Study of Some Heavy Metals and Radioactive Element from Soil Samples, Nyala Area -Sudan

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Abstract: In this work X-ray fluorescence (XRF) technique was used to evaluate the soil pollution with heavy metals for 40 surface and sub-surface soil samples (0–5 cm in depth) from various locations to cover the area of Nyala city, Sudan. Concentrations of eleven elements Cr, Ni, Cu, Zn, Pb, Co, Fe, Zr, Y, Rh and V were determined. The study established as the data baseline to the major and minor trace elements from study area that has not been investigated before. The elemental concentrations were compared with the normal values and other studies in different locations from the world. The correlation between elements indicates that no pollution exists inside the investigated area. The results indicated that all the samples analyzed are safe in general for the toxicity levels. The results establish a database reference of radioactivity background levels for the study around Nyala city.

Keywords: XRF, Heavy metals, Soil samples, Environmental pollution, Nyala area.

1. Introduction

Heavy metals are defined as metallic elements that have a relatively high density compared to water [1]. With the assumption that heaviness and toxicity are inter related, heavy metals also include metalloids, such as arsenic, that are able to induce toxicity at low level of exposure [2]. In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by these metals. Also, human exposure has risen dramatically as a result of an exponential increase of their use in several industrial, agricultural, domestic and technological applications [3]. Sources of heavy metals in the environment include geogenic, industrial, agricultural, pharmaceutical, domestic effluents, and atmospheric sources [4]. Environmental pollution is very prominent in point source areas such as mining, foundries and smelters, and other metal-based industrial operations [1, 3, 4].

Heavy metals induced toxicity and carcinogenicity involves many mechanistic aspects, some of which are not clearly elucidated or understood. However, each metal is known to have unique features and physico-chemical properties that confer to its specific toxicological mechanisms of action. This review provides an analysis of the environmental occurrence, production and use, potential for human exposure, and molecular mechanisms of toxicity, genotoxicity, and carcinogenicity of arsenic, cadmium, chromium, lead, and mercury [1, 2, 3, 4]. Measurements and studies of natural radioactivity in soil and rocks are very important to determine the amount of change of the natural background activity with time as a result of any radioactive release; monitoring of any release of radioactivity to the environment is important for environmental protection [3].

In recent years, attention has been drawn to the development and steady introduction of analytical methods suitable for quantification of thorium and uranium tracers. From the viewpoint of radiation protection, determination of natural radionuclide’s such as $^{238}$U, $^{40}$K and $^{232}$Th in soil samples are also important.

Studying the levels of radionuclide distribution in the environment provides essential radiological information [5,6,7,8]. As a result of rapid urbanization and industrial development, heavy metal contamination has been threatening human health [9].

A soil pollution assessment becomes very complex when different sources of contamination are present and their products are variably distributed. In these cases, the spatial variability of heavy metal concentrations in soils is basic information for identifying the possible sources of contamination and to delineate the strategies of site remediation. The main objective of this study is to determine the level of soil pollution and assess the heavy metal and trace elements contamination for surface and subsurface soil samples of Nyala Area, and to compare with other studies, whose activity of human lasted few years, being one of the most important metallurgical complexes and representing a great potential of environmental contamination [5-8, 10].

2. Material and Methods

40 soil Samples were collected during July 2015 and August 2015, at surface level (0–5 cm in depth) from various locations to cover study area, Nyala city is the capital of South Darfur state in the western part of the Sudan. Its located at elevation 2,208 feet (673 m) in Darfur region,[11] located at the intersection of longitude 24.53 degrees east and latitude 12.03 degrees north, It is important to note that this area is high density populated and tourism area. The soil samples were dried, homogenized and sieved at 200 mesh grain size. Pressed powder pellets were prepared to avoid the elements contaminations, heavy metals and trace element analysis of samples by X-Ray fluorescence performed using a Philips PW XU unique, This instrument is connected to a computer system using X-40 program for spectrometry. The trace elements concentrations are calculated from the program’s calibration curves which were set up according to international reference materials, (standards). The detection limit is the lowest concentration, and it is function of the level of background noise relative to
an element signal [12]. The distance between each successive sample about one kilometer.

Figure 1: Map of Nyala city, South Darfur state, Sudan [11]

3. Results and Discussion

The concentration of heavy metals elements for Nyala area from 24 soil selected samples are presented here:

Table 1: Heavy metals concentration (in ppm) using XRF techniques for some selected soil samples from Nyala city.

| No | Sample | Depth | Cr  | Ni  | Cu  | Zn  | Pb  | Co  | Fe  | Zr  | Y   | Rb | V   |
|----|--------|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|-----|
| 1  | S01E   | 0     | 0.012 | 0.007 | 0.008 | 0.033 | 0.008 | 0.007 | 2.880 | 372.820 | 25.660 | 92.290 | 61.590 |
| 2  | S02E   | 5     | 0.022 | 0.003 | 0.005 | 0.011 | 0.008 | 0.000 | 1.314 | 198.401 | 10.165 | 89.321 | 65.321 |
| 3  | S05E   | 0     | 0.016 | 0.008 | 0.007 | 0.013 | 0.007 | 0.000 | 3.048 | 200.231 | 11.289 | 85.320 | 60.215 |
| 4  | S06E   | 5     | 0.028 | 0.002 | 0.002 | 0.004 | 0.003 | 0.000 | 1.023 | 154.254 | 13.967 | 88.321 | 55.321 |
| 5  | S09E   | 0     | 0.019 | 0.007 | 0.007 | 0.005 | 0.001 | 0.000 | 0.842 | 198.879 | 14.212 | 83.001 | 50.214 |
| 6  | S10E   | 5     | 0.023 | 0.003 | 0.004 | 0.009 | 0.002 | 0.000 | 1.373 | 198.458 | 15.154 | 88.321 | 27.675 |
| 7  | S01W   | 0     | 0.015 | 0.007 | 0.004 | 0.004 | 0.002 | 0.000 | 2.471 | 343.733 | 17.146 | 90.812 | 41.761 |
| 8  | S02W   | 5     | 0.017 | 0.003 | 0.007 | 0.004 | 0.003 | 0.000 | 1.212 | 200.215 | 14.121 | 55.658 | 41.761 |
| 9  | S05W   | 0     | 0.023 | 0.001 | 0.002 | 0.001 | 0.000 | 0.000 | 1.119 | 197.666 | 10.089 | 51.085 | 39.698 |
| 10 | S06W   | 5     | 0.017 | 0.004 | 0.001 | 0.001 | 0.000 | 0.000 | 1.084 | 315.635 | 12.980 | 4.713 | 44.226 |
| 11 | S09W   | 0     | 0.025 | 0.000 | 0.003 | 0.001 | 0.000 | 0.000 | 1.119 | 105.514 | 9.666 | 8.0756 | 41.666 |
| 12 | S10W   | 5     | 0.013 | 0.003 | 0.006 | 0.001 | 0.003 | 0.007 | 2.684 | 198.401 | 11.200 | 154.321 | 36.108 |
| 13 | S01S   | 0     | 0.016 | 0.000 | 0.001 | 0.004 | 0.002 | 0.000 | 0.059 | 105.514 | 13.808 | 114.300 | 31.178 |
| 14 | S02S   | 5     | 0.019 | 0.003 | 0.002 | 0.004 | 0.004 | 0.000 | 0.847 | 198.401 | 15.128 | 77.326 | 29.640 |
| 15 | S05S   | 0     | 9.726 | 3.106 | 0.852 | 0.167 | 0.000 | 0.000 | 29.18 | 171.760 | 13.422 | 68.617 | 39.698 |
| 16 | S06S   | 5     | 0.024 | 0.003 | 0.012 | 0.003 | 0.002 | 0.000 | 1.182 | 263.028 | 15.545 | 69.604 | 42.783 |
| 17 | S09S   | 0     | 0.023 | 0.000 | 0.051 | 0.001 | 0.001 | 0.000 | 1.217 | 213.277 | 14.321 | 48.759 | 29.640 |
| 18 | S10S   | 5     | 0.015 | 0.002 | 0.053 | 0.002 | 0.002 | 0.000 | 1.671 | 699.122 | 28.543 | 56.325 | 43.175 |
| 19 | S01N   | 0     | 0.014 | 0.006 | 0.006 | 0.021 | 0.007 | 0.000 | 2.791 | 442.841 | 29.556 | 95.088 | 69.071 |
| 20 | S02N   | 5     | 0.027 | 0.008 | 0.002 | 0.004 | 0.002 | 0.000 | 1.892 | 295.127 | 18.947 | 74.986 | 52.745 |
| 21 | S05N   | 0     | 0.019 | 0.005 | 0.004 | 0.004 | 0.002 | 0.000 | 1.267 | 215.350 | 16.001 | 56.325 | 69.071 |
| 22 | S06N   | 5     | 0.018 | 0.007 | 0.004 | 0.004 | 0.000 | 0.004 | 2.894 | 298.218 | 17.923 | 69.084 | 70.604 |
| 23 | S09N   | 0     | 0.026 | 0.004 | 0.001 | 0.001 | 0.002 | 0.000 | 1.541 | 858.960 | 31.22 | 65.324 | 52.908 |
| 24 | S10N   | 5     | 0.031 | 0.003 | 0.000 | 0.002 | 0.003 | 0.000 | 1.542 | 215.35 | 15.020 | 56.325 | 50.654 |

XRF results for the collected soil samples evident the existence of the following elements: Co, Fe (major) Cr, Ni, Cu, Zn, Pb, Zr, Y, Rb and V (minor).

The average concentrations of heavy metals Cr, Cu, Ni, Pb and Zn for more than one measurements of each of the soil samples presented in part per million (ppm) units are given in Table 1 [10]. It was found that Fe concentrations for all studied sites are very high (2.880 ± 1.160208 ppm), near the

Volume 4 Issue 12, December 2015

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values of standard reference materials (SRM) for IAEA. The high Fe value confirms with the fact that the soil is clay. The high concentration of Fe clay soils cannot cause any risks, because Fe is not a contaminant element. Fe is important in plant nutrition and an essential crop micronutrient, while most the Cr, Ni, Cu, Zn, Pb, Co, Fe, Zr, Y, Rb and V concentrations are (0.4245, 0.1331, 0.0435, 0.0127, 0.0027, 0.0011, 2.7521, 277.547, 16.4618, 72.6376 and 47.7802) (ppm) respectively.

4. Conclusions

XRF technique has been employed in order to reveal their complex when different sources of contamination are were determined. A soil pollution assessment becomes very significant at the 0.01 level.

**Correlation is significant at the 0.01 level.**

Table 2: Descriptive Statistics Report

| Element | Cr (ppm) | Ni (ppm) | Cu (ppm) | Zn (ppm) | Pb (ppm) | Co (ppm) | Fe (ppm) | Zr (ppm) | Y (ppm) | Rb (ppm) | V (ppm) |
|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|
| Mean    | 0.4245   | 0.1331   | 0.0435   | 0.0127   | 0.0027   | 0.0011   | 2.7521   | 277.547  | 16.4618  | 72.6376  | 47.7802 |
| Std. Deviation | 1.9812 | 0.6332 | 0.1728 | 0.0337 | 0.0025 | 0.0026 | 5.6838 | 175.198 | 6.135 | 30.708 | 13.148 |
| Variance | 3.9250 | 0.4010 | 0.0300 | 0.0010 | 0.0000 | 0.0000 | 32.306 | 30694.3 | 37.646 | 943.013 | 172.871 |
| Geometric Mean | 0.0252 | 0.0000 | 0.0000 | 0.0041 | 0.0000 | 0.0000 | 1.5110 | 242.873 | 15.563 | 61.3784 | 46.0348 |
| Range    | 9.7140   | 3.1060   | 0.8520   | 0.1660   | 0.0080   | 0.0080   | 29.1190  | 753.446 | 21.554 | 149.608 | 42.929 |

Table 3: Comparison of trace element concentrations (in ppm) for studied samples with other studies in different locations from the world.

| Element | Lake[13] | Wadi El Rayan[13] | Marmara Sea[14] | Gulf of Naples[15] | Saros Gulf[16] | (ISIW) at Romania[17] | Hyderabad, India[18] | Threshold values[19] | Tirana,Sediment sample[20] | Haweja Kirkuk[21] |
|---------|----------|------------------|-----------------|-------------------|----------------|------------------------|----------------------|----------------------|------------------------|------------------|
| Cr      | 26-98    | 23-203           | 65-85           | 11-66             | 35-75         | 52.9-101.3             | 12.3-480.6           | 10-50                 | -                      | -                |
| Ni      | 9-46     | 14-18            | 35-50           | 0.01-26.7         | 5-75          | 41.9-65.6              | 12.6-132.0           | 10-50                 | -                      | -                |
| Cu      | 34-46    | 43-52            | 20-80           | 3-664             | <0.5-48       | <15-52.8               | 11.1-186.6           | 10-40                 | -                      | -                |
| Zn      | 25-90    | 60-145           | 77-1765         | 25-120            | 0.0-121.0     | 40.8-882.2             | 20-200               | 60-145               | -                      | -                |
| Pb      | u.d-17   | -                | -               | -                 | 11.0-52.2     | 42.9-1832.5            | 10-30                | -                    | -                      | -                |
| Co      | -        | -                | -               | -                 | -             | -                      | -                    | -                    | -                      | -                |
| Fe      | -        | -                | -               | -                 | 4.39          | 1.55                   | -                    | -                    | -                      | -                |
| Zr      | 79-231   | 98-737           | -               | -                 | 9-38          | -                      | -                    | 100-1000             | -                      | -                |
| Y       | 11-34    | 9-38             | -               | -                 | -             | -                      | -                    | -                    | 100-1000              | -                |
| Rb      | 16-51    | 18-25            | -               | -                 | -             | -                      | -                    | -                    | -                      | -                |
| V       | 7-57     | 11-17            | -               | -                 | 95.5-110.7    | 30-150                 | -                    | -                    | -                      | -                |

-Not limited

Table 4: Person Correlation matrix of selected major and trace elements for soils samples-Nyla city

| Element | Cr    | Ni    | Cu    | Zn    | Pb    | Co    | Fe    | Zr    | Y     | Rb    | V     |
|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Cr      | 1     | -043  | 1     | -043  | 1     | -043  | 1     | -043  | 1     | -043  | 1     |
| Ni      | -043  | 1     | -043  | 1     | -043  | 1     | -043  | 1     | -043  | 1     | -043  |
| Cu      | .997**| -.051 | 1     | .971**| 1     | .997**| 1     | .997**| 1     | .997**| 1     |
| Zn      | .975**| -.054 | .971**| 1     | -.054 | .977**| 1     | .977**| 1     | .977**| 1     |
| Pb      | -.230 | -.056 | -.235 | -.054 | 1     | -.054 | 1     | -.054 | 1     | -.054 | 1     |
| Co      | -.091 | -.091 | -.011 | .204  | 1     | -.011 | .204  | 1     | -.011 | .204  | 1     |
| Fe      | .990**| -.032 | .987**| .982**| -.167 | -.030 | 1     | -.167 | -.030 | 1     | -.167 |
| Zr      | -.129 | .020  | -.105 | -.109 | .078  | .018  | .088  | 1     | .018  | .088  | 1     |
| Y       | -.106 | .085  | -.085 | -.021 | .239  | .100  | -.056 | .874**| 1     | -.056 | .874**|
| Rb      | -.029 | .017  | -.039 | .042  | .459* | .385  | .018  | -.073 | .077  | 1     | -.073 |
| V       | -.131 | .080  | -.149 | -.028 | .447* | .110  | -.058 | .226  | .322  | .017  | 1     |

**. Correlation is significant at the 0.01 level.

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