P- ISSN 1991-8941 E-ISSN 2706-6703 Journal of University of Anbar for Pure Science (JUAPS) Open Access
2015, 9 (2) :74-79

Mathematical Modeling of Determining the Average of Uranium Concentration in the Urine for the Radiation Workers According to the Number of Working Years.

Ghassan E. Arif[*], Ammar A. Battawy[**], Zakariya A. Hussein[***], Nada F. Tawfiq[****], Mohamad S. Jaafar[*****], Iskandar Sh. Mustafa[*****], Faris M. Ahmed [**] Anas A. Abdullah[**]

[*] Tikrit University - College of Education for Pure Sciences.
[**] Tikrit University - College of Education for Pure Sciences
[***] Koya University- Faculty of Sciences and Health.
[****] AL -Nahrain University - College of Science.
[*****] USM, School of physics.

ARTICLE INFO

Received: 19 / 5 /2022
Accepted: 28 / 5 /2022
Available online: 3/5/2017
DOI: 10.37652/juaps.2015.124503

Keywords:
Mathematical modeling;
Determination;
Uranium concentrations;
Urine samples for radiation workers;
Working years.

ABSTRACT

In our work, we have used mathematical modeling to determine the uranium concentrations in the urine samples of workers in radiation field according to the number of working years. The work aims at constructing a mathematical model to determine the uranium concentrations in the urine of the radiation workers based on the number of working years. The obtained values, which have been determined by the constructed model, gave reasonable results and a good agreement with the other experimental results.

Introduction:

Since Mathematics has a great variety of applications in the physical sciences, this study sheds light on solving a problem in health physics. The goal of the current study is to find the determinations of the uranium concentrations in the urine of the radiation workers based on the number of working years and by using mathematical modeling. Thus, in this work, the importance, main features and process of mathematical modeling will be tackled.

Mathematical modeling is described as a conversion activity of a real problem in a mathematical form. Modeling involves formulating the real-life situations to a mathematical formula. Mathematical model is a mathematical form like a formula or equation that reflects the important features of a given situation whereas mathematical modeling is defined as the process to develop a mathematical model [1] and shown to fit within the general context of problem solving.

A problem solving process is described and detailed with examples from mathematical modeling [2]. Mathematical modeling is meant to help us better understand the world [3].

In this study, a new mathematical model is constructed to solve a problem in health physics, a problem of determining the uranium concentrations in urine of radiation workers by relying on the number of working years. The current proposed model is considered as an assistance for the physicists to conduct their determinations.

Most of the researches related to radioactive concentration of uranium in the human body were conducted by using urine samples.Schramel *et al.* (1997) calculated the limit of thorium and uranium concentration in urine using inductively coupled plasma mass spectrometry (ICP-MS) to analyze aqueous solutions of 0.5ng/L and 1 ng/L for both elements, with a precision of nearly ±10% in the concentration range of approximately 10 ng/L [4].

Using a different method, Zarkadas *et al.* (2001) analyzed the quantity identifying of uranium by the way of entire reflection X-ray fluorescence in human urine. This technique utilizes open vessel digestion of uranium pre-concentration and urine

* Corresponding author at: Tikrit University - College of Education for Pure Sciences
.E-mail address: *ghasanarif@yahoo.com

sample using Sodium Dibenzyldithiocarbamate as the complexing cause. The urine chemical treatment, joint with the investigative capabilities of Total Reflection X-Ray Fluorescence (TXRF) offers discovery limits which allow for the uranium monitoring uptake more than the normal levels, comparatively quicker compared with other analytical techniques [5].

Krystek and Ritsema (2002) also determined uranium concentration in urine using inductively coupled plasma mass spectrometry (ICP-MS). The stability and the storage condition effects for the matrix urine were analyzed by samples of "real-life" urine in unexposed Dutch people. For samples storage under acidified and refrigeration, the results varying from 0.8 to 5.3ng/L were in the normal variation range while reduction in uranium concentration was observed for samples storage without acidification at room temperature [6].

Al-Jundi *et al.* (2004) studied the effect of age and residential area on thorium and uranium involved in human urine. Their measurements have showed that the average ^{232}Th level of 34.8μBq/d in urine resulting from an input of 25.4Bq/d is consistent by means of levels regarded as usual by modern global studies. Using the adult intake dose factor of 2.3×10^{-7} Sv/Bq (ICR, 1995) would result in an effectual interior dose of 5.8μSv/d, that is small compared to the dose resulting from natural potassium content of about 190μSv/d due to ^{40}K [7].

Trešyl *et al.* (2004) measured the isotopic of uranium effect in human urine samples by magnetic sector-field inductively coupled plasma mass spectrometry. This work explains the certification to 2.5% relative combined uncertainty of n (^{235}U) / n (^{238}U) at ultralow uranium levels (~5-20 pg/g) in human urine samples. A single-detector magnetic sector-field ICP-MS device fixed with an ultrasonic nebulizer was used to calculate the isotope ratios after sample decomposition and matrix separation [8].

Benkhedda *et al.* (2005) discovered that the detection limits of ^{238}U and ^{232}Th in a 10 ml urine sample were 0.02 and 0.03 ng/L, correspondingly by using the flow-injection method for resolving of thorium and uranium isotopes. Spike-recovery measurements made the system accuracy specific. Levels of thorium and uranium in human urine were established to vary between 1.86 – 5.50 and 0.176 – 2.35 ng/L, which is consistent with levels considered normal for the unemployment of exposed persons [9].

Ejnik *et al*. (2005) also analysed the concentration of uranium in urine using inductively coupled plasma dynamic reaction cell mass spectrometry (ICP-MS). Normal populations displayed urine uranium concentrations from 1 pg/mL to above 500 pg/mL, which makes urine uranium concentrations a poor indicator for low-level DU exposure [10].

Manickam *et al.* (2008) designed a method to validate the determination of uranium levels in human urine using high-resolution alpha spectrometry. For this method, radiochemical recovery was measured using ^{232}U tracer. The typical minimum detectable concentration for total uranium for 24 h urine samples was found to be approximately 0.6 mBq/d or 0.019 mg/d [11].

Employing ^{232}U tracer, anion-exchange resin and alpha-spectrometry, Kumar *et al.* (2009) assessed uranium isotopes in urine samples from radiation workers. As a result, the rate of loading, washing and elution was improved with minimum volume of acid concentration and fixed at 0.3 – 0.4 mL/min. For the eight urine samples, the study discovered that radiochemical recoveries ranged between 51% and 67% [12]

Cosio (2010) studied the concentration of arsenic and uranium in urine as a measure of exposure to contaminants in private drinking water wells in central and northeastern Massachusetts. The findings showed urinary uranium levels averaged approximately 0.9 μg/g which suggested that long-term exposures to uranium in drinking water had no adverse health effects on the people concerned [13].

Ahmed F. Saleh Al –Jobouri. 2012 determined the uranium concentration in urine of Tall Al-Ragrag residents (Iraq) are in the range of 0.410 ± 0.008 to 3.011 ± 0.072μg/l with mean value of 1.125 ± 0.001 μg/l, and for Al-Jesira residents (Iraq) are in the range of 0.552 ± 0.009 to2.925 ± 0.053 μg/l with mean value of 1.338 ± 0.003 μg/l. using fission track etching technique [14].

A small part of the alpha emitting elements swallowed will also be found in the blood, and the blood carries it throughout the body. Most of it leaves through the urine in a few days, but a little stays in the kidney and bones.

Ionizing particles passing through polymeric track detectors produce latent track, which are trails of radiation damage. The best means of observing the tracks is by etching the SSNTDs material with a chemical solution, which preferentially attacks the damaged material and enlarges the original track to a size, which is visible in the optical microscope [15].

In this research, we are collecting the samples of human urine from different radiation workers in different government hospitals departments [Computed Tomography Scanner (CTS), Nuclear Medicine and X-ray unit], and from the Ministry of Science and Technology MST (previously known as the Iraqi Atomic Energy Commission). Different working years is considered as well.

Mathematical modeling of uranium concentrations in urine

Once the framework of the proposed mathematical model has been constructed, it is important to choose the mathematical model that will solve the problem of determining uranium concentrations in urine samples for radiation workers according to the number of working years.

The mathematical model is constructed by counting on several manual trials to obtain the suitable equation that helps determine the uranium concentrations in the urine samples for radiation workers based on the number of working years. So after several attempts [16,17], depending on general guidelines and typical steps followed in constructing mathematical models, the proposed model of determining uranium concentrations in urine takes the form as:

$$U(W) = 1.66\,\lambda\,\sqrt[4]{W^{0.75}}$$

where U refers to uranium concentrations, W is the rate center of working years, and λ is a parameter appropriate for CTS group & MST group (λ=0.91), and other groups (λ=0.8).

To get better results, the parameters λ= 0.8 and λ=0.91 are used, with variable (W) between 3 and 28 as input data, to get uranium concentrations between $1.81 \le U \le 3.04$ as output data. The error percentage is minimized in the study as shown in the tables. The results and methodology of our work are significant for a wide range of applications as the determined values are in a good agreement with experimental results.

References

[1] S. Dundar, B. Gokkurt, Y. Soylu, Mathematical Modelling at a Glance: A Theoretical Study, Procedia-Social and Behavioral Sciences, 46, (2012), 3465-3470.

[2] R.D. Noble, Mathematical modelling in the context of problem solving, Mathematical Modelling, 3, (1982), 215-219.

[3] E. Özdemir, D. Üzel, Student Opinions On Teaching Based On Mathematical Modelling, Procedia-Social and Behavioral Sciences, 55, (2012), 1207-1214.

[4] Schramel P., Wendler I., Roth P. and Werner E., Method for the determination of Thorium and Uranium in urine samples by ICP-MS, *Mikrochim. Acta.*, (1997), 126, 263-266.

[5] Zarkadas C., Karydas A. G. and Paradellis T., Determination of uranium in human urine by total reflection X-ray fluorescence, *Spectrochimica Acta. Part B*, (2001), 56, 2505-2511.

[6] Krystek P. and Ritsema R., Determination of uranium in urine – measurement of isotope ratios and quantification by use of inductively coupled plasma mass spectrometry, *Anal. Bioanal. Chem.*, (2002), 374, 226–229.

[7] Al-Jundi J., Werner E., Roth P., Höllrieg V., Wendler I. and Schramel P., Thorium and uranium contents in human urine: influence of age and residential area, *J. Environ. Radioact.*, (2004), 71, 61-70.

[8] Trešyl I., Wannemacker G. D., Quétel C. R., Petrov I., Vanhaecke F., Moens L., and Taylor P. D. P., validated measurements of the uranium isotopic signature in human urine samples using magnetic sector-field inductively coupled plasma mass spectrometry, *Environ. Sci. Technol.*, (2004), 38, 581-586.

[9] Benkhedda K., Epov V. N. and Evans R. D., Flow-injection technique for determination of uranium and thorium isotopes in urine by inductively coupled plasma mass spectrometry, *Anal. Bioanal. Chem.*, (2005), 381, 1596-1603.

[10] Ejnik J. W., Todorov T. I., Mullick F. G., Squibb K., McDiarmid M. A. and Centeno J. A., Uranium analysis in urine by inductively coupled plasma dynamic reaction cell mass spectrometry, *Anal. Bioanal. Chem.*, (2005), 382, 73-79.

[11] Manickam E., Sdraulig S. and Tinker R.A., Method design and validation for the determination of uranium levels in human urine using high-resolution alpha spectrometry, *Journal*

of Environmental Radioactivity, (2008), 99, 491-501.

[12] Kumar R., Yadav J. R., Rao D. D., Chand L., Determination of uranium isotopes in urine samples from radiation workers using ^{232}U tracer, anion-exchange resin and alpha-spectrometry, *Journal of Radioanalytical and Nuclear Chemistry*, (2009), 279, (3), 787-790.

[13] Cosio J., Evaluation of arsenic and uranium in urine as a measure of exposure to contaminants in private drinking water wells in Central and Northeastern MA, Northeast Epidemiology Conference - (2010), November 4.

[14] Ahmed F. Saleh Al –Jobouri, *Determination of Uranium Concentration in Human Urine for Selected Regions in Iraq Using Laser-Induced Kinetic Phosphorimetry and CR-39 Nuclear Track Detector*, MSc dissertation, Dept. Phys. College of Science, Al-Nahrain Univ., Iraq, 2012.

[15] B.A. Marouf, Environmental Impact of Depleted Uranium (DU) Contamination in Iraq, *The Conference on The Effects of The Use of Depleted Uranium Weaponry on Human and Environmental in Iraq*, Baghdad-Iraq, (2002), 1, 116-122.

[16] [17] Arif, G. E., Al-Douri, Y., Abdullah, F. A., & Khenata, R., Differential equations to determine the ionicity factor of hexagonal structure semiconductors. *Superlattices and Microstructures*, (2013), *53*, 24–30.

[17] Abu-Farsakh, H., & Qteish, A., Ionicity scale based on the centers of maximally localized Wannier functions. *Physical Review B*, (2007), *75*(8), 085201-085206.

[18] Abdullah, A. A. *Internal and External Radiation Exposure Evaluation Amongst Selected Workers and Locations in Iraq*, PhD. Theses, School of Physics, USM, Malaysia, (2013).

Table 1. Comparison between the values, determined by the proposed mathematical model, of uranium concentrations in the urine samples for the Computed Tomography Scanner (CTS), and the experimental values of Abdullah [18].

No.	No. of working years	Rate Center for working years (*W*)	CTS unit Exp.	CTS unit Cal.	(%)
1	Below6	3	1.85	1.847	0.001
2	6-10	8	2.19	2.229	0.01
3	11-15	13	2.70	2.44	0.09
4	16-20	18	3.04	2.596	0.1
5	21-25	23	-	2.71	0.00
6	26-30	28	-	2.821	0.00

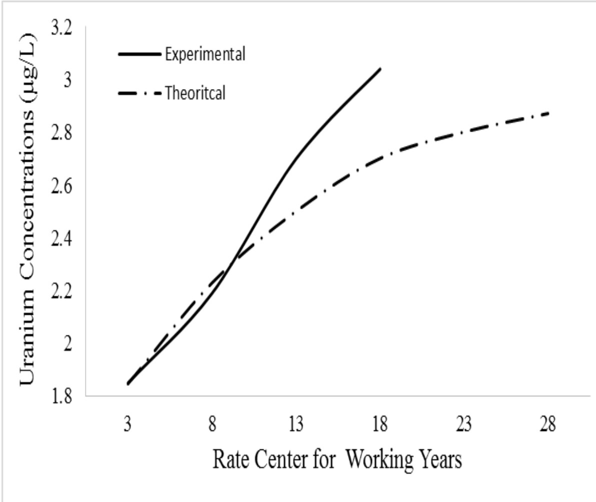

Fig. 1 Comparison between the values, determined by the proposed mathematical model, of uranium concentrations in the urine samples for the Computed Tomography Scanner (CTS), and the experimental values of Abdullah [18].

Table 2. Comparison between the values, determined by the proposed mathematical model, of uranium concentrations in the urine samples for the Nuclear Medicine workers, and the experimental values of Abdullah [18].

No.	No. of working years	Rate Center of working years (*W*)	Nuclear Medicine Exp.	Nuclear Medicine Cal.	(%)
1	Below6	3	1.99	1.624	0.01
2	6-10	8	2.05	1.96	0.04
3	11-15	13	2.16	2.147	0.006
4	16-20	18	2.20	2.282	0.03
5	21-25	23	2.36	2.39	0.01
6	26-30	28	2.43	2.48	0.02

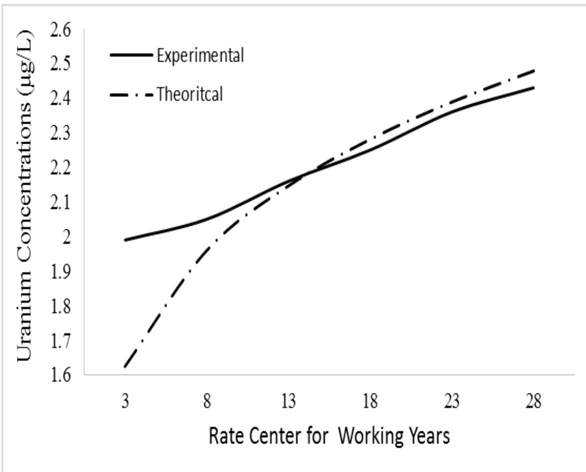

Fig. 2 Comparison between the values, determined by the proposed mathematical model, of uranium concentrations in the urine samples for the Nuclear Medicine workers, and the experimental values of Abdullah [18].

Table 3.
Comparison between the values, determined by the proposed mathematical model, of uranium concentrations in the urine samples for the X-ray unit workers, and the experimental values of Abdullah [18].

No.	No. of working years	Rate Center for working years (*W*)	X-ray unit Exp.	X-ray unit Cal.	(%)
1	Below6	3	1.88	1.624	0.01
2	6-10	8	2.04	1.96	0.03
3	11-15	13	2.09	2.147	0.02
4	16-20	18	2.19	2.282	0.04
5	21-25	23	2.15	2.39	0.01
6	26-30	28	2.17	2.48	0.01

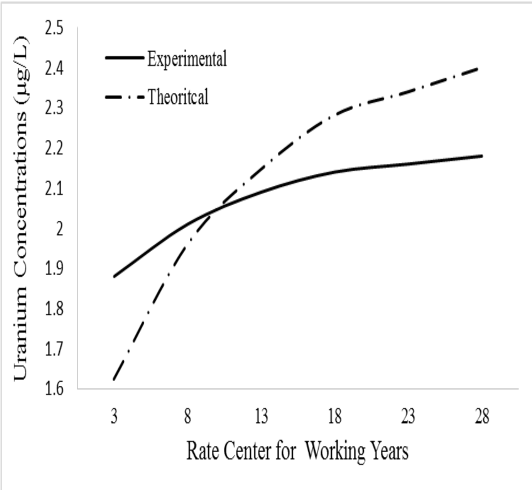

Fig. 3 Comparison between the values, determined by the proposed mathematical model, of uranium concentrations in the urine samples for the X-ray unit workers, and the experimental values of Abdullah [18].

Table 4. Comparison between the values, determined by the proposed mathematical model, of uranium concentrations in the urine samples for the Ministry of Science and Technology (MST) workers, and the experimental values of Abdullah [18].

No.	No. of working years	Rate Center for working years (*W*)	MST Exp.	MST Cal.	(%)
1	Below6	3	1.81	1.847	0.02
2	6-10	8	1.93	2.229	0.08
3	11-15	13	2.25	2.44	0.08
4	16-20	18	2.78	2.596	0.06
5	21-25	23	2.80	2.71	0.03
6	26-30	28	2.85	2.821	0.01

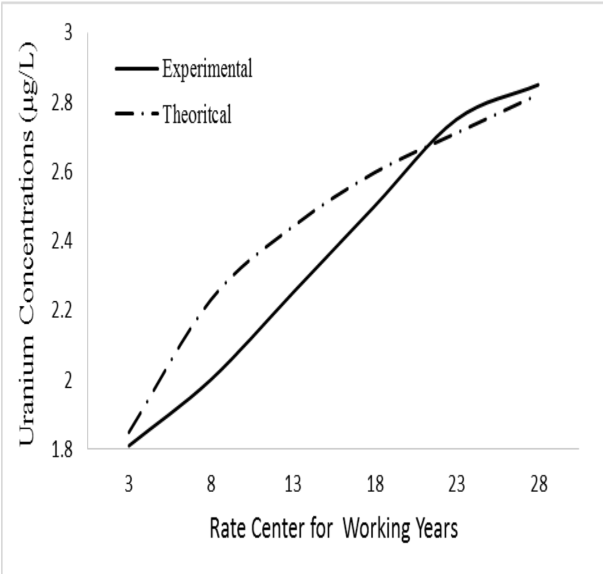

Fig.4 Comparison between the values, determined by the proposed mathematical model, of uranium concentrations in the urine samples for the Ministry of Science and Technology (MST) workers, and the experimental values of Abdullah [18].

نمذجة الرياضية لتحديد متوسط تراكيز اليورانيوم في إدرار عمال الإشعاع وفقا لعدد سنوات العمل.

غسان عزالدين عارف عمار عبد البطاوي زكريا عادل حسين ندى فاضل توفيق محمد سهيمي جعفر إسكندر شاه رم مصطفى فارس ماهر أحمد الدوري أنس عبد عبدالله

E-mail: *ghasanarif@yahoo.com

الخلاصة :

استخدمت في هذه الدراسة عملية النمذجة الرياضية لحساب تراكيز اليورانيوم في عينات الادرار لدى العاملين في مجال الاشعاع نسبة إلى عدد سنوات الخدمة في العمل . تهدف الدراسة إلى بناء نموذج رياضي لتحديد تراكيز اليورانيوم في عينات الادرار لدى عمال الاشعاع بالاعتماد على سنوات العمل، والقيم التي حصلنا عليها من خلال النموذج المبني كانت مطابقة جداً للنتائج التجريبية الاخرى.