

Field Method for Gross Detection of Alpha and Beta Radionuclides in Water Samples

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Abstract:- A new field technique for detecting alpha and beta radionuclides in water samples has been developed. The technique entails concentrating a 0.5 L water sample with Actinide Resin (Eichrom Technologies, Inc.), then co-precipitating MnO₂ and detecting the results with a GQ GMC-600+. Geiger Muller's counter. A standard method was also used to detect the gross alpha and beta activity in the same samples of water. A total of 10 samples were collected from wells and boreholes in different locations within the Pankshin metropolis. The result of the analysis shows that the field method has alpha activity that ranges from 0.021 ± 0.002 to 0.698 ± 0.014 Bq/L while the beta activity ranges from 0.713 ± 0.107 to 6.034 ± 0.131 Bq/L respectively, the result for the standard methods also has alpha activity ranging from 0.004 ± 0.002 to 0.073 ± 0.003 and beta from 0.252 ± 0.012 to 12.520 ± 0.201 Bq/L. From the result of the analysis, it is evident that this approach produces a useful tool for quick field analysis, risk assessment, and initial decision-making capability.

Keywords: Gross Alpha, Gross Beta, Well Water, Borehole Water, Field Methods.

I. INTRODUCTION

Water is so important to humans that its availability in sufficient quantity and of high quality is critical to their survival. Water is one of the essential elements that sustains all forms of vegetation and animal life (Vanloon and Duffy, 2005). The supply of pure and large quantity of water is a greatest problem facing the present civilization (Gyuk, *et al.*, 2017). The availability of clean and quality water is of great concern to relevant authorities and stakeholders. A number of the contaminants that affects the quality of water consists of heavy metals, radionuclides and gaseous emission and so on. Natural radionuclides and their decay products are usually found in every type of water used for domestic purposes from various sources (Rajamannan, *et al.*, 2013). Water is mainly obtained from natural sources which consist of surface water inclusive of water from lakes, rivers, stream and ground water which consist of borehole water and well water (Mendie, 2005). Anthropogenic and some natural phenomenon might also pollute this water and for this reason affecting its quality. Among these human activities are sewage disposal, fertilizer leaching from soil, commercial waste disposal, and others. A number of these waste disposals might also regularly include some radioactive substances which contribute drastically to the background activity of the water bodies (Gondar, 2011). Other kinds of water pollution can be due to rock types containing radioactive materials known as Naturally

Occurring Radioactive Materials (NORM). These materials break down, emitting alpha, beta, or gamma radiation as a result. Drinking water obtained from deep wells and boreholes is typically expected to contain a high concentration of radionuclides because they pass through bedrock fractures or inside soil containing mineral deposits that may contain radioactive components, causing the radionuclides to leak into waterway. One of the main ways that radionuclides from the environment enter the human body is through drinking water, which could potentially lead to radiation-induced disease (USEPA, 2010). Research on both humans and animals has shown that exposure to radiation at low to moderate doses can also increase the long-term occurrence of most cancers and that the risk of genetic malformations may be increased by radiation exposure (Otton, 1994). It is therefore crucial to determine the amount of radionuclides in consuming water for each location wherein people live in, which is a good way to shield against health hazards (WHO, 2006)

Contaminants are transferred to sources of drinking water during groundwater transport through the aquifer. The radiological characterization of drinking water is started with a gross alpha and beta analysis, which is also used as a screening technique for radioecology, environmental monitoring, and industrial applications. The majority of natural radionuclides are part of a complicated decay chain (Jobbagy, *et al.*, 2010). The determination of gross alpha and beta activities is complicated by combinations of various radionuclides present in various decay schemes. Because parent-to-daughter concentration ratios can vary over time, a laboratory analysis is necessary to identify the specific radionuclides in a given sample. The majority of analytical detection methods used in field environments are hindered by the requirement for sophisticated detection systems.

Environmental site assessment groups are able to analyze the chemistry of different water sources, including pH, dissolved solids, conductivity, and different salts. Despite these capabilities, many organizations are only partially or completely unable to detect radionuclides in field aqueous samples (Bartram and Gordon, 2008). Currently, aqueous environmental sample collection and analysis are done off-site. The off-site analyses are usually time-consuming as they may require several hours per sample. This might lead to delays in decision-making that could add up to two weeks in turnaround times for critical risk assessments or decisions about the potability of water sources in emergency situations.

The goal of this study is to create a workable field method for the detection of alpha and beta radionuclides in water using instruments for radiation detection and conventional aqueous chemistry procedures.. This method can help in decision-making without the logistical restrictions of outsourcing sample analysis by assisting in the identification of contaminant levels above the maximum permitted levels. The principles of radionuclide complexation, redox, and chemical solubility serve as the method's cornerstones.

II. MATERIALS AND METHODS

The equipment that were used for the research work are GQ GMC-600+ Geiger Muller counter, Hanna pH meter 208 Romania, distilled deionized water (DDI), 2L sampling container, Actinides resin (Eichrome Technologies Inc.), Planchet, hydrochloric acid, MnO₂, MnCl₂, NaOH.

A. Study Area

The study was carried out in Pankshin Local Government Area of Plateau State. A total of ten (10) samples of drinking water from different sources were collected from different locations within the metropolis.

B. Sample collection and treatment

The samples were collected in a 2 Litre container which was previously washed and rinsed with distilled water. A total of ten (10) samples were collected from boreholes and wells within the study area. As soon as the samples were collected, three drops of concentrated HNO₃ was added to each of the samples, this is to prevent the radionuclides from being adsorbed by the walls of the container. The samples were labeled as PKN 01 to 10 respectively and transported to the laboratory for further analyses.

C. Sample concentration:

Co-precipitation and extraction chromatographic resin were chosen as the methods for concentrating the relevant radionuclides in the water samples. Together, these methods were chosen because they were complementary, simple to use, required few materials, and produced little waste. Co-precipitation's ability to scavenge a variety of multivalent ions and the selectivity of the resin are complementary capabilities for effectively concentrating radionuclides.

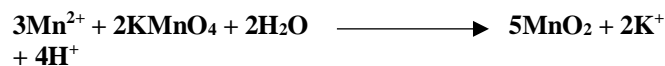
D. Actinide Extraction with Actinide Resin

A chromatographic resin for extraction, was utilized due to its high selectivity in the extraction of actinide radionuclides, which is a significant source of alpha-decay radionuclides. In this method, 0.1 grams of Actinide resin were added to 500 millilitres of water. After that, the resin was acidified with HCL to bring the pH down to 2, primarily to prepare the resin for optimal extraction. A magnetic stirrer was used in a beaker to stir the mixture at a low speed of 100 revolutions per minute. Even though it was allowed to remain overnight to achieve optimal mixing, the resin was allowed to stir in the solution for at least four hours (Horwitz et al., 1997). After that, it was vacuum-filtered, and the effluent was used in the next step. After being rinsed with 5 cm³ of deionized water, the resin was transferred to a steel planchet with a

diameter of 50 mm, where it was dried under a heat lamp. The co-precipitation of the effluent with MnO₂ took place as follows.

E. Extraction of Metals Cations by MnO₂ Co-precipitation

Co-precipitation is an efficient method for scavenging and concentrating metals from a sample solution. In the current review, multivalent metal particle was concentrated utilizing KMnO₄ and MnCl₂ by adopting the techniques of Kim *et al.* (2009). The actinides resin's effluent volume was increased by 200 mL of 0.2M KMnO₄ to begin the method. Concentrated NaOH was then used to bring the pH level up to 9. After this, 300 mL of 0.2M MnCl₂ was added to seed the precipitation, and the sample was stirred for an hour at a low speed (100 rpm) to ensure uniform mixing. Because hydrogen ions are released during the co-precipitation process, it is necessary to maintain a pH of 9 by adding additional concentrated NaOH as required. After an hour, the mixture was stopped from being stirred, and the precipitate was left to settle over night. The volume was reduced by pouring off the supernatant. After the sample's volume was reduced to less than 100 cm³, it was divided equally between two centrifuge vials of 50 cm³. In accordance with the parameters derived from the method of Kim *et al.* (2009) the samples were then centrifuged for 25 minutes (2009). The supernatant was poured out of the tube, and 3 cm³ of deionized water was added to the mixture of the precipitated particles from the two vials. Under a laboratory heat lamp, the solution was evaporated to dryness in a 50 mm stainless steel planchet. To prevent sample loss, the heat was turned off at the dry point. Using a Geiger Muller counter detector, the resin and the precipitate were counted separately. The procedure was repeated for the beta activities, and the alpha activities of the precipitate and the resins were added together.



F. Geiger Muller Counter Detection System

The measurement was carried out using a Geiger Muller Counter Detection System. The device first detects and measure the gross reduction (i.e. α , β and γ). A plane sheet of paper was used to extract the alpha (α) radiation from the beta (β) and the gamma (γ) radiation since alpha radiation cannot penetrates a plane sheet of paper. This was done by covering the sensor part of the device using a plane sheet of paper. The amount of radiation detected and measured was then recorded. The difference between this recorded radiation and the gross radiation measure at the first instance represent alpha radiation.

To extract β – radiation, an aluminum sheet was used since both α and β - radiation cannot penetrates aluminum sheet. The aluminum sheet was placed to cover the sensor part of the device so that both alpha and beta reduction cannot be detected by the device. This procedure was repeated for all the samples collected.

III. RESULT AND DISCUSSION

Table 1: The result for gross alpha and gross beta radioactivity of the field method in drinking water of some locations in Pankshin Local Govt. Area compared with Standard methods

SAMPLE ID	EPA method 900.0 standard method		Integration method (Field method)	
	α -activity (Bq/L)	B-activity (Bq/L)	α -activity (Bq/L)	β – activity (Bq/L)
PK 01	0.088 ± 0.003	4.366 ± 0.122	0.063 ± 0.001	3.175 ± 0.312
PK 02	0.021 ± 0.002	14.321 ± 0.311	0.033 ± 0.001	12.520 ± 0.201
PK03	0.064 ± 0.015	0.713 ± 0.107	0.032 ± 0.021	0.852 ± 0.306
PK04	0.046 ± 0.021	6.034 ± 0.131	0.031 ± 0.310	5.301 ± 0.202
PK05	0.098 ± 0.014	2.213 ± 0.152	0.073 ± 0.003	1.634 ± 0.004
PK06	0.051 ± 0.001	1.009 ± 0.051	0.041 ± 0.001	0.973 ± 0.310
PK07	0.006 ± 0.007	3.035 ± 0.334	0.034 ± 0.002	2.252 ± 0.012
PK07	0.053 ± 0.002	0.766 ± 0.019	0.042 ± 0.004	0.801 ± 0.006
PK09	0.071 ± 0.002	0.812 ± 0.106	0.053 ± 0.003	0.643 ± 0.002
PK10	0.042 ± 0.006	2.206 ± 0.213	0.031 ± 0.005	1.982 ± 0.006
AVERAGE	0.054 ± 0.007	3.548 ± 0.164	0.040 ± 0.038	2.576 ± 0.136
WHO Limit	0.5	1.0	0.5	1.0

Table 1 shows the results of a new method that was developed to detect gross alpha and gross beta in drinking water samples from various sources in comparison to standard methods. Pre-concentration of the sample using an extraction chromatographic resin, co-precipitation, and counting of the alpha and beta field method pre-concentration product using a Geiger Muller counter detector are the two step field methods. The two approaches produced very different outcomes. Gross beta activity ranges from 0.713 ± 0.107 to 6.034 ± 0.131 Bq/L with an average of 3.548 ± 0.164 , while gross alpha activity ranges from 0.021 ± 0.002 to 0.098 ± 0.014 with an average of 0.054 ± 0.007 in the EPA method 900.0 standard method. Where as those of the field techniques for alpha and beta ranges from 0.004 ± 0.002 to 0.073 ± 0.003 and 0.252 ± 0.012 to 12.520 ± 0.201 Bq/L with an average of 0.040 ± 0.038 and 2.576 ± 0.136 respectively. The EPA method's 900.0 result was higher than that of the field methods. When compared to the EPA method 900.0, the field method was statistically effective enough to identify the presence of gross alpha and beta activity. The EPA standard method detected the lowest amounts, 0.021 ± 0.002 Bq/L for alpha and 0.713 ± 0.107 Bq/L for beta, while the field methods detected 0.031 ± 0.005 Bq/L and 0.643 ± 0.002 Bq/L, respectively. As a result, it was suggested that environmental screening using the field method is preferable to environmental monitoring.

IV. CONCLUSION

The gross alpha and gross beta radionuclides in water can be detected using the field method. The procedure can be carried out with little to no technical knowledge. As a result, the methods should be used as a screening technique in the field to determine whether additional analysis is necessary. Compared to other gross alpha and beta detection methods, this one has the advantage of being field-portable and versatile when used with accessory probes. This approach produces a useful tool for quick field analysis, risk assessment, and initial decision-making capability.

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