European Journal of Biotechnology and Bioscience
Online ISSN: 2321-9122
Received: 10-01-2016: Accepted: 12-02-2016
www.biosciencejournals.com
Volume 4; Issue 2; February 2016; Page No. 43-47

EPR signals in plant systems and their informational content for environmental studies

[1] Aygun Nasibova, [1, 2] Rovshan Khalilov, [1] Uzeyir Qasumov, [3] Boris Trubitsin, [3] Alexander Tikhonov

[1] Institute of Radiation Problems, ANAS

[2] Baku State University Azerbaijan.

[3] Moscow State University named after M.V. Lomonosov, Moscow.

Abstract

The influence of increased background radiation on the formation of magnetic nanoparticles of iron oxide (magnetite – Fe_3O_4 and maghemite – γ- Fe_2O_3) in the dominant plant species of Absheron Peninsular has been investigated by EPR method. It was shown that the intensity of a broad EPR signal, characterizing the magnetic nanoparticles of iron oxide, registered in dried leaves of studied plants, collected in various times of the year noticeably increases with increasing radiation background. Also in two investigating species of plants, it has been shown that the intensity of the broad EPR signal of seeds has been much lower than in their leaves. Such behavior has been observed with control plants, and also plants growing on polluted radionuclide soils (55 and 130 mR/hour). The elemental composition, radionuclide composition and specific activity of radionuclides in the studied plants have been determined.

Keywords: Radioactive contamination, exposure dose, magnetic nanoparticles, EPR signals.

1. Introduction

It is known that radioactive contamination occurring in environment under the influence of wastes of chemical products and industry, also other anthropogenic factors break ecological equilibrium from serious danger for lively organisms. Recently, connecting with the contaminated environment by radioecological factors, the investigation of these factors influence on lively organisms, induces to a great interest for scientists. As known, the contamination of soils and water by oil production and gas industry is the ecological problem [1, 2].

In some areas of Absheron Peninsular the increased natural background radiation is still remains as ecological problem. In accordance with that, the radioecological studies have been conducting in these areas for a long years [3, 4]. The territory of Iodine Factory (at present it doesn't exist) locating in Ramana districs of Absheron Peninsular is the place of our investigation. We conducted comparative experiments with control and plants exposing to chronic gamma radiation, in order to study radioactive contamination influence on the formation of magnetic nanoparticles in some plant species, growing in this territory. In the work [5] the magnetic nanoparticles accumulate in plants having grown in soils of this territory (territory of Iodine Factory) by electron paramagnetic resonance method.

In the present work, the influence of increased background radiation on the formation of magnetic nanoparticles in dominant plant species having grown in the areas of Iodine Factory locating in the Absheron Peninsular in various times of the year.

2. Materials and methods

2.1. Collection of plant samples

We collected leaves and seeds of plants (Elaeagnus L., Juncus L., Zygophyllum L.) on environmentally clean (control) and radioactive contaminated areas. During the investigation of radioactive contaminated territory, the exposure dose (PED) was measured by radiometer-dosimeter MKS-AT 1125, Atomtex (Belarus).

Investigations were conducted on dominant species of the Apsheron peninsula having grown on radionuclide contaminated soils and on control plots. The irradiation dose rate of control plants did not exceed 10 mR/hr. Investigations were conducted on freshly collected and dried at 60 °C plants.

The investigations have been conducted in some dominant plant species *Elaeagnus L.* (elaeagnus), *Juncus L.* (rush), Zygophyllum L. (bean caper) in Absheron Peninsular, having grown on radioactive contaminated and control areas (fig.1).

A

B

C

Fig 1: (A) Elaeagnus L., (B) Juncus L., (C) Zygophyllum L.

2.2. EPR studies

The freshly collected and dried leaves at room temperature (25-27 °C) and seeds of upmentioned plants were used. The spectra of investigating plant objects have been registered by EPR-spectrometer Varian E4 (USA) at room temperature (293 K), in observing condition, and were shown in indications with respective figures.

2.3. Gamma-spectrometric studies

By gamma-spectrometer method, the radionuclide content and specific activity of radionuclides have been determined in investigating plants. For that, plant samples were collected from investigating locations then were dried. For the appearance of radioactive equilibrium the samples were kept in hermetic Marinelli vessels. After 3-weeks' keeping the samples in that condition, the determination of radionuclide content and specific activity of radionuclides was conducted by gamma spectrometer "CANBERRA" detector HP.Ge. The condition and time (4 hours) were the same for the all samples.

The quantity of various elements in samples contain was determined at roentgen (X-ray)-fluorescent spectrometer XRF-Analyzer, Innov-X firms (USA).

3. Results

3.1. Registration of broad EPR signal in plant samples (leaves and seeds of plants from control and radioactive contaminated areas.)

EPR spectra of leaves of *Elaeagnus L.* (elaeagnus), having dried at room temperature was shown in figure 2, which were collected from radioactive contaminated areas, registered at room temperature 297 K.

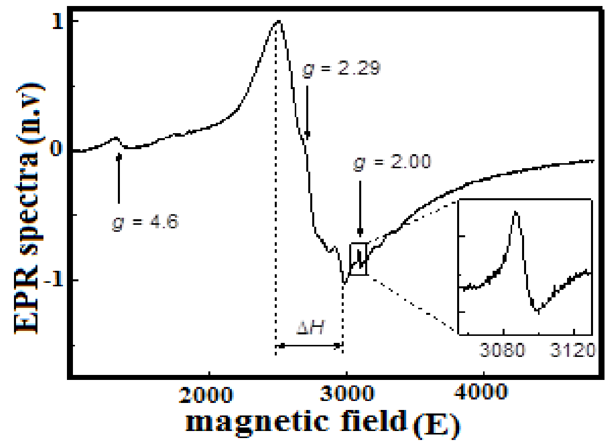


Fig 2: EPR spectra of leaves of *Elaeagnus L.* having dried at room temperature, collected from radioactive contaminated areas (PED 140 mR/hour). The registration condition: UHF power 10 mW, magnetic field HF-modulation amplitude 0,5 mTl, field center 2800 mTl, field scanning 4000 mTl, temperature 297 K.

It is seen from the figure, the main contribution, includes a board EPR signal to this spectra, in which the maximum position of the low-field component changed from g=2,29 and signal of half-width 320 mTl. Apart of this signal, in this spectrum one discloses a narrow intensive signal of free radicals and a weak signal of trivalent iron complexes at g=4,6. A broad EPR signal was registered in leaves of *Elaeagnus L.*, which were collected in various times of year (fig.3).

It is seen from the figure that during the spectra registration at room temperature every time one observes a characteristic broad EPR signal, in which the maximum position of the low – field component changed from g=2,38 and signal of half-width 320 mTl.

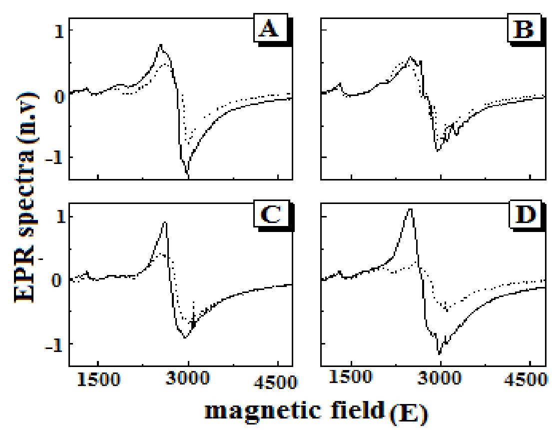
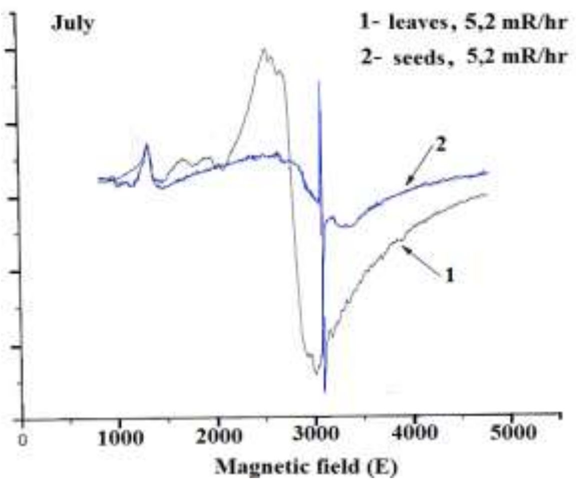
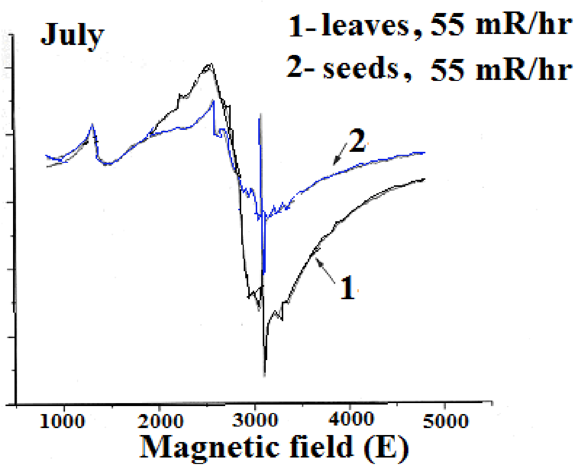


Fig 3: EPR spectra of the dried at room temperature leaves Elaeagnus angustifolia collected at different times of the year: A-May.; B-June; C – July; D – October. With dashed lines shows EPR spectra of leaves samples of the plants growing on control sites; solid line-EPR spectra of the leaves of plants growing in a contaminated area (140 ± 20 mR/hr).

Apart of this signal, in the spectrum one also has disclosed a narrow intensive signal of free radicals and a weak signal of trivalent iron complexes at g=4,6. The amplitude of a broad EPR signal, having registered in dried leaves of *Elaeagnus L.* noticeably increased with the increasing exposure dose. Every time to a great PED corresponded great amplitude of the broad EPR signal. In all the investigating leaves, having grown on radioactive contaminated soils, the intensity of the broad EPR signal was noticeably increased as compared with the intensity of an analogous signal in control samples. Apart that, the comparative EPR investigation was conducted in the leaves and seeds of these plants from control and radioactive contaminated areas. The board EPR signal of seeds and leaves of *Elaeagnus L.* was registered (fig.4 A, B).



A



B

Fig 4: The EPR spectra of the seeds and leaves *Elaeagnus L.* growing in the control (A) and experimental (B) areas. Conditions of registration: Microwave power is 10mW, the amplitude of the RF magnetic field modulation 8 G, 2800 G center field, 4000 E field scan, temperature of 297 K

The signal intensity of seeds of *Elaeagnus L.* was substantially less, than in their leaves. Such behavior was observed also in control plants and in plants having grown on contaminated radionuclide soils at the dose 55 mR/hour. In the spectrum of seeds and leaves was also registered a narrow intensive signal of free radicals and a signal of trivalent iron complexes.

Apart that, such change of signal intensity was observed in seeds and leaves of *Juncus L.* (rush), (fig.5).

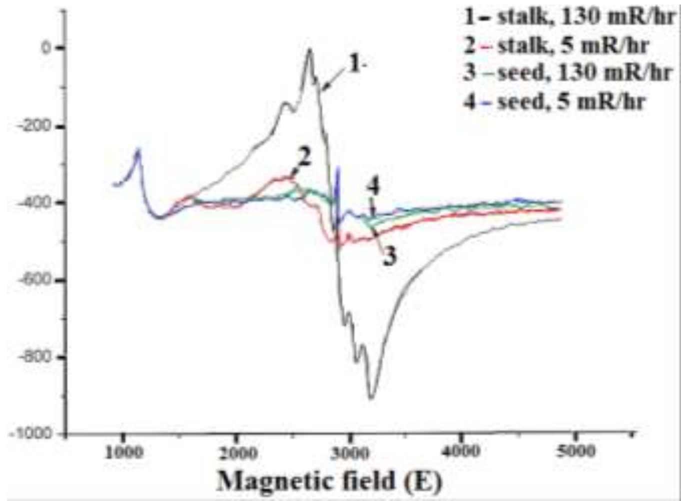


Fig 5: The EPR spectra of the seeds and leaves *Juncus L.* grown on control and contaminated soil. Registration conditions: microwave power 10 mW, the amplitude of the RF magnetic field modulation 8 G, 2800 G center field, the field scan 4000 E, temperature 297 K.

The intensity decrease of a broad signal of control objects, as compared with experimental, was also observed in seeds of *Elaeagnus L.*

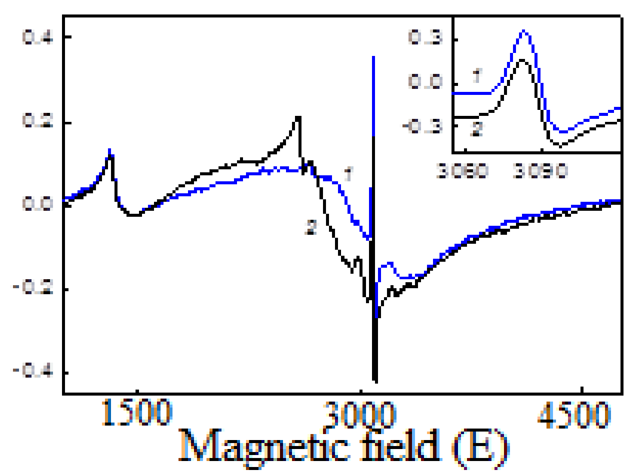


Fig 6: The EPR spectra of seed *Elaeagnus L.* collected from the control (1), and radioactively contaminated (2) area (52 mR/ hr). Registration conditions: UHF power 10 mW, magnetic field HF-modulation amplitude 4 mTl, field center 2800 mTl, field scanning 4000 E, temperature 297 K.

As evident from the figure, the amplitude of broad EPR signal, being registered in seeds of control plant was substantially lower as compared with the signal amplitudes of plant seeds from radioactive contaminated area (PED 55 mR/hour).

3.2. Radionuclide composition and specific activity of radionuclides studied plants

In table 1, were presented the radionuclide content and specific activity of radionuclides of plants as *Zygophyllum L.* and Elaeagnus L. having collected in areas of PED. As evident from the table in samples were discovered only natural radionuclides (^{40}K, ^{226}Ra, ^{228}Ra, ^{235}U, ^{238}U). In plant samples having collected from control areas, where the background radiation didn't increase to 5-6 mR/hour, specific activity of radionuclides was substantially lower compared with plant samples which were collected from the areas with increased background radiation.

Table 1: Radionuclide content and specific activity of plants having grown on radioactive contaminated and control areas of Iodine Factory.

The name of the sample		**bean caper *(Zygo-phyllum L.)* 5 mR/hr**	**bean caper *(Zygo-phyllum L.)* 170 mR/hr**	**bean caper *(Zygophyllum fabago L.)* 200 mR/hr**	**elaeagnus *(Elaeagnus L.)* 5 mR/hr**	**elaeagnus *(Elaeagnus L.)* 140 mR/hr**
	unit of measure	Specific activity of radionuclides				
^{40}K	Bq/kg	151±18	305 ± 18	596 ± 17	205 ± 10	234 ± 26
^{226}Ra	Bq/kg	4,4±1,4	14,2 ± 1.1	214,3 ± 1.4	2,2 ± 0.7	6,6 ± 2.1
^{228}Ra	Bq/kg	0,4±0,8	0.5 ± 0.6	2,2 ± 0,8	1.3 ± 1.1	2.3±0,04
^{235}U	Bq/kg	0,9±0,2	0.80 ± 0.09	16.6 ± 1.0	0,20 ± 0,06	0,20 ± 0,04
^{238}U	Bq/kg	19,5±4,0	17,4 ± 1.9	360,2 ± 21.7	4,3 ± 1.1	4,3 ± 0.8

We also determined the elemental content of being studied plants (table 2). The quantity of various elements in the sample content has been determined at the Roentgen (X-ray) – fluorescent spectrometer XRF Analyzer, (Innov-X, Firm Omega).

Table 2: Elemental plant content having grown on radioactive contaminated and control areas of Iodine Factory.

Element	**unit of measure**	**Bean caper (*Zygophyllum L.*)**			**elaeagnus (*Elaeagnus L.*)**	
		The radiation background of area (mR/hr)				
		5	170	200	5	140
Ca	ppm	1533±220	1468±278	1510±241	15245±2896	16679±3169
Fe	ppm	221±35,3	219±32,8	231±41	2272±408	2392±454,4
K	ppm	157±25,1	159±25,4	162±27	1721±275	1636±294
Ti	ppm	237±38	263±44,7	305±51	29,1±4,9	28,8±4,6
Mn	ppm	46,9±6,9	46,4±6,9	46,6±7,4	556±94,5	580±92,8
Sr	ppm	40,7±6,5	38,4±6,3	39,7±6,7	378±64,2	405±60,7
Ba	ppm	31,7±5,3	24,8±3,9	19,5±2,9	217±34,7	269±45,7
Zn	ppm	15,5±2,3	15,3±2,3	13,3±2,1	13,6±2,04	23,8±3,8
Zr	ppm	13,5±2,1	12,4±1,8	12,4±1,8	15,6±2,6	11,1±1,8
Cr	ppm	6±0,9	6,5±1,04	5,3±0,8	141±25,3	< LOD
Pb	ppm	3,2±0,4	3,6±0,5	3,8±0,5	32±4,8	44±7,4
Cu	ppm	< LOD	< LOD	< LOD	< LOD	49±7,3
Co	ppm	< LOD	< LOD	< LOD	< LOD	< LOD
Mo	ppm	< LOD	< LOD	< LOD	< LOD	< LOD
Ni	ppm	< LOD	< LOD	< LOD	< LOD	< LOD
As	ppm	6±0,9	6±0,9	6±0,9	18±2,7	7±1,05
Se	ppm	11±1,6	9±1,4	10±1,7	10±1,5	11±1,65
Rb	ppm	3±0,45	3±0,48	3±0,5	3±0,45	3±0,5
S	ppm	< LOD	< LOD	< LOD	< LOD	< LOD
Cl	ppm	< LOD	< LOD	< LOD	< LOD	< LOD

1 ppm (parts per million) = 0,001 ‰ = 0,0001 % = 0,000001 = 10^{-6}.

4. Discussion

In work [4, 5], by EPR method was presented the accumulation of nanoparticles of magnetite in plants characteristic with a broad signal of half width 320 mTl at g=2,38. The registered broad EPR signals in agents of synthesized magnetite nanoparticles (Fe_3O_4+PE) with own parameters by the character of change upon lowering temperature from room to 80 K, they coincided with the analogous signals registered in plant leaves. The lowering of registration temperatures led to noticeable broading of these signals and then accordingly to a sharp drop of its amplitude [4].

In the present work has been studied the influence of increased background radiation on the formation of magnetic nanoparticles of iron oxide in leaves and seeds of investigating plants in various times of the year.

We presented that, in investigating plants, having grown on radioactive contaminated soils of Absheron Peninsular, the content of nanoparticles, judging by the intensity of their characteristic broad EPR signal, proved substantially increased. Such behavior of signals was observed in all plant samples, having grown in various times of year (fig.3).

It is interesting, that in seeds, the amplitude of being registered EPR signal proved substantially reduced, than in leaves. Such results were obtained both with control plants and also plants from radioactive contaminated soils (fig.4,5). Besides that, in plant seeds having grown on radioactive contaminated soils, as compared with control seeds by the intensity of their characteristic broad EPR signal proved substantially increased (as in leaves).

It was shown that, specific activity of radionuclides which were determined in the content of *Zygophyllum L.* and *Elaeagnus L.* from radioactive contaminated areas, proved a little higher, than in control plants.

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