# Evaluation of Natural Radioactivity Levels for Local and Import of Cement in Iraq

Ali A. Abojassim Mohammed H. Al-Taweel Talib A. Abdulwahid

**Abstract**— Cement samples were collected from Iraq market. Radioactivity was measured using *(NaI)Tl* detector, specific activity levels due to $^{226}$Ra, $^{232}$Th and $^{40}$K were measured in 11 cement samples. The average activity concentration Bq/Kg in the collected cement samples were found the range from (17.027±4.609) to (95.436±5.565) Bq/Kg with an average value of (40.49391±3.09627) Bq/Kg for $^{226}$Ra, $^{232}$Th specific activities range from (2.303 ±0.319) to (8.8159±0.366) Bq/Kg with an average of (4.79±0.3455) Bq/Kg and $^{40}$K specific activity range from (84.135±5.387) to (389.436±8.364) Bq/Kg with an average value of (275.8±5.763) Bq/Kg . The average value of the radium equivalent was found (68.21907) Bg/Kg, while the average value of the absorbed dose in air, external hazard index and internal hazard index were found (32.9866) nGy/h, (0.2937) and (0.184298) respectively. The results were compared with international recommended values and found to be with in the international level.

**Keyword**— Radioactivity, cement in Iraq, radiation hazard indices and gamma spectroscopy, university of kufa, materal building in Iraq.

## 1 Introduction

ALL raw building materials and products from soil and rock contain radionuclides of two series $^{238}$U and $^{232}$Th and the radioactive isotope $^{40}$K, so the decay of $^{238}$U series yield the radioactive isotope $^{226}$Ra which can be considered a reference instead of $^{238}$U. These radionuclides are considered as sources to external and internal radiation exposures in dwellings . The external exposures is due to gamma rays radiation while inhalation of radioactive inert gas as radon $^{222}$Rn which is the progeny of $^{226}$Ra and $^{232}$Th , the secondary products with short half- life lead to internal exposure of the respiratory tract to the alpha particles . The specific activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in raw building material and the product of material building depends mainly on geological conditions as well as geochemical characteristics of those material [1]. It is necessary to know the limits of radiation exposure dose to nature radiation from radionuclide in soil , water, food and building's interior [2]. It is important to assess the concentration of radio elements in building materials since population spend 80% of their time inside the buildings . The average indoor absorbed dose rate in air from terrestrial sources of radioactivity in estimated to be 70 nGy/h [3]. Many studies has been published to determine radionuclide concentrations in building materials in many countries [4-19]. The goal of this study is to assess the natural radioactivity which are $^{226}$Ra, $^{232}$Th and $^{40}$K in cement used inside Iraq by using gamma ray spectrometry , also to calculate Radium equivalent Ra eq., external hazard index ($H_{ex}$), internal hazard index ($H_{in}$) and absorbed dose rate, then compare our results with those reported in other countries .

*Ali A. Abojassim is doctor in nuclear physics and enviromental for University of Kufa/ Faculty of Science/ Department of Physics/Iraq, E-mail ali.alhameedawi@uokufa.edu.iq.*
*Mohammed H. Al-Taweel is master in nuclear physics for University of Kufa/ Faculty of Science/ Department of Physics/Iraq, E-mail mohammed_hider_m@yahoo.com .*
*Talib A. Abdulwahid is master in nuclear physics for University of Kufa/ Faculty of Science/ Department of Physics/Iraq, E-mail Taliba.jabir@uokufa.edu.iq.*

## 2 Materials and Methods

### 2.1 Sampling and sample preparation

A total of eleven sample of building material cement , these samples have been collected from local Iraq market , measurement of radioactivity concentration in different cement samples which that shown in Table(1), it is measured without any processing since they are already in powdered form the samples were packed into a plastic one liter marinelli beaker weighted and hermetically sealed and left for four weeks to reach radioactive equilibrium before measurement.

**Table 1:** Types and made of cement samples in this study

| *Sample code* | *Name of Samples* | *Made of samples* |
|---|---|---|
| S1 | Kubasa | Iraq |
| S2 | Bridge | Iraq |
| S3 | Crystal white | Iraq |
| S4 | Crystal | Iraq |
| S5 | Al kaim | Iraq |
| S6 | Elam(1) | Iran |
| S7 | Almas | Iraq |
| S8 | Elam(2) | Iran |
| S9 | Kufa | Iraq |
| S10 | Al-Najaf | Iraq |
| S11 | Crystal | Iraq |

### 2.2 Instrument and Calibration

Radioactivity measurements were performed by gamma ray spectrometry which consists of detector NaI(Tl) the volume of crystal is (“3 x 3”) and multichannel analyzer (4096 channel) and deseparation energy (FWHM) in the peak 1.33KeV for Co60 is 7% . The radioactive background decrease for different radiations by using shield which consist of two layers , first one of stainless steel with width ( 10 mm) and the second layer lead (30 mm). Energy calibration and efficiency calibration of gamma spectrometer were carried out using (Co-60 ,Cs-137, Na-22) calibration sources in one liter marinelli beaker covering the energy from 25 Kev to 2500 Kev . The standard source put over the detector with a geometric match exactly to the geometrical sample form and with same distance between the sample and the detector. The counting time for each sample, as well as for background was 1000 sec. The absolute efficiency was calculated the equation[1]

$$Eff = (100\, N_p)\,/\,(I\gamma . T_{OC}\, .\, A)$$

Where: $N_p$: net peak area (count/ sec) at $E_\gamma$, $I_\gamma$: intensity of emitted gamma ray (%), $T_{oc}$: time of counting (sec.) and A: activity of standard source in (Bq).

### 2.3 Calculation of Activity

The natural radioactivity of cement samples is usually determined from $^{226}$Ra, $^{232}$Th and $^{40}$K contents. To decreased the scattering radiation from the interaction of the radiation in the sample with shield. the sample was put in the middle of room shield with period about (5 hours) according to radioactivity for each of K-40 , Ra-226 and Th-232 using (EC & NORTEC) program. The natural radioactivity for the light peaks determined for K-40 at energy (1460 KeV) ,U-238 from the daughter (Bi-214) at energy of (1764.49 KeV) and Th-232 from the daughter (Ti-208) at energy (2614 KeV)[20,22]. The specific activity represented by [1]

$$A = (N_p)\,/\,(e\, .\mu\, .\, m)$$

Where : $N_p$: is the net peak counts, e: is the abundance of the gamma line in a radionuclide, µ: is the measured efficiency for each gamma line and m: is mass of the sample in Kg.

### 2.4 Calculation of radiological effects

The most widely used radiation hazard index Ra eq. is called radium equivalent activity which represents the activity of $^{226}$Ra, $^{232}$Th and $^{40}$K . The Ra eq. activity is mathematically defined by [21]

$$\text{Ra eq. (Bq/ Kg)} = A_{Ra} + 1.43A_{Th} + 0.77A_k$$

Where: $A_{Ra}$ , $A_{Th}$ and $A_k$ are activity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K respectively . The above equation depends on the assumption that 10 Bq/Kg of $^{226}$Ra, 7 Bq/Kg of $^{232}$Th and 130 Bq/Kg of $^{40}$K produce equal gamma dose. The total air absorb dose rate (n Gy / hr) due to mean activity concentration of $^{238}$U, $^{232}$Th and $^{40}$K (Bq/Kg) can be calculated using the formula of UNSCEAR(2000) [21].

$$D\left(\frac{nGy}{h}\right) = 0.462A_{Ra} + 0.621A_{Th} + 0.0427A_K$$

The external hazard index , $H_{ex}$ is defined as :

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810}$$

The internal exposure to radon and its daughter products is quantified by internal hazard index $H_{in}$ , which is given by equation :

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810}$$

The value of $H_{ex}$ and $H_{in}$ must be less than unity for safety

## 3. Results and Discussion

The activity concentration due to $^{226}$Ra, $^{232}$Th and $^{40}$K and radium equivalent activity in different kinds of samples has been measured as shown in table (2) and Figures (1), (2) and (3) respectively. The specific activity of $^{226}$Ra was found in the range of (17.027±4.609) to (95.43±5.565)Bq/kg, $^{232}$Th from (2.303±0.319) to (8.8159±0.366)Bq/kg and $^{40}$K from (84.135±5.387) to (475.331±10.568)Bq/kg. There is a variation in the concentration of radionuclides in different cement samples , for example (S11) which is Turkish white cement has lowest $^{226}$Ra concentration and the maximum value (S9) which Iraq Kufa cement , the lowest $^{232}$Th concentration is (S10) is Iraq Najaf cement while the maximum is (S3) Iraq crystal white cement and the lowest $^{40}$K concentration is (S4) which is Iraqi crystal cement and the maximum is (S11) Turkish white cement .These variations in the activity of $^{226}$Ra, $^{232}$Th and $^{40}$K contents under the earth crust , from where the raw material Ra eq. (Bq/ Kg) for different kinds of cement samples varies from the lowest value of (S2) Iraqi bridge cement (41.252472) Bq/Kg to maximum value of (S9) Iraqi Kufa cement (131.933824) Bq/kg. It is observed that the Ra eq. value for all the studied samples are lower than recommended maximum value of 370 Bq/ kg. Thus, these samples are within the recommended safety limit. The calculated internal hazard ($H_{in}$) and external hazard ($H_{ex}$) indices for cement samples are shown in table(3) varied from (0.172784) to (0,614414) with an average (0.2937) and from (0.11144) to (0.35647) with an average (0.184298) respectively . These values of ($H_{in}$) and ($H_{ex}$) is less than unity , therefore these Iraqi cements are regarded as safe for construction purposes . Also the table (3) show the absorbed dose rate in air for Iraqi cement samples varies from (20.084544) to (63.183224) nGy/h with an average value (32.9866) so we can say that the Iraqi cement samples used in Iraq is lower than world average indoor absorbed gamma dose rate of(84) nGy/h (UNSCEAR 2000,2008). Figure (5) shows the compared between radiation hazard indexes according to results of this study with limited level world. In table(4) represented a comparison of the mean values of $^{226}$Ra , $^{232}$Th , $^{40}$K and radium equivalent ($Ra_{eq.}$) activities in different countries . It is observed from the table that Australia, Austria, Algeria, Bangladesh, Brazil , China, Egypt, Greece are higher in $^{226}$Ra concentration from that used in Iraq market like Finland, Ghana, India, Italy, Japan, Netherland, Pakistan, Tunisia and Turkey are less than the average of the kinds used in Iraq markets , but it is obvious that the average value of specific activity $^{232}$Th is higher than Iraqi cement , also the specific activity of $^{40}$K is higher than the Iraqi cement , in country like Algeria ,Bangladesh, Brazil , Greece, and India but the table show lower values of specific activity than in the Iraqi cement . When we compare Ra eq. we notice that Austria and Tunisia are less than Iraq cement but the other countries in the table are higher.

**Table2** : Specific activity of $^{226}$Ra , $^{232}$Th and $^{40}$K in some types of cement

| *Sample Code* | *Specific activity in (Bq/Kg)* | | |
|---|---|---|---|
| | **$^{40}$K** | **$^{226}$Ra** | **$^{232}$Th** |
| S1 | 227.933±3.744 | 83.014±2.345 | 4.965±0.274 |
| S2 | 185.836±2.898 | 22.696±1.612 | 2.970±0.258 |
| S3 | 110.321±3.116 | 37.781±2.974 | 8.8159±0.366 |
| S4 | 84.135±5.387 | 33.838±2.795 | 6.327±0.465 |
| S5 | 182.087±3.016 | 35.790±1.802 | 5.371±0.283 |
| S6 | 339.556±4.184 | 41.585±2.010 | 5.026±0.293 |
| S7 | 251.727±4.373 | 35.578±2.676 | 3.604±0.242 |
| S8 | 389.436±8.364 | 23.791±3.591 | 3.752±0.380 |
| S9 | 387.882±9.934 | 95.436±5.565 | 4.637±0.425 |
| S10 | 295.562±7.811 | 63.852±4.080 | 2.303±0.319 |
| S11 | 475.331±10.568 | 17.027±4.609 | 5.080±0.496 |
| **Average** | 275.80±5.763 | 40.49391±3.096 | 4.79±0.3455 |

**Table** 3 : Radiological hazard indexes in some types of cement

| *Sample Code* | *Raeq. (Bq/ Kg)* | *Absorbed Dose rate (nGy/h)* | *Internal hazard index* | *External hazard in-dex* |
|---|---|---|---|---|
| S1 | 66.514791 | 32.234514 | 0.282433 | 0.179692753 |
| S2 | 41.252472 | 20.084544 | 0.172784 | 0.111443065 |
| S3 | 58.882454 | 27.4131076 | 0.261196 | 0.159084794 |
| S4 | 49.364005 | 22.988334 | 0.224828 | 0.133374309 |
| S5 | 57.491229 | 27.426718 | 0.252053 | 0.155323107 |
| S6 | 74.917992 | 36.509326 | 0.314783 | 0.20239106 |
| S7 | 60.114699 | 29.186386 | 0.258563 | 0.16240591 |
| S8 | 59.142932 | 29.613962 | 0.22405 | 0.159750312 |
| S9 | 131.933824 | 63.183224 | 0.614414 | 0.356479358 |
| S10 | 89.903564 | 43.30424 | 0.415485 | 0.242912266 |
| S11 | 60.891887 | 30.898696 | 0.210473 | 0.1644543232 |
| **Average** | 68.21907 | 32.9866 | 0.2937 | 0.184298 |

.



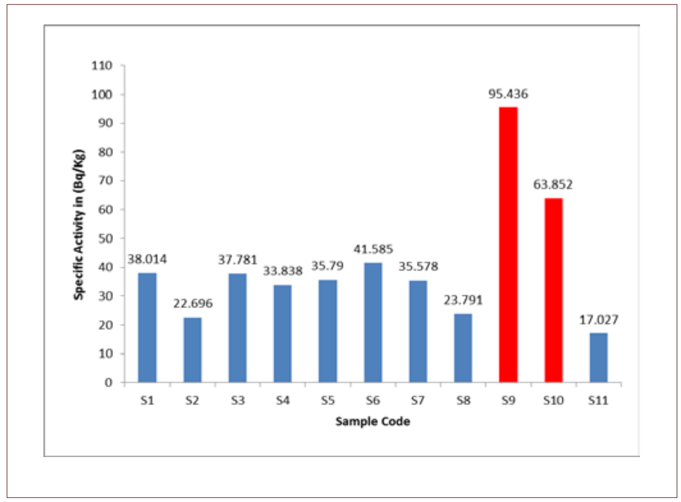


**Figure 1**: Specific Activity of $^{226}$Ra in (Bq/Kg)

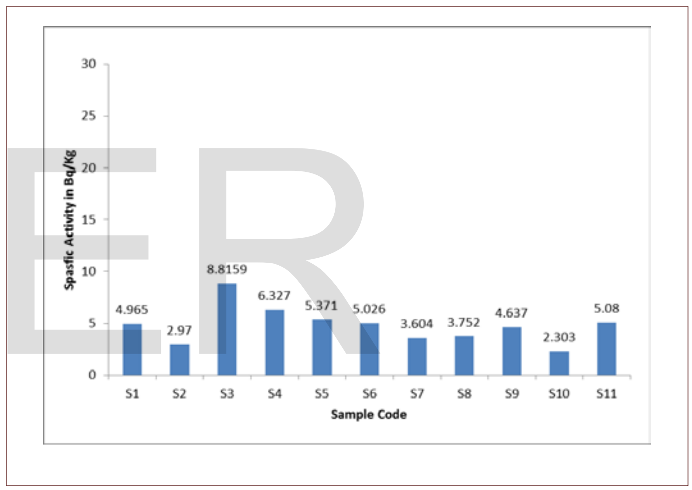


**Figure 2**: Specific Activity of $^{232}$Th in (Bq/Kg)

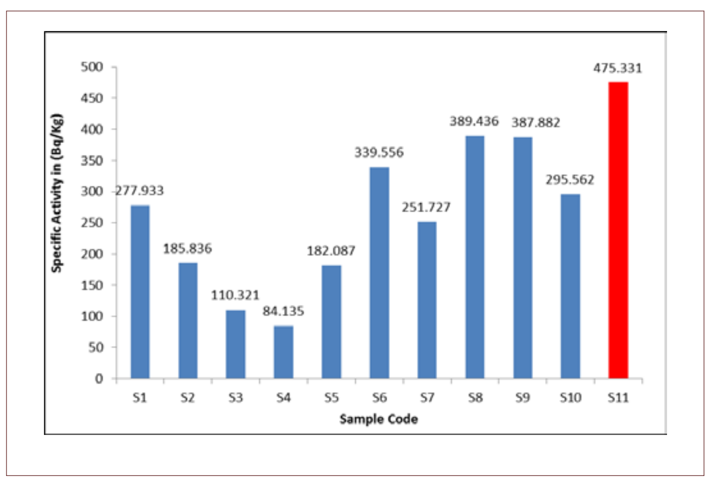


**Figure 3**: Specific Activity of $^{40}$K in (Bq/Kg)

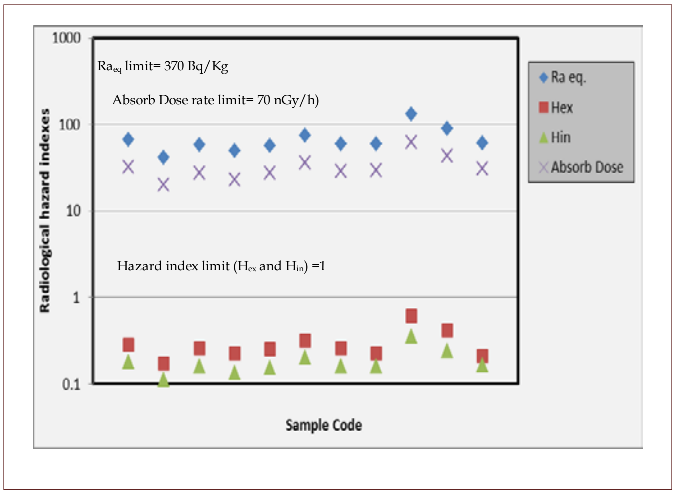


**Figure 4**: A comparison of radiation hazard indexes with the worldwide average and permissible limit for cement samples

**Table 4** : Comparison of mean values of $^{226}$Ra , $^{232}$Th , $^{40}$K and radium equivalent (Ra eq) activities in Iraq cement samples with data from other countries [4-19] .

| *Country* | *Raeq. (Bq/Kg)* | *Specific Activity (Bq/Kg)* | | |
|---|---|---|---|---|
| | | $^{226}$Ra | $^{232}$Th | $^{40}$K |
| Australia | 129.4 | 51.5 | 48.1 | 114.7 |
| Austria | 63.1 | 26.7 | 14.2 | 210 |
| Algeria | 112.0 | 41.0 | 27.0 | 422.0 |
| Bangladesh | 172.8 | 62.3 | 59.4 | 328.9 |
| Brazil | 188.8 | 61.7 | 58.5 | 564.0 |
| China | 122.0 | 56.5 | 36.5 | 173.2 |
| Egypt | 151.0 | 78 | 33.30 | 37.0 |
| Finland | 88.0 | 40.0 | 20.0 | 251.0 |
| Greece | 117.0 | 62.8 | 23.8 | 284.1 |
| India | 104.7 | 37.0 | 24.10 | 432.2 |
| Turkey | 99.1 | 40.0 | 28.0 | 248.3 |
| Italy | 92.0 | 38.0 | 22.0 | 218.0 |
| Japan | 77.0 | 35.8 | 20.7 | 139.4 |
| present study | 68.21 | 40.49 | 4.79 | 275.8 |

## 4. Conclusion

From the above results, we can notice that the (S11) has higher specific activity for $^{40}$K compared with other cements samples investigated while (S9) has higher specific activity for $^{226}$Ra compared with other Iraqi cement samples while sample (S3) has higher specific activity for $^{232}$Th, but all values of $^{226}$Ra , $^{232}$Th and $^{40}$K specific activity are with safety limits and also ($H_{in}$) and ($H_{ex}$) are safe so we can say that all samples of Iraqi cement can be used without any effects on public health.

## Acknowledgment

I would like to knowledge all those contributed in declaring this issue. Special thanks to the staff of the department of physics at Kufa university.

## References

[1] El-Taher A., "Assessment of natural radioactivity levels and radiation hazard for building materials used in Qassim area", Rom. Journ. Phys., Vol. 57, No. 3–4, P. 726–735, Bucharest, 2012.

[2] El-Taher A., "Gamma spectroscopic analysisand associated radiation hazards of building materials used in Egypt", Radia.port.dosi. 138(2),158-165, 2010.

[3] Kpeglo D.O., Lawluvi H., Faanu A., Awudu A.R., Deatanyah P., Wotorchi S.G., Arwui C.C., Emi-Reynolds G. and Darko E.O. ," Natural radioactivity and its associated radiological hazards in Ghanaian cement ", Research Journal of Environmental and Earth Sciences 3(2): 160-166, 2011.

[4] Beretka, J., Mathew P.J., "Natural Radioactivity in Australian building materials, industrial wastes and by-products", Health Physics, Vol. 48(1), 87-95,1985.

[5] Sorantin H. and Steger F.," Natural Radioactivity of building materials in Austria, Radiat. Prot.Dosim. 7 1-4 , 59-61,1984.

[6] Amrani D and Tahtat M., " Natural radioactivity in Algerian building materials", Appl Radiat Isot. Apr;54(4):687-9 ,2001.

[7] Chowdhury I.M., M. N., Alam M.N. and Ahmed A.K.S., " Concentration of radionuclides in building and ceramic materials of Banglesh and evaluation of radiation hazard. J. Radioanal. Nucl. Chem., 231(1-2): 117-122 , 1998.

[8] Malanca A., Pessina V. and Dallara G., Radionuclide Content of Building Materials and Gammaray Dose Rates in Dwellings of Rio Grande do Norte, Brazil. In: Radiation Protection Dosimetry,
48,( 2) :199-203(1993).

[9] Xinwei, L. ,"Natural radioactivity in some building materials and by-products of Shaanxi, China",. J. Radioanal. Nucl. Chem. 262,775–777, 2004.

[10] El Afifi E.M., Hilal M.A. , Khalifa S.M. and Aly H.F.," Evaluation of U,Th ,K and emanated radon in some NORM and TENORM samples", Radiat. Meas,41, 627-633, 2006.

[11] Mustonen, R., “Natural Radioactivity in and Radon Exhalation from Finnish Building Materials”, Health Phys., 46,1195-1203, 1984.

[12] Rizzo,s.m Barai, s. Basile s. Bellia and s. Hauser," Gamma activity and geochemical features of building materials : estimation of gamma dose rate and indoor radon levels in sicily ", Appl.Radiat Isot. , 55: 259-265, 2001

[13] Papastefanou C, Stoulos S, Manolopoulou M," The radioactivity of building materials", J Radioanal Nucl Chem, 266(3):367–372, 2005.

ISSN 2229-5518

[14] Kumar, V., Ramachandran, T.V., Prasad, R.," Natural radioactivity of Indian building materials and by products", Int. J. Appl. Radiat. Isot. 51, 93–96,1999 .

[15] Suzuki A. , Iida T., Moriizumi, J.; Sakuma, Y. , The effevt of different types of concrete on population doses , Radiat Protect Dosim, 90,437- 443,2000.

[16] Ackers, J.G., Den Boer, V.F., De Jong, P. and Wolschrijn, R.A., "Radioactivity and radon exhalation rates of building materials in the Netherlands", The Science of the Total Environment 45,151 156,1985.

[17] Khan K., Khan, H.M., " Natural gamma-emiting radionuclides in Pakistani Portland cement", Applied Radiation and Isotopes 54, 861-865, 2001 .

[18] Hizem, N., A.B. Fredj and L. Ghedira,," Determination of natural radioactivity in buildingmaterials used in Tunisian dwellings by gamma ray spectrometry", Radiat. Prot. Dosim., 114: 533-537,2005.

[19] Turhan, S. and G. Gürbüz, " Radiological significance of cement used in building construction in Turkey", Radiat. Protect. Dosim., 129: 391-396, 2008.

[20] Yousuf R. M. , " Measurment of natural radioactivity in some marble samples used as building materials" , journal of Rafiden Science, 19/L , 134-143, 2008.

[21] Diab, H.M., Nouh, S.A., Hamdy, A., El-Fiki, S.A. ," Evaluation of natural radioactivity in a cultivated area around a fertilizer factory", Journal of Nuclear and Radiation physics, 3: (1), 53-62,2008.

[22] Lederer C.M., Shirley V.S., Browne E., Dairiki J.M., Doebler R.E., Shihab-Eldin A.A., Jardine L.J., Tuli J.K., and Buyrn A.B., Table of Isotopes, 7th edition, John Wiley and Sons, New York (1978).