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NON-DESTRUCTIVE NUCLEAR TECHNIQUE USED FOR A COMPARISON STUDY BETWEEN WATER HYACINTH AND COMMON REED AS BIOINDICATORS OF POLLUTION

Two aquatic weeds naturally grown on different water bodies in the Ismaillia governorate were investigated (seasonally during 1995–1996) to determine the potential pollution sources in the area studied. The selected aquatic weeds differ in type, because a water hyacinth WH *(Eichhornia crassipes)* is a floating plant, and common reed CR (*Phragmites australis*) is an emergent plant. Heavy metals and rare -earth elements were determined in plant samples using a non-destructive nuclear technique (delayed neutron activation analysis). The aim of the study is to compare heavy metals composition of two different aquatic weeds at selected sites to determine their potential use in a bio-monitoring technique.

The concentrations of six heavy metals (scandium, chromium, iron, cobalt, zinc and antimony) in the plant samples are determined. Heavy metals' content in plant samples differed, depending on the plant type, part, season of sample collection and sample location. The highest levels of iron, cobalt, antimony and scandium were determined in the WH samples.

1. INTRODUCTION

Neutron activation analysis as a non-destructive method is considered as a technique of high accuracy and an effective tool, especially useful in qualitative and quantitative analyses of heavy metals and rare-earth elements [1]–[4]. The neutron activation analysis is used to determine the elements present in the samples irradiated in the nuclear reactor. The nuclear reactor is considered as the strongest neutron source where irradiation of samples can occur with a neutron flux of about 10^{12} n per $cm^{-2}\cdot s^{-1}$or more. In addition, due to a special ability of thermal neutrons to activate reactions, nuclear reactors are the most used irradiation sources to activate reactions. The reaction of thermal neutrons with atomic nuclei is essential for this process. The reaction cross-section is the physical quantity, which describes the probability of a certain reaction. It is highly dependent on the neutron energies. On the other hand, nuclear reactors provide a continuous spectrum of neutrons with very wide range of energy up to 15 MeV.

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Concern about the contamination by heavy metals, which have serious effects on evironment and accumulate in lethal or sub-lethal concentrations in the members of food chain, has been grown. It is known that heavy metals, which are most often investigated in the ecosystem, cannot be destroyed biologically and if they enter once the environment (e.g. rivers, lakes) they may accumulate or be inactivated there. Therefore it is of great importance to use the NAA technique to investigate low levels of trace elements in environmental samples.

The accumulation of heavy metals in aquatic plants has been documented by a number of authors (DIETZ [5], RAY and WHITE [6] and ABD EL-SABOUR et al. [7]). It was reported that metal accumulation in aquatic plants varies with plant species (ABO RADY [8] and LOW et al. [9]). SAWIDIS et al. [10] studied the uptake of heavy metals by aquatic plants of the Pinios river (Greece) and found that *Ceratophyllum demersum* accumulated greater amounts of zinc, manganese and nickel, while *Paspalum pasolodes* accumulated greater amounts of iron, copper and chromium.

Different parts of aquatic plants vary in their heavy metal content and metals tend to accumulate more in roots than in stems and leaves (ABDEL-SABOUR et al. [7]). However, the chemistry and mobility of the metals in question will determine their uptake and translocation in aquatic plant tissues (JANA [11]). For example, NIR et al. [12] indicated that *Eichhornia crassipes* exposed for 3 weeks to the solution which contained 0.4 ppm of cadmium accumulated maximally about 703 ppm of this metal in roots (about 80% of cadmium removed from solution), and only 67 ppm in its leaves.

Emergent plants are rooted in the soil and have their leaves above the water surface. They uptake carbon dioxide from the air, and nutrients from the soil below the water surface. Their occurrence is restricted to the area near the banks and to rather shallow waters. The common reed (*Phragmites australis*) has creeping-rhizomes, which usually invade the soil of the channel side slopes and bottom. A mature plant is 1–4 m high, depending on its habitat. Its leaves are arranged in two distinct rows on each side of the straight stem. Recently, the interest to utilize some aquatic plants for wastewater biological treatments is growing. ALI [13] investigated the removal of heavy metals (cadmium, cobalt, lead and nickel) from solutions by selected aquatic plants (water hyacinth and coontail). He indicated that both plants were capable of removing heavy metals tested with different ratios, whereas the removal rate depended on both metal type and its concentration.

The aim of this study is to investigate, using the NAA technique, the efficiency of two different aquatic weeds (floating and emergent) as bio-indicators of pollution of the Temsah lake.

2. MATERIALS AND METHODS

2.1. SAMPLE PREPARATION

In the Ismaillia governorate, there are several point sources known as potentially pollution points (ATTWA [14]). Sanitary wastewater sources (i.e. El-Forsan and El

Bahtini drains), industrial wastewater sources (i.e. El-Temsah, El-Karakat and Arab contractors workshops) and agricultural wastewater (i.e. Abu Gamous drain and El-Mahsama drain) are potential sources of pollution.

Four sampling stations were selected, namely El-Mahsama drain (I), Bahatini drain (II), Western Lagoon (III) and El-Temsah Workshop (IV). Surface water samples (4 dm^3 each) were collected, acidified with nitric acid (pH < 2) and kept for heavy metals analysis using ion coupled plasama technique (SALTANPOUR [15]).

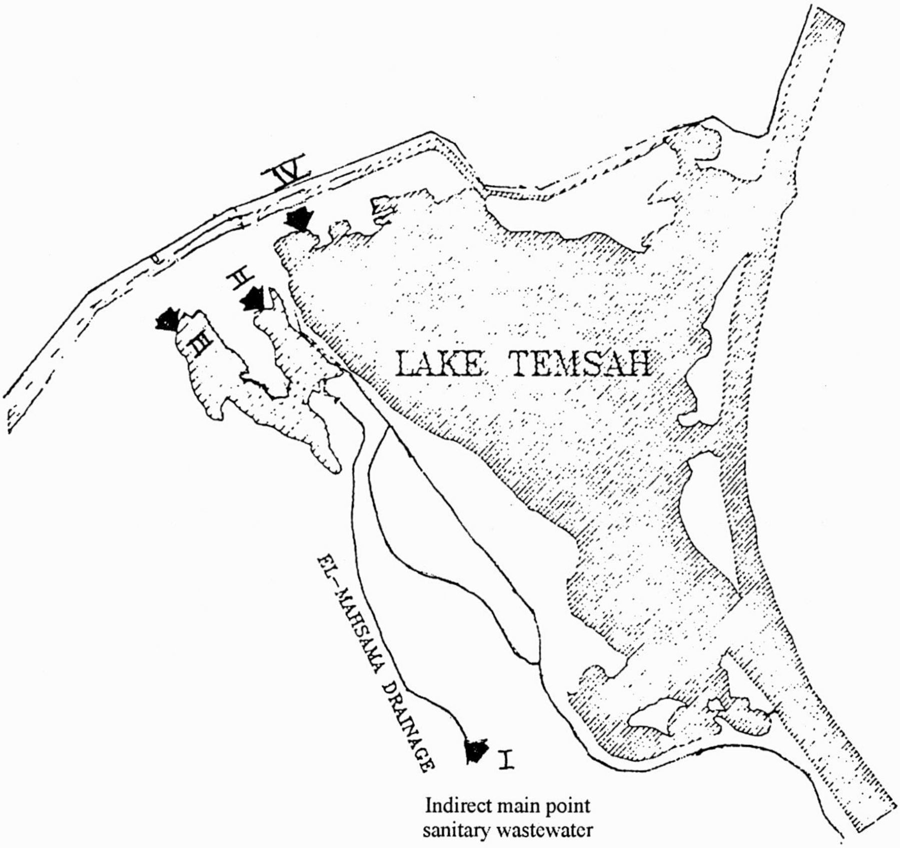

Fig. 1. Sampling sites

Natural habitat of aquatic weeds found in these water bodies was investigated and samples of plants were collected seasonally (10 plant samples per each site) from sites I, II, III, and IV (figure 1). Two species of aquatic weeds were investigated, i.e. common reed (*Phragmites australis*) and water hyacinth (*Eichhorina crassipes*) as biological accumulators of heavy metals. Samples of water hyacinth (divided into shoots and roots) and of common reed (shoots) were rinsed with fresh water to remove dust and dirt, then washed out with distilled water, dried up at 65 °C until they had a constant weight. Next, the samples were ground into a fine powder (800 μ) according to APHA [16].

2.2. NEUTRON ACTIVATION AND γ-RAY DETECTION SYSTEM

The core of the ET-RR-1 at Anshas was used for irradiating the samples under investigation. Each sample of an accurate weight (100 mg) was enclosed in a capsule made of aluminium foil. Also a known mass of standard material NBS-1571 (Standard Reference Material [17]) was packed in a clean aluminium foil. Empty aluminium foil of a known weight was irradiated under the same conditions as all samples for identifying and subtracting the background due to aluminium envelope.

A monitor gold sample was used to estimate the thermal neutron flux. All samples were irradiated for 48 hours with a thermal neutron flux of $4 \cdot 10^{12}$ n per $cm^{-2} \cdot s^{-1}$. The irradiated samples were left to cool for one week. The hyperpure germanium detector, i.e. GEM 1590 with a crystal diameter of 50 mm and the length of 49.3 mm, was applied. The detector was equipped with a 571 ORTEC spectroscopy amplifier and the multi-channel analyzer card (ORTEC ACE) mounted on an IBM compatible personal computer. The FWHM of the spectrometer was about 1.95 keV for the 1332.5 keV of 60Co, and the peak-to-Compton ratio was 55:1. A multi-gamma ray standard source MGS-4(17) (nuclear measurements group, microanalysis group, Oxford instruments Inc.) was used to generate the energy and to assess the efficiency of calibration of the detection system.

A linear least-square fitting program was used. The counting time was 7200 s for all samples. The distance between the sample and the detector was about 10 cm. The calibration of the detector was repeated before each counting series. The absolute efficiency was obtained as a function of energy (in the range from 100 keV to 3000 keV). The measurements were repeated once a weak for three runs for each sample to confirm the presence of the corresponding elements.

3. RESULTS AND DISCUSSION

3.1. ANALYSIS OF WATER SAMPLES

Table 1 shows some selected concentrations of heavy metals in filtrated water samples. The levels of the heavy metals tested showed tendency to increase in spring and to decrease in summer. The highest iron level was observed at the site IV (El-Temsah workshop for shipbuilding), while the highest zinc level was at the site III (the western lagoon polluted with sewage effluents). The highest cobalt and chromium levels were at the sites I (El-Mahsama drain) and IV (Bahatini drain), respectively (table 1). These levels of heavy metals are higher by several orders of magnitude than the normal levels (OUTRIDEG and NOLLER [18]).

Table 1

Selected concentrations of heavy metals (ppb) in water samples collected in different seasons

Site	Season	Fe	Zn	Co	Cr
I	summer	123.6	41.2	0.62	0.82
	autumn	172.5	16.4	0.30	0.64
	winter	168.0	25.1	0.48	0.92
	spring	183.3	82.1	1.16	3.96
	mean	162.0	41.2	0.64	1.58
II	summer	137.1	37.8	0.56	1.60
	autumn	191.4	15.0	0.26	1.22
	winter	188.4	23.0	0.44	1.76
	spring	203.1	75.4	1.06	3.50
	mean	180.0	37.8	0.58	1.50
III	summer	157.5	43.8	0.54	0.78
	autumn	220.0	17.4	0.26	0.60
	winter	216.8	26.8	0.42	0.86
	spring	233.7	87.4	1.02	3.76
	mean	207.0	43.8	0.56	1.50
IV	summer	219.2	36.6	0.60	0.98
	autumn	306.0	14.6	0.28	0.76
	winter	301.5	22.4	0.46	1.10
	spring	325.2	73.0	1.14	4.76
	mean	288.0	36.6	0.62	1.90

3.2. HEAVY METALS IN THE AQUATIC WEED SAMPLES TESTED

The sensitivities of the well resolved and intense γ-ray lines of the γ-ray spectra obtained were calculated according to [18], taking account of our experimental conditions. Calculations were done for the identified pure γ-ray lines available for each product nuclide. For example, the isotope ^{46}Sc was chosen since in the ^{45}Sc (n, γ) ^{46}Sc reaction, the natural abundance of ^{45}Sc is 100%, and the half-life time of the product ^{46}Sc is 83.81 d. ^{46}Sc decays to ^{46}Ti through 889.28 and 1120.5 keV γ-rays. The 889.25 keV was selected since 1120.50 keV may have a contribution from 1120 keV of ^{152}Eu and 1121 keV of ^{226}Ra, which may be present in the Al envelope. Mean concentrations of the elements in the common reed and water hyacinth samples are listed in tables 1 and 2, respectively. Portions of γ spectra are shown in figures 2 and 3.

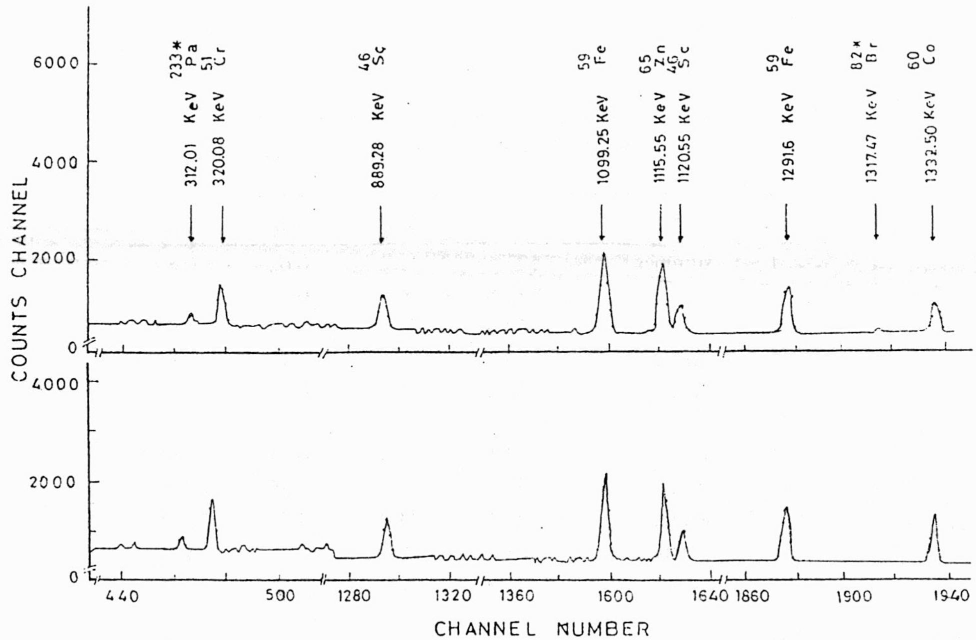

Fig. 2. Portion spectra of shoot and root of water hyacinth for site A (El-Mahsama drain)

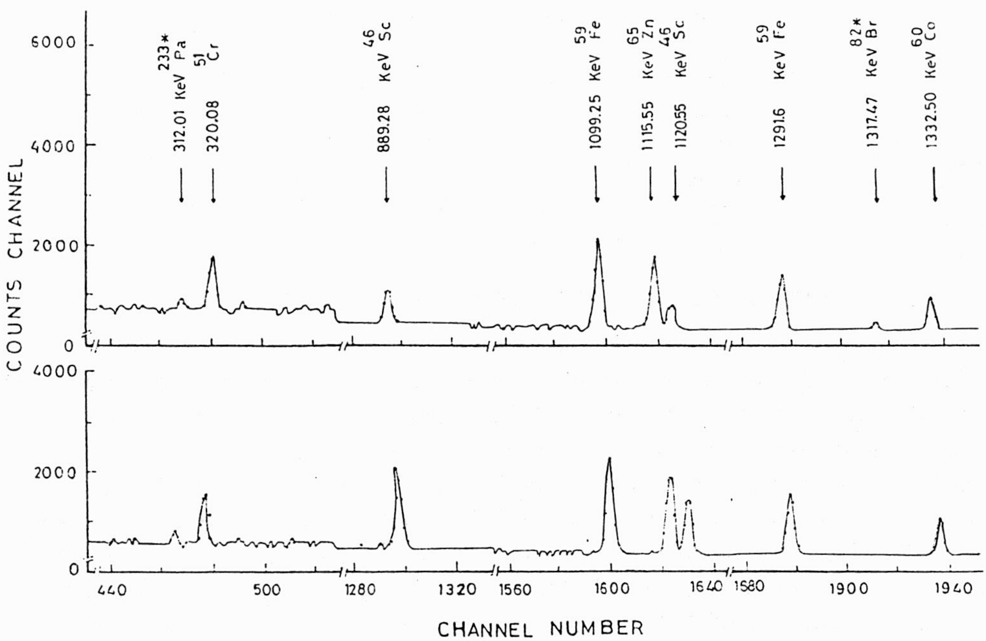

Fig. 3. Portion spectra of water hyacinth shoot for the site C (Western Lagoon) and root for the site D (outlet of the lagoon)

Table 2

Concentrations of heavy metals (mg/kg) in common reed shoots from different sites

Site	Season	Fe	Zn	Co	Cr	Sb	Sc
I	summer	159.20	7.85	0.19	1.08	1.97	0.005
	autumn	213.95	13.75	0.38	1.47	2.56	0.006
	winter	208.98	9.82	0.86	1.46	1.00	0.003
	spring	228.88	11.78	0.95	1.53	1.29	0.003
	mean	204.00	10.80	0.59	1.39	1.70	0.004
II	summer	117.78	4.83	0.27	1.44	0.29	0.001
	autumn	87.49	8.59	1.42	1.10	1.72	0.005
	winter	77.40	10.74	0.31	1.58	1.95	0.006
	spring	565.33	16.11	0.04	1.08	2.46	0.007
	mean	212.00	10.20	0.51	1.30	1.60	0.005
III	summer	167.00	10.10	0.37	0.99	1.30	0.005
	autumn	388.90	13.90	0.31	2.31	2.39	0.009
	winter	37.36	7.79	0.49	0.22	0.75	0.003
	spring	72.50	8.66	0.25	0.44	0.77	0.003
	mean	167.00	10.10	0.37	0.99	1.30	0.005
IV	summer	206.00	3.12	0.53	1.86	5.45	0.003
	autumn	178.20	9.00	0.40	1.64	7.46	0.005
	winter	58.47	5.19	0.27	0.53	7.07	0.004
	spring	128.10	9.69	0.40	1.16	6.31	0.003
	mean	142.00	9.00	0.40	1.30	6.5	0.004
	total mean	166.0+ 0.2	10.0+0.3	0.47+0.3	1.2+0.5	2.79+2.3	0.005+0.002

Results in table 2 showed explicitly that common reed samples collected at the site I (El-Mahsama drain) uptook the highest concentrations of zinc, cobalt and chromium, while those at the site IV – the highest concentrations of antimony. It is worth mentioning that the El-Mahsama drain exerted a significant impact on the Temsah lake due to its high discharge rate (about 700,000 m^3 of wastewater/day according to ATTWA [14]). Generally, the concentrations of the metals tested in common reed varied seasonally, being higher in spring and lower in summer. This variability could be attributed to metal bioavailability due to temperature, oxidation and various biological activity which depended on season. In general, mean iron, zinc and cobalt concentrations in common reed were found to be 166.0, 10.03, 0.47 ppm, respectively. These contents were lower than those reported by ATTWA [14]. This difference could be attributed to the analytical technique applied. In his work, Attwa used the ICP technique.

Table 3

Concentrations of heavy metals (mg/kg) in water hyacinth shoots from different sites

Site	Season	Fe	Zn	Co	Cr	Sb	Sc
I	summer	157.2	11.60	0.58	0.90	14.5	0.011
	autumn	221.1	4.62	0.28	0.70	5.78	0.014
	winter	215.0	7.07	0.45	1.00	8.84	0.007
	spring	234.9	23.12	1.09	4.34	28.9	0.007
	mean	207	11.6	0.60	1.73	14.5	0.009
II	summer	177.5	12.5	0.55	1.41	15.63	0.006
	autumn	247.8	4.96	0.26	1.08	6.20	0.032
	winter	243.9	7.61	0.43	1.55	9.51	0.038
	spring	262.9	24.93	1.04	6.70	31.16	0.045
	mean	233	12.5	0.57	2.68	15.6	0.032
III	summer	213.0	14.20	0.53	0.99	13.7	0.019
	autumn	297.5	5.64	0.26	0.76	5.44	0.034
	winter	293.3	8.69	0.41	1.10	8.38	0.011
	spring	316.1	28.3	1.00	4.79	27.30	0.011
	mean	280	14.2	0.59	1.91	13.7	0.019
IV	summer	255.7	9.2	0.62	1.39	11.7	0.024
	autumn	357.0	3.67	0.29	1.08	4.67	0.040
	winter	351.8	20.67	0.47	1.55	26.29	0.032
	spring	379.4	18.35	1.18	6.74	23.34	0.024
	mean	336.0	9.2	0.64	2.69	11.7	0.032
	total mean	264.0+61	12.6+7.1	0.59+0.28	2.3+1.89	14.8+8.4	0.022+0.013

The concentrations of heavy metals in shoots or roots of water hyacinth at the sites III and IV were often higher than the corresponding levels at the site I (table 3). The roots of water hyacinth accumulated higher concentrations of iron, zinc and cobalt than its shoots. However, the levels of chromium, antimony and scandium in hyacinth shoots were higher than in the roots.

A comparison between heavy metals' contents in the shoots of water hyacinth and the samples of common reed proves that the former often accumulates higher concentrations of heavy metals as shown in tables 1 and 2. This may suggest that water hyacinth is more effective as an accumulative bioindicator of heavy metals than common reed. Thus it can be used in order to monitor the pollution of water bodies with heavy metals as it has been suggested by several researchers (KAISER et al. [21], ABDEL-SHAFY et al. [22] and ABDEL-SABOUR et al. [7]). ABDEL-SABOUR et al. [7] reported that water hyacinth showed higher ability to accumulate metals, i.e. iron, zinc, copper,

Table 4

Concentrations of heavy metals (mg/kg) in water hyacinth roots from different sites

Site	Season	Fe	Zn	Co	Cr	Sb	Sc
I	summer	159.5	18.20	0.55	0.74	2.90	0.010
	autumn	224.3	7.25	0.27	0.58	1.16	0.012
	winter	218.1	11.09	0.43	0.83	1.77	0.006
	spring	238.3	36.27	1.04	3.59	5.78	0.006
	mean	210	18.2	0.57	1.43	2.90	0.008
II	summer	187.4	14.6	0.60	0.88	6.31	0.002
	autumn	261.6	5.79	0.28	0.68	2.50	0.008
	winter	257.5	8.89	0.47	0.97	3.84	0.010
	spring	277.6	29.12	1.13	4.20	12.58	0.011
	mean	246.0	14.6	0.62	1.68	6.3	0.008
III	summer	255.6	18.80	0.65	0.71	2.8	0.010
	autumn	357.0	7.47	0.32	0.55	1.1	0.020
	winter	351.9	11.51	0.50	0.79	1.7	0.006
	spring	379.3	37.46	1.22	3.44	5.6	0.006
	mean	336	18.8	0.72	1.37	2.8	0.010
IV	summer	466.5	17.80	0.70	0.74	2.7	0.006
	autumn	651.3	7.10	0.33	0.57	1.1	0.010
	winter	642.0	39.99	0.53	0.82	6.1	0.008
	spring	692.2	35.50	1.33	3.56	5.4	0.006
	mean	613	17.8	0.72	1.42	3.8	0.008
	total mean	351.3+169	18.8+11.0	0.65+0.3	1.5+1.2	3.96+2.7	0.008+0.004

nickel, chromium, cadmium, lead and mercury, and a good response to metal levels in its water habitat. This confirms recent findings by ALI [13] who has stated that the most efficient aquatic weeds as far as heavy metals' accumulation is concerned are as follows: water hyacinth (floating plant), coontail (submerged plant), and common reed (emergent plant).

4. CONCLUSIONS

The neutron activation analysis technique (non-destructive technique) may give a clear picture of some elemental contents which cannot be indicated by other techniques.

Use of some aquatic plants as bioindicators of metals is obviously potentially very useful. It can be concluded that water hyacinth may be used for monitoring the metal loads in different water bodies. It appears, however, that adoption of this approach to pollution control is limited, since the technique is in its infancy and much more experience is necessary before its implementation in pollution monitoring. Also more information is needed to establish prediction models for potential pollution in water pathways.

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NIENISZCZĄCA TECHNIKA JĄDROWA ZASTOSOWANA DO PORÓWNANIA HIACYNTU WODNEGO I TRZCINY JAKO BIOINDYKATORÓW ZANIECZYSZCZENIA ŚRODOWISKA

Badano dwa chwasty wodne rosnące w różnych zbiornikach wodnych w Ismailli (Egipt), aby zidentyfikować potencjalne źródła skażenia na tym obszarze. Badania prowadzono sezonowo od 1995 r. do 1996 r. Wybrane rośliny należą do dwóch różnych typów – hiacynt wodny (*Eichhornia crassipes*) jest rośliną pływającą, a trzcina (*Phragmites australis*) – rośliną wynurzoną. Zawartość metali ciężkich i tlenków lantanowców oznaczano w próbkach roślin, stosując nieniszczącą technikę jądrową (analiza aktywacyjna za pomocą opóźnionych neutronów). Celem pracy jest porównanie stężenia metali ciężkich w obu roślinach z wybranych stanowisk, aby określić ich potencjalne wykorzystanie jako bioindykatorów.

Oznaczono stężenia sześciu metali ciężkich (skandu, chromu, żelaza, kobaltu, cynku i antymonu) w próbkach roślin. Stężenia te różniły się w zależności od gatunku, części rośliny, terminu zbioru próbek i stanowiska. Największe stężenia żelaza, kobaltu, antymonu i skandu stwierdzono w próbkach wodnego hiacynta.

chwasty wodne, rośliny wodne, zbiorniki wodne,
oznaczanie metali ciężkich