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Estimation of Concentration of K-40 by Gamma Spectroscopy and Atomic Emission Spectroscopy in the Environmental Samples of Northern Kathmandu Valley

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Abstract

The concentration of K-40 was estimated by atomic emission spectroscopy (AES) and specific activity by gamma ray spectroscopy using by means of a multichannel analyzer (MCA) in the soil and water samples of northern parts of the Kathmandu valley. AES method was found to be sensitive and rapid for the routine analysis of water samples, however, cannot implement for the analysis of soil samples due to the loss of significant amount of potassium during the extraction process. The specific activity determined by a MCA in water samples ranged from 2.25 Bq/Kg to 17.87 Bq/Kg and for soil samples, from 17.48 Bq/Kg to 412.26 Bq/Kg.

Keywords: *Potassium-40, Gamma spectroscopy, Atomic emission spectroscopy, Soil and water samples.*

Introduction

Exposure to ionizing radiation from natural sources is a continuous and unavoidable feature of life on earth. The greatest contribution to mankind's exposure comes from natural background radiation and the worldwide average annual effective dose per capita is 2.4 mSv. The major sources responsible for exposure are naturally occurring radio nuclides in the earth's crust such as ^{232} Th, ^{238}U and ^{40}K [1] (A. K., Mohanty, 2004). Among these radio nuclides, K-40 occurs extensively in nature and is found in mineral ores, soils, rocks, sand, rivers, etc. The decayed residues of animal and plant organisms also contain this radioisotope. As a result of the process of breakdown of rocks and their weathering, K-40 may migrate and follow the food pathways, ultimately affecting human health[2] (B. R. Shah, 1994). Hence, as there are risks of health hazards due to exposure of human body to the natural radioactivity, it is therefore important to estimate the activity concentration due to K-40 in the environmental samples.

Experimental Methods

Sampling and sample preparation

The ground radiometric measurements were done initially by portable scintillation counter and at the locations where radioactive materials were detected were selected for this research work. High radioactivity was detected in Chunikhel area of northern Kathmandu valley and the samples from this area were collected. Sampling was done with the help of a small hand spade and stored in marked polythene bags with zippers. The bags were then made tightlipped with rubber. Almost 1.5 to 2 kilograms of the soil and more than 1 liter of water were taken at each sampling sites. Top vegetation layer each with 5 to 10 cm soil depth was removed at each site for the collection of soil samples. The samples were collected from almost a circle of radius 1 meter. The soil samples were sun dried and then were crushed

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and crumbled into the finer soil particles manually with hand and crusher and sieved. Stones and extra materials were thus removed from it and the samples were dried in an oven at 110 ^oC.

Preparation of water samples

100 mL of water sample was mixed with 5 mL of concentrated nitric acid in a 250 mL conical flask. It was heated on a hot plate till the volume was reduced to 10 mL. The hot solution was filtered into 100 mL volumetric flask and diluted up to the mark. This procedure was repeated for all the water samples as described elsewhere[3] (S. L. Clesceri, 1998).

Preparation of soil samples

0.1 g of dry, finely ground and sieved soil was taken in a beaker. 25 mL of 1 N HNO_3 was added and placed on a stand over a gas burner. When the boiling started, the flame was reduced and the suspension was boiled gently for 10 minutes. The flask was removed and the content was poured into a filter. The filtrate was received in a 100 ml volumetric flask. The soil was washed with four 15-mL portions of 0.1 N HNO_3. The solution was allowed to cool and diluted up to the mark, mixing it thoroughly, using double distilled water. A blank solution was also prepared and blank determination was also carried out in the same way. The samples were run in the emission mode.

Instrumentations

Perkin-Elmer Analyst 100 was used for Atomic Emission Spectroscopic analysis and ORTEC-NORLAND Multichannel Pulse Height Analyzer was used to determine the specific activity.

Estimation of Radioactivity of K-40

The standard method was applied to find out the concentration of K-40 (specific activity, Bq/Kg) in the soil and water samples that is, for potassium, the peak at 1.46 MeV was used for analysis[4] (L. Xinwei, 2005). The detector system coupled with 3” x 3” NaI crystal with 1024 channel was used for the process of measurement. And a Cs^{137} (AMERSHAM. 74 KBq, manufactured on December 1986) was taken as standard source for calibration. The source was kept for set time 500 seconds within the lead shield above the crystal system. For potassium (1460 KeV) 593 channels was used. The efficiency of the system was found to be 5.80% during the measurement. Analytical grade potassium chloride (Himedia) of 500 g of the same geometry was used as the standard source of K-40 [4](L. Xinwei, 2005). The ROI was determined in each peak and the same ROI was taken to determine the count rate in background spectrum. Each sample was counted twice before an average was taken. The same method was repeated to calculate the activity of all the soil samples taking 500 g soil in each measurement. For water samples, 500 ml of the samples were taken. The attenuation constant of Marinelli beaker for water (μd) was 0.000427 $cm^2\ g^{-1}$ (ORTEC-NORLAND. 1986)[5].

Quantitative Analysis of K-40 in the Sample

The ratio of K-40 to total K is constant throughout natural samples. It was sufficient to measure the total K content of a sample and multiply by the ratio of K-40 to total K which equals 0.00012 [6] (Fairbridge, 1972). By this way, the concentration of K-40 in both soil and water samples were evaluated.

Results and Discussions

Calibration of the Atomic Emission spectrometer

The recommended wavelength for potassium and slit width for the instrument were set to 766.5 nm and 0.7 mm respectively. The rest of the required parameters were set to calibrate. The emission values of the working potassium solutions of various concentrations were measured. The emission value at 766.5 nm was plotted against the known amount of potassium in the solution in ppm amounts. A linear correlation was found between the concentration of potassium and emission values. The plot obtained is presented in the Fig 1.

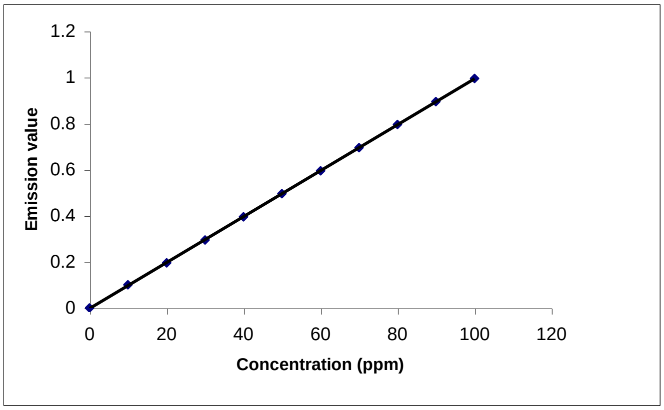

Fig1: *Calibration plot using Potassium chloride solution to determine the concentration of Potassium.*

Results of the atomic emission analysis

Table I: *Analysis of water samples*

Sample Number	Concentration (K) (ppm)	Concentration of K-40 measured by AES in ppm
W-1	7	0.42
W-2	4.4	0.26
W-3	1.5	0.09
W-4	5.8	0.34
W-5	2.6	0.15
W-6	3.2	0.19
W-7	4.2	0.25
W-8	3.4	0.2
W-9	2.7	0.16
W-10	3.7	0.22
W-11	3.9	0.23
W-12	3.1	0.18
W-13	4.9	0.29
W-14	2.1	0.12
W-15	1.3	0.07
W-16	1.5	0.09
W-17	2.1	0.12
W-18	2.1	0.12
W-19	1.8	0.1
W-20	1.5	0.09
W-21	2	0.12
W-22	2.1	0.12

Table II**:** *Analysis of soil samples*

Sample Number	Concentration (K) (ppm)	Concentration of K-40 measured by AES in ppm
ST-1	34.4	2.06
ST-2	12.2	0.73
ST-3	14.6	0.87
ST-4	20.3	1.21
ST-5	12.3	0.73
ST-6	35.6	2.87
ST-7	31.2	2.13
ST-8	15	0.9
ST-9	27.2	1.63
ST-10	11.3	0.67
ST-11	32.2	1.93
ST-12	88.5	9.86
ST-13	75.3	7.51
ST-14	81.2	8.9
ST-15	45.6	4.73
ST-16	40.7	4.44
ST-17	42.1	3.52
ST-18	63.6	6.81
ST-19	74	4.44

The concentration of potassium obtained in the water and soil samples are presented in Table I and Table II respectively. The maximum concentration of potassium in the soil samples was found to be 88.5 ppm and the minimum was 11.3 ppm. Similarly the maximum and minimum concentrations of potassium in water samples were found to be 7.0 ppm and 1.3 ppm respectively. The range of concentration of potassium in water samples were found to be within the given range of 0.5-10 ppm[3] (S. L. Clesceri, 1998). Using these concentrations, the concentration of K-40 were also determined with the help of fixed K-40:K ratio i.e. 0.00012 [6] (R.W. Fairbridge, 1972).

The activities of soil and water samples were calculated with 0.5 kg of soil and 500 mL of water respectively. The specific activity and concentration of K-40 in the same set of samples were determined by Multi -Channel Analyzer and the results are illustrated in Table III and Table IV respectively for water and soil samples.

The specific activity due to K-40 among the water samples varied from a minimum of 2.25 Bq/L to a maximum of 13.35 Bq/L and that of the soil samples the specific activity due to K-40 varied from minimum of 17.48 Bq/Kg to maximum 412.26 Bq/Kg respectively. It was well noted in the results that the increase in radioactivity was in good agreement with the corresponding increase in specific activity concentration K-40 as calculated. The results obtained for the soil samples falls in between the range of 26 Bq/Kg to 716 Bq/Kg in Kathmandu valley[2] (B. B Shah, 1994). The activity of K-40 in all the taken samples was found to be less than the typical average of 500 Bq/Kg. Most of these samples were taken from Chunikhel (northern part of the Kathmandu) where higher radioactivity was determined during the radiometric measurements done by portable scintillation counter[7,8] (K. K Shrestha, 2004, K. K Shrestha, *et al.* 2004). This might indicate that the significant abundance of other natural isotopes such as ^{232}Th, ^{238}U are responsible for higher radioactivity Therefore, it is important to have further investigation upon the concentrations of ^{232}Th, ^{238}U.

The concentrations of K-40 obtained by AES and MCA were compared as shown in Fig. 2 and Fig. 3. For the water samples almost similar results were obtained by both the process whereas a clear difference in concentration of K-40 calculated by the said process was observed for the soil samples. For all the soil samples the concentrations calculated by MCA method were higher than the values obtained from AES method. The reason to this might be due to the loss of potassium during the extraction by mineral hydrolysis[9] (W. D. Billings1989). Thus resulting in low concentration of K-40 as count rate for the spectrum of K-40 is directly proportional to its concentration in its source [10] (Scintrex).

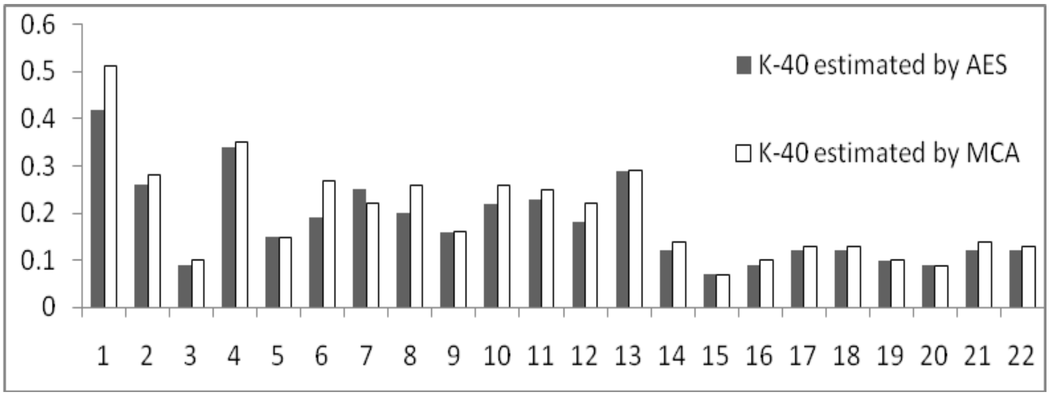

Fig 2: *Comparison of the concentrations of K-40 determined by AES and MCA methods in water samples.*

Table III : *Specific activity and concentration of K-40 in water samples.* ***Table IV :*** *Specific activity and concentration of K-40 in soil samples.*

Sample Number	Radioactivity (Bq/L)	Concentration of K-40 measured by MCA in ppm
W-1	17.87	0.51
W-2	10.01	0.28
W-3	3.2	0.1
W-4	13.35	0.35
W-5	6.67	0.15
W-6	9.29	0.27
W-7	9.98	0.22
W-8	8.34	0.26
W-9	6.95	0.16
W-10	9.04	0.26
W-11	9.18	0.25
W-12	9.2	0.22
W-13	11.75	0.29
W-14	5.87	0.14
W-15	2.25	0.07
W-16	2.69	0.1
W-17	6.15	0.13
W-18	6.41	0.13
W-19	3.72	0.1
W-20	3.57	0.09
W-21	5.91	0.14
W-22	5.87	0.13

Sample Number	Activity (Bq/Kg)	Concentration of K-40 measured by MCA in ppm
ST-1	55.94	3.24
ST-2	24.66	0.98
ST-3	33.26	1
ST-4	46.01	1.5
ST-5	24.37	1.03
ST-6	78.86	3.12
ST-7	73.69	3.27
ST-8	29.69	1.03
ST-9	59.18	2.26
ST-10	17.48	0.87
ST-11	68.66	3.84
ST-12	412.26	12.32
ST-13	382.12	10.57
ST-14	403.06	11.78
ST-15	87.34	3.76
ST-16	90.56	3.8
ST-17	88.37	3.78
ST-18	229.28	6.05
ST-19	258.1	7.72

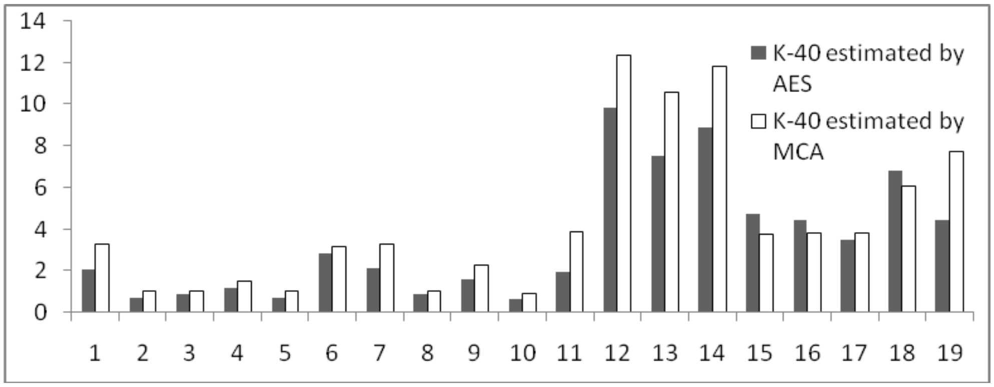

Fig 3: *Comparison of the concentrations of K-40 determined by AES and MCA methods in soil samples.*

Conclusions

In this study, the concentration of K-40 in the water and soil samples was determined using two different methods and compared. The K-40 concentrations obtained by both methods for water samples are very close. So the sensitive and rapid AES method can be implemented for the routine analysis to calculate the specific activity concentration of K-40 only in water samples, than time-consuming MCA method. On the other hand for the soil samples, AES method is found to be inaccurate due to the loss of potassium during the extraction process. The minimum and maximum specific activity due to K-40 in the water samples, were found to be 2.25 Bq/Kg and 17.87 Bq/Kg respectively. Similarly, the specific activity due to K-40 in the soil samples was found to be between 17.48 Bq/Kg and 412.26 Bq/Kg.

As the sampling sites showed high level of radioactivity during the radioactive measurements, it appeared that there could only be partial contribution from K-40 radio nuclides in the total radioactivity. Large concentration of other species such as ^{232} Th, ^{238}U might be playing huge role along with K-40 species.

Acknowledgments

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