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Evaluation of Radiation Emissions, Physico-Chemical Parameters and Insect Fauna around the Environment of National Institute of Radiation Protection and Research (NIRPR), Ibadan, Nigeria

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Abstract: Radiation emissions from the University of Ibadan National Institute of Radiation Protection and Research (NIRPR), physico-chemical properties measurement and insect's fauna collection around the surrounding of the Institute were conducted for a period of six months (November, 2011-April, 2012). Radiation survey meter model (RDS-30) type was used to take readings along the immediate surroundings of the NIRPR surroundings. Soil samples were collected at five points in the study site at a distance of 50 m from the Institute and the football pitch with a distance of 250 m away from the Institute as control site. Heavy metals (Fe, Cu, Zn, Cr, and Pb) were analysed using MiniPal 4 energy-dispersive X-Ray fluorescence (EDXRF) bench top spectrometer. Pit falls and sweep net were used in collection of crawling and flying insects respectively, some other arthropods were also collected. Results showed that radiation emission values of 0.012-0.016 μSv/hr was recorded, which was higher than the control site with reading of 0.009 μSv/hr. Heavy metal readings showed that iron (Fe) was higher at the sites than other metals. Correlation between chromium and lead was high (0.797) at ($p<0.01$). Diversity indices (Margalef, Shannon Wiener and Evenness respectively) for control site (3.56, 0.54, and 0.52) were higher than at the study site (2.62, 0.15 and 0.17). There was no correlation between arthropods abundance and radiation. This result therefore suggests that radiation could not be implicated in abundance and distribution of these arthropods.

Keywords: Abundance, heavy metals, insects, radiation, soil

INTRODUCTION

Radiation is a fact of life. We live in a world in which radiation is naturally present everywhere. Light and heat from nuclear reactions in the sun are essential to our existence. Radioactive materials occur naturally throughout the environment, and our bodies contain radioactive materials such as carbon-14, potassium-40 and polonium-210 quite naturally. All life on earth has evolved in the presence of this radiation (IAEA, 2004).

Since the discovery of X-rays and radioactivity more than 100 years ago, we have found ways of producing radiation and radioactive material artificially. The first use of X-rays was in medical diagnosis, within six months of their discovery in 1895. So a benefit from the use of radiation was established very early, but equally some of the potential dangers of radiation became apparent on the doctors and surgeons who unwittingly overexposed themselves to X-rays in the early 1900s. Since then, many different applications of radiation and radioactive materials have been developed (IAEA, 2004).

Radiation is classified according to the effects it produces on matter, into ionizing and non-ionizing radiation. Ionizing radiation includes cosmic rays, X-rays and the radiation from radioactive materials. Non ionizing radiation includes ultraviolet light, radiant heat, radio waves and microwaves (IAEA, 2004). There are different types of radiation which include Alpha radiation, Beta radiation, Gamma radiation, X-rays, Neutron radiation, and cosmic radiation.

Mining, manufacturing, and the use of synthetic products (e.g., pesticides, paints, batteries, industrial waste, and land application of industrial or domestic sludge) can result in heavy metal contamination of urban and agricultural soils (USDA, 2000). Heavy metals also occur naturally, but rarely at toxic levels. Potentially contaminated soils may occur at old landfill sites (particularly those that accepted industrial wastes), old orchards that used insecticides containing arsenic as an active ingredient, fields that had past applications of waste water or municipal sludge, areas in or around mining waste piles and tailings, industrial areas where chemicals may have been dumped on the ground, or in areas downwind from industrial sites (USDA, 2000).

Excess heavy metal accumulation in soils is toxic to humans and other animals. Exposure to heavy metals is normally chronic (exposure over a longer period of time), due to food chain transfer.

Arthropods contribute to the human food supply both directly as food, and more importantly as pollinators of crops. Some specific species are known

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to spread severe disease to humans, livestock, and crops (Gallai *et al*., 2008).

Due to 1960's nuclear weapon test in the Sahara desert samples were sent to UK for analysis by Nigeria Meteorological Center. To be self reliance the Federal Radiation Protection Service (FRPS) was set up (Farai, 1984). The FRPS has since 2006 metamorphosed to the National Institute for Radiation Protection and Research (NIRPR), an arm of the Nigerian Nuclear Regulatory Authority (NNRA). During this transformation phase, both infrastructural and facility modifications took place to accommodate the heavy radiation emitting devices such, ^{137}CS and ^{60}Cs Irradiators, X-ray machine and Radiotherapy calibration bunker (Farai, 1984).

This study aimed at assessing the environmental status of the Nigerian Institute of Radiation Protection and Research (NIRPR) building surroundings using the occurrence and species diversity of insect fauna, measurement of the quantity of radiation emissions and heavy metals constituents of the soil around the institute.

MATERIALS AND METHODS

Study area: The study area is the immediate vicinity of the National Institute of Radiation Protection and Research (NIRPR) building, University of Ibadan, Ibadan, Oyo state, Nigeria. This study area is located on Latitude 07º26' to 37º08' North and longitude 03º53' to 36º89' East at an altitude 229 m. The control site is located on Latitude 07º26' to 43º12' North and longitude 03º53' to 45º11' East at an altitude 246 m. Being a research institute, some equipments/facilities installed in this building are capable of emitting radiations/rays into the immediate environment when used. Such radiations emitted from the building find their ways into the surrounding, soil and water in the environment. The presence of these radiations in the environment may cause some adverse effects on the flora and fauna inhabiting the vicinity of the building especially man, birds, arthropods, reptiles, and vegetations.

Sampling around the building was carried out for 6 months from November, 2011 to April, 2012. The control site for study was the foot ball pitch which is located at 250 m away from the building. This control site may be relatively free from any radiation effect from NIRPR building. However the Botany nursery bed was used as the control site for insect collection.

Collection of insects: Flying insects such as butterflies and dragonflies were collected using sweep net of 0.20 m diameter and 1.27 m handle while crawling insects were collected using 10 pitfall traps of 450 L volume by 5 cm diameter. The insects collected were identified in the Department of Zoology (Entomology unit), University of Ibadan. The arthropods identified were carefully labeled and kept in the insect boxes for storage. Botany Department nursery bed about 250 m away from NIRPR was used as a control site.

Soil collection: Soil samples were collected at five points in the study site. This was done at 50 m away from the Institute. Samples were collected for a period of six months and the collected soil samples were labeled at site (distance and date).

Soil analysis: Soil samples were dried at room temperature between 27-30ºC until weight was appreciably less. The soil samples were ground to a fine state using mortar and pestle, and sieved with a 0.5 mm mesh sieve. The samples were taken to the Federal University of Technology, Akure (FUTA) Postgraduate Central Research Laboratory for analysis using MiniPal 4 Energy-Dispersive X-Ray Fluorescence (EDXRF) bench top spectrometer (www.panalytical.com).

Radiation measurement: Radiation measurement was done with model meter RDS-30 type. Readings were taken along the immediate surroundings of the NIRPR surroundings at a distance of 50 m interval in different locations/points on the study site. All the readings were replicated three times for a period of six months. Readings were also taken at the control site at a distance of 250 m away from the NIRPR building, three replicated were also taken.

Statistical analysis: Margalef's diversity index (D) and Shannon-Wiener's diversity index (H): The total numbers of species collected were subjected to Margalef's species richness. The family and species abundance and diversity were calculated using Shannon-Wiener's diversity index. Evenness index (E) was used to observe the evenness of the species distribution to the maximum.

Analysis of variance (ANOVA): Analysis of variance (ANOVA) was used to test for statistical difference between the means of seven different heavy metals collected from six different sites.

Duncan's Multiple Range Test (DMRT): Duncan's Multiple Range Test (DMRT) was also used for multiple comparisons of the means of the heavy metals so as to measure the similarities of the sampling sites.

Pearson correlation coefficient (r): Pearson's Correlation Coefficient (r) was used to determine the significance relationship between the arthropod collected at the study site close to the NIRPR building and the control site, it was also used to determine the interdependence of the heavy metals where they correlated with themselves and to determine the interdependence between the arthropods and heavy metals, arthropods and each of the physico-chemical parameters.

Total radiation value was calculated using mean.

RESULTS

Table 1 show the number of species, mean±Standard Deviation (SD) and Percentage values of Arthropods orders encountered at both study and control sites. Eight orders were encountered at the study site totaling 474 species. On the other hand, eleven orders were encountered at the control site, making a total of 644 species.

Species richness and diversity: Species richness and diversity were calculated for both control and study sites using Magalef's, Shanon-Weiner's and Evenness indices. The study site had the lower species richness index of 2.62 compared to the control site with higher value of 3.56. Similarly, lower diversity index of 0.15 was calculated for the study site while higher value of 0.54 was recorded for the control site. Moreover, Evenness index in the study site was lower (0.15) than that in the control site which was 0.17 (Table 2).

Soil heavy metal values: During the survey work, five different heavy metals were encountered at the study site. These include iron, copper, zinc, chromium, and lead. Iron (Fe) was the highest recorded values from all the points in the study and control sites, with a value of 385.14±22.99 mg/g (Table 3). However, iron (Fe), zinc (Zn) and lead (Pb) were significant at 95% confidence level using ANOVA. Chromium (Cr) and lead (Pb) were significantly increased at point 4 in comparison to other points and control site.

Table 4 shows Pearson's Correlation (r) values between the heavy metals at the six sites for the period of six months. The table indicates that there was no significant relationship between the heavy metals,

Table 1: Number of species, Mean±Standard Deviation (SD) and percentage values of arthropods orders encountered during the study

	Arthropod species population		Arthropod Mean± SD* values		Arthropod percentage values	
Collected arthropod order	Study site	Control site	Study site	Control site	Study site	Control site
Coleoptera	14	44	2.3±1.3	7.3± 4.8	2.9	6.8
Orthoptera	8	65	1.3±1.2	10.8±2.7	1.7	10.1
Odonata	3	13	0.5±0.3	2.2±1.2	0.6	2.0
Araneae	2	44	0.3±0.3	7.3±4.5	0.4	6.8
Lepidoptera	1	21	0.2±0.2	3.5±1.4	0.2	3.3
Hymenoptera	443	427	73.8±5.1	71.2±20.7	93.3	66.3
Heteroptera	1	18	0.2±0.2	3.0±2.6	0.2	2.8
Diptera	3	9	0.5±0.3	1.5±0.6	0.6	1.4
Isoptera	0	1	0	0.2±0.2	0	0.2
Homoptera	0	1	0	0.2±0.2	0	0.2
Hemiptera	0	1	0	0.2±0.2	0	0.2
Total	475	644				

SD*: Standard Deviation

Table 2: Species richness and diversity for study and control sites

Statistical package	Study site	Control site
Margalef species richness index (d)	2.62	3.56
Shannon-Weiner diversity index (H)	0.15	0.54
Evenness (E)	0.17	0.52

Table 3: Mean values ±SD (mg/g) of the heavy metals form soil from sampled sites

	Mean±sd values of heavy metals from (50 m interval from nirpr)						
Heavymetal	Point 1	Point 2	Point 3	Point 4	Point 5	Control site	F- values
Iron	325.47±14.23[a]	320.58±19.56[a]	328.06±17.20[a]	328.64±15.31[a]	304.06±13.69[a]	385.14 ±22.99 [b]	3.066*
Copper	8.97±4.49[a]	21.20±3.59[ab]	16.70±2.99[ab]	16.33±3.94[ab]	15.58±4.48[ab]	18.17 ±1.82[b]	1.211
Zinc	0.00 ±0.00[a]	5.08±0.93 [c]	2.95±1.24[bc]	1.42±0.69[ab]	1.45±0.53[ab]	1.67 ±0.77[ab]	4.830*
Chromium	0.25 ±0.17[a]	0.00±0.00 [a]	0.25±0.17[a]	1.50±0.84[b]	0.33±0.21[a]	0.00 ±0.00[a]	2.360
Lead	0.72 ±0.29[a]	0.00±0.00 [a]	1.33±0.68[a]	6.14±3.13[b]	1.67±0.83[a]	0.00 ±0.00[a]	2.887*

Means with different superscript in a row shows significant difference ($p<0.05$) using Duncan Multiple Range Test (DMRT)

Table 4: Pearson's Correlation (r) value between the heavy metals at the study and control sites for the period of six months

Heavy metal	Fe	Cu	Zn	Cr	Cd	Pb	Ni
Fe	1						
Cu	-0.094	1					
Zn	0.155	0.171	1				
Cr	-0.179	0.248	-0.143	1			
Cd	0.0	0.0	0.0	0.0	1		
Pb	-0.167	0.180	-0.082	0.797**	0.0	1	
Ni	0.0	0.0	0.0	0.0	0.0	0.0	1

**: Correlation is significant at p = 0.01 level (2-tailed)

Table 5: Radiation Readings (mSv/hr) from the Study and Control sites spanning the period of 6 months

	Radiation values for the months Nov.2011- Apr.2012 (µSv/h)						
Study site (around NIRPR)	NOV	DEC	JAN	FEB	MAR	APR	MEAN±SD*
Point 1 (50 m to the west of NIRPR)	0.01	0.02	0.02	0.02	0.02	0.01	0.016±0.0006
Point 2 (50 m to the east of NIRPR)	0.02	0.01	0.02	0.02	0.01	0.02	0.015±0.0006
Point 3 (50 m to the north of NIRPR)	0.01	0.02	0.02	0.02	0.02	0.02	0.015±0.0005
Point 4 (100 m to the east of NIRPR)	0.01	0.02	0.01	0.02	0.02	0.02	0.015±0.0006
Point 5 (150 m to the east of NIRPR)	0.01	0.01	0.01	0.01	0.01	0.01	0.012±0.0003
Control site (250 m away from NIRPR)	0.01	0.01	0.01	0.01	0.01	0.01	0.001±0.0004

SD: Standard Deviation; NIRPR: National Institute of Radiation Protection and Research

except between chromium and lead which was shown to be highly significant at p = 0.01.

Radiation values reading: The radiation values (µSv/hr) from the six sampling points were recorded for the period of six months starting from November, 2011 to April, 2012 as shown in the Table 5. The means values for each of the sites were also recorded. The closest 50 m distance from NIRPR had the highest mean value of 0.016±0.0006 µSv/hr, while the control site of about 250 m had the least mean value of 0.01±0.0004 µSv/hr.

DISCUSSION

The study conducted depicts that there were differences between the arthropod fauna in the study area and control site. The differences in the diversity could be influenced by vegetation rather than by radiation effect since no correlation occurred between the arthropods fauna and radiation. Some studies have showed negative relationship between the Shannon Wiener's index and heavy metal pollution (Read *et al*., 1998) but for most studies, there was no correlation between these two parameters (Muskett and Jones, 1980; Pizl and Josens, 1995). There was decrease in the arthropod diversity and abundance in the study area when compared to the control site as revealed by the study where more taxa and individual species were recorded from the control site. This finding corroborates early report by Strojan (1978) who observed a decrease in arthropod density as a result of increased Zn, Pb, Cu and Cd concentrations near a metallurgical plant. Difference in the species richness could be attributed to the vegetation of the control site and less anthropogenic factors rather than radiation. Eight arthropod orders were encountered in the study site, while eleven arthropod orders were encountered in the control site. Specifically, Isoptera, Homoptera, and Hemiptera were absent in the study area but present in the control site. Margalef's index, values greater than 3 indicate clean conditions, values less than 1 indicate heavy pollution due to less number of species recorded, while values raging from 1-3 indicate moderate pollution as a result (Lenat *et al*., 1980). Margalef's index for study area was 2.62 which indicate moderate pollution.

Heavy metals encountered were in the following sequence: Fe>Cu>Zn>Pb>Cr. The heavy metal readings obtained were less compared to those reported by Ahmed and Goni (2010). These values were less when compared to Mahmoud and Ibrahim (2010). The values recorded for this study, were within the permissible levels in agricultural soils as reported by Kabata-Pendias and Pendias (1985). The values recorded for these heavy metals were low which may be due to reduced agricultural and industrial activities around the study area. Application of pesticides and chemical fertilizers are known to be the common sources of heavy metal pollution in the soils where agricultural and industrial activities are predominant. It was noticed that point 2 in the study site recorded relatively higher concentrations of copper and zinc. This could be due to the discharge of laboratory wastes from the Chemistry Department which is very close to the study site.

Radiation values recorded in this study are of very low intensity and within the United Nations (2000) dose standards for natural radiation dose level. So, their effects on the abundance of insects in the study area may be a threat to life. Furthermore, paucity of scientific information on the biological impacts of radiations on arthropods made may not allow for specific statement on the impact. It is generally recognized that, except for optical radiation, there is scarce data on the quantitative relationships between exposures to different types of non-ionizing radiation and pathological responses in humans Ng (2003).

CONCLUSION

Margalef, Shannon-Wiener and Evenness indices show number of species, diversity and uneven distribution in the study site compared to the control site. However, further research should be conducted to ascertain the likely biological effects of this radiation on the insects. Also, Iron was found to be of higher values at the sampling points very close to Chemistry Department. This could be due to disposal of chemicals and laboratory glass wares. So, proper disposal should be adopted. Radiation decreases with distance from the NIRPR building into the vicinity. Radiation had strong relationship with the study site. Reduced intensity of radiation appears to favour the abundance of the arthropod population as more taxa were recorded in the control site. However, this may not be due to radiation quantum emitted. Although certain quantity of radiation was measured, the radiation was low and not deleterious. So, the activities of NIRPR can be said not to have any serious noticeable negative impact on the fauna now.

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