Asian Journal of Research and Reviews in Physics

1(2): 1-8, 2018; Article no.AJR2P.41787

Gamma Spectrometry Analysis of Natural Radionuclide Contents of Three Mushroom Species Commonly Grown in Benue State, Nigeria

A. A. Nathan[1*], T. Sombo[1], B. V. Gurgur[1], A. A. Avaa[1] and T. A. Fadeyi[1]

[1]Department of Physics, Federal University of Agriculture, Makurdi, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Authors AAN and AAA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BVG and TAF managed the analyses of the study. Author TS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJR2P/2018/v1i224610
Editor(s):
(1) Dr. Jelena Purenovic, Assistant Professor, Department of Physics and Materials, Faculty of Technical Sciences, Kragujevac University, Cacak, Serbia.
Reviewers:
(1) Shaban Ramadan Mohamed Harb, South Valley University, Egypt.
(2) Francisco José Fonseca Ferreira, Federal University of Paraná, Brazil.
(3) Maria Quarto, University of Naples Federico II, Italy.
Complete Peer review History: http://www.sciencedomain.org/review-history/25582

Original Research Article

Received 29th March 2018
Accepted 9th June 2018
Published 18th July 2018

ABSTRACT

The activity concentration and Annual Effective doses of ^{40}K, ^{226}Ra, and ^{232}Th in some edible mushroom species (*Cantharellus cibarius, Agaricus campestris, Termitomyces robustus*) found in three Local Government Areas of Benue state-Nigeria were determined using Gamma Spectrometry; the 1460KeV gamma-radiation of ^{40}K was used to determine the concentration of ^{40}K, gamma transition energy of 1764.5KeV ^{214}Bi was used to determine the concentration of ^{226}R, while the gamma transition energy of 2614KeV ^{208}Tl was used to determine the concentration of ^{232}Th. The activity concentration due to ^{226}Ra, ^{232}Th and ^{40}K in the samples ranged from 10.06 ± 1.6 - $14.19 \pm 3.01 Bqkg^{-1}$; 10.88 ± 2.65 to $15.38 \pm 4.30 Bqkg^{-1}$ and 202.31 ± 1.4 to $318.44 \pm 3.20 Bqkg^{-1}$ respectively; the highest activity due to ^{226}Ra was found in *Termitomyces robustus* grown in Gboko; that due to ^{232}Th was recorded in *Agaricus campestris* grown in Buruku L.G.A., while the highest activity concentration due to ^{40}K was recorded in *Termitomyces robustus* found in Buruku. Generally, ^{40}K recorded the highest activity concentration in each mushroom

**Corresponding author: E-mail: prophnaths@gmail.com;*

species examined. Annual Effective Dose from these species sampled ranges from $0.0006952\ mSv\ y^{-1}$ (in Makurdi- *Termitomyces robustus species*) - $0.0008467\ mSv\ y^{-1}$ (in Buruku *Termitomyces robustus species*). The average effective dose value of $0.00788 \pm 0.000186\ mSv\ y^{-1}$ obtained in this work is below the maximum permissible level established by ICRP (1996). Thus, these mushrooms species will not pose any apparent risk to human health.

Keywords: Gamma spectrometry; radionuclide; mushroom; activity concentration; annual effective dose.

1. INTRODUCTION

Plants are one of the sources for elements and radionuclides for a human. Measuring the radioactivity concentration of an environment, food products from plants such as mushroom is of importance in determining the radiation levels to which consumers of such food is exposed to directly or indirectly. Mushrooms are a special group of fungi which are saprophyticnature. They lack chlorophyll and consequently cannot use solar energy in manufacturing their food. Their mode of nutrition is by producing a wide range of enzymes that can break down complex substances after which they can absorb the soluble substances so formed [1]. Consumption of edible mushroom lead to improved nutritional intake of humans, because mushroom contains vitamins such as thiamine riboflavin, ascorbic acid, ergosterine, niacin, vitamins C, B1, B5 and vitamin D, fat, Iron, phosphorus which produce a range of metabolites of intense interest to the nutraceutical, pharmaceutical (e.g. antitumor) and food (e.g. flavor compound) industries [2,3,4,5].

Most species of mushroom if not all, contain biologically active polysaccharides, these include edible/medicinal species like *Pleurotus Ostreatus*; poisonous species such as *Amanita Phalloides* and *Hallucinogenic* species like *Psilocyte Mexicana* [4]. According to the traditional believes among native people, consumption of *Pleurotus* species of mushrooms was believed to prevent high blood pressure, impact long life and vigour while also acting as an aphrodisiac, hypertensive, immunomodulatory and antitumor activities of polysaccharide-protein complex (PSPC) because of its high content of retene ($C_{18}H_{18}$) [6,7].

Giving attention to the studies of radionuclides in mushroom has drawn the attention of many scholars over the ages, for instance, Kuwahara et al. [8] and Bazala et al. [9] found out that different species of mushroom have the capacity to retain high concentrations of radionuclides and metals from the soil. Some radionuclides easily accumulated by mushroom according to these authors are ^{40}K, ^{137}Cs, ^{226}Ra and ^{228}Ra. De Castro et al. [2] in their study on “artificial (^{137}Cs) and natural radioactivity (^{40}K, ^{226}Ra, ^{228}Ra)” determined in 17 mushroom sampled from 3 commercial edible mushroom species in São Paulo, Brazil adducting the techniques developed by Figueira et al. (2007) as quoted by Silva et al. [10]. De Castro et al. [2] concluded that the gamma spectrometry methodology allowed the determination of ^{137}Cs, ^{40}K, ^{226}Ra and ^{228}Ra levels present on edible mushroom samples with better precision and accuracy.

Activity concentration of mushrooms is affected by several factors such as species, contamination of soil, time of the disaster and the soil horizon from which species takes nutrients and moisture [11,12,13,14].

The rural communities in Benue State consume a lot of natural and locally grown mushrooms, and as a result of the wide spreads of radioactive isotopes, quantitative determination of radionuclides in these mushrooms is of scientific interest to determine the gamma radioactivity levels [15] in selected edible mushroom species consumed in three selected location within the State in Nigeria. Hence, to estimate the activity concentration (Bq/kg) of radionuclides; the annual effective dose (μSv/y) from ingesting the mushroom samples; also to determine whether the concentration activity of the radionuclides in these mushrooms pose any threat to human health.

2. MATERIALS AND METHODS

For this work, three (3) different species of edible mushrooms which includes: *Cantharellus cibarius, Agaricus campestris, Termitomyces robustus* were obtained from three selected Local Government Areas: Gboko (7.3368^{o}N, 9.0018^{o}E), Makurdi (7.7322^{o}N, 8.5391^{o}E) and Buruku (7.4178^{o}N, 9.2231^{o}E) all within

Fig. 1. Google map of the study areas

Benue State Nigeria; these samples were labeled according to sampling sites. Major materials used include Lyophilizer, Domestic blender, spring balance, Thallium – doped sodium iodide (NaI (Tl)) scintillation detector, Multi-channel Analyzer.

These Samples were washed, lyophilised using the lyophilizer at the Chemistry Department, Fountain University, Osogbo, Osun State, Nigeria for 12 hrs for dehydration. A mechanical blender was used to pulverise the dried samples into powder. Nine samples were prepared. Twenty (20 g) of each dried mushrooms were packaged in polyethene beakers, sealed and allowed to stand for at least 28 days to establish radioactive equilibrium.

2.1 Determination of Activity Concentration and Effective Annual Dose

Gamma spectrometry measurements were carried out at the Radioactivity Measurement Laboratory, Department of Pure and Applied Physics, Ladoke Akintola University of Technology Ogbomoso, Oyo State Nigeria, using a calibrated NaI (Tl) and a well-shielded detector coupled to a computer resident quantum MCA2100R Multichannel analyser for 36,000s. The detector efficiency was at 98.67%. To determine the concentration of ^{40}K in the sample, 1460KeV gamma-radiation of ^{40}K calibration was calibrated. The gamma transition energy of 1764.5KeV ^{214}Bi was established to determine the concentration of ^{226}Ra; gamma transition energy of 2614KeV ^{208}Th was used to determine the concentration of ^{232}Th.The efficiency calibration of the detector was done using a reference standard mixed source traceable to Analytical Quality Control Service (AQCS, USA).

The activity concentration, *A* (Bq/kg) of the radionuclides were computed and obtained using the equation;

$$\mathbf{A(BqKg^{-1})} = \frac{\mathbf{C_s}}{\mathbf{\varepsilon P_\gamma M_s}} \quad (1)$$

Where, C_s = Count rate under each photo peak due to each radionuclide, P_γ = Absolute transition probability of the specific gamma field, ε = Detector efficiency for the specific γ-ray energy, M_s = Mass of the sample (dry mass).

The samples collected from Gboko, Makurdi and Buruku were coded as *SG, SM,* and *SB* respectively.

To assess the radiological health risk associated with the consumption of the mushrooms in the researched areas, the average annual committed effective dose (E_{ave}) was estimated using the equation

$$E_{ave=} C_r \; X \; DCF_{ing} \; X \; A_s \quad (2)$$

Where; DCF_{ing} is the dose convection factor for ingestion, for each radionuclide (i.e., 4.5 × 10^{-5}mSv Bq^{-1}, 2.3 × 10^{-4}mSv Bq^{-1} and 6.2 × 10^{-6}mSv Bq^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively) for an adult [16,17]. C_r = consumption rate from intake of naturally occurring radioactive materials in mushrooms and $A_s$is the activity concentration in the sample.

3. RESULTS AND DISCUSSION

The activity concentration of **^{40}K** varied from 202.31±1.4 to 318.44±3.2Bq $kg^{-1}$with an average value of 235.76 ± 27.32Bq kg^{-1}. The activity concentration of **^{226}Ra** in the mushroom collected ranged from 10.06±1.6 to 14.19±3.01Bq kg^{-1} with an average value of 12.58 ± 3.58 Bq kg^{-1} as indicated in Table 1. The highest activity concentration of **^{226}Ra** was recorded for *Termitomyces robustus* found in Gboko local government (SG3) while *Agaricus campestris* found in Buruku local government (SB8) had the lowest activity concentration of ^{226}Ra. For the activity concentration of **^{232}Th**, it varied from 10.88 ± 2.65 to 15.38 ± 4.3 Bq kg^{-1} with an average value of 12.61±3.0 Bq kg^{-1}in the mushrooms. The highest and lowest activity concentration was recorded for *Agaricus campestris* found in Buruku local government (SB8), and *Agaricus campestris* found in Gboko local government (SG2) respectively. **^{40}K** recorded the highest activity concentration in all the mushrooms compared to the activity concentration of **^{226}Ra** and **^{232}Th** observed.

Termitomyces robustus found in Buruku (SB_9) had the highest activity concentration of **^{40}K,** next to it was *Cantharellus cibarius,* and the lowest was recorded in *Agaricus campestris* (SB_8). In Gboko, *Agaricus campestris* has the highest records of **^{40}K** concentration with a value of 228.18 ± 45.75 Bq/kg while *Termitomyces robustus* has the lowest activity concentration of **^{40}K** with a value of 204.16 ± 64.01 Bq/kg.

Termitomyces robustus and *Agaricus campestris* have highest and lowest activity concentrations of **^{226}Ra** with values of 14.19±3.01 Bq/kg and 12.25±3.59 Bq/kg respectively. *Agaricus campestris* and *Termitomyces robustus* were discovered to have the lowest and highest **^{232}Th** concentration in Gboko 10.88 ± 2.65 Bq/kg and 13.83 ± 2.08 Bq/kg respectively.

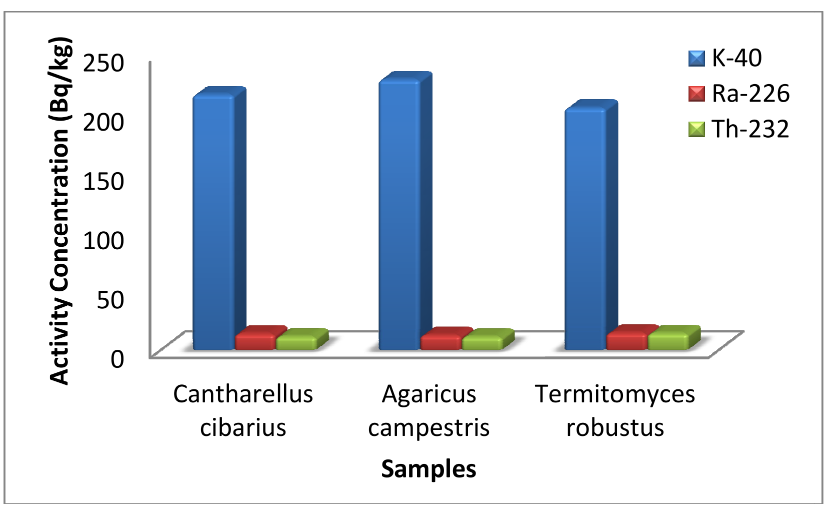

Fig. 2. Activity concentration (Bq/kg) of Mushroom species from Gboko

The result obtained for Makurdi presented in Fig. 2, indicate lowest values of **^{40}K**, **^{226}Ra** and **^{232}Th** found in *Termitomyces robustus*, accorded values of 212.16 ± 70.01 Bq/kg, 10.25 ± 3.99 Bq/kg and 12.03 ± 5.16 Bq/kg respectively. As shown in Fig. 2 also, the highest value of **^{40}K** was found in *Cantharellus cibarius*, while *Agaricus campestris* has the highest values of **^{238}Ra** and **^{232}Th** with values of 235.6 ± 3.1Bq/kg, 13.50 ± 6.38 Bq/kg and 12.54 ± 3.64 Bq kg^{-1} respectively.

In Buruku Local Government Area, Fig. 4 shows that *Termitomyces robustus*, recorded the highest ^{40}K concentration of 318.44 ± 3.2 Bq kg^{-1} while *Agaricus campestris* shows the lowest activity concentration for **^{40}K** and ^{226}Ra with a value of 202.31 ± 1.40 Bq kg^{-1} and 10.06± 1.60 respectively.

Cantharellus cibarius and *Agaricus campestris* are found to have the lowest and highest **^{232}Th** concentration for Buruku with values of 12.06 ± 1.4 Bq kg^{-1}and 15.38 ± 4.3 Bq kg^{-1} respectively.

The activity concentration of **^{40}K** is usually high compared to **^{238}Ra** and **^{232}Th**, and forms an integral part of all organic constituents. The high activity concentration of **^{40}K** recorded for *Termitomyces robustus* among all the samples could aid in its therapeutic purposes for the treatment of High Blood Pressure as patients with High Blood Pressures have low concentration of Potassium in their blood stream.

The mean activity concentration of the radionuclide in the various mushroom samples is shown in Table 2.

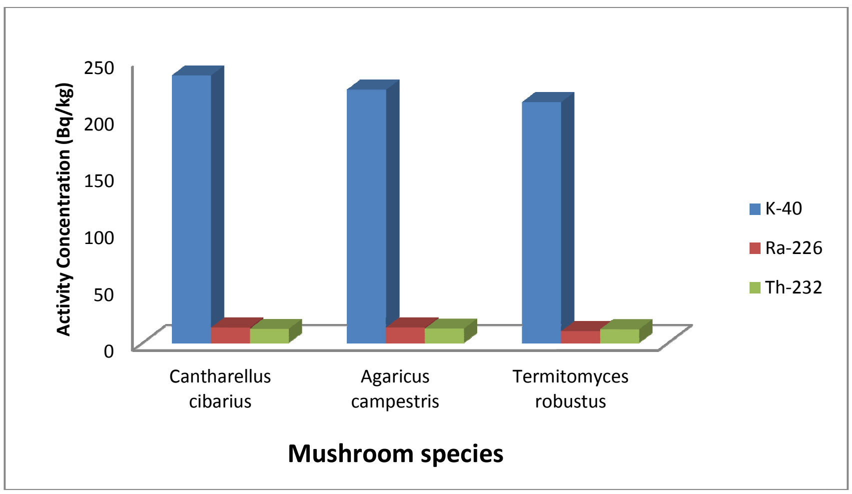

Fig. 3. Activity concentration (Bq/kg) of Mushroom species from Makurdi

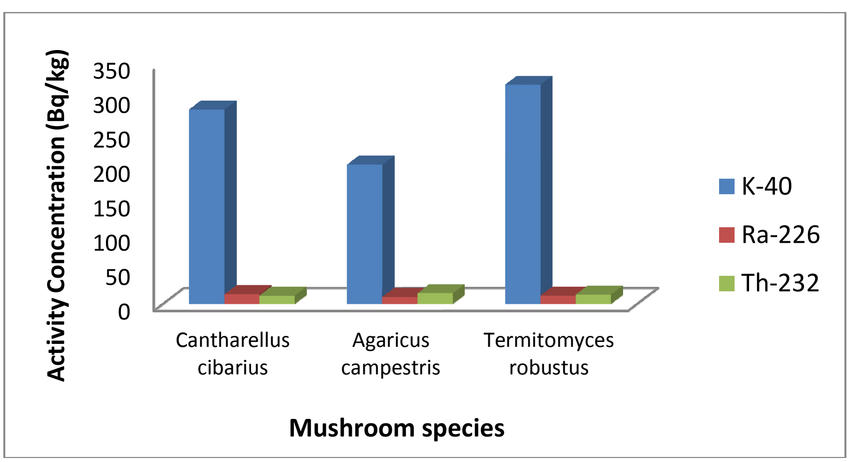

Fig. 4. Activity concentration (Bq/kg) of Mushroom species from Buruku

Table 1. Activity concentrations of ^{40}K, ^{238}Ra and ^{232}Th in the mushroom species collected

Samples codes	Sample name	Location (L.G.A.)	Activity concentrations			Annual committed effective dose for 1kg y^{-1} (mSv y^{-1})
			K-40	Ra-226	Th-232	
SG_1	*Cantharellus cibarius*	Gboko	215.43 ± 41.50	13.43 ± 3.19	11.03 ± 4.71	0.007633
SG_2	*Agaricus campestris*	Gboko	228.18 ± 45.75	12.25 ± 3.59	10.88 ± 2.65	0.007347
SG_3	*Termitomyces robustus*	Gboko	204.16 ± 64.01	14.19 ± 3.01	13.83 ± 2.08	0.008420
SM_4	*Cantharellus cibarius*	Makurdi	235.60 ± 03.10	13.49 ± 5.29	12.28 ± 1.85	0.008062
SM_5	*Agaricus campestris*	Makurdi	223.16 ± 15.77	13.50 ± 6.38	12.54 ± 3.64	0.008048
SM_6	*Termitomyces robustus*	Makurdi	212.16 ± 70.01	10.25 ± 3.99	12.03 ± 5.16	0.006952
SB_7	*Cantharellus cibarius*	Buruku	282.36 ± 01.10	13.92 ± 3.00	12.06 ± 1.40	0.008422
SB_8	*Agaricus campestris*	Buruku	202.31 ± 01.40	10.06 ±1.60	15.38 ± 4.30	0.007609
SB_9	*Termitomyces robustus*	Buruku	318.44 ± 03.20	12.14 ±2.20	13.45 ±1.20	0.008467

Table 2. Mean values of activity concentrations (Bq Kg^{-1}) of species

Sample species	K-40	Ra-226	Th-232
Cantharellus cibarius	244.463±15.23333	13.6133±3.826667	11.7900 ±2.653333
Agaricus campestris	217.883±20.97333	11.9367±3.856667	12.9333±3.530000
Termitomyces robustus	244.920±45.74000	12.1933±3.066667	13.1033±2.813333

Table 3. Average annual committed effective dose and threshold consumption rate associated with each sample

Samples	Sample name	Location (L.G.A.)	AACED for 1kgy^{-1} (mSv y^{-1})	Threshold consumption rate (kg y^{-1})for E_{ave}=1mSv y^{-1} (ICRP)	Threshold consumption rate (kg y^{-1}) for E_{ave}=0.3mSvy^{-1} (UNSCEAR)
SG_1	*Cantharellus cibarius*	Gboko	0.007633	393.0320	117.9096
SG_2	*Agaricus campestris*	Gboko	0.007347	408.3235	122.4970
SG_3	*Termitomyces robustus*	Gboko	0.008420	356.2991	106.8897
SM_4	*Cantharellus cibarius*	Makurdi	0.008062	372.1013	111.6304
SM_5	*Agaricus campestris*	Makurdi	0.008048	372.7731	111.8319
SM_6	*Termitomyces robustus*	Makurdi	0.006952	431.5124	129.4537
SB_7	*Cantharellus cibarius*	Buruku	0.008422	356.2086	106.8626
SB_8	*Agaricus campestris*	Buruku	0.007609	394.2947	118.2884
SB_9	*Termitomyces robustus*	Buruku	0.008467	354.3156	106.2947

3.1 Discussion

The calculated average annual committed effective dose to any individual due to the ingestion of natural radionuclides for these mushrooms species researched is far below the average radiation dose of 1 mSv/y (ICRP 1996) and 0.3 mSv/y (UNSCEAR 2000). The threshold consumption rate being the limiting value of AACED become greater than 1mSv for any of these species sampled; as indicated in Table 3, the lower the AACED, the greater the threshold value for the mushroom. This provides a baseline data indicating that an adult with consumption rate below the threshold values would be exposed to insignificant radiological health risk while those whose consumption rate is higher are prone to significant radiological health risk.

Comparing these results with other published data, in Ekiti State Nigeria [4], *Termitomyces robustus* being a species considered in this study presents an average activity concentration of 339.05 ± 87.76 of ^{40}K, 15.78 ± 4.98 of ^{226}Ra and 14.31 ± 6.01 of ^{232}Th. Data from other countries indicates that the average activity concentration values obtained for ^{238}U (^{226}Ra), ^{232}Th and ^{40}K in this study are less than the published work as shown by De Castro, (2012) in *Agaricus species* obtained 1215 ±5 of ^{40}K, 18 ± 3 for ^{226}Ra and 38.1 ± 1.2 for ^{228}Ra.

These variations in the activity concentrations of this research work with those from other countries may be as result of differences in the geological location of the fungi and the radiochemical composition of the soils in which these mushrooms are grown or cultivated since the levels of activity concentration of natural radionuclides are not normalized across the globe and the species' ability to efficiently absorb certain natural radionuclide more than others and nature of soil.

4. CONCLUSION

The natural radionuclide contents of three (3) mushroom species from three (3) different locations in Benue State Nigeria have been analysed by means of Gamma Spectrometry with NaI (TI) detector. The results obtained from this work indicated that **^{40}K** recorded the highest activity concentration in all the mushrooms compared to the activity concentration of **^{226}Ra** and **^{232}Th** observed. The activity concentration of **^{40}K** varied from 202.31 ± 1.4 to 318.44 ± 3.2 Bq/kg with an average value of 235.76 ± 27.32 Bq/kg. The average annual committed effective dose were found to be lower than the average world value of 0.3 mSv/y as recommended by UNSCEAR (2000) and 1 mSv/y as recommended by ICRP (1996) [18].

The threshold consumption rate for each mushroom; annual committed effective doses were found to be below the maximum permissible levels established by national legislations ICRP and UNSCEAR. Thus these mushroom species can normally be consumed by the populace without any apparent risks to their health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chang ST, Wasser PS. The role of culinary-medicinal mushrooms on human welfare with a pyramid model for human health. International Journal of Medicinal Mushrooms. 2012;95-134.
   DOI: 10.1615/IntJMedMushr.v14.i2.10
2. De Castro LP, Maihara VA, Silva PSC, Figueira RCL. Artificial and natural radioactivity in edible mushroom from Sao Paulo Brazil. Journal of Environmental Radioactivity. 2012;113:150-154.
   Available:http//dx.doi.or/10.1016/j.jenvrad.2012.05.028
3. Akindahunsi AA, Oyetayo FL. Nutritional and antinutrient of edible mushroom. Pleurotus Tuber-regium (fries) Singer LWT- Food Science and Technology. 2006;39(5):548-553.
4. Faweya EB, Ayeni MJ, Kayoed J. Accumulation of natural radionuclides by some edible wild mushrooms in Ekiti State, South-western, Nigeria. World Journal of Nuclear Science and Technology. 2015;5: 107-110. Published Online April 2015 in Sci. Res.
   Available:http://www.scirp.org/journal/wjnst
5. Chang ST, Lau OW, Cho K. The cultivation and nutritional value of Pleurotus Sajor-Caju. European Journal of Applied Microbiological Biotechnology. 2001;12:58-62.
6. Carini F. Radionuclide transfer from soil to fruit. Journal of Environmental Radio-activity. 2001;52:237-279.

7. Das RL, Mahapatra SC, Chattopadhyay RN. Use of wild grasses as substrates for the cultivation of oyster mushroom in South West Bengal. Mushrooms Research. 2000;9(2):95-99.
8. Kuwahara C, Fukumoto A, Ohsone A, Furuya N, Shibata H, Sugiyama H, Kato F. Accumulation of radiocesium in wild mushrooms collected from a Japanese forest and cesium uptake by microorganisms isolated from the mushroom-growing soils. The Science of the Total Environment. 2005;345:165e17.
9. Bazala MA, Golda K, Bystrzejewska-Piotrowska G. Transport of radiocessium in mycelium and its translocation to fruit bodies of a saprophytic macromycete. Journal of Environmental Radioactivity. 2008;99:1200e1202.
10. Cardoso-Silva S, de Lima Ferreira PA, Moschini-Carlos V. Temporal and spatial accumulation of heavy metals in the sediments at Paiva Castro Reservoir (São Paulo, Brazil) Environ Earth Sci. 2016;75:9. Available:https://doi.org/10.1007/s12665-015-4828-2
11. Guillen J, Baeza A, Ontalba MA, Migeuz MP. ^{210}Pb and stable lead content in fungi: It's transfer from soil. Science of the Total Environment. 2009;407:4320-4326.
12. Vaarama K, Solatie D, Aro L. Distribution of ^{210}Pb and ^{210}Po concentrations in wild berries and mushrooms in boreal forest ecosystems. Science of the Total Environment. 2009;408:84-91.
13. Khater A, Al-Sewaidan HA. Radiation exposure due to agricultural uses of phosphate fertilizers. Radiation Measurements. 2008;43:1402-1407.
14. Bikit I, Slivka J, Veskovic M, Verga E, Zikic-Todorovic N, Mrda D, Forkapic S. Measurement of danube sediment radioativity in Serbia and Montenegro using gamma ray spectrometry. Radiation Measurement. 2006;41:477-481.
15. Ayaakaa DT, Sombo T, Utah EU. Assesssment of radioactivity of some surface soils in Gboko Local Government Area of Benue State and Health Implication, North Central Nigeria. Asian Journal of Engineering and Technology. 2016;4(4):1-8.
16. UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation. "Sources and Effects of Ionizing Radiation", UNSCEAR 2000 Report Vol. 1 to the General Assembly, with scientific annexes, United Nations Sales Publication, United Nations, New York; 2000.
17. Kalac P. Radioactivity of European species of wild growing edible mushrooms: In "Mushrooms: Types, Properties and Nutrition". ISBN: 978-1-61470-110-1 2012 Nova Science Publishers, Inc.; 2012.
18. ICRP. (International Commission for Radiation Protection). Age dependent doses to members of the public from intake of radionuclides. Part 5. Compilation of ingestion and inhalation dose coefficients. Publ. No. 72. Annals of the ICRP. Oxford, UK: Pergamon Press. 1996;26(1).

© 2018 Nathan et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/25582