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Determination of Radioactive Elements Concentrations in Soils of Selected Areas in Akwa Ibom State, Nigeria by Instrumental Neutron Activation Analysis

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Abstract
A determination of radioactive elements concentrations in soils in selected parts of Akwa Ibom state, Nigeria were carried out by Instrumental Neutron Activation Analysis (INAA) technique. The soil analysis was conducted at the Nigeria Nuclear Research Reactor (NIRR – 1) at center for Energy Research and Training (CERT), Ahmadu Bello University Zaria, Nigeria. Twenty elements that include short lives, intermediate lives and long lives radioactive elements were detected in soil samples used for the analysis. The obtained radionuclides includes Na, Ti, V, As K, Mn, Sb, Fe, Dy, Pa, Mg, Sc, Yb, Ce, Co, Sm etc. The results show that INAA of soil samples of the area under investigation gave concentration of 20.05± 0.60ppm for K, 9.36± 0.79ppm for Na, 5.73± 0.50ppm for Fe, 5.38± 0.62ppm for Cr, 4.24± 0.25ppm for As and 3.65± 0.32ppm for Sb, etc. Comparison of the result from this with other studies show difference in the number of elements obtained which is attributed to the difference in the geology of these areas.
Keywords: Soil, INAA, concentration, Radionuclides and NIRR-1

INTRODUCTION

Human health status is a function of his immediate environment. The level of the contamination of our environment therefore has a great effect on the quality of human health. Importantly, human activities have lead to an enhanced level of air, soil and water pollution in our environment. At has been observed that air pollution and water pollution can have inimical effect to soil, thereby altering its elemental composition also the activities in the universe has direct or indirect effect to the soil [1]. These effects include the change in the nutrition content of soil, soil toxicity level as well as soil degradation rate. Elemental analysis of soil particles has become necessary due to the effects of these particles on the environment and health [2]. Elemental particles associated with natural sources like soil and ocean are found to contain with the coarse particulate while elemental emission from anthropogenic sources are associated with fine particulate. Anthropogenic sources have also been found to be responsible for the concentration of trace metals in barks of trees [3].

Nowadays, there exists a need to determine not only the total concentration of elements in examined soil samples, but also concentrations of various forms in which these elements could exist. Bioaccumulation and influence on living organisms of these elements depend on their physiochemical forms. Examination of element distribution in soil is very important because under environmental conditions, it can accumulates or release them. Although mineral elements are essential in the nutrition of green plants, but their abundance beyond the required amount in soils becomes a problem to soil microbes and the healthy growth of plants.

Air pollution caused by trace metal like lead from motor vehicles is capable of resulting into serious health consequences such as impairment of circulatory, reproductive and nervous systems as well as kidney problems. Lead has also been linked with hyperactivity and lowered hearing ability in children. Other elements which are constitute of crude oil soil such as V, Cd and As are released into the atmosphere during the combustion of petroleum products. Heavy metals like Fe, Ni, Cr, Sb, Zn, which are essential components of motor vehicles parts like tyres and brakes, are also emitted as a result or wear and tear. When the concentrations of some of these elements exceed a certain limits in the body, they become toxic, posing health hazards.

Studies of concentration of element in the soils using destructive methods also detects the presence of major, minor and trace elements in different media. In dumpsite, Zn Cd, Co, Cr, Cu, Fe, Pb Mn and Ni were detected [4,], accumulation of radioactive elements also detected in vegetable leaves [5]. High concentration of Ni and Pb were observed within the vicinity of an automobile workshop by [6]. The mean concentration of Cu in soils and vegetations of about 2.57±1.87 ppm and 1.48± 1.61ppm respectively and other elements such as Zn, Pb were detected at a dumpsite in Nigeria using atomic absorption spectrometry were also found at a dumpsite in Kaduna, Nigeria [7].

It has been established that air and soils pollution constitute major health hazards to environmental subsystems and the exposure of human beings, plants, and animals to toxic trace pollutants in the ambient outdoor air depends mainly on the quantity emitted, closeness to sources and prevailing weather conditions, and these toxic elements could have a reasonable high resident time in the air and finally settle down on soils surface [8]. It has been established that air and soils pollution constitute major health hazards to environmental

subsystems. In addition, the presence of radioisotopes in materials causes external exposures to people who are living in the building built from them. The source of ^{236}Ra and ^{234}Th increases the concentration the concentration ^{222}Rn and ^{220}Rn and their progenies. The inhalation of these Radon isotope leads to the internal exposure of the respiratory track [7]. Radioisotopes found in the soil samples are categorized as short lived isotopes (Mg, Al, Ti, V, Ba and Eu), intermediate lived isotopes (Na, K, mn, Dy) and long lived isotopes (Sc, Cr, Fe, Co, Ce, Rb, La, Hf, Sm and As) [8].

Instrumental Neutron Activation Analysis (INAA) is a quantitative and qualitative method for the precise determination of a number of major, minor and trace elements in different types of samples. It is a useful method for the simultaneous determination of more than 30 elements of geological, environmental, biological samples in ppb-ppm range without or with chemical separation [7]. In The method is based upon the conversion of stable atomic nuclei into radioactive nuclei by irradiation with neutrons and subsequent measurement of the intensity of the characteristic gamma ray lines in the spectra [8].

The thermal neutron flux (Q_{ith}) used in the analysis is given by the equation below [9]

$$Q_{ith} = \frac{\frac{dN}{dt}}{\varepsilon_G I_\gamma K \sigma m N_A f (1-e^{-\lambda T})(1-e^{-\lambda t_m})} A e \lambda t_d \qquad (1)$$

where t_m is the real time measurements, t_d is the transporting time, ε_G is the geometry dependent efficiency of the detector, σ, thermal neutron capture cross section, λ = decay constant of product nuclei, A is the atomic weight of element, m is the mass of the bombarding element, $\frac{dN}{dt}$ is the activity of emitted gamma, N_A is the Avogadro number, f is the isotopic abundance of the target nuclei, I_γ is the intensity of the gamma ray lines and K is the correction for the self absorption of gamma ray in the samples. The detector efficiency is obtained from

$$\varepsilon = \frac{n}{tP_\gamma(E)N_0 e^{-\lambda t_d}} \qquad (2)$$

where n is the net area under the full energy peak of gamma ray energy E, within the counting time t, $P(E)$ is the gamma emission probability at energy E, N_0 is the activity of the source, t_d is the time decay and λ the decay constant. The thermal neutron cross section and isotopic abundance values of the sought elements and gamma emission probability are obtained from published standards values in [13, 14].

Instrumental Neutron Activation Analysis has been employed for the analysis of element content of rock samples from Ugep region of Cross River State [15]. This same analytical tool has been used to determine large data sets of elements in Nigerian Coal subject to cluster procedures [16] and also to evaluate the homogeneity of reference samples [17]. About 70% of the elements in nature have nuclide possessing properties suitable for INAA [18] and with this technique, it is possible to measure more than thirty elements in a sample and other applications of INAA ranging from the analysis of biological materials to ambient air particulate matter have been reported in many journal articles [3,1].

Presently, there are no data available on the elemental concentration in soils and their distribution pattern in Akwa Ibom State, Nigeria. This work is aimed at developing baseline study of the radioisotopes concentrations in soils of some selected areas of Akwa Ibom State Nigeria using INAA.

2.0 MATERIALS AND METHODS

2.1 Study Area.

The areas selected for this study were Uyo and Etinan Local Government Areas. These are among the major cities in the North East region of Akwa Ibom State, Nigeria. Uyo is the State capital that harbors many industrial firms and is characterized by high level of commercial activities. It is highly densely populated. Etinan is a semi-urban area that also harbors industrial firms and is partly bordered by Uyo. It is less densely populated. Soil samples were collected at strategic positions.

2.2 Sample collection

At each of the sample location, the top surface of the soils was scraped off to a depth of 20cm. This was done in order to remove any trace of contamination of top soil surface within the 20 cm depth location due to human activities. Five kilogram (5kg) soil sample were collected at a depth of 5cm using plastic hand trowel to eliminate the possible addition of any major, minor or trace element from a metallic trowel to the field samples.

Each of the collected soil samples was thoroughly mixed, sieved and loaded in a polythene bag and properly labeled for easy identification. The samples were thereafter transported to the laboratory of the Reactor at the Center for Energy Research and Training (CERT), Ahmadu Bello University (ABU), Zaria, for analysis.

2.3 Samples preparation

Within the laboratory of the Reactor Facility Section of the Center for Energy Research and Training (CERT), Ahmadu Bello University (ABU), Zaria, the soil samples were exposed to ambient air in a dust-free environment before being dried to a constant weight for 48 hours in a monitored KETONG 101 oven maintained at 150^0c in the balance room of the research center. Each of the dried samples were re-homogenized and quartered. 150mg of each soil samples was weighed and wrapped in acid-cleaned polythene film and heart-sealed and labeled before irradiation. A similar treatment was also given to standard reference materials (SRMS). Two samples were prepared for each location for long and short irradiation respectively. The prepared samples and standard were packed with cotton wool and heat-sealed in $7cm^3$ rabbit capsule and sent through pneumatic rabbit transfer system for irradiation. Instrument neutron activation analysis of the samples within the capsule was then performed using the Nigerian Research Reactor -1 (NIRR -1) of the center for Energy Research and Training, Ahmadu Bello University, Zaria operated at power level of 1.0×10^{11} neutron per cm^2 per second. For short irradiation regime, the duration was 10-12 minutes while for long irradiation regime, the duration was beyond 30 minutes for the samples. The gamma rays emitted by these radionuclides when they decay to stable forms are used to both identify the isotopes (elements) and to determine their absolute concentrations [19]. After correction for geometry, flux variations and decay times by a computer assisted program (SPAN -50 data acquisition software), absolute elemental concentrations in the samples were determined by reference to the certified reference materials (CRMs).

3.0 RESULTS AND DISCUSSION

The soil sampling locations, location codes and location description are presented in Table 1 with locations in Uyo local government areas codes UYY 01 to UYY 05 while locations in Etinan local government areas Coded ETN 01 to ETN 05. Location UYY 03 is soil sample within the premises of a brewery while ETN 04 is a health institution.

The results of the concentration of the elements detected in the soils of selected areas by INAA techniques measured in part per million (PPM) are reported in Figs. 1 and 2.

Table 1: Soil sampling locations within the study Areas

Location Code	Sampling Location
UYY 01	An automobile workshop
UYY 02	Motor Park
UYY 03	Brewery
UYY 04	Market place
UYY 05	School
ETN 01	Paint industry
ETN 02	Road Junction
ETN 03	School
ETN 04	Health facility
ETN 05	Efa Community

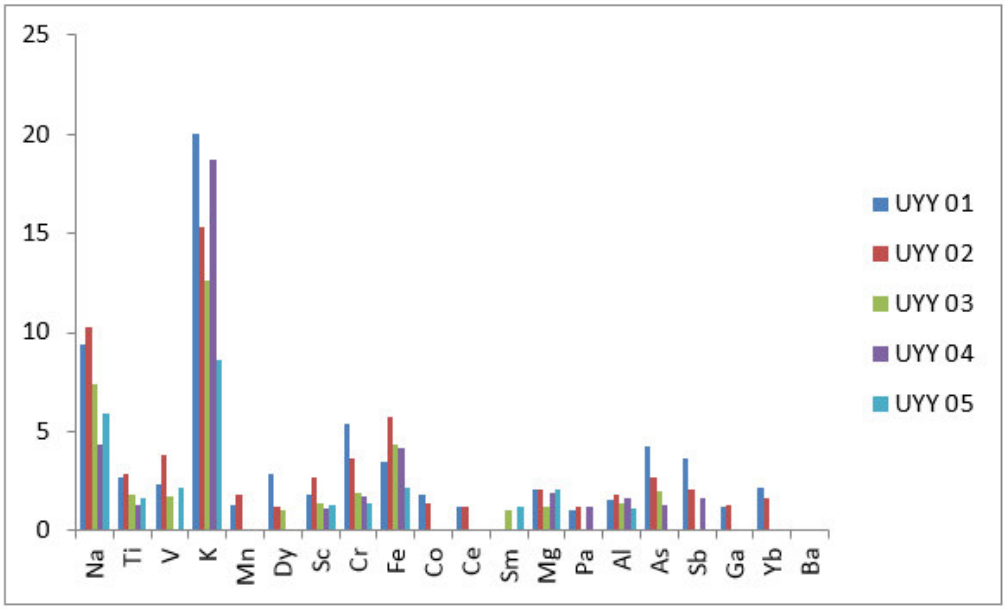

Fig.1: The concentrations of the elements in soils in Uyo Local government area.

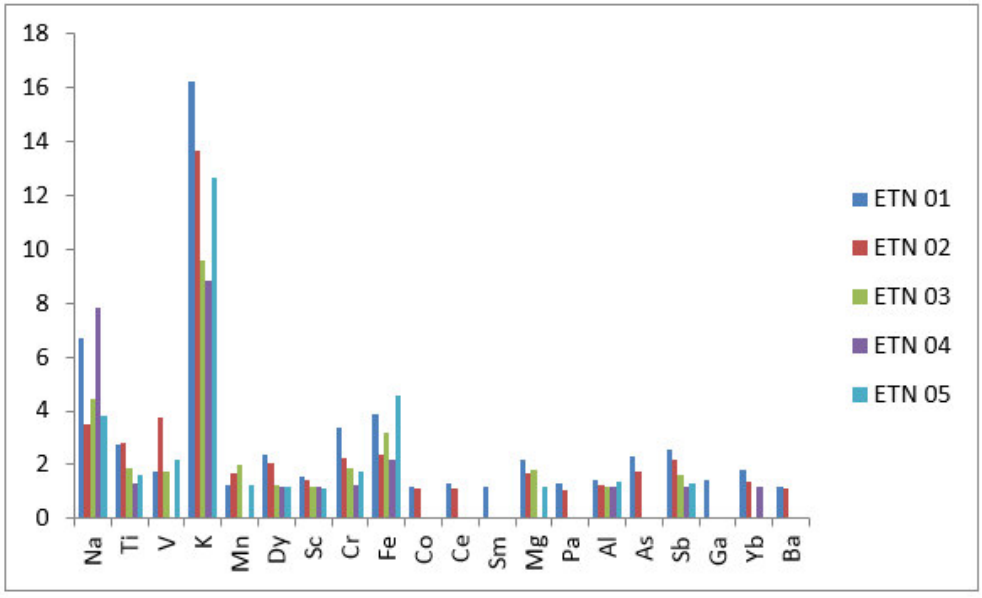

Fig. 2: The concentrations of the elements in soils in Etinan Local government area.

Twenty elements were detected in the soil sample using the INAA technique. Some of the elements in figures 1 and 2 were below the detection limit of the instrument. Essential mineral elements such as K, Mg, Al, Na, Ti, V, Dy, As, among others which are of interest in soil mineralogy were determined. Although the concentrations determined in the soil may not be readily available for plants, the soils under investigation are not completely deficient in macro-nutrients [20].

Heavy metal like Arsenic (As), which is semi-metallic element, is known to be highly poisonous, while protactinium (Pa) is radioactive in nature. The availability of these elements in the soil has the potential of increasing health threat to human population mostly when they find themselves into edible crops, through their roots [2]. The elements like Gallium, magnesium, manganese, Arsenic were not detected in some locations while some were below the detection limit of the instrument. These show the elements are scarcely present and not uniformly distributed in the study area.

However, elements which are needed in trace amount by plants were detected in the area of this study, thus suggesting that the soil under investigation is suitable for the cultivation of certain crops. For the purpose of comparison of the results of this study, the reference materials; IAEA soil 7 was used as analytical quality control to validate the produce for all the elements in the samples. The concentration of each of the elements determined from this work was compared with certified values measured in part per million (ppm) as shown on Table 3. The results reveal that the concentrations of the elements are within the certified range of confidence

value [21]

Table 3: Radionuclide of the elements and comparison with IAEA soil 7 - Using NIRR -1

Elements	Nuclide	ɣ(Ke V)	Confidence value (PPM)	Range (PPM)	This Work (PPM)
Na	^{24}Na	1368.5	-	-	17600±85
V	^{52}V	1434.0	-	-	4.82 ±0.08
As	^{76}As	559.1	23.6	22.9-24.3	19.23 ±0.84
K	^{42}K	1524.6	24900	17700-32100	27330 ± 410
Dy	^{165}Dy	94.0	-	-	7.20± 0.11
Sb	^{122}Sb	564.2	1.81	1.62-2.60	1.98±0.43
Mn	^{56}Mn	1810.4	-	-	2.49± 0.40
Sc	^{46}Sc	889.3	13.52	11.53-15.51	12.28± 0.22
Fe	^{30}Fe	1099.3	37400	36700-38100	35600± 450
Ga	^{72}Ga	834.1	-	-	14.58± 3.20
Th	^{233}Pa	312.1	14.3	12.2-16.4	13.76± 0.68
Al	^{28}Al	1779.0	-	-	573.0± 10.0
Cr	^{51}Cr	320.1	84	80-88	68.0± 41.0
Mg	^{27}Mg	1014.4	19700	-	14700.0± 210.0
Ce	^{141}Ce	145.4	-	-	79.43± 2.38
Co	^{60}Co	1173.2	13.7	13.0-14.4	12.84± 0.67
Ba	^{131}Ba	123.8	-	-	289.7± 24.6
Sm	^{153}Sm	103.2	6.86	6.50-7.22	8.05± 0.26
Yb	^{175}Yb	282.5	3.04	2.19-3.89	1.92± 0.41

Table 4: Comparison of the concentration of elements in the soil of the study area with other studies

Radionuclide	This work (ppm)	Ikot Abasi (ppm)	Abuja (ppm)
^{24}Na	17600±85	16660±67	2633 ±13.17
^{40}K	27330±410	24830±397	0.6196±0.076
^{26}As	19.23± 0.84	21.18±0.59	4.439±0.32
^{30}Fe	35600± 450	36680± 550	0.6641±0.017
^{60}Co	12.84± 0.60	14.17± 0.57	22.50±1.17
Mg	14700±210	ND	7957.0± 2220.0
Ti	2.52± 0.18	ND	9821± 756.22

ND: Not detected

Comparison of the concentration of some of these radionuclides obtained in this work with other studies within Nigeria (Table 4) shows difference in concentrations. Higher concentration of As and ^{30}Fe were observed in Ikot Abasi a local government area of Akwa Ibom State, Nigeria over other local government areas. This could be a result of smelting activities in Ikot Abasi [24]. In addition there is difference in the number of radioisotopes obtained from the different areas of studies, 25 elements were obtained in Ikot Abasi [2], 30 elements in Abuja [25] while 20 elements are obtained in this study. This difference is due to the difference in the geology of these areas.

4.0 CONCLUSION

In instrumental Neutron Activation Analysis (INAA) technique has been employed to determine twenty elements in the soil of Uyo and Etinan local government areas, Nigeria. The elements determined include heavy metals like Fe, Sb, Sm, Cr, Yb, Co, etc, as well as trace elements like Mn, V, Ti, K, etc. Some of these determined heavy metals are known to be toxic and dangerous to human mostly through their in-take by ground waters and growing crops. While some of the trace elements are favorable to plants existence. Some of these elements determined show concentrations as high as 20.05 ± 0.50ppm for Fe 5.38 ±0.62ppm for Cr, 4.24 ±0.25ppm for As. The determined elements are not uniformly distributed in the soil of the studied area because of the difference in the geology of the areas.

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