6]. Heavy metals do not degrade but remain in the environment for a long time even after the removal of the pollution source [7]. Once heavy metal concentrations surpass a certain threshold in soils, they tend to cause serious environmental problems due to their toxicity, non-biodegradable properties, and widespread distribution [8].

Military activities are one of the anthropogenic sources of toxic metal contaminations to soil and tend to contaminate the soils without appropriate recovery of polluted soil [9]. Shooting ranges are characterized by shooting of bullets and deposit of explosives which releases toxic metals like lead (Pb), Antimony (Sb), Copper (Cu), Nickel (Ni) and Zinc (Zn) [10]. Lead concentrations exceeding 10,000 mg /kg in soil are commonly reported at shooting ranges around the world. 60,000 tons per year in the United States, 800 tons annually in Denmark and 500 tons in Switzerland [11]. Grazing animals have also been confirmed to have ingested large quantities of these heavy metals from unrestricted shooting ranges, which have crops richly grown on such site leading to animal poisoning, death, and human sickness all over the world [12].

In order to combat these teeming challenges which are becoming persistent in all military shooting sites involving heavy metal deposit into the soil, the determination of the free

Published on December 23, 2020.
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metal ion in soil solution becomes important [13]. Meanwhile, the concentration of heavy metals in soil solution plays a critical role in controlling the availability of ions to plants. The physiochemical properties of the soil are also considered such as the soil pH, electro conductivity, clay content and organic matter content [14]. Total metal content of soils is useful for many geochemical applications but often the speciation (bioavailability) of these metals is more of an interest agriculturally in terms of what is biologically extractable and scientifically to researchers [15].

The use of sequential extraction procedure for environmental studies provides an important tool for the determination of the different chemical forms or ways of binding between trace metals and soil components [16]. This extraction enables us to associate the metals with one of the following geochemical phases which are the acid-soluble phase, reducible phase, oxidizable phase and the residual phase. This gives a clear indication of the metal reactivity, strength, and phase association of the metal in soil, sediments and water [17].

In Nigeria there are several shooting ranges and the concentrations of heavy metals in the soils of these shooting ranges have not been fully researched. Kwanar – Doya is one of the shooting sites in the Nigerian Army Military Training, Base Camp located in Kachia Local Government Area, Kaduna State. The Nigerian Army Base Camp, Table hill, Kachia, Kaduna State over the years, is been used as the field training exercise ground for military personnel.

The military training undergone at the exercise ground includes leadership and adventure training, practical map reading test, company level field training exercise, navigational training and field firing of weapons [18]. The objectives of this paper were to study some physico-chemical parameters, toxic metal content of the soil and its speciation. This research will also help provide vital information, which will be useful for future reference in shooting ranges research in Nigeria.

II. MATERIALS AND METHOD

A. Sample Collection and Preparation

Soil samples were collected from the Kwanar –Doya Shooting site in the Nigerian Army Base Camp military shooting range, Kachia Local Government, Kaduna State. A transect, 1000×1000 meters long was demarcated with a wheel-able measuring meter within the shooting areas and soil samples were collected within the measured areas. Surface soil samples were collected at the various sample areas from a surface level (0-30 cm in depth) with a Soil auger [19]. Ten (10) Composite samples were collected in duplicates within the grid in the sampling location and stored in labelled polyethylene bags [20]. The collected samples were air-dried, grinded with a mortar and pestle and sieved with a 1mm sieve into coarse and fine fraction sand thoroughly homogenized. This was then transferred into a plastic container for analysis [21].

Fig. 1. The Map of Nigeria, showing Kaduna State and its Local Government Areas including Kachia Local Government Area (Source: Nigerian Defence Academy (NDA) Geography Department, Kaduna State).

Fig. 2. The Map of the Nigeria Army Base Military Shooting Ranges in which the sampled shooting site is included in Kachia Local Government, Kaduna State, Nigeria. (Source: Nigerian Defence Academy (NDA) Geography Department, Kaduna State).

B. Method of Analysis

1. Soil pH Determination

20 g of the sample soil was weighed in duplicates into two 250 cm³ beakers. 50 cm³ of distilled water was added to the first and second set of beakers. 150 cm³ of 0.01 M CaCl₂ was added to the second set of beakers containing the soil solution and the two sets of beakers was stirred for 1 minute and left to stand for 15 minutes. Again, the mixture was stirred and left for another 15 minutes. While waiting for the last 15 minutes, the pH meter was standardised using different pH buffer solutions of pH 4, 7 and 9. After the last 15 minutes, the electrode of the pH meter was then inserted into the supernatant liquid to read the pH values. The pH reading in both water and calcium chloride was recorded [22].

2. Soil Electrical Conductivity Determination

2 g of each air-dried sieved soil was weighed into a 250 cm³ conical flask and 20 cm³ of distilled water was added and the mixture stirred. The electrode of the conductivity meter was inserted into the supernatant liquid to read the value of the conductivity of the soil [23].

3. Total Metal Content of the Soil Samples

2.0 g of pulverized soil sample was added in a 250 cm³ beaker and moistened with few drops of deionized water to prevent loss by spattering during digestion. The sample was digested with 10 ml of concentrated HNO₃ on a hotplate in a

fume cupboard to volume of about 3 ml. The residues obtained was further digested with a mixture of concentrated acids containing 5 ml each of concentrated HCl, HNO₃ and HClO₄ at room temperature for 10 minutes until the solution final volume was about 5 ml on a hot plate in fume cupboard. The digest was then allowed to cool and then filtered into a 100 ml volumetric flask using Whatman No.40 filter paper and made up to the mark with distilled water. Then it was then transferred to a plastic sample bottles and analyzed with an Atomic Absorption Spectrophotometer (Thermo Scientific Model: iCE 3000 v1.30) for metal content analysis [24].

4. Speciation Determination

The sequential extraction method described by Tessier, A., Campbell, P. G. C and Bisson, M.1979) was adopted.

The Exchangeable fraction: 1.0 g of finely divided soil sample was added with 40 cm³ of 1mol per dm³ MgCl₂ solution at pH 7.0 and agitated using a Stuart flask shaker for 1 hour. The mixture was filtered and made up to 50ml volume with distilled water.

The Carbonate fraction: The sediment residue from exchangeable fraction was leached with 40 cm³ of 0.1 mol per dm³ of sodium acetate (adjusted to pH 5 with 1M acetic acid) and agitated for 5hr using a Stuart flask shaker.

The Easily Reducible fraction: The residue from carbonate fraction was added with 50 cm³ of 0.04 mol per dm³ NH₂OH.HCl in 10 ml of 25%(v/v) acetic acid and heated for 6hr in a thermostated water bath at a temperature of 96±2 °C and the solution was stirred occasionally. The mixture was cooled, filtered, and made up to 50 ml volume with distilled water and analyzed.

The Organic fraction: The residue from the easily reducible fraction was mixed with 15 cm³ of 0.02 mol per dm³ HNO₃ and 25 cm³ of 30% H₂O₂ and heated for 2hr at 85 °C

with intermittent agitation in a thermostated water bath. After cooling, 25 cm³ of 3.2 mol per dm³ CH₃COONH₄ was added in 20% (v/v) acetic acid and transferred to the mixture and agitated continuously at room temperature for 30 minutes. After each successive extraction, the sample was centrifuged at 4500 rpm for 20 minutes. The supernatant was removed with a pipette and filtered with Whatman no 40 Filter paper.

The Residual Fraction: The residue from the organic fraction was washed with distilled water and the supernatant discarded. Then 5 ml Concentrated HF and 10ml Concentrated HClO₄ was added to the residue and the sample digested. The digest was then filtered, and the filtrate analyzed for the residue bound metals ions. Each filtrate will be analyzed using Atomic Absorption Spectrophotometer (Thermo Scientific Model: iCE 3000 v1.30).

III. RESULTS AND DISCUSSION

TABLE 1: THE pH READINGS OF THE SOIL SAMPLES

Serial Number	Sample Location	pH Readings (Distilled Water)	pH Readings (Distilled Water + Calcium Chloride Solution)
1	Kwanar-Doya A	4.53	3.81
2	Kwanar-Doya B	4.49	4.06
3	MEAN	4.51	3.93
4	Control Point	4.72	4.18

TABLE 2: THE ELECTRO CONDUCTIVITY READINGS OF THE SOIL SAMPLES USING DISTILLED WATER

Serial Number	Sample Location	Electro Conductivity Reading (ms /cm)
1	Kwanar-Doya A	0.12
2	Kwanar-Doya B	0.10
	MEAN	0.11
3	Control Point	0.055

TABLE 3: CONCENTRATIONS OF TOXIC METALS CONTENT (MG/KG) IN SOIL SAMPLE

Sample Location	Cobalt	Arsenic	Chromium	Nickel	Manganese	Lead	Zinc	Copper
Kwanar-Doya A	134.5	82	42.15	8.97	64.34	45.3	38.32	9.19
Kwanar-Doya B	190.5	528	56.49	17.93	91.90	36.3	19.57	6.3
MEAN	162.50	305	49.32	13.45	78.12	40.6	28.94	7.74
Control	18.42	35	36.48	3.677	165.92	33.29	55.5	12.40
WHO	19	20	50	20	0.04	10	250	2

WHO values were obtained courtesy of [25].

TABLE 4: MOBILITY FACTOR (%) OF THE TOXIC METALS IN THE SOIL SAMPLE

Serial Number	Sample Location	Co %	As %	Cr %	Ni %	Mn %	Pb %	Zn %	Cu %
1	Kwanar – Doya Site	45.21	58.26	73.64	77.85	48.15	30.11	70.48	48.32
2	Control Site	23.30	19.10	33.40	12.67	42.41	23.86	47.58	58.04

TABLE 5: DISTRIBUTION OF TOXIC METALS BOUNDS TO EACH FRACTION FROM SOIL SAMPLE

S/N	Sample Location	Fractions	Co %	As %	Cr %	Ni %	Mn %	Pb %	Zn %	Cu %
1	Kwanar – Doya Site	F1	14	BDL	23.85	23.79	7.08	10.03	2.36	12.40
2	Kwanar – Doya Site	F2	15.9	26.98	28.09	21.38	14.41	12.26	2.39	10.07
3	Kwanar – Doya Site	F3	14.23	31.27	21.69	32.66	26.65	7.80	65.72	25.83
4	Kwanar – Doya Site	F4	14.23	15.08	17.53	8.9	9.51	24.53	5.81	8.39
5	Kwanar – Doya Site	F5	40.55	26.64	8.82	13.20	42.33	45.35	23.69	43.28

TABLE 6: DISTRIBUTION OF TOXIC METALS BOUNDS TO EACH FRACTION FROM SOIL SAMPLES FROM THE CONTROL SITE

S/N	Sample Locations	F	Co %	As %	Cr %	Ni %	Mn %	Pb %	Zn %	Cu %
1	Control Site	F1	11.40	9.97	8.01	0.98	20.79	13.83	17.65	32.16
2	Control Site	F2	5.55	5.12	8.23	2.53	14.18	5.15	20.71	0.69
3	Control Site	F3	6.35	4.04	17.15	9.15	7.34	4.88	9.22	25.17
4	Control Site	F4	58.05	64.38	47.21	35.21	31.24	59.31	28.72	38.46
5	Control Site	F5	18.64	16.52	19.37	52.11	26.44	16.81	23.69	34.96

Note: F1 and F2 represent the Exchangeable fraction and Carbonate Fraction. F3 and F4 represent the Easily Reducible Fraction and Organic Fraction. F5 represents Residual Fraction in the Sequential Extraction Procedure.

Fig. 3. Partition of toxic metals into different fractions in the kwanar –doya soil.

A. Physico-chemical Parameters (pH and Electro Conductivity)

Analysis of the soil samples revealed that the electro conductivity value was very low in the Kwanar–Doya shooting site, which also corresponds with the low values recorded at the control site, as displayed in Table 2. These values recorded at both sampled sites were below 200 $\mu\text{S}/\text{cm}$ (0.2 ms/cm). This indicates that the soil does not have enough nutrients available to the plants and could perhaps show a sterile soil with little microbial activity [26]. It was reported that decreased conductivity in soil may be attributed to high amount of metal substances in the soil [25]. Similarly, it was also suggested that increase in the concentration of some soluble salts in the soil could be as result of anthropogenic sources which could lead to increase in the electro conductivity of the soil [27]. The low electro-conductivity value observed in the soil could also be associated with its inability to conduct electric current as high electro-conductivity value were a good indicator for the presence of soluble substances such as potassium, chlorides, sodium, and sulphates [28]. The low electro conductivity values recorded at the Kwanar-Doya shooting site could not be related to the shooting activities, which takes place at the site; as the control site also had a low electro conductivity value as observed.

Low pH values were also recorded in the sampled site and the control site as displayed in Table 1. The pH values were below the neutral pH value of 7, indicating that the soils in both the Kwanar–Doya shooting site and the control site were acidic. A similar report was obtained in the soils of Kachia and the pH values recorded in his research showed that the soils were also acidic [29]. The acidity of the soil at the Kwanar-Doya shooting site could not be related to the shooting activities going there, as the control site had a low pH value with no shooting activity observed there.

B. Toxic Metal Concentrations

Results showed that the toxic metals concentrations in the Kwanar-Doya shooting soil were higher in the shooting range than the control site. According to [10] military activities such as shooting were responsible for the large deposit of toxic metals in the soils of all shooting sites observed in her research. It was also reported similar occurrence of toxic metal deposit especially components of bullets such as lead and nickel [11].

High copper concentrations were recorded in the control site as compared to the Kwanar-Doya site as displayed in Table 3. The values obtained from both sites were above the WHO permissible limit for copper in soil. The high content of copper in the control may have resulted from the use of copper fertilizer [30] as the control site is known to be an active farmland. The copper content in the shooting site can be related to the shooting activities undergoing there as there were no observed farming activities at the shooting site. This is rather much as compared to the values obtained at the Kwanar-Doya shooting site, but its presence is a confirmation of the shooting activity as its prime source in the soil.

Lead concentration in both sampled soils was higher than the WHO values recommended for toxic metals in soil. The lead value for Kwanar–Doya shooting range was higher than the control sites as observed in Table 3.3. The value obtained at the shooting sites tends to correlate with some values in the lead content obtained by [10] in military training areas in one division, Kaduna Nigeria. The amount of lead recorded at the control site could not be attributed to any shooting range activities as the Kwanar–Doya shooting site. The presence of lead could either be as a result of other anthropogenic source such as the use of pesticides and fertilizers [25] by the farmers, as there were no observed metallic producing industries at the site. The harmful effects of lead metal to humans are damage to kidneys, nervous system, learning ability, ability to synthesize protein, and nerve and red blood cells.

Chromium values at the shooting site were in the exact threshold limit of chromium metals in soil as recommended by W.H.O. The chromium content in the shooting site was higher than the chromium content in the control site as displayed in Table 3.3. The presence of chromium metal to the point of it being in the same limit as the recommended value showed that, its deposition was as a result of shooting activities in the shooting range. The control site had a chromium concentration that was below the recommended value but still poses as a serious threat in the future; as its increase could be absorbed by the crops been grown at the farm land. This could be as result of other anthropogenic factors excluding military input. The presence of chromium in the control site could also be as result of weathering of the soil bedrock or other anthropogenic source except from shooting activity and metal production industries. Chromium has been found to be a very important component in weaponry fabrications of arms and thus its presence in all military sites to be unarguable due to its use. Although chromium toxicity to the environment is relatively unpopular, it still presents some risk to the human health, since chromium can be accumulated in the liver, dorsal spine, hair, nails and placenta [31].

Nickel concentration in this study was below the W.H.O permissible value for nickel metal in soil. The obtained at the

Kwanar–Doya shooting site was above the amount recorded in the control site. The increase in the value of nickel concentration in the shooting site can be related to shooting activities been performed by military personnel. Nickel directly forms a component of 0.5% in bullet making [32], [33] also reported that most of the Swiss military shooting sites were heavily toxic with a mean of 917 mg / kg making the soil very dangerous for animals to consume plants grown on the soil. The values of Nickel obtained at the shooting site were lesser than the values recorded by the authors above. This is good for effective monitoring and available remediation, so as effectively curb its toxicity in the soil before its values reaches a much higher quantity as reported [10]. The nickel content of 3.67 mg/kg in the soil of the control site may be as result of the weathering of the bedrock in that sampling area. Since nickel cannot be deposited by any agricultural practices except through metallic sources [13].

Zinc concentrations for the shooting site and the control site were below the WHO permissible limit for Zinc in soil as displayed in Table 3. Zinc in the control site tends to be higher in value as result of the application of agrochemicals in the farmland. The amounts of extractable zinc in the shooting site were smaller than the control site.

3.3. Sequential Extraction

Fractionation of total metal content may give indications of the origin of the metals. High level in the exchangeable, acid soluble and reducible fraction may indicate pollution from anthropogenic origin [35]. The results of the distribution of the toxic metals are displayed in Table 5, 6 and Fig. 3. While the mobility factor results of the toxic metals were displayed in Table 4.

Cobalt: The potential bioavailability of the cobalt metal in the shooting site soil were as follows in this order: Residual fraction (40.50%) > Bound to carbonate (15.90%) > Exchangeable (14.30%) > Fe – Mn Oxide (14.23%) > Organic (14.23%). This clearly shows that the bulk of the cobalt metal which was distributed in the residual fraction and the least at the organic fraction. The result as displayed in Table 3.5-3.6 shows that most of the cobalt metals are in the non-active forms and thus that percentage in the residual and organic fraction poses no serious threat to the plants and the outer environment. The mobility factor of cobalt as displayed in Table 4 is 45.21%, thereby making the metal to be readily bioavailable as a result of the combined fractions in the bioavailable regions.

Chromium: The order of bioavailability of chromium metal in the shooting site is as follows: Bound to carbonate (28.09%) > Exchangeable (23.85%) > Fe – Mn Oxide (21.69%) > Organic (17.53%) > Residual (8.82%). The distribution of chromium shows that the metal is more represented in the bioavailable fractions and thus its origin could be anthropogenic. The mobility factor of the metal in the soil is 73.64%, thereby making the metal more bioavailable to the plants and animals.

Nickel: Nickel metal in the shooting site soil tends to have a higher mobility factor of 77.85%, making the metal more bioavailable to the plant, although being lower than the W.H.O value for nickel in soil. The mobility of nickel shows that the plants might absorb the metals very quickly in a short period of time. The order of bioavailability is as follows: Fe – Mn Oxide (32.66%) > Exchangeable (23.79%) > Bound to

carbonate (21.38%) > Residual (13.20%) > Organic (8.9%). The bioavailable fractions of the shooting site soil had nickel highly distributed in it and thus be more reactive to the soil solution in the shooting site.

Arsenic: The arsenic value obtained from the shooting site soil was far above the WHO permissible limit and the mobility factor of arsenic was 58.26%. This made the mobile phase appreciable and thus the rate of the metals to reach the outer environment fast. The order of the distribution of arsenic in the different fractions is as follows: Fe – Mn Oxide (31.27%) > Bound to carbonate (26.98%) > Residual (26.64%) > Organic (15.08%) > Exchangeable (BDL). These values confirm the presence of arsenic metal for easy uptake by the plant and animals.

Manganese: The order of distribution of manganese metal in the shooting site soil is as follows: Residual (42.33%) > Fe – Mn Oxide (26.65 %) > Bound to carbonate (14.41%) > Organic (9.51%). The result shows that manganese was highly distributed in the residual fraction and the least distribution occurring at the organic fraction. The mobility factor of manganese in the soil was 48.15%, thereby making it bioavailable to the plants and animals.

Lead: The total content of lead in the shooting range soil was above the WHO permissible limit, making it a huge concern for the existing environment. The mobile phase of lead in the soil was 30.11%, thereby making it readily available for uptake by plants and animals. The potential bioavailability of lead is as follows: Residual (45.35%) > Organic (24.53%) > Bound to carbonate (12.26%) > Exchangeable (10.03%) > Fe – Mn Oxide (7.80). the non-reactive fraction had the highest distribution of lead at the shooting site soil, while the least distribution occurred at the reducible fraction.

Zinc: The value of zinc in the total toxic metal content in the shooting range soil was below the WHO permissible limit. The percentage of metal in the mobile factor is 70.8% making it readily available for plant uptake. The order of bioavailability is as follows: Fe – Mn Oxide > Residual > Organic > Bound to carbonate > Exchangeable. This result shows that the soil was highly distributed in the non-reactive fractions and little reactive forms of zinc were available for the outer environment.

Copper: The potential bioavailability of the copper metal in the shooting range soil are in the following order: Residual (43.28%) > Fe –Mn Oxide (25.83%) > Exchangeable (12.40%) > Bound to carbonate (10.07%) > Organic (8.39%). Copper was evenly distributed between the bioavailable fractions and the non-reactive fractions as displayed in Figure 1. The mobility factor of copper in the sampled soil was 48.32%, thereby making it more bioavailable to the plants for absorption.

IV. CONCLUSION

This study has revealed that the soil sample obtained from the Kwanar-Doya shooting site of the Nigerian Army Military Training Ground, camp highland, Kachia, Kaduna State was acidic and had little nutrients in the soil. From the total toxic metals in the soil, it can be seen the concentration of the metals were above the WHO permissible limit for toxic metals except for zinc and Nickel. Its distribution showed that

most of the metals was highly distributed in the bioavailable fractions and had high mobility factors in all the toxic metals in the soil, making them readily available for plants uptake. Phyto –remediation of affected soil should be affected as it will help reduce the deposit of these toxic metals in the soil and also preserve the environment and the site. The continual use of the site should be done with caution and the use of agricultural activities should be minimized to avoid bioaccumulation and eventual transfer to humans.

ACKNOWLEDGMENTS

The authors wish to acknowledge the sponsorship of the project by the Tartary Education Fund (TertFund) for the 2017/18 session. The great assistance of the Commandant Nigerian Defence Academy and the authorities of Defence Industries Cooperation of Nigeria Kaduna in the use of their analytical instruments is highly appreciated.

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