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EVALUATION OF VEGETABLE CONTAMINATION NEAR THE IFE IRON AND STEEL INDUSTRY, ILE-IFE, NIGERIA

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ABSTRACT

Radioactivity in vegetable samples in cultivated land in the vicinity of the Ife Iron and Steel industry in Ile-Ife, Nigeria was carried out to assess the potential radiological impact of the industry on its immediate environment. Vegetable samples widely consumed in the local community such as green/African spanich (amaranthus cruentus), waterleaf (talinum triangulare), ewedu/arira (corchorus capsularis), okra (abelmoschus esculentus) and tomatoes (lycopersicon esculentum) were collected from two of the farmlands at 100 m and 300 m away from the industry. The activity counting was carried out using Sodium Iodide gamma spectrometry. The annual committed effective dose for the vegetables in the farmlands due to uranium (^{238}U) and thorium (^{232}Th) was assessed. The mean activity concentration of radionuclides in the vegetable samples ranges from 2.07 ± 0.05 to 13.17 ± 2.11 Bq/kg for ^{238}U, 1.69 ± 0.62 to 29.48 ± 2.24 Bq/kg for ^{232}Th and 107.04 ± 2.33 to 259.08 ± 10.38 Bq/kg for ^{40}K. At a distance of 100 m from the industry, the annual intake of ^{238}U and ^{232}Th from the consumption of green were 2.46 Bq/kg and 5.90 Bq/kg, for water leaf 2.63 Bq/kg and 5.34Bq/kg, for ewedu/arira 2.45 Bq/kg and 5.59 Bq/kg, for okra 2.24 Bq/kg and 4.72 Bq/kg, and for tomatoes 2.54 Bq/kg and 5.63 Bq/kg respectively. The committed effective doses from the consumption of green, water leaf, ewedu/arira, okra, and tomatoes were 1.5 μSvy^{-1}, 1.3 μSvy^{-1}, 1.4 μSvy^{-1}, 1.2 μSvy^{-1}, and 1.4 μSvy^{-1} respectively.

Keywords: Contamination, Committed Effective Dose, Environment, Industry, Radioactivity, Radionuclides, Vegetables.

1. Introduction.

Natural radioactive materials (NORM), which can be enriched and released into the environment by industrial operations, are used in traditional industries including iron and steel, coloring, clothes, luminous paint, lime-burning, and construction. Industrial activity-related contaminants are released into the air, land, and water, as well as into fish, animals, food crops, and vegetables [1]. The primary natural radionuclides, uranium, thorium, potassium, and radium, are naturally taken up by plants due to their nutrient requirements, according to Ahmed [2]. Natural radioactive materials are taken up by the plant through the mineral absorption process and accumulate in the edible and essential parts of the plant. Plants absorb radionuclides through some of the same mechanisms as animals due to their similar chemical and physical features. As a result, radionuclides are ingested into the human body for an extended period of time, exposing people to them internally [3]. To determine potential radiation doses in the environment, it is required to evaluate the radionuclide content of vegetables near the Ife Iron and Steel facility and other significant sites. To estimate the uptake and retention of these radionuclides in the human body, it is also crucial to understand how ^{238}U and ^{232}Th enter the food chain. Vegetables were noted as one of the sources of daily intakes of ^{238}U and ^{232}Th in investigations by Shiraishi et al. [4] and Okeji et al. [5]. Iron and steel industry operations have contaminated land and water bodies, which has major detrimental effects on people's health, socioeconomic well-being, and way of life. Because contaminated water threatens freshwater fisheries and community access to water bodies, contaminated soil has an influence on agricultural production.

The management of the Ife Iron and Steel Melting Factory has been ordered by the Osun State Government to take urgent corrective action for all observed abnormalities resulting from hostile environmental practices that could endanger public health. The company was also warned of the need to provide a quick solution to the incessant problems associated with emissions by ensuring containment to per missible levels in line with World Health Organisation (WHO) guidelines [6]. Therefore, this study was carried out in the vicinity of the Ife Iron and Steel industry in Ile-Ife, Nigeria to assess the potential radiological impact of the industry on its immediate environment.

2. Materials and Method

The study was conducted in farmlands close to the Ife Iron and Steel Company in the Nigerian state of Osun. It is situated between the campuses of the Obafemi Awolowo University and the Oduduwa University, Ile-Ife, in the Ife Central Local Government Area along the Ile-Ife/Ibadan express road. The Industry is located in the Fashina satellite neighborhood at latitude 7029′41″ and longitude 4028′36″ East of the Greenish Meridian. In the area near farms, homes, and water resources, the iron and steel industry's effluent is released into the environment.

Vegetable samples widely consumed in the local community such as green/African spanich (amaranthus cruentus), waterleaf (talinum triangulare), ewedu/arira (corchorus capsularis), okra (abelmoschus esculentus) and tomatoes (lycopersicon esculentum) were collected from two of the farmlands at 100 and 300 meters away from the industry. At each farmland, three sets of samples were collected for each vegetable but at different locations. The vegetable samples were washed immediately to remove adhering soils and stored in clean labeled plastic bags. Care was taken to avoid contamination.

2.1 Sample Preparation

The vegetable samples were dried at room temperature and crushed in a mortar, then sieved with a 2 mm - sieve. Special plastic containers measuring 7.0 cm in diameter by 9.00 cm in height designed to fit into the sodium iodide gamma spectrometer counting chamber were washed in 0.1M hydrochloric acids, rinsed in distilled water, and dried to avoid contamination. Then 350 g of each of the samples was sealed in the plastic containers and kept for 28 days for the short-lived ^{238}U and ^{232}Th to attain secular equilibrium before the gamma counting. The control vegetable samples were collected in farmland 30 km from the industry. They were treated in the way as the other samples.

2.2 Gamma Spectrometric Analysis.

The activity concentrations of ^{238}U, ^{232}Th and ^{40}K were measured using gamma ray spectroscopy method. The measuring system consists of a scintillation detector sealed with a photo multiplier tube and connected through a preamplifier base to a Canberra series 10 – plus multi-channel analyzer (MCA). The detector is a 3 cm × 3 cm NaI(Tl) (Model No. 3M3/3). The detector has a resolution of about 8% at 0.662 MeV of ^{137}Cs. The detection Energy calibration of the system was carried out using reference standard source (IAEA- 444) prepared from the Radiochemical Centre, Amersham, England [7]. The 1.460 MeV photopeak was used for the measurement of ^{40}K while the 1.120 MeV photopeak from ^{214}Bi and the 0.911 MeV photopeak from ^{288}Ac were used for the measurement of ^{238}U and ^{232}Th, respectively. Each sample was counted for 8 hours. The MAESTRO software program automatically searched for the peak, evaluated the peak position in energy, and identifies the radionuclides by use of the nuclide library. It calculates the net peak areas, subtracts the background count and then displays the activity concentration in selected units. The empty container with the background was counted for 17 h and then subtracted from the values.

3. Results and Discussion

The mean activity concentration of radionuclides in the vegetable samples ranges from 2.07 ± 0.05 to 13.17 ± 2.11 Bq/kg for ^{238}U, 1.69 ± 0.62 to 29.48 ± 2.24 Bq/kg for ^{232}Th and 107.04 ± 2.33 to 259.08 ± 10.38 Bq/kg for ^{40}K. (Table 1). These values are much greater than the normal values in vegetables, 0.02 Bq/kg for ^{238}U and 0.015 Bq/kg for ^{232}Th [8]. This result shows that the ^{238}U and ^{232}Th activity concentrations in the vegetable samples decrease as the sampling distance from the industry increases. This may be due to the contribution of the fallout of wastes and dusts generated during the processing of raw materials in the immediate vicinity of the Ife Iron and Steel industry.

Table 1: Mean Concentration of Radionuclides in Vegetables 100 m, 300 m and 30 km from the Industry

Mean Concentration of Radionuclides in Vegetables 100 m from the Industry			
Vegetable	^{226}Ra (^{238}U) (Bqkg^{-1})	^{228}Ra (^{232}Th) (Bqkg^{-1})	^{40}K (Bqkg^{-1})
Green (amaranthus crentus)	12.28 ± 1.20	29.48 ± 2.24	259.08 ± 10.38
Water leaf (Talinum triangulare)	13.17 ± 2.11	26.68 ± 3.46	236.31 ± 13.44
Ewedu/Arira (Corchorus capsularis)	12.24 ± 1.44	27.94 ± 2.49	246.87 ± 11.67
Okra (Abelmoschus esculentus)	12.28 ± 1.57	23.60 ± 3.66	215.39 ± 9.45
Tomatoes (Lycopersicon esculentum)	12.69 ± 1.56	28.13 ± 4.47	156.51 ± 8.55
Mean Concentration of Radionuclides in Vegetables 300 m from the Industry			
Green (amaranthus crentus)	10.47 ± 2.61	22.14 ± 3.57	257.31 ± 6.16
Water leaf (Talinum triangulare)	9.79 ± 1.37	21.46 ± 2.56	185.58 ± 3.37
Ewedu/Arira (Corchorus capsularis)	8.06 ± 1.61	23.69 ± 2.52	134.73 ± 3.69

Okra (Abelmoschus esculentus)	11.51 ± 2.31	22.40 ± 4.12	156.17 ± 4.10
Tomatoes (Lycopersicon esculentum)	8.51 ± 1.31	20.40 ± 2.12	316.17 ± 6.10
Mean Concentration of Radionuclides in Vegetables 30 km from the Industry (Control Vegetable Samples)			
Green (amaranthus crentus)	4.43 ± 0.22	2.00 ± 0.34	153.02 ± 3.23
Water leaf (Talinum triangulare)	5.29 ± 0.45	1.79 ± 0.23	136.05 ± 2.22
Ewedu/Arira (Corchorus capsularis)	3.28 ± 0.22	2.26 ± 0.24	114.45 ± 3.41
Okra (Abelmoschus esculentus)	2.07 ± 0.53	1.69 ± 0.62	107.04 ± 2.33
Tomatoes (Lycopersicon esculentum)	4.04 ± 0.41	1.83 ± 0.37	128.23 ± 3.82

The committed effective dose to members of the public due to ^{238}U and ^{232}Th radionuclides from consumption of vegetables cultivated in the vicinity of the effluent is given by:

$E_u = I_u \times e(g)_u$ Misdaq et al., [9] (1)

$E_{Th} = I_{Th} \times e(g)_{Th}$ Rzama, et al. [10] (2)

Where I_u (Bq) and I_{Th} (Bq) are the annual intake of ^{238}U and ^{232}Th radionuclides respectively, $e(g)_u$ and $e(g)_{Th}$ are the ICRP ingestion dose coefficients for ^{238}U and ^{232}Th radionuclides respectively [11]. The ICRP values of the ingestion coefficient for ^{238}U ($e(g)_u$) and ^{232}Th ($e(g)_{Th}$) radionuclides are 4.5×10^{-8} SvBq^{-1} and 2.3×10^{-7} SvBq^{-1} respectively.

The radioactivity intake, I, is activity concentration of radionuclides multiplied by usage or dietary intake. The usage intake factor of vegetables in Nigeria is 0.2 kg/y. [5].

Table 2. Annual Intake of ^{238}U and ^{232}Th in Vegetables/ The Committed Effective Doses At Different Distances

Annual Intake of ^{238}U and ^{232}Th in Vegetables /The Committed Effective Dose at 100 m					
Vegetable	**I_U (Bq/kg)**	**I_{Th} (Bq/kg)**	**E_U (µsv/y)**	**E_{Th} (µsv/y)**	**E (µsv/y)**
Green (amaranthus crentus)	2.46	5.90	0.11	1.36	1.5
Water leaf (Talinum triangulare)	2.63	5.34	0.12	1.23	1.3
Ewedu/Arira (Corchorus capsularis)	2.45	5.59	0.11	1.29	1.4
Okra (Abelmoschus esculentus)	2.24	4.72	0.10	1.09	1.2
Tomatoes	2.54	5.63	0.11	1.30	1.4

(Lycopersicon esculentum)					
Annual Intake of ^{238}U and ^{232}Th in Vegetables/ The Committed Effective Dose at 300 m					
Green (amaranthus crentus)	2.09	4.43	0.09	1.02	1.1
Waterleaf (Talinum triangulare)	1.96	4.29	0.09	0.99	1.1
Ewedu/Arira (Corchorus capsularis)	1.61	4.74	0.07	1.09	1.2
Okra (Abelmoschus esculentus)	2.30	4.48	0.10	1.03	1.1
Tomatoes (Lycopersicon esculentum)	1.70	4.08	0.07	0.94	1.0
Annual Intake of ^{238}U and ^{232}Th in Vegetables/ The Committed Effective Dose at 30 km					
Green (amaranthus crentus)	0.89	0.40	0.04	0.09	0.1
Waterleaf (Talinum triangulare)	1.06	0.36	0.05	0.08	0.1
Ewedu/Arira (Corchorus capsularis)	0.66	0.45	0.03	0.10	0.1
Okra (Abelmoschus esculentus)	0.44	0.34	0.02	0.08	0.1
Tomatoes (Lycopersicon esculentum)	0.81	0.37	0.04	0.09	0.1

At a distance of 100 m from the industry, the annual intake of ^{238}U and ^{232}Th from the consumption of green were 2.46 Bq/kg and 5.90 Bq/kg, for water leaf 2.63 Bq/kg and 5.34Bq/kg, for ewedu/arira 2.45 Bq/kg and 5.59 Bq/kg, for okra 2.24 Bq/kg and 4.72 Bq/kg, and for tomatoes 2.54 Bq/kg and 5.63 Bq/kg respectively (Table 2). Also, at a distance of 300 m, the annual intake of ^{238}U and ^{232}Th from the consumption of green was 2.09 Bq/kg and 4.43 Bq/kg, for water leaf 1.96 Bq/kg and 4.29 Bq/kg, for ewedu/arira 1.61 Bq/kg and 4.74 Bq/kg, for okra 2.30 Bq/kg and 4.48 Bq/kg, and for tomatoes 1.70 Bq/kg and 4.08 Bq/kg respectively

The values of the annual intake of ^{238}U in the five vegetables at distances of 100 m and 300 m were observed to be below the reference level of 5.7 Bq/kg. However, the values of the annual intake of ^{232}Th in the five vegetables were three times the reference value of 1.7 Bq/kg in the diets [8]. The consumption of these vegetables can lead to enhanced dietary intakes of thorium series radionuclides. The committed effective doses from the consumption of green, water leaf, ewedu/arira, okra and tomatoes were 1.5 µSvy^{-1}, 1.3 µSvy^{-1}, 1.4 µSvy^{-1}, 1.2 µSvy^{-1}, and 1.4 µSvy^{-1} respectively at a distance of 100 m from the industry. The values are above the [8] reference value of 0.32 µSvy^{-1}. More so, the committed effective doses for the five vegetables at 300 m distance from the industry are above the [8] reference value of 0.32 µSvy^{-1}. Table 2 also shows that at a distance of 30 km (the control distance), the values of the annual intake of ^{238}U and ^{232}Th, the committed effective doses of the control vegetables are below the [8] reference values.

4. Conclusion

The assessment of the release of radionuclides in the immediate environment of the Ife Iron and Steel industry was conducted. The concentrations of the natural radionuclides in the vegetable samples were observed to be much greater than the normal values in vegetables, The values of the annual intake of ^{238}U in the vegetables were observed to be below the reference level of 5.7Bq/kg while the values of the annual intake of ^{232}Th in the vegetables were three times the reference value of 1.7 Bq/kg [8]. The committed effective doses for the vegetables at 100 m and 300 m distances from the industry are above the [8] reference value of 0.32 µSvy^{-1}. Although it may not be possible to draw a direct relationship between radionuclide contamination of the environment and the health detriments resulting from the intake of vegetable grown thereof, there is a need to constantly monitor releases of radioactive materials to ensure that it is within the acceptable range.

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