Nigerian Journal of Physics (NJP)
ISSN online: 3027-0936
ISSN print: 1595-0611
DOI: https://doi.org/10.62292/njp.v32i4.2023.167
Volume 32(4), December 2023

Radiometric Evaluation of Annual Effective Dose in Water from Zobe Dam, North-Western, Nigeria

[*1]Bello, I. A., [1]Vatsa, M. A. [2]Momoh, A. H. [3]Kure, N. and [4]Bello, A. A.

[1]Department of Physics, Ahmadu Bello University Zaria, Kaduna, Nigeria
[2]Department of Physics, Confluence University of Science and Technology Osara, Kogi State, Nigeria
[3]Department of Physics, Faculty of Science, Kaduna State University, Kaduna, Nigeria.
[4]Department of Chemical Engineering, Ahmadu Bello University Zaria, Kaduna, Nigeria

[*]Corresponding author's email: dbell1066@yahoo.com Phone: +2347035152954

ABSTRACT
The communities located closed to the Zobe Dam which flows through many tributaries in Kastina State, utilizes the dam water for irrigation, drinking and other domestic activities. The level of radionuclide in water varies due to human factors, geological and geographical locations. There is need to evaluate the radiological health risk of the communities that uses the water for domestic activities, due to extensive farming around the dam. The annual effective dose (ADE) due to gross alpha and beta particles assists to estimate the radiological risks connected with making use of water in Zobe Dam for domestic purposes, were estimated. The low background Gas-less Alpha/Beta counting system (MPC 2000DP), was used to evaluate the alpha and beta activity concentration of the sample. The alpha activity ranged was 0.735±0.43 to 11.401±0.29 Bq/L, while the beta activity ranged from BDL to 11.891±0.57Bq/L. The AED varied from 0.150 to 8.319 mSv/year for adults, 0.075 to 4.160 mSv/year for children, and 0.038 to 2.080 mSv/year for infants, respectively. The average AED in adults, children and infant exceeded the ICRP dose limits of 0.1mSv/year. Water utilized for domestic purposes from the Dam could be quite risky because of intense farm activities and existence of natural radionuclide, if sufficient steps are not performed.

Keywords:
Effective dose,
Gross alpha and beta,
Water,
Farm,
Zobe Dam.

INTRODUCTION

The concentration of radioactivity may have an impact in water by factors such as parent radionuclide, geographical location and hydrological conditions (Canbazoglu*et al.*, 2001). Several health hazards are associated with the presence of radioactive materials in water, especially when these radioniclides are accumulated within human tissues through ingestion or digestion (Bello et al., 2018). The type of radioactive pollutant, the amount of contaminant, and other criteria determine the risks that radiation pollution poses to people, the environment, and the extent of the dispersal (Ogundare and Adekoya, 2015). The surface water through irrigation and farming activities could contaminate Dam water by transporting leached radionuclide (Pajol and Sanchez, 2000). Research had revealed that transported leached radionuclides to surface water from farm activities such as fertilizer application, herbicide and insecticide application could raise the levels of naturally occurring radioactivity in water (Boukhenfouf et al., 2011, Bramki et al., 2017 Chauhan et al., Khater et al., 2008 and Ravisankar et al., 2012).

Alpha and Beta are particles emitted by dissolved radionuclide in water, which progressively harm living tissues (Gruber et al., 2009). Gamma rays have greatest penetrating potential compared to alpha and beta particles, however, because of their ionizing potential, alpha and beta particles have more harmful effects. River water may contain beta emitters like ^{40}K, ^{228}Ra, and ^{210}Pb as well as alpha emitters like ^{234}U, ^{226}Ra, and ^{210}Po. (Jobbagy et al., 2010). One of the main ways in which radionuclide are deposited in the body is through ingestion or digestion of drinking water with radionuclide particles, which might consequently head to radiation simulate disorder (USEPA, 2010).

The estimation of the yearly effective dosage from gross alpha and beta particles assists to estimate the radiological hazards associated with utilization of water in Zobe Dam for domestic purposes. Relative researches were performed in different part of world (Garba, 2011, Rafik *et al.*, 2014, Servitzoglou*et al.*, 2018 and Bello *et* *al.*, 2020). It was discovered that the levels of radionuclide varies due to human factors, geological and geographical locations. The Dam tributaries flow through many communities in Kastina state, Nigeria and it is majorly used for irrigation activities. Also, the communities located closed to the Dam utilizes the dam water for drinking and other domestic activities. Due to the extensive farming around the research location, the annual effective dosage as a result of to gross alpha and beta radiation has yet to be established. The ultimate focus of evaluating gross alpha and beta activities is to make sure the committed effective dose level (0.1 mSv) from a year of drinking water intake is not exceeded (IAEA, 2001).

Till present, there is no known literature of annual effective dose due to the intake of gross alpha and beta of water at Zobe Dam or radiological health risk of the communities that uses the water for domestic activities. Therefore, the annual effect dose (ADE) due to intake of alpha and beta particles of water in the proximities of farming activities at Zobe dam need to be evaluated.

MATERIALS AND METHOD

The Study Area

The Zobe Dam is located in Northern region of Nigeria, Dutsin-ma Local Government Area, Kastina State, Northern region of Nigeria. Located between latitudes 120 20'30" and 120 23' 29" north and between longitudes 70 27' 82" and 70 34' 41" east. The main tributaries of the dam are the Rivers Karaduwa and Gada. The dam can store 179 Mca of water and capable of irrigating 8,000 hectares of land (Wikipedia of Zobe dam, 2020).

Fishing and farming activities are highly intensive in the area. Agrochemical particles such as fertilizers, herbicides and pesticides are the major contaminant of the dam reservoir due to the farm activities around the area. Figure 1 shows the study location map.

Figure 1: Map of the study location.

Sample Collection

The samples locations were selected based on intensive farming activities in the area. The samples were gathered utilizing the grab sampling technique in the early hours of the morning from the domestic water fetching location of the host community, according to Avwiri and Agbalagba (2007). The sample containers rinsed was done with water twice and later with concentrated Nitric acid. 2 L plastic container with about 1% space left for thermal expansion was used for collection of the water sample at each sampling location. Nitric acid (HNO_3) was used to acidify the sample, to prevent micro-organisms growth after collection and taking immediately to the laboratory for analysis.

Sample preparation

The sample preparation procedures reported by (ISO, 1992) were used as guide for the sample preparation. A 600 ml open beaker was used to evaporate 1 L of each water sample, at moderate heat temperature using hotplates. Complete evaporation of 1 L of each sample was done in 16 hrs. During evaporation, the sample was placed into the petri dish when there were approximately 50 ml of sample remaining in the beaker. After that, the sample was exposed to infrared light to dry the residue. The sample was cooled before being weighed.

Sample analysis

The sample analysis was done using normal practices reported by (ISO, 1992). The The Gas-less Alpha/Beta counting system with low background (MPC 2000DP) calibrated with ^{239}Pu and ^{90}Sr standard source, was applied to determine sample concentrations of alpha and beta activity. The Passivated Implanted Planar Silicon detector was used for the alpha and beta detection. About 200 minutes were spent counting samples, with a detection limit of 0.14 and 1.47 cpm for alpha and beta concentrations, respectively. The alpha and beta concentration background measurements were 0.14 and 77.82 cpm, respectively. Efficiency of alpha and beta were 87.95 and 42.06 percent respectively. The analysis was conducted at Low background laboratory, Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria. Standard procedures were used for the sample efficiency, background measurements, and plateau test. (ISO, 1992).

$$\textit{Sample efficiency} = \frac{W_{B+S}-W_B}{0.077}\ x\ 100\% \quad (1)$$

Where: W_B is theweight of the empty planchet, $W_{B+S}$is the weight of planchet plus sample after evaporation, and 0.077A (*mg*) is the anticipated mass of the residue in the planchet.

Alpha and beta radioactivity concentration determination

Analysis was conducted with the aid of a non-gas proportional counter and the MPC 2000DP single channel analyzer to determine the concentration of alpha and beta radioactivity. The samples were counted for 5 cycles at a rate of 2700 seconds each cycle at a high voltage of 1650V. According to the recommended count mode (either only, only, or mode), the alpha and beta counting was carried out using the necessary sample information, such as (Channel efficiency, background count rate, sample volume, and sample efficiency) (ISO, 1992). Pu-239 was used for the calibration as standard alpha source, which has alpha decay energy of 5.245 MeV and a half-life of 24,200 years. While, Sr- 90 was used for the calibration as standard alpha source, the energy of the beta decay is 0.546 MeV, and the half-life is 28.8 years. The alpha or beta count was calculated with equation (2) (ISO, 1992).

$$\textit{The alpha or beta count rate } (\alpha/\beta)\ (count/s) = \frac{Raw(\alpha/\beta)\ count\ \mathrm{x}\ 60}{Counttime\ (sec)} \quad (2)$$

The alpha or beta activity concentration was determined with equation (3) (ISO, 1992).

$$alpha\ or\ beta\ activity\ (\mathrm{Bq/l}) = \frac{\alpha \text{ or } \beta\ count\ Rate\ (cpm)\ - \text{bkg count rate (cpm)}}{detector\ eff.\ x\ sample\ eff.\ x\ sample\ vol.}\ x\ 0.0167 \quad (3)$$

Estimation of annual effect dose (ADE)

The principal alpha and beta emitters' annual committed effective doses in the ^{238}U and ^{232}Th series of the radionuclide that occur naturally were averaged to calculate the annual alpha and beta effective dose as a result of water ingestion is as shown in equation (4) as reported by (Bello et al., 2018).

$$E_{avg}(\alpha/\beta)(\mathrm{mSv/yr}) = \sum_i^{R(\alpha/\beta)} A_{i(\alpha/\beta)}\ (Bq/l)\ X\ DCF_{i(\alpha/\beta)}(mSV/Bq)\ X\ 730\ (l/yr) \text{ ---- } (4)$$

Where:$A_{i(\alpha/\beta)}$ = gross alpha or beta activity concentration (Bq/L),$E_{avg}(\alpha/\beta)$ = average gross annual alpha or beta committed effective dose in drinkable water, and $DCF_{i(\alpha/\beta)}$= dose conversion factor for ingestion of the specific natural radionuclides taken for an adult from UNSCEAR (2000) report. DCF for ^{226}Ra was 2.80 x 10^{-4} mSvBq^{-1}while for 6.90 x 10^{-4}^{210}Pb and ^{228}Ra it was 6.90 x 10^{-4} mSvBq^{-1}was utilized to calculate the effective dose. (WHO, 2004).It was considered that ^{226}Ra an alpha particles, contribute more than half of the annual dose comes through water consumption (Damla, 2006). Also, the main attribute of gross β activities in drinkable water are ^{210}Pb and ^{228}Ra (Gorur*et. al.,* 2011). Due to the machine's restricted capabilities, it was impossible to determine the radionuclides that contribute to the overall alpha and beta activity in the sample water. Water intake per day of 2 l/day estimated from (EPA, 2000) therefore, leads to annual consumption rate of 730 l/year for Adult (>12yrs), 365 L for child (1-12yrs), and 182.5 L for infant (≤1 yr) (Bello et al., 2020).

RESULTS AND DISCUSSIONS

Gross alpha and beta particle activity concentration

The measured values for the gross alpha and beta concentration are displayed in Table 1.The alpha activity ranged from 0.735±0.43 to 11.401±0.29 Bq/L, while the beta activity ranged from BDL to 11.891±0.57Bq/L as shown in table 1. The Garhi-East (GE) has the highest alpha and beta activity concentrations; intense farm activities found around the location might be the cause. The standard deviation derived from repeated measurements is indicated by the error in the table 1.

Table 1: The mean alpha and beta activity concentration in Zobe Dam water

Location	Sample ID	N0. Of Samples	Statistics	Radioactivity Measurement (Bq/l)	
				Alpha Activity	Beta Activity
Makera-North	MN	5	Mean ± r	8.972±0.41	11.128±0.55
Makera-South	MS	6	Mean ± r	0.735±0.43	BDL
Tabobi-North	TN	5	Mean ± r	6.287±0.23	8.036±0.29
Tabobi-South	TS	2	Mean ± r	9.058±0.27	10.927±0.85
Garhi-North	GN	4	Mean ± r	7.678±0.42	9.838±0.52
Garhi-South	GS	5	Mean ± r	8.528±0.32	BDL
Garhi-East	GE	3	Mean ± r	11.401±0.29	11.891±0.57
Garhi-West	GW	5	Mean ± r	7.263±0.46	7.167±0.48

BDL: Below detection limit

In Figure 2., the mean Alpha activities in all the analyzed water samples exceed the aproved limits of 0.1 Bq/L (ICRP, 1991).The high level of Alpha activities in the water could occur from the percolation of alpha-emitting radionuclide (e.g^{226}Ra) from the farm soil to the dam. Also, the Beta activities exceed the specific limit of 1.0 Bq/L with exception of sample MS and GS which were below detection limits as shown in Figure 3. The high level of Beta activities in the water might occur from the percolation of beta-emitting radionuclide (e.g^{210}Pb and ^{228}Ra) from the farm soil to the dam.

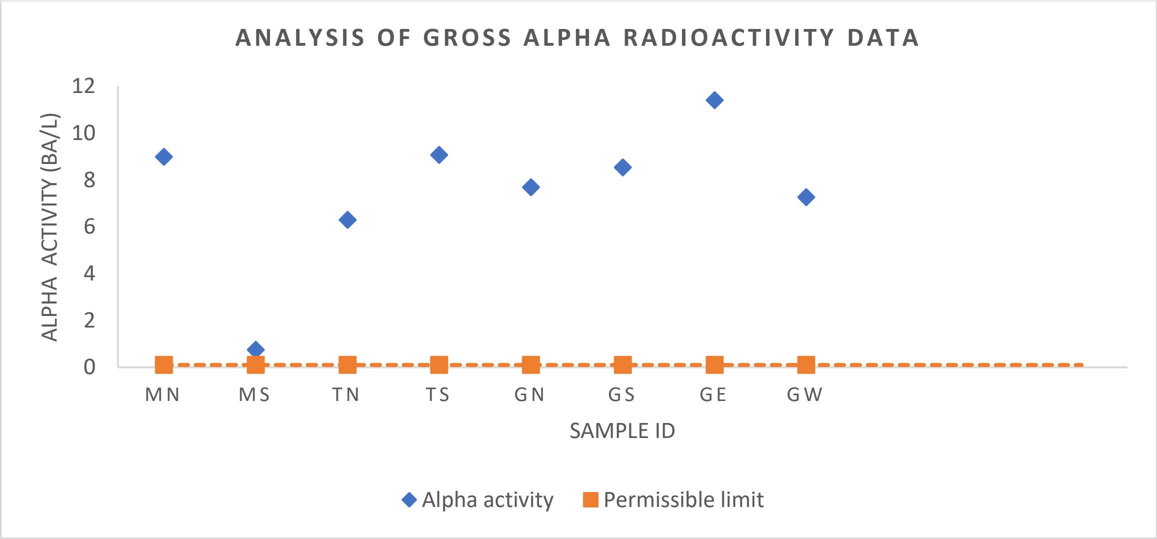

Figure 2: Gross Alpha Radioactivity Data with reference dose level (RDL)

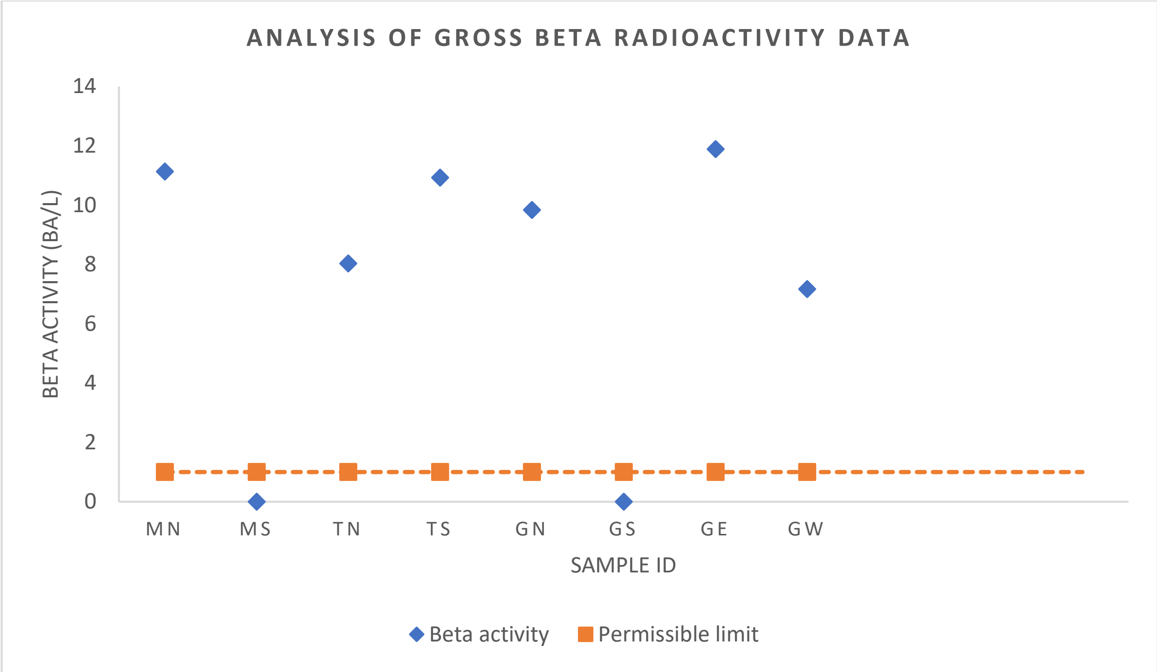

Figure 3: Gross Beta Radioactivity Data with reference dose level (RDL)

Due to the machine's restricted capabilities, it was impossible to identify the radionuclides in the sample water that generate alpha and beta radiation. The measured values of gross alpha and beta concentration compared favorably with existing literatures in Table 2.

Table 2: Comparison of gross alpha and beta concentration in Zobe dam with related studies

Country	***α*(Bq/L)**		***β*(Bq/L)**		**References**
	Average	***Range***	***Average***	***Range***	
Zobe dam, Nigeria	-	0.735 – 11.401	-	BDL – 11.891	Present Study
Owvian, NIgeria	-	0.006 – 0.018	-	0.046-0.182	Ogundare and Adekoya, 2015
Shanono, Nigeria	0.142	0.024 – 6.650	0.285	0.007 – 1.326	Bello et al., 2020
Obajana, Nigeria	-	0.003 - 0.053	-	0.294 - 39.960	Bello et al., 2018
Batman, Turkey	0.038	0.010 – 0.073	0.079	0.003 – 0.347	Damla et al., 2009
Marche, Italy	-	0.018 – 0.128	-	<0.042 – 0.259	Desideri et al., 2007
Saratonga, Usa	-	<0.040 – 0.310	-	0.110 – 0.189	Kitto et al., 2005
Hail, Saudi Arabia	0.215	0.017 – 0.541	0.260	0.480 – 0.516	Shabana and Kinsara 2014

Effective dose

Table 3, shows the adults, children and infants, annual effective doses (AED) from gross alpha and beta (mSv/year) with respect to each water sample taken from the research region.

The AED for adults, children and infants ranged from 0.150 – 8.319, 0.075 – 4.160 and 0.038 –2.080 mSv/year, respectively. The AED ranged from 0.150 to 8.319 mSv/year for adults, 0.075 to 4.160 mSv/year for children, and 0.038 to 2.080 mSv/year for infants, respectively.Makera-South (MS) had the lowest AED value, with annual AED values for adults, of 0.150 mSv, children of 0.075 mSv, and infants of 0.038 mSv, respectively. Garhi-East (GE) had the highest AED values of 8.319, 4.160, 2.080 mSv/year for adults, children and infants, respectively. Average AED in adults, children and infant surpassed ICRP dose limits of 0.1mSv/year (ICRP, 1990, ICRP, 2005). The high level of AED in the sample could be linked to high alpha and beta activity concentrations in the water sample, which is agreement with (Bello et. al., 2018). The high activity concentrations in alpha and beta might be attributed radionuclides from chemicals used for farm activities around the farm and geological nature of the area (Ogundare and Adekoya, 2015).

Table 3:Effective equivalent dose at all the sampled site

Sample	AED_{α}(mSv/y)			AED_{β}(mSv/y)			Total *AED*		
	Adult	Child	Infant	Adult	Child	Infant	Adult	Child	Infant
MN	1.834	0.917	0.458	5.605	2.803	1.401	7.439	3.720	1.859
MS	0.150	0.075	0.038	-	-	-	0.150	0.075	0.038
TN	1.285	0.643	0.321	4.048	2.024	1.012	5.333	2.667	1.333
TS	1.851	0.926	0.463	5.504	2.752	1.376	7.355	3.678	1.839
GN	1.569	0.785	0.392	4.955	2.478	1.239	6.524	3.263	1.631
GS	1.743	0.872	0.436	-	-	-	1.743	0.872	0.436
GE	2.330	1.165	0.583	5.989	2.995	1.497	8.319	4.160	2.080
GW	1.485	0.742	0.371	3.610	1.805	0.903	5.095	2.547	1.274

CONCLUSION

The research evaluated the Annual Effect Dose (ADE) resulting from the intake of alpha and beta particles of water in the proximities of farming activities at Zobe dam. The annual effective doses adults, children, indicated that majority of the water sample exceeded the ICRP dose limits of 0.1mSv/year. The high level of AED in the sample might be attributed to high alpha and beta activity concentrations in the sample. The detector's limited functionality prevented the determination of the radionuclide. Therefore, water from the research area might be at high risk due to intense farm activities and presence of natural radionuclides in Zobe dam, if appropriate action is not done.

REFERENCES

Avwiri, G.O., Agbalagba, E.O., (2007): Survey of gross alpha and gross beta radionuclideactivity in Okpare-Creek Deltal State Nigeria. Asian network for scientific information. J. Appl.SC. 7 (22), 3542 - 3546.

Bello, I.A**.,** Zakari, Y.I., Garba, N.N., Vatsa, A.M. and Kure, N. (2018). Radioactivity level in water around a Cement factory in North Central Nigeria. *Science World Journal.* 13(1):56-60. Faculty of Science, Kaduna State University. ISSN: 1597-6343

Bello, S., Nasiru, R., Garba, N.N., and Adeyemo, D.J.(2020). Annual effective dose associated with radon, gross alpha and gross beta radioactivity in drinking water from gold mining areas of Shanono and Bagwai, Kano State, Nigeria. Microchemical Journal 154 (2020) 104551.

Boukhenfouf, w., &boucenna, A. (2011). The radioactivity measurements in soils and fertilizers using gamma spectrometry technique. Journal of EnvironmentalRadioactivity, 102, 336-339.

Bramki A., Ramdhane M., and Benrachi F., (2017). Natural radioelement concentrations in fertilizers and the soil of the Mila region of Algeria. *Journal of Radiation Research and Applied Sciences* xxx (2017). 1-7.

Canbazoglu,C., Şahin, S., and Doğru, M. (2001). Determination of the gross alpha and the gross beta radioactivity concentration in some medicinal plants, Balkan Phys. Lett. (2001). Special Issue 59-63.

Chauhan, P., Chauhan, R., & Gupta, M. (2013). Estimation of naturally occurring radionuclides in fertilizers using gamma spectrometry and elemental analysis by xrf and xrd techniques. Journal of Microchemical Journal, 106, 73-78.

Damla, N., Cevik, U., Karahan, G., Kobya, A.I., Kocak, M., and Isık, U. (2009). Determination ofgross α and β activities in waters from batman, turkey, Desalination 244 (2009)208–2014.

Damla, N., Cevik, U., Karahan, G., &Kobya, A. I. (2006). Gross alpha and beta activities in tap water in eastern black sea region of Turkey. *Chemosphere*, 62937), 957-960

Desideri, D., Roselli, C., Feduzi, L., and Meli, M. A. (2007). Radiological characterization ofdrinking waters in central Italy, Microchem. J. 87 (2007) 13–19.

Ebro river basin (Northeast Spain), *Journal of Environmental Radioactivity* 51(2): page 181-210

Garba, N. N. (2011). Determination of radon concentration in water sources of Zaria andenvirons using liquid scintillation counter, An unpublished M.*Sc.* thesis AhmaduBello University, Zaria, 2011.

Gorur, F. K., Keser, R., Akcay, N., As, N., &Dizman, S. (2011). Annual effective dose and concentration levels of gross alpha and beta in Turkish market tea. *Iran Journal of Radiation Research, 10(2): 67-72.*

Gruber, V., Maringer, F. J., and Landstetter, C., (2009). Radon and other natural radionuclides indrinking water in Austria: measurement and assessment, *Appl. Radiat. Isot*. 67 (5)(2009) 913–917.

IAEA. (2001). Extent of Environmental Contamination by Naturally Occurring Radioactive Material (Norm) and Technological Options for Mitigation. Technical Reports SeriEs No.4I9.

ICRP (1991). The 1990 Recommendation of the International Commission of Radiological Protection,ICRP Publication 60. 21-23 *Elsevier Health Sciences*, USA.

ICRP (2005). International commission on radiation protection, *Ann. ICRP 60 (2005). 411–440.*

Internation Standard Organization (ISO), (1992). Water Quality Measurement of Gross Alpha Activity in Non-saline Water,International Standard Organization, 1992 (ISO 9696). Pp8.

International Commission of Radiological Protection (ICRP), (1990).

Jobbagy, V., Watjen, U., and Meresova, J. (2010). Current status of gross alpha/beta activityanalysis in water samples: a short overview of methods, *J. RadioanalNucl. Chem* 286 (2010) 393–399.

Khater, A., & AL-Sewaidan, H. (2008). Radiation exposure due to agricultural uses of phosphate fertilizers. Radiation Measurements, 43, 1402-1407.

Kitto, M. E., Parech, P. P., Torrs, M. A., and Schneider, D. J. (2005). Radionuclides and chemicalconcentration in mineral waters at Saratonga springs, New york, J. Environ.Radioact. 80 (2005) 327–329.

Ogundare F.O., and Adekoya, O.I. (2015). Gross alpha and beta radioactivity in surface soil anddrinkable water around a steel processing facility, J. Rad. Res. Appl. Sci. 8 (2015)411–417.

Onoja R.A. (2011). Determination of Natural Radioactivity and Committed Effective DoseCalculation in Borehole water Supply in Zaria, Nigeria, Ahmadu Bello University,Zaria, 2011 A PhD Dissertation.

Pujol L. and Sanchez C. (2000): Natural and artificial radioactivity in surface waters of thewheat cultivation. *Radiation Protection Dosimetry (2018)*, pp.1-9.

Rafik, M., Rahman, S. U., Basharat, M., Aziz, W., Ahmad, I., Lone, K. A., et al. (2014). Evaluation of excess life time cancer risk from gamma dose rates in jhelum valley. Journal of Radiation Research and Applied Sciences, 7, 29-35.

Ravisankar, R., Chandrasekaran, A., Vijayagopal, P., Venkatraman, B., Senthilkumar, G., Eswaran, P., et al. (2012). Natural radioactivity in soil samples of yelagiri hills, Tamil Nadu, India and the associated radiation hazards. Radiation Physics and Chemistry, 81, 1789 - 1795.

Servitzoglou, N.G., Stoulos, S., Katsantonis, D., Papageorgiou, M., and Siountas, A., (2018). Natural radioactivity studies of phosphate fertilizers applied on Greek farm soils used for

Shabana, E. I. andKinsara, A. A. (2014). Radioactivity in groundwater of high background radiationarea, J. Environ. Radioact. 137 (2014) 181–189.

Taskin, H., Karavus, M., Ay, P., Topuzoglu, A., & Karahan, G. (2013). Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey. Journal of Environmental Radioactivity, 100, 49-53.

United Nations Scientific Committee on Effects of Atomic Radiation,(UNSCEAR) 2000. Sources and Effects of Ionizing Radiation (Report to the General Assembly) New York: United Nation). *UNSCEAR Report, New York.*

United State Environmental Protection Agency (USEPA) 2010. Decontamination research and development conference. *Environmental Protection Agency, Washington, DC, EPA/600/R-11/052.*