Calculation of Radiation Nuclei Concentrations in Fertilized and Unfertilized Plants Samples Using Gamma Spectroscopy

Adawiya M. ALwan[1*], Auday T. Al-Bayati[2], Khalid H. Mahdi[3], Hazim L. Mansour[4]

Abstract

The aim of this work was to estimate the concentrations of natural and artificial nuclides in some fertilized and unfertilized plant samples. These samples were collected and prepared in a petri dish for the measurements using gamma spectroscopy. The average values of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs for the unfertilized plant samples were (11.964 ± 3.226, 8.273 ± 2.639, 402.436 ± 18.099, and 2.761 ± 1.613) respectively, and for the fertilized plant samples were (30.434 ± 5.282, 22.584 ± 4.620, 711.332 ± 25.806, and 6.986 ± 2.542) respectively. The average values of radiological hazard indices, Ra_{eq}, D, D for ^{137}Cs, $(AEDE)_{in}$, $(AEDE)_{out}$, I_γ, H_{in}, and H_{out} for the unfertilized plant samples were (54.782 ± 7.216, 27.306, 0.469, 0.134, 0.033, 0.431, 0.180, and 0.148) respectively, and for the fertilized plant samples were (117.502 ± 10.747, 57.364, 1.188, 0.281, 0.070, 0.903, 0.400, and 0.317) respectively. The present results have indicated that the fertilized plant samples have more concentrations than the unfertilized plant samples.

Key Words: Fertilized Plants, Unfertilized Plants, Radiation, Radium Equivalent, Gamma Spectroscopy.

DOI Number: 10.14704/nq.2021.19.2.NQ21012 **NeuroQuantology 2021; 19(2):13-18**

Introduction

In our life there are two types of radiation sources, natural and artificial, the natural radiations can be classified into cosmic and terrestrial radiation. All internal and external exposure might provide a radiation risk, the radio nuclides that are present in different types of natural sources such as uranium, Nitrogen, phosphate, and potassium fertilizers are one of the most important radiation sources[1].

Plants need nutrients and some chemical elements which might found in fertilizers and soil. Fertilizers become important in agricultural, which increase crop production and to improve the nutrient-deficient properties of lands.

Different types of fertilizers usually employed in the agriculture contain traces of heavy metals and relatively high concentrations of naturally occurring radio nuclides. Fertilizers containing Phosphate have been used worldwide to increase the quantities of the micronutrients, that take off from the soil due to farming activities. At the same time, the use of such fertilizers is the main anthropogenic source of the uranium input in the environment (about 73% of the total input of uranium) [2].

Corresponding author: Adawiya M. ALwan
Address: [1*]Directorate General of Vocational Education, Khadija El Kobra Preparatory School for Girls; [2]Physics Department, University of Baghdad, College of Education for Pure Science, Ibn-Al Haitham, Baghdad, Iraq; [3]Physics Department, Fin Faculty, Karabuk University, Karabük, Turkey; [4]Physics Department, College of Education, University of Al-Mustansiriyah, Baghdad, Iraq.

Received: 17 October 2020 **Accepted:** 18 February 2021

The extensive use of fertilizers can increase the number of radio nuclides in soils and in groundwater and consequential ingestion by humans through exposure routes such as drinking water and the food chain will affect the humans health [4,5].

The aim of this study is to determine the activity concentrations of ^{238}U, ^{232}Th,^{40}K and ^{137}Cs in some different plants which were planted in fertilized soils and unfertilized soils by using gamma spectroscopy.

Experimental Part

1. Samples Collection: Ten different types of plants were transplanted into two types of soil, the first is a natural soil, and the second is fertilized soil (using fertilizer mixture). After the period of plant maturing, they were collected for preparation.
2. Preparation of samples: All the collected samples were cleaned by removing the sticking dust, then they were dried by sun exposure for two weeks and the grinded crushes were hand milled to get rid of strange objects and then they were well crushed further to get homogeneous samples and then were sifted potted (Petri dish) and sealed tightly and left for a period of time to obtained secular equilibrium between the radionuclide.
3. Measurement system of gamma radiation which consists:- The HpGe detector which has a 40% efficiency and a resolution of 2.2 kV for energy (1332 keV) of (^{60}Co). The
4. detector was surrounded with 10cm of lead to reduce the radiation background, as well as, a container which consisted of three layers of aluminum, cadmium, and iron (1 mm) to minimize the impact of x-rays on the detector.
5. Experimental method:
    - Energy calibration: The measuring system was energy calibrated using a (^{152}Eu) source. The time of measurement was (1000) seconds, and the background was recorded and subtracted from the spectra.
    - The detector efficiency for different energies was obtained using the standard source of (^{152}Eu) from the following equation[6]:

$$\varepsilon(E\gamma) = \frac{\text{Net}}{\text{A x I}(E\gamma)\text{x T}} \text{ x } 100\% \qquad (1)$$

Net: represents the net peak area.

I: The relative intensity of each energy present.

A (Bq): represents the radiation activity of the standard source at the measurement time which has been corrected by the following equation[7].

$$A = A_o e^{-\lambda t} \qquad (2)$$

Where:

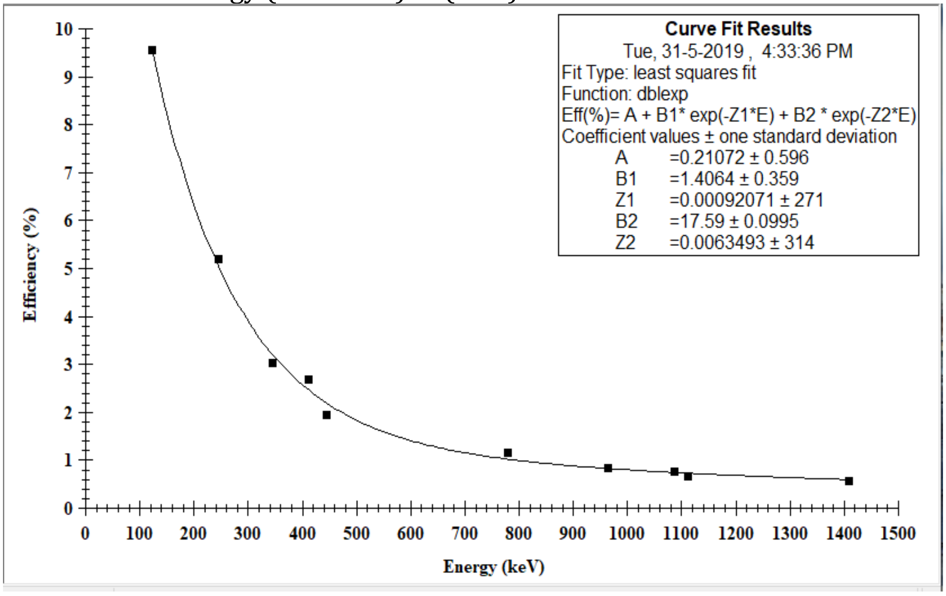
A_o: is the source activity at manufacturing time.

A: is the source activity at measuring time.

λ: is the decay constant

t: is the measurement Time

The relationship between energy and relative efficiency of the standard source is shown in Figure (1).



```
Curve Fit Results
Tue, 31-5-2019 ,  4:33:36 PM
Fit Type: least squares fit
Function: dblexp
Eff(%)= A + B1* exp(-Z1*E) + B2 * exp(-Z2*E)
Coefficient values ± one standard deviation
      A       =0.21072 ± 0.596
      B1      =1.4064 ± 0.359
      Z1      =0.00092071 ± 271
      B2      =17.59 ± 0.0995
      Z2      =0.0063493 ± 314
```

Figure 1. Efficiency Calibration Curve of (HPGe) Detector Using ^{152}Eu Plant Standard Source (Petri Dish).

Efficiency was obtianed through the energy relationship using the Igor program. The relationship was as follows:

$$Eff(\%) = A + B_1 * \exp(-Z_1 * E) + B_2 * \exp(-Z_2 * E) \quad (3)$$

$A = 0.2107 \pm 0.596$
$B1 = 1.4064 \pm 0.359$
$Z1 = 0.00092071 \pm 271$
$B2 = 17.59 \pm 0.0995$
$Z2 = 0.0063493 \pm 314$

Where E represents peak energy

- Determination of S.A. (Specific activity concentration) of uranium, thorium, potassium, and cesium were carried out using the following relation [8]:

$$S.A(E_\gamma) = \frac{Net}{T \times I(E_\gamma) \times \varepsilon(E_\gamma) \times m} \quad (4)$$

Where:
Net: is the net peak area of energy selected.
ε: is the efficiency of selected energy.
I::is the relative intensity of the gamma rays.
w: weight of the sample.

The S.A. was obtained by measuring the equivalent S.A. of ^{214}Bi, ^{214}Pb for uranium,^{228}Ac, ^{212}Pb and ^{208}Tl for thorium, ^{40}K and ^{137}Cs as shown in Table (1).

Radiological hazard indices can be obtained as followed by Radium Equivalent activity (Ra_{eq}) using the equation [9]:

$$Ra_{eq} = A_U + 1.43\, A_{Th} + 0.07\, A_K \quad (5)$$

Where

A_U, A_{TH}, and A_K are the specific activity concentrations of uranium-226, thorium-232, and potassium-40 in Bq / kg, respectively. The maximum permissible value of radium equivalent activity is 370 Bq / kg [9].

The absorbed dose rate in air (D) is given by the following equation [10]:

$$D_\gamma\, (nGy.h^{-1}) = 0.462\, A_U + 0.604\, A_{Th} + 0.0417\, A_K \quad (6)$$

Where:

D is the gamma absorbed dose rate absorbed by $nGy.h^{-1}$

The conversion factors used to calculate the gamma absorbed dose rate in the air correspond to 0.462 nG / h for the uranium-238 and 0.604 nGy / h for thorium-232 and 0.0417 nGy / h for potassium-40.

But the Annual Effective Dose Equivalent (AEDE) is calculated as $AEDE_{out}$ and $AEDE_{in}$ which can be estimated by using the conversion factor (0.7 Sv / Gy), which converts the absorbed dose into the air to the effective dose, as well as using the outdoor occupancy factor (0.2) and the indoor occupancy factor (0.8) as in the following equations [9, 11]:

$$AEDE_{out}\, (mSv.y^{-1}) = D_\gamma\, (nGy/h) \times 10^{-6} \times 0.2 \times 0.7\, (Sv/Gy) \quad (7)$$

And

$$AEDE_{in}\, (mSv.y^{-1}) = D_\gamma\, (nGy/h) \times 10^{-6} \times 0.8 \times 0.7\, (Sv/Gy) \quad (8)$$

Then the hazard Index (H) given by the following equations [12]:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (9)$$

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (10)$$

Where

The external hazard index (H_{ex}) and internal hazard index (H_{in}) must also have a value of less than one [12].

And the representative level index (Iγ) was obtained by the following relation:

$$I_\gamma = \frac{1}{150} A_U + \frac{1}{100} A_{Th} + \frac{1}{1500} A_K \quad (11)$$

The representative level index for gamma rays must also be less than one [11].

Results and Discussion

The results of S.A. of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs are shown in Tables (1-A), (1-B) which indicated that, in general, the fertilized plant samples contained concentrations of radionuclides more than the unfertilized plant samples. From these tables we can also note that the concentration of ^{238}U was ranged from (10.466 ± 3.235 Bq/kg) to (58.303 ± 7.636 Bq/kg) for fertilized plant samples and from (2.246 ± 1.499Bq/kg) to (32.637 ± 5.713 Bq/kg) for unfertilized plant samples, the concentration of ^{232}Thwas ranged from (8.906 ± 2.984Bq/kg) to (40.193 ± 6.340 Bq/kg) for fertilized plant samples and from (1.104 ± 1.051Bq/kg) to(23.837 ± 4.882 Bq/kg) for unfertilized plant samples, but the concentration of ^{40}K was ranged from (70.714 ± 8.409Bq/kg) to (1038.107 ± 32.220 Bq/kg) for fertilized plant samples and from (41.022 ± 6.405Bq/kg) to (1007.994 ± 31.749 Bq/kg) for unfertilized plant samples also the concentration of ^{137}Cs was ranged from (2.977 ± 1.725Bq/kg) to (14.476 ± 3.805 Bq/kg) for fertilized plant samples and from (0.624 ± 0.790Bq/kg) to (4.238 ± 2.059 Bq/kg) for unfertilized plant samples.

The radiological hazard indices, Ra_{eq}, D, D for ^{137}Cs, $(AEDE)_{in}$, $(AEDE)_{out}$, Iγ, H_{in}, and H_{out} for fertilized plant samples were ranged (72.271 ± 8.676 to 183.581 ± 13.549), (37.744 to 88.255), (0.506 to 2.461), (0.185 to 0.433), (0.046to 0.108), (0.594to 1.382), (0.250to 0.653), and (0.203to 0.496) respectively, and for the unfertilized plants were ranged (18.978 ±4.356 to 98.080 ± 9.904), (9.051 to48.604), (0.106 to 0.720), (0.044 to 0.238), (0.011 to 0.060), (0.136 to0.781), (0.087 to 0.280), and (0.051 to 0.265) respectively.

Table 1-A. Specific activity concentration results for fertilized plant samples

No.	Name of Sample	U-238 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)	Cs-137 (Bq/Kg)
1	Arugula Fertilized	20.893 ± 4.571	22.947 ± 4.790	874.814 ± 29.577	6.852 ± 2.618
2	Fenugreek Fertilized	50.702 ± 7.121	40.193 ± 6.340	70.714 ± 8.409	11.172 ± 3.342
3	Cress Fertilized	10.981 ± 3.314	22.898 ± 4.785	906.187 ± 30.103	4.823 ± 2.196
4	Spinach Fertilized	24.680 ± 4.968	27.465 ± 5.241	956.545 ± 30.928	14.476 ± 3.805
5	Dill Fertilized	58.303 ± 7.636	38.293 ± 6.188	915.827 ± 30.263	2.977 ± 1.725
6	Radish Fertilized	10.466 ± 3.235	8.906 ± 2.984	764.684 ± 27.653	3.655 ± 1.912
7	Celery Fertilized	17.257 ± 4.154	9.663 ± 3.109	573.958 ± 23.957	3.536 ± 1.880
8	Coriander Fertilized	46.739 ± 6.837	17.749 ± 4.213	1038.107 ± 32.220	4.584 ± 2.141
9	parsley Fertilized	47.681 ± 6.905	12.362 ± 3.516	459.894 ± 21.445	12.857 ± 3.586
10	Mint Fertilized	16.643 ± 4.080	25.361 ± 5.036	552.597 ± 23.507	4.925 ± 2.219
	Average	30.434 ± 5.282	22.584 ± 4.620	711.332 ± 25.806	6.986 ± 2.542
	Minimum	10.466 ± 3.235	8.906 ± 2.984	70.714 ± 8.409	2.977 ± 1.725
	Maximum	58.303 ± 7.636	40.193 ± 6.340	1038.107 ± 32.220	14.476 ± 3.805

Table 1-B. Specific activity concentration results for unfertilized plant samples

No.	Name of Sample	U-238 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)	Cs-137 (Bq/Kg)
1	Arugula Unfertilized	2.306 ± 1.518	6.328 ± 2.516	765.602 ± 27.670	4.238 ± 2.059
2	Fenugreek Unfertilized	32.637 ± 5.713	2.230 ± 1.493	41.022 ± 6.405	3.360 ± 1.833
3	Cress Unfertilized	7.197 ± 2.683	19.914 ± 4.462	270.187 ± 16.437	3.052 ± 1.747
4	Spinach Unfertilized	5.653 ± 2.378	23.837 ± 4.882	757.667 ± 27.525	3.682 ± 1.919
5	Dill Unfertilized	18.484 ± 4.299	7.961 ± 2.821	106.641 ± 10.327	1.468 ± 1.212
6	Radish Unfertilized	7.477 ± 2.734	4.663 ± 2.159	591.544 ± 24.322	1.822 ± 1.350
7	Celery Unfertilized	13.057 ± 3.613	1.104 ± 1.051	56.395 ± 7.510	3.427 ± 1.851
8	Coriander Unfertilized	2.246 ± 1.499	7.578 ± 2.753	1007.994 ± 31.749	0.624 ± 0.790
9	parsley Unfertilized	16.141 ± 4.018	5.310 ± 2.304	261.719 ± 16.178	1.781 ± 1.334
10	Mint Unfertilized	14.444 ± 3.801	3.806 ± 1.951	165.593 ± 12.868	4.153 ± 2.038
	Average	11.964 ± 3.226	8.273 ± 2.639	402.436 ± 18.099	2.761 ± 1.613
	Minimum	2.246 ± 1.499	1.104 ± 1.051	41.022 ± 6.405	0.624 ± 0.790
	Maximum	32.637 ± 5.713	23.837 ± 4.882	1007.994 ± 31.749	4.238 ± 2.059

Table 2-A. Radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose, activity concentration index and hazard indices for fertilized plant samples

Name of sample	Ra_{eq}(Bq/kg)	D (nGy/h)	D(nGy/h) for Cs-137	(AEDE)(mSv/y)		I_γ	H_{in}	H_{ex}
				in	out			
Arugula Fertilized	121.068 ± 11.003	59.992	1.165	0.294	0.074	0.952	0.383	0.327
Fenugreek Fertilized	113.623 ± 10.659	50.650	1.899	0.248	0.062	0.787	0.444	0.307
Cress Fertilized	113.501 ± 10.654	56.691	0.820	0.278	0.070	0.906	0.336	0.306
Spinach Fertilized	137.609 ± 11.731	67.879	2.461	0.333	0.083	1.077	0.438	0.372
Dill Fertilized	183.581 ± 13.549	88.255	0.506	0.433	0.108	1.382	0.653	0.496
Radish Fertilized	82.082 ± 9.060	42.102	0.621	0.207	0.052	0.669	0.251	0.222
Celery Fertilized	75.271 ± 8.676	37.744	0.601	0.185	0.046	0.594	0.250	0.203
Coriander Fertilized	152.054 ± 12.331	75.603	0.779	0.371	0.093	1.181	0.537	0.411
parsley Fertilized	100.770 ± 10.038	48.672	2.186	0.239	0.060	0.748	0.401	0.272
Mint Fertilized	95.459 ± 9.770	46.050	0.837	0.226	0.056	0.733	0.303	0.258
Average	117.502 ± 10.747	57.364	1.188	0.281	0.070	0.903	0.400	0.317
Minimum	72.271 ± 8.676	37.744	0.506	0.185	0.046	0.594	0.250	0.203
Maximum	183.581 ± 13.549	88.255	2.461	0.433	0.108	1.382	0.653	0.496

Table 2-B. Radium equivalent activity, absorbed gamma dose rate, indoor and outdoor annual effective dose, activity concentration index and hazard indices for unfertilized plant samples

Name of sample	Ra_{eq}(Bq/kg)	D (nGy/h)	D(nGy/h) for Cs-137	(AEDE)(mSv/y)		I_γ	H_{in}	H_{ex}
				in	out			
Arugula Unfertilized	70.306 ± 8.385	36.813	0.720	0.181	0.045	0.589	0.196	0.190
Fenugreek Unfertilized	38.985 ± 6.244	18.136	0.571	0.089	0.022	0.267	0.194	0.105
Cress Unfertilized	56.478 ± 7.515	26.620	0.519	0.131	0.033	0.427	0.172	0.153
Spinach Unfertilized	98.080 ± 9.904	48.604	0.626	0.238	0.060	0.781	0.280	0.265
Dill Unfertilized	38.079 ± 6.171	17.795	0.250	0.087	0.022	0.274	0.153	0.103
Radish Unfertilized	59.694 ± 7.726	30.938	0.310	0.152	0.038	0.491	0.181	0.161
Celery Unfertilized	18.978 ± 4.356	9.051	0.583	0.044	0.011	0.136	0.087	0.051
Coriander Unfertilized	90.698 ± 9.524	47.648	0.106	0.234	0.058	0.763	0.251	0.245
parsley Unfertilized	43.887 ± 6.625	21.578	0.303	0.106	0.026	0.335	0.162	0.119
Mint Unfertilized	32.637 ± 5.713	15.877	0.706	0.078	0.019	0.245	0.127	0.088
Average	54.782 ± 7.216	27.306	0.469	0.134	0.033	0.431	0.180	0.148
Minimum	18.978 ± 4.356	9.051	0.106	0.044	0.011	0.136	0.087	0.051
Maximum	98.080 ± 9.904	48.604	0.720	0.238	0.060	0.781	0.280	0.265

Conclusion

From this work, we can conclude the following:

1. Using fertilizer materials have led to increases in the radionuclide in most types of plant sample sand thus their radiation hazard will be greater.
2. Some plant samples have higher concentrations of radio nuclides because they have transfer factor more than the other plant samples and that this subject need more attention and further study in the future
3. The added fertilizer soil was of ratio more than 20 kg/10000 m^3, so from the data of this work, the fertilized plant samples have concentrations of ratio nuclides more than unfertilized plant samples, this result will leads us to reduce the fertilizer soil ratio in order to reduce the radiation hazard effects.

References

Ghosh D, Deb A, Bera S, Sengupta R, Patra KK. Assessment of alpha activity of building materials commonly used in West Bengal, India. *Journal of environmental radioactivity* 2008; 99(2): 316-321.

Stojanović M, Stevanović D, Milojković J, Mihajlović M, Lopičić Z, Šoštarić. Influence of soil type and physical-chemical properties on uranium sorption and bioavailability. *Water Air Soil Pollute* 2012; 223(1): 135-144.

Cimpeanu C, Podina C, Barna C, Iliescu M. ^{32}P – Radioactive Tracer for the Evaluation of Fertilizers Influence on Nutrients Translocation Process from Soil to the Plants. *Romanian Journal of Physics* 2012; 63(5): 548–552.

Bolca M, Sac M, Cokuysal B, Karalı T, Ekdal E. Radioactivity in soils and various foodstuffs from the Gediz River Basin of Turkey. *Radiation Measurements* 2007; 42(2): 263-270.

Righi S, Lucialli P, Bruzzi L. Health and environmental impacts of a fertilizer plant-Part I, assessment of radio active pollution*. Journal of Environmental Radioactivity* 2005; 82(2): 167–182.

Gilmore GR. *Practical Gamma-ray Spectrometry.* 2nd Edition, Wiley-VCH Verlag, Wenheim, Germany 2008.

Ahmed SN. *Physics and engineering of radiation detection*. Academic Press 2007.

Ehsanpour E, Abdi MR, Mostajaboddavati M, Bagheri H. ^{226}Ra, ^{232}Th and ^{40}K contents in water samples in part of central deserts in Iran and their potential radiological risk to a human population. *Journal of Environmental Health Science and Engineering* 2014; 12(1): 1-7.

Mehra R. Use of Gamma-Ray Spectroscopy Measurements for Assessment of the Average Effective Dose from the Analysis of ^{226}Ra, ^{232}Th, and ^{40}K in Soil Sample. *Indoor and Built Environment* 2009; 18(3): 270-275.

Belivermis M, Kılıç Ö, Çotuk Y, Topcuoğlu S. The effects of physicochemical properties on gamma emitting natural radionuclide levels in the soil profile of Istanbul. *Environmental monitoring and assessment* 2010; 163(1-4): 15-26.

Kadum A, Bensaoula AH, Dahmani B. Natural Radioactivity in Red Clay Brick Manufactured in Tlemcen-Algeria, Using Well-Shape NaI(Tl) Detector. *Advances in Physics Theories and Applications* 2013; 25: 120-128.

Faanu A, Adukpo OK, Tettey-Larbi L, Lawluvi H, Kpeglo DO, Darko EO, Agyeman L. Natural radioactivity levels in soils, rocks, and water at a mining concession of Perseus gold mine and surrounding towns in Central Region of Ghana*. Springer Plus* 2016: 5(1): 1-16.

Farnia V, Alikhani M, Davarinejad O, Golshani S, Salemi S, Hookari S, Jalali A, Radmehr F, Ramyar H. A discriminant analysis of psychological and brain-behavioural system features to predict methamphetamine dependence. *NeuroQuantology* 2019; 17(8): 24-32.

Torkamani F, Nazaraghaie F, Nami M. Geometric meditation-based cognitive behavioural therapy in obsessive-compulsive disorder: A case study. *NeuroQuantology* 2019; 17(8): 33-42.