Arab J. Nucl. Sci. Appl., Vol. 58, 1, 13-28 (2025)

ISSN 1110-0451

Arab Journal of Nuclear Sciences and Applications

Web site: ajnsa.journals.ekb.eg

(E S N S A)

Phytoremediation of Uranium and Thorium in Some Limited Areas Old and Reclaimed Soils

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ARTICLE INFO

Article history:

Received: 18th Oct. 2024

Accepted: 27th Nov. 2024

Available online: 21st Dec. 2024

Keywords:

Accumulation;
Fertilizers;
Mine Soil;
Thorium;
Uranium.

ABSTRACT

This study investigates some radioactive elements in reclaimed phosphate mine soil and old soil fertilized with phosphate by Phytoremediation using 3 types (*Helianthus annuus L, Phragmites australis and Cyperus*) over harvest periods of 30,45 and 60 day from start planting so as ascertain of uranium, thorium being absorbed by plant.and changes concentrations over time in different types plant, by cultivating previous plant types in pots 2 kg from 3 soil type. Two soils examined was taken from East, West Nile. The phosphate mines soil of Nasr Mining Company in Aswan governorate (reclaimed soil) that has been cultivated Wadi al-shaghb (East Nile) more than 20 years, (the reclaimed soil) and soil Sebaiya (reclaimed soil) more than 3 years of (West Nile) near phosphate crushers site. The third was taken from permanent experiment of Bahteem Agricultural Research Station Qalyubiya Governorate (old soil fertilized with Phosphate fertilizer since 1912). The plant harvested after three periods 30,45 and 60 day from cultivation of 75 pots for each sample. The results showed that, the concentration of elements uranium and thorium was as follows. 1- The highest concentration uranium element in shoots *Helianthus annuus L*, was 211.3 mg kg^{-1} at 60-day soil Bahteem old, while lowest concentration shoots *Helianthus annuus L*, was 8.37 mg kg^{-1} at 30 day of Wadi al-shaghb. 2- The highest thorium concentration roots *Cyprus* was 28.8 mg kg^{-1} at 30 day in Wadi al-shaghb, while lowest concentration roots was 1.11 mg kg^{-1} roots *Helianthus annuusL* at 30 day in soil Wadi al-shaghb.

INTRODUCTION

Egyptian agriculture has increased the use of modern technology, to increase crop yields over the past 30 years, including the large-scale application of Phosphate fertilizers. Environmental and human health risk assessments have been conducted on the impact of P fertilizers on U and Th concentrations in agricultural soils [1]**.** In phosphate rich soils and Th concentrations are frequently higher**.** [2,3] Several investigations have found increased U concentrations in the soil's surface horizon as a result of ongoing chemical fertilizer applications. [4,5,6]. Long term applications of fertilizer on the other hand, may result in significant soil degradation and contamination with uranium and thorium. Phosphate rocks, which are used to manufacture phosphate fertilizer, are a natural source of radionuclides such as uranium (^{238}U) and thorium (^{232}Th) is decay products. [7,8]. Because phosphate fertilizers include a considerable quantity of uranium and thorium, improper fertilizer application could raise uranium and thorium levels in agriculture soils.

Arable land is subject to excessive and repeated application of Phosphate fertilizer because soluble forms of Phosphate fertilizer can easily precipitate into insoluble forms. Phosphorus has been found to form insoluble complexes with aluminum and iron in acidic soils, while in alkaline soils it combines with calcium and magnesium. [9]. Application of phosphate rocks fertilizer is generally accepted. Phosphate rock phosphate fertilizer despite its comparatively slow release of soluble Phosphate. It is also noted that:

(a) The pH of Egyptian agricultural lands ranges from 7.8-8.2, (b) The subject requires in depth research, including the study of different cultivated soil types (clay, sand, and limestone), as well as different phosphate rocks types (Nile Valley, Red Sea, and Abu tartur phosphate rocks) as variety of adverse environmental impacts on agricultural soils. Since the amounts fertilizers applied are much larger than the amount of soil. However the uptake of radionuclides by plant depends on many factors, including the way they interact with the material and their physiological

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DOI: 10.21608/ajnsa.2024.329257.1857
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characteristics. properties of ttypes as well factors such as mobility, bioavailability, and concentrations of radioactive elements in surface and subsurface geological systems. [10].

Environmental and human health risk assessments on effects of phosphorus fertilizers on uranium and thorium concentrations in agricultural soil it has been implemented. [11]. In phosphate rich soils, Uuranium and Thorium concentrations are often higher**.** [12,13]. Several surveys have identified elevated uranium concentrations in the soil surface horizon as a result of application of continued application at chemical fertilizer. [14,15and 16]. On the other hand, the use of fertilizers can lead to significant soil degradation and uranium and thorium contamination. Phosphate rocks which used to make phosphate fertilizer are natural source of radioactive elements such as uranium (U) and thorium (Th) [17,18] Because phosphate fertilizers contain significant amounts of uranium and thorium, improper fertilizer application increase uranium and thorium levels in agricultural soils. Soil degradation caused by fertilizer related U and Th contamination is currently recognized as global public health problem. Phosphate rocks contain high concentrations of uranium, up to (100 ppm). Have been documented in the literature. [18,19]. Furthermore, it is common to find uranium and thorium together, which invariably results in their co-contamination of the environment [20]. Because soluble fertilizer has derived uranium from agricultural soils which is mobile in surface soil as uranyl complex, it can be up taken by plant or transported ground and surface waters leading, resulting to spread uranium throughout of region. [21]. The behavior of radio elements in soils and rock, with focus on U and Th, Is critical issue from an ecological point of view. [22].

Generally speaking, variety of factors, including soils types, plant types, roots development, target element concentration, organic matter content affect how much radioactivity plants can absorb [23]. Phytoremediation, as an exclusive or complementary technique to eliminate soil and water pollution, shows promise for both developing and developed countries. Phytoremediation as single remediation approach is less expensive than traditional chemical and physical remediation methods in economically developing countries procedures, and requires the least amount of engineering technology [24].

The newly reclaimed soils of Wadi al-shaghb and Sebaiya which belong to Al-Nasr Mining Company in Aswan Governorate, represent one of the soils contaminated with radioactive elements, as they were originally phosphate quarries that were exploited for mining purposes before they were reclaimed, especially the Sebaiya area west Nile. It is known that phosphate rock is a sustainable source of uranium and other radioactive elements, in addition to the soil of the Bahteem Agricultural Research Station Qalyubiya Governorate, which are planted with strategic crops for conducting experiments on them (permanent experiment), and which have been fertilized with phosphate fertilizers since 1912, which leads to the presence of environmental risks in these areas due to phosphate rocks as a source material for the soil and the excessive use of phosphate fertilizers for the purpose of increasing crop productivity.

The aim of this study to Phytoremediation of uranium and thorium in some limited areas old and reclaimed soils by *Helianthus annuus L.* and *Phragmites australis* and *Cyprus* during time periods of 30, 45 and 60 day to study uptake of uranium and thorium by temporal changes of uranium and thorium concentrations in the different plant species. Thus, the behavior of uranium and thorium in soil can be followed and the radiation status can be evaluated, which allows solving many environmental problems.

MATERIAL AND METHODS

Study area

Test samples were taken from three different soil types at depth 0-30 cm, from the soil surface, with the first soil sample being taken from Wadi al-shaghb (East Nile) and second sample being taken from Sebaiya (West Nile) both of which were the Affiliated Al- Nasr Mining Company in Aswan Governorate. The third soil sample was taken from Bahteem Research Station in Qalyubiya Governorate (fertilized with Phosphate fertilizers since 1912). The locations of three soil samples examined are shown in fig. 1 and fig 2.

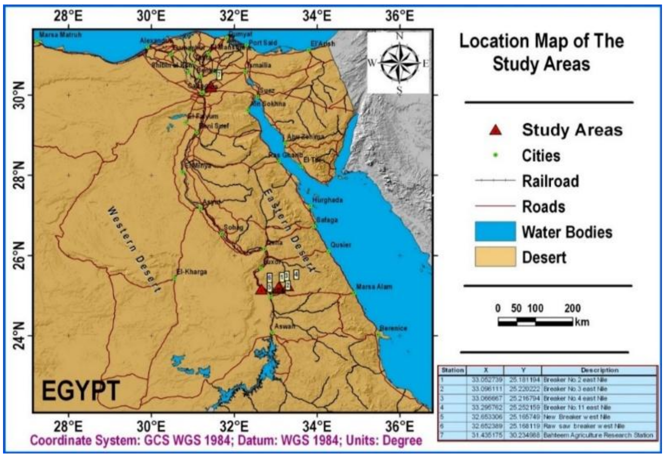

Fig. (1): Map showing the location of the studied soil sample

Fig. (2): showing the soil in the three studied areas.

Experiment design

The experiment was conducted as follows; 490 kg /soil was taken from the three soils at rate of 163 kg / soil per 3 treatments (one treatment contained 75 pots of 2 / kg capacity from three soil). The seeds of three plant species were taken, *Helianthus annuus L*, *Phragmites australis* and *Cyprus* were planted in 75 pots for each soil type of crop periods at 30, 45 and 60 days As shown in Fig (3). Soil moisture content was maintained at around 60 – 70 % of field capacity (FC) [25]. was conducted out in an experiment green house on leased soil in Abu Rawash area private farm, located 8 km north at Giza governorate of Egypt.

Fig (3): Stages of preparing the experiment.

Soil Analysis

Heavy metals

Soil subsamples were taken to characterize the soil. Soil pH was tested using distilled water and 1 M KCl solution at solid to liquid ratio of 1:2.5. [26]. The traditional pipette method was, used for particle size measurement and loss on ignition was used to calculate the amount of organic matter (LOI). To calculate the total cation exchange capacity of the sports complex, the hydrolytic acid and total exchangeable basis were combined (CEC). [27].

The heavy metals present in the three soils were estimated as follows.by atomic absorption spectrometry (AAS)., as follows. Three concentrations of a standard solution of a specific metal were selected for metal analysis. The aspirated blank solution was set to zero. A calibration curve was created. For the relationship between absorbance and standard solution concentration. Direct readings from the instruments were taken for the prepared sample solution. The following formulas were used for the calculation:

According to [28].

Result = AAS Reading X Volume / Weight (1)

Plant analysis

After harvest

After cultivation period of (30,45and 60) day, plant species (*Helianthus annuus L*, *Phragmites australis* and *Cyperus*) were harvested from the soil. Each plant component was thoroughly washed with tap water and then with distilled water to eliminate dust and soil particles. For 24 hours, the clean plant components (roots and shoots) were dried at 105 °C in oven. The plant samples were then ground using pestle and mortar.

Moisture Content

According to [29], the wet basis moisture content for the *Helianthus annuus L*, *Phragmites australis* and *Cyperus* plants under test were determined by selecting random samples from prior to drying, separating them to be prepared for drying, and then drying them in an air-forced electric heater at 105 °C at atmospheric pressure for three hours. The following equation was used to determine the moisture content.

Mcwb = (M wet – M dry) / M wet X 100 (2)

Where:

Mcwb = Moisture content, (wet basis %)

M wet = Mass of wet samples, g.

M dry = Mass of dry samples, g.

Microwave-assisted digestion of soil and plant samples

Plant material was digested by using an open vessel (50 mL polypropylene tube with lid with 3.2 mm diameter vent hole drilled in the center), and then a microwave digestion system (CEM Mars 5, manufactured by CEM Corp., USA), by initial Quantification. using ICP-OES. The sample and HNO_3 mixture were heated at 75 °C for 10 minutes, followed by then to 109 °C for 15 minutes; (2) After cooling for 10 minutes, 1 mL of H_2O_2 was added to each vessel through the vent hole and the sample mixture was heated at 109 °C for additional 15 minutes to a nearly dry state. ICP-MS was used to measure the amount of uranium and thorium in the residue after it had been dissolved in 15 cm3 of 5% HNO_3 and diluted three times. Samples of plant were analyzed using a microwave-assisted digestion method. Teflon bombs containing about 0.5 g of sample were weighed. The samples were then digested using the EPA 3052 procedure after 10 cm3 of HNO_3 was introduced. Following digestion, the materials were quantitatively moved into 10-cm³ polypropylene tubes. The U and Th concentrations were then quantified by ICP-MS with external calibration using Tl as an internal reference after a three-fold dilution. [30]. analyzed using ICP/OES with RF current 1200W and Nebulizer gas pressure 36 L/mi. [31].

Reagents and materials

All acids were of inductively coupled plasma quality (Burdick & Jackson, Germany).The standards used for calibration and overview of the physical operating parameters were ICP-AES and ICP-MS and ICP-OES standard solutions with 1000 ppm peaks on 4 % HNO3 manufactured in Canada. High purity water with resistivity >18MΩ was obtained from Human Lab Instrument Co. and fed with de-ionized water (Aquatron).

In order to validate the U and Th results for soil and plant samples, an IAEA-385.

Transfer Factor (TF) for Plant

The mechanism by which radioactive elements are Transfer factor from soil to plant and from one plant component to another through the roots system is expressed by the transfer factor (TF) parameter. [32].

Transfer factor (TF) = concentration radioactive elements in plant / concentration radioactive elements in soil (3)

The relationship was used to determine the soil to plant transfer factor [33].

Removal Efficiency (RE)

The removal efficiency (RE) of uranium and thorium was calculated using equation after harvest periods (30, 45 and 60 day). Where the initial (Ci_ and final (Cf) concentrations. [34].

Removal efficiency (RE %) = X 100 % (mg / g) (4)

Statistical analysis

Using Microsoft Excel (2016), the plant data were subjected to basic descriptive statistical analysis that comprised measures of dispersion (such as S.D and Average, min and max) for U and Th. These fundamental statistical techniques were applied methodically to enable thorough and rigorous data set investigation, which made it easier to extract insightful information and conclusions that were supported by evidence.

RESULTS AND DISCUSSION

Physical and chemical properties the investigated soils

Representative physical properties of soil in study area are listed (Table1). which show that, the structural composition of the sandy loam soil comes from the source material of the study area in flounced by parent materials in very innovative way [35]. It is an inherent property of soil that is not over affected short period of time [36].

Where the sandy loam texture predominates soil of Wadi al-shaghb (East Nile) and Sebaiya (West Nile) contain enough clay and sediment to provide some structure and fertility, while the clay texture of Bahteem Agricultural Research Station endurance experiment prevails.

Based on the classification by [37], the pH value lies between very slightly acidic and strongly acidic level values across all land use types and both soil depths.

In general, as with most Egyptian soil, the soil pH values studied are above 7.0 with range 7.75 - 8.05.

The Phosphate (P) content of examined soils was between 0.11- 11.96 % which represents sufficient value for plant growth and can be attributed to the continuous application of (P) based fertilizers, This is similar to observation of [38] who reported that, the highest available (P) value in agricultural soil use of study area is 1.56 - 1.69 dS / m^{-1}. while $CaCO_3$ values of all soil samples ranges between 2.30 - 11.75 %.

The total (K) content in the examined soils varied between 0.024 and 21.29 %, especially soil of Bahteem is considered high and sufficient for grown plant.

Table (1): Some physical and chemical properties of the investigated soils.

location / Soil Properties	Wadi Al-shaghb	Sebaiya	Bahteem
pH	8.05	8.01	7.75
Organic matter (%)	2.13	2.19	3.60
EC (dS/m^{-1})	1.56	1.62	1.69
U ($mg\ kg^{-1}$)	70	54	50
Th ($mg\ kg^{-1}$)	18	13	n.d
Co ($mg\ kg^{-1}$)	39	26	12
Mg (%)	0.16	0.12	0.09
K (%)	0.052	0.024	21.29
Fe (%)	2.1	1.99	4.31
Al (%)	0.58	0.49	1.14
SO_3 (%)	1.99	1.74	1.61
CaO ($mg\ kg^{-1}$)	3.8	3.6	1.29
$CaCO_3$ (%)	11.75	10.91	2.30
P (%)	11.79	11.96	0.11
SO_3 (%)	1.99	1.74	1.61
Cl (%)	0.03	0.01	0.09
Zn ($mg\ kg^{-1}$)	277	234	294
Textural class	Sandy loam	Sandy loam	Clay

(n.d non-detectable) means <10µg).

Mean Concentrations of Uranium and Thorium in Soil

In this work the concentration of uranium and thorium was determined at three investigated sites with concentration of range of 50-70 mg kg^{-1} for (U), (Th) 13-18 mg kg^{-1}. Table 2 and Fig (4).

According to [39] the average concentrations of uranium and thorium in sandy loam soil are uranium 2.2 mg kg^{-1} and thorium 9.6 mg kg^{-1}, while in agricultural soils the average uranium is 5.8 mg kg^{-1}. According to [40]. These results are higher than previously mentioned. In addition, the results are higher than in studies by [12,·41and 42]. Different Th and U concentrations can be present in natural soils. In general, certain differences in radionuclide bioavailability between soil can be attributed to on just quantitative features soil [43].

Table (2): Mean concentrations (mg $kg^{-1)}$ of Uranium and Thorium of different soils studied start of planting.

location	U concentration (mg kg^{-1})	Th concentration (mg kg^{-1})
Wadi al-shaghb (East Nile).	70	18
Sebaiya (West Nile).	54	13
Bahteem	50	n. d
Average	58	15.50
Min	50	13
Max	70	18
S.D	10.5830	3.5355

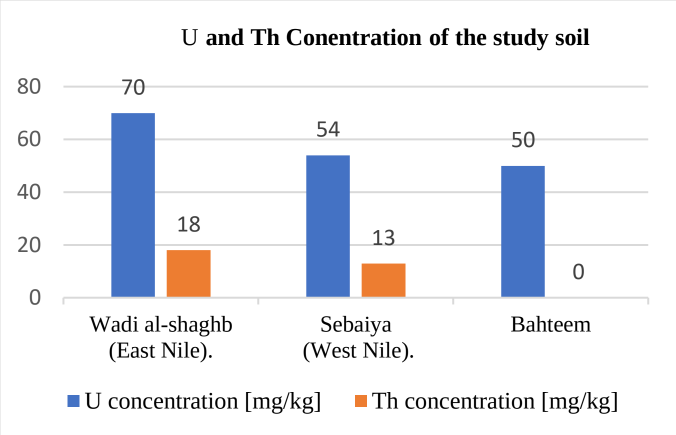

Fig. (4): Mean concentrations (mg kg^{-1}) of U and Th of different soil studied at start of planting.

Effect of temperature on moisture content of plants and drying time

The parts of each plant were weighed separately before drying and placed in oven at temperature of 70 °C one 72 hour to check the percentage weight loss according to the following equation:

Loss %= Dec. (fresh weight-dry weight) /fresh weight x 100.

Moisture content is typically higher at the beginning of drying and then decreases to its lowest value at the end of drying at all temperatures levels. In addition, the exhaust gas temperature of the dryer is lower than the compliance temperature at the beginning of the drying process. Over time, the temperature will increase until it reaches the temperature at the entrance of the dryer, indicating the completion of drying. At this point temperature curve and the curve cross at this point. The connection point takes place earlier than the drying process is normally assumed to take place. When arraying out the drying process, especially at low temperatures, the point in time of the moisture curve and the temperature curve before the intersection point is important. Before the turning point, the entire range between the temperature and moisture curve is used for drying. The entire heat input of the system is used completely for dehumidification.

Fresh and dry yields of the studied plant species

Tables (3,4 and 5). shows the fresh and dry yields of the three plant species three soil types examined in the examined over three periods,.e, 30. 45 and 60 days after cultivation. The data showed that there are generally statistically significant differences between the different time groups (30, 45, 60) days, this applies to roots and total yield. It can also be seen, that Helianthus annuus L plants the highest values of the plant organs examined followed by Phragmites australis and Cyperus The trends obtained were found in the three soil types studied except for plants grown in Sebaiya soil where the lowest yields for shoots and roots as well as the total yield after 45 days post cultivation were obtained for Helianthus and Phragmites plants. It is also important to mention that the yields of the plants studied (shoots, roots and total yield) showed the higher values for all plants growing in Wadi al-Shaghb soils and competed with plants grown in Sebaiya or Bahteem soils, grew where plants grew in Bahteem Soils showed the last values. This may be due to the long period of P fertilization in Bahteem soils, which can negatively impact the yield of the cultivated crops.

Here, too, it is notice able that there are large differences in the fresh and dry yield content of the examined plants and plant organs which can be attributed to calculation of the percentage decrease. In general, the (percentage decrease) varied with harvest period and plant organs in the soils studied. These data. These obtained were consistent with the finding of [44,45].

Table (3): Fresh and dry yields (g /plant) of studied plants grown in Wadi Al-Shaghb soil (East Nile).

Plant organ	Periods (days)	*Helianthus annuus L*			*Phragmites australis*			*Cyperus*		
		Fresh (g)	Dry (g)	Dec. %	Fresh (g)	Dry (g)	Dec. %	Fresh (g)	Dry (g)	Dec. %
Shoots	30	40.33	29.33	27.27	59.33	38.33	35.39	53.67	32.33	39.75
Roots		30.67	17.33	43.48	29.33	20.33	30.68	32.33	21.67	32.99
Total biomass		71.00	46.67	34.27	88.67	58.67	33.83	86.00	54.00	37.21
Shoots	45	58.33	39.33	32.57	71.33	42.67	40.19	62.33	45.67	26.74
Roots		40.67	27.33	32.79	35.33	45.33	28.30	42.33	38.33	9.45
Total biomass		99.00	66.67	32.66	106.67	88.00	17.50	104.67	84.00	19.75
Shoots	60	63.67	42.67	32.98	82.67	51.67	37.50	78.33	52.33	33.19
Roots		45.67	36.33	20.44	45.33	50.33	11.03	53.33	48.67	8.75
Total biomass		109.33	79.00	27.74	128.00	102.00	20.31	131.67	101.00	23.29

* Loss % = Dec. (fresh weight - dry weight) / fresh weight x 100.
* Total biomass = (shoots + roots).

Table (4): Fresh and dry yields (g / plant) of the studied plants grown in Sebaiya soil (West Nile).

Plant organ	Periods (days)	*Helianthus annuus L*			*Phragmites australis*			*Cyperus*		
		Fresh (g)	Dry (g)	Dec. %	Fresh (g)	Dry (g)	Dec. %	Fresh (g)	Dry (g)	Dec. %
Shoots	30	45.33	23.33	48.53	45.33	27.33	39.71	21.33	14.33	32.81
Roots		24.67	17.33	29.73	23.33	14.67	37.14	13.33	11.33	15.00
Total biomass		70.00	40.67	41.90	68.67	42.00	38.83	34.67	25.67	25.96
Shoots	45	54.33	35.33	34.97	50.67	38.33	24.34	38.33	28.67	25.22
Roots		34.33	23.33	32.04	35.67	23.33	34.58	19.67	11.33	42.37
Total biomass		88.67	58.67	33.83	86.33	61.67	28.57	58.00	40.00	31.03
Shoots	60	63.67	42.67	32.98	61.33	49.67	19.02	58.33	40.33	30.86
Roots		48.33	35.33	26.90	45.00	34.67	22.96	25.33	18.67	26.32
Total biomass		112.00	78.00	30.36	106.33	84.33	20.69	83.67	59.00	29.48

* Loss % = Dec. (fresh weight - dry weight) / fresh weight x 100.
* Total biomass = (shoots + roots).

Table (5): Fresh and dry yields (g / plant) of the studied plant grown in Bahteem soil.

Plant organ	Periods (days)	*Helianthus annuus L*			*Phragmites australis*			*Cyperus*		
		Fresh (g)	Dry (g)	Dec. %	Fresh (g)	Dry (g)	Dec. %	Fresh (g)	Dry (g)	Dec. %
Shoots	30	43.33	35.67	17.69	36.33	26.33	27.52	25.33	19.33	23.68
Roots		30.00	22.33	25.56	25.33	18.33	27.63	12.33	8.67	29.73
Total biomass		73.33	58.00	20.91	61.67	44.67	27.57	37.67	28.00	25.66
Shoots	45	50.33	39.67	21.19	46.67	31.67	32.14	34.67	27.33	21.15
Roots		45.33	29.33	35.29	34.67	22.33	35.58	19.33	11.33	41.38
Total biomass		95.67	69.00	27.87	81.33	54.00	33.61	54.00	38.67	28.40
Shoots	60	65.33	45.33	30.61	54.67	41.67	23.78	49.33	31.67	35.81
Roots		50.33	40.33	19.87	43.33	35.33	18.46	23.33	14.33	38.57
Total biomass		115.67	85.67	25.94	98.00	77.00	21.43	72.67	46.00	36.70

* Loss % = Dec. (fresh weight - dry weight) / fresh weight x 100.
* Total biomass = (shoots + roots).

Accumulation of uranium and thorium in different parts of collected plants

Under different conditions, the rates uptake of uranium and thorium in plants vary greatly, as he said [46]. In data (Table 6) the study showed that, in general the amounts of both U and Th are higher in shoots than roots with values fluctuating between high and low depending on the type of plant and the time of year it was harvested. these observed findings point to the great mobility of both elements from roots to aerial plant parts (shoots)

The highest accumulation of uranium in shoots was 211.30 mg $kg^{-1}$of *Helianthus annuus L* in soil Bahteem, followed by Cyperus 193.20 mg kg^{-1} followed by 203.41mg kg^{-1} of *Phragmites australis* in Wadi al-shaghb, While the highest accumulation thorium in Wadi al -shaghb soil was shoots of *Helianthus annuus L* 20.51 mg kg^{-1}, followed by 16.70 mg kg^{-1} of *Cyperus*, followed by *Phragmites australis*, 5.27 mg kg^{-1} of soil in Sebaiya, While the accumulation of uranium in roots varied, recorded as *Helianthus annuus L* 191.7 mg $kg^{-1}$of soil in

Bahteem soil followed by 179 mg kg^{-1}of *Cyperus*, followed by *Phragmites australis* 177.60 mg kg^{-1} of Wadi al-shaghb.

Thorium was recorded at 6.81 mg kg^{-1} of *Helianthus annuus L* in Sebaiya soil and 28.8 mg kg^{-1} of *Cyperus* of Wadi al-shaghb soil.

Additionally, increase the length of time that plant spend in soil causes an increase of analyzed elements the examined plant species and organs. It's also vital to note that (U) content in plant is almost always higher than (Th) content.

It is known that, (U) is more mobile in soil than (Th) and thus, it is more bioavailable. These data agreed with findings of [47].

It is important to mention that the content arranged in Ascending order (U) in plant grown in Bahteem soil > Sebaiya > Wadi al-shaghb soil. This may be due to the ability of these elements with to be higher of Bahteem soil than in other soil studied other studied. (Th) also occurs found in plant cultivated in Wadi al-shaghb, followed by the Sebaiya soil, while it was not found the Bahteem soil. This could be reason for the absence of (Th) the clay soil.

Table (6): Accumulation (mg kg^{-1}) of U and Th in different parts three plant species after (30,45 and 60 day) growth period of study location.

location	Period (days)	Radioactive element (mg kg^{-1})	Plant species					
			Helianthus annuusL		Cyperus		Phragmites australis	
			Shoots (mg kg^{-1})	Roots (mg kg^{-1})	Shoots (mg kg^{-1})	Roots (mg kg^{-1})	Shoots (mg kg^{-1})	Roots (mg kg^{-1})
Wadi Al-shaghb	30	U	8.37	n. d	23.78	n. d	81.39	37.00
		Th	20.51	1.11	16.70	28.80	n. d	n. d
	45	U	178.2	n. d	134.8	48.8	189.4	159.4
		Th	n. d	n. d	n. d	n. d	n. d	n. d
	60	U	199.23	n. d	152.9	61.9	203.41	177.6
		Th	n. d	n. d	n. d	n. d	n. d	n. d
Sebaiya	30	U	49.44	55.00	44.75	79.52	27.52	79.62
		Th	12.65	5.37	3.61	8.91	3.01	n. d
	45	U	63.90	62.00	50.48	85.72	31.12	84.22
		Th	18.10	6.81	3.91	9.87	3.41	n. d
	60	U	66.70	63.97	5.07	12.38	33.69	94.79
		Th	18.97	7.45	5.07	12.38	5.27	n. d
Bahteem	30	U	63.40	117.7	97.40	118.5	142.70	n. d
		Th	n. d	n. d	n. d	n. d	n. d	n. d
	45	U	196.40	187.60	185.10	165.40	186.40	n. d
		Th	n. d	n. d	n. d	n. d	n. d	n. d
	60	U	211.30	191.70	193.20	179.00	194.10	n. d
		Th	n. d	n. d	n. d	n. d	n. d	n. d
Average			85.16	69.87	70.52	67.59	91.78	105.43
Min			8.37	1.11	3.61	8.91	3.01	37
Max			211.30	191.70	193.20	179.00	203.41	177.60
S.D			79.9522	73.0825	72.7140	60.1537	84.4613	52.9776

(n.d non-detectable) means <10μg).

Transfer factor (TF) for plants and removal efficiency (RE%)

(Table 4, Fig 5,6 and 7) show the transfer coefficient and removal ratio of uranium and thorium. The results showed that the transfer factor (TF) values among the studied plant species varied significantly during the studied harvest periods. The values of Transfer factor (TF) for Uranium in Wadi al-shaghb ranged ascendingly as follows:0.11- 2.54 -2.84 mg kg $^{-1}$ of *Helianthus annuus L* after three harvest periods of the experiment, while the Transfer factor (TF) of *Cyprus* plant ranged ascendingly 0.33-2.62 -3.06 mg kg^{-1}, while of the *Phragmites australis* plant the results were ascendingly 1.69 - 4.98 - 5.44 mg kg^{-1}

The lowest Transfer factor (TF) 0.11 mg kg^{-1}of 30 day harvest period of *Helianthus annuus* L, while the highest Transfer factor is 5.44 mg kg^{-1}of *Phragmites australis.*

In Sebaiya, the results of Uranium were Transfer factor (TF) ascending:

Helianthus annuus L. 1.93-2.33 - 2.41 mg kg^{-1}, *Cyperus*.2.30 - 2.52 - 0.32 mg kg^{-1},

Phragmites australis.1.98 -2.13 - 2.37 mg kg^{-1} The lowest transfer factor (TF) was 0.32 mg kg^{-1}at harvest period at 60 day of *Cyprus*, while highest transfer facto (TF) was 52.2 mg kg-^{1} of *Cyprus.*

Also in Bahteem, the results came in ascending order as follows:

Helianthus annuus L. 3.62-7.68 - 8.06 mg kg^{-1}, *Cyperus*.4.31 -7.01 -7.44 mg kg^{-1},

*Phragmites australis.*2.85 -3.72-3.88 mg kg^{-1}The lowest transfer factor (TF) was 3.62 mg kg^{-1} at harvest period of 30 day at *Helianthus annuus L,* while the highest transfer factor (TF) was 8.06 mg kg^{-1} of *Helianthus annuus L*.

The Transfer factor (TF) of plant studied varied between high and low depending at harvest time of plant, plant species, temperature, It was noted of study transfer factor (TF) coefficient in three plants was high in growth stages at 45 and 60 day compared at 30 day [48].

Noticed by experience thorium and uranium can be strongly absorbed by *Phragmites australies* [47] *Cyperus* have a higher potential for treating soil contaminated with uranium and thorium and are superior in terms of both concentration and TF [23], the Transfer factor (TF) is 1 > meaning that *Helianthus annuus L*, *Cyperus* and *Phragmites australis* can be used to detect radioactive elements and perform phytoremediation, when uranium and thorium accumulate in different plant parts roots and shoots [49].

In experience removal efficiency (RE%).of uranium in Wadi al-shaghb of total three harvest periods was as follows: *Helianthus annuus L*.was 33.33 mg kg^{-1} Cyperus 23.81mg kg^{-1} and *Phragmites australis* 42.86 mg kg^{-1} The total removal efficiency (RE%) of Sebaiya at *Helianthus annuus L*.was 51.88 mg kg^{-1}, Cyperus 26.15 mg kg^{-1} and *Phragmites australis* 31.88 mg kg$^{-1.}$ The results of Bahteem were 58.34 mg kg^{-1} of *Helianthus annuus L*.,16.21 mg kg^{-1} of *Cyperus* and 25 mg kg $^{-1}$of *Phragmites australis*.

The highest uranium removal efficiency (RE%). of Bahteem was recorded for *Helianthus annuus L* plant, where it was 58.34 mg kg^{-1} , While the lowest removal efficiency (RE%) was recorded at 15.26 mg kg^{-1} at Cyperus plant of Sebaiya.

The removal efficiency (RE%) of thorium in Wadi al-shaghb of total harvest periods was as follows: *Helianthus annuus L*. was 42 mg kg, *Cyperus* 16 mg kg^{-1} and *Phragmites australis* 35 mg kg^{-1} . The total removal efficiency (RE%) in Sebaiya of *Helianthus annuus L*.was 13.75 mg kg^{-1}, *Cyperus* 2.50 mg kg^{-1} and *Phragmites australis* 35 mg kg^{-1}, While the element thorium was (n.d non-detectable) the soil of Bahteem, The highest thorium removal efficiency (RE%). of Bahteem was recorded for *Helianthus annuus L* plant, where it was 42mg kg^{-1}, While the lowest removal efficiency (RE%). was recorded at 2.5 mg kg^{-1} of *Cyperus* plant in Sebaiya.

Table (4): Transfer factor (TF), Removal efficiency (RE). of plant collected for uranium and thorium in studied plant types grown of study.

location	Period (day)	Radioactive element	Plant species					
			Helianthus annuusL		*Cyperus*		*Phragmites australis*	
			TF (mg kg-1)	RE % mg kg-1)	TF (mg kg-1)	RE % (mg kg-1)	TF (mg kg-1)	RE % (mg kg-1)
Wadi Al-shaghb	30	U	0.11	7.14	0.33	4.76	1.69	9.52
		Th	1.20	17.50	2.52	11.25	n. d	n. d
	45	U	2.54	11.90	2.62	14.29	4.98	14.29
		Th	n. d	25.00	n. d	2.50	n. d	n. d
	60	U	2.84	14.29	3.06	4.76	5.44	19.05
		Th	n. d	n. d	n. d	6.25	n. d	n. d
Sebaiya	30	U	1.93	16.25	2.30	3.75	1.98	6.25
		Th	1.38	13.75	0.96	2.50	0.23	35.00
	45	U	2.33	16.88	2.52	4.38	2.13	8.75
		Th	1.91	n. d	1.05	n. d	0.26	n. d
	60	U	2.41	18.75	0.32	8.13	2.37	16.88
		Th	2.03	n. d	1.34	n. d	0.40	n. d
Bahteem	30	U	3.62	16.67	4.31	2.50	2.85	6.67
		Th	n. d	n. d	n. d	n. d	n. d	n. d
	45	U	7.68	19.17	7.01	5.38	3.72	7.50
		Th	n. d	n. d	n. d	n. d	n. d	n. d
	60	U	8.06	22.50	7.44	8.33	3.88	10.83
		Th	n. d	n. d	n. d	n. d	n. d	n. d
Average			2.92	16.85	2.75	6.06	2.49	13.47
Min			0.11	7.14	0.32	2.5	0.23	6.25
Max			8.06	25	7.44	14.29	5.44	35.00
S.D			2.3513	4.6964	2.2884	3.5842	1.7573	8.7294

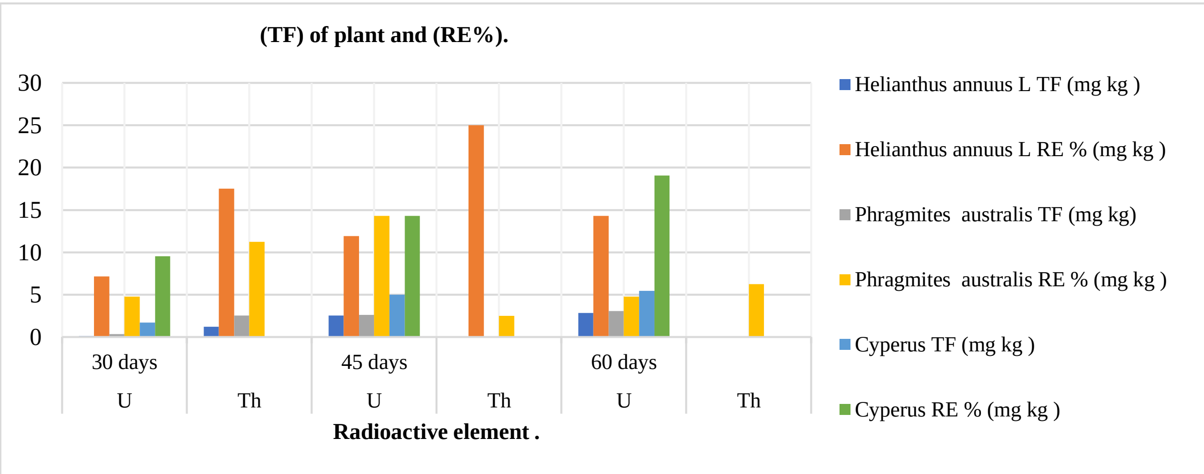

Fig. (5): Transfer factor (TF) of plant and Removal efficiency (RE%) in Wadi al-shaghb

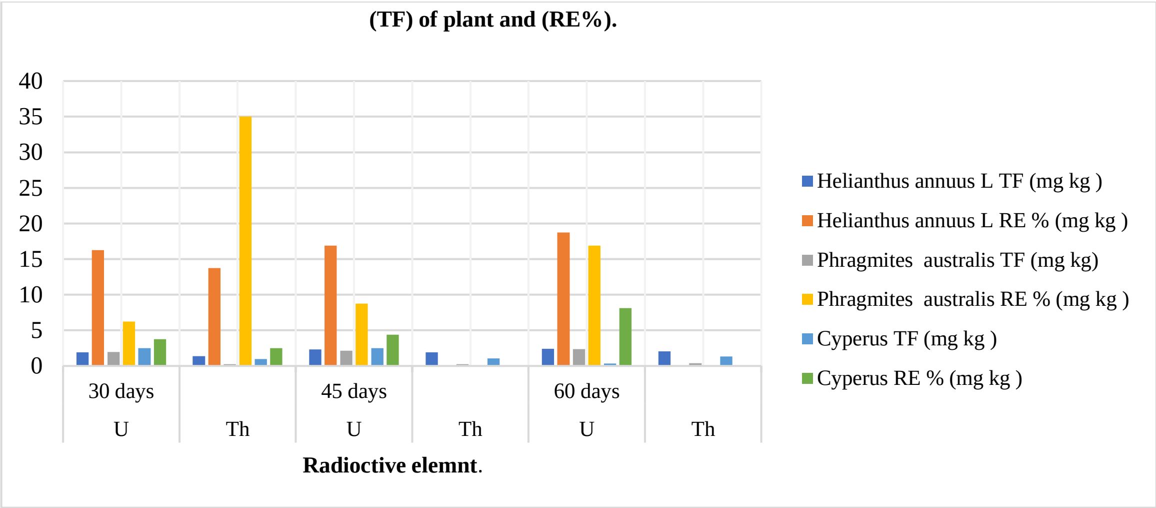

Fig. (6): Transfer factor (TF) of plant and Removal efficiency (RE%) in sebaiya.

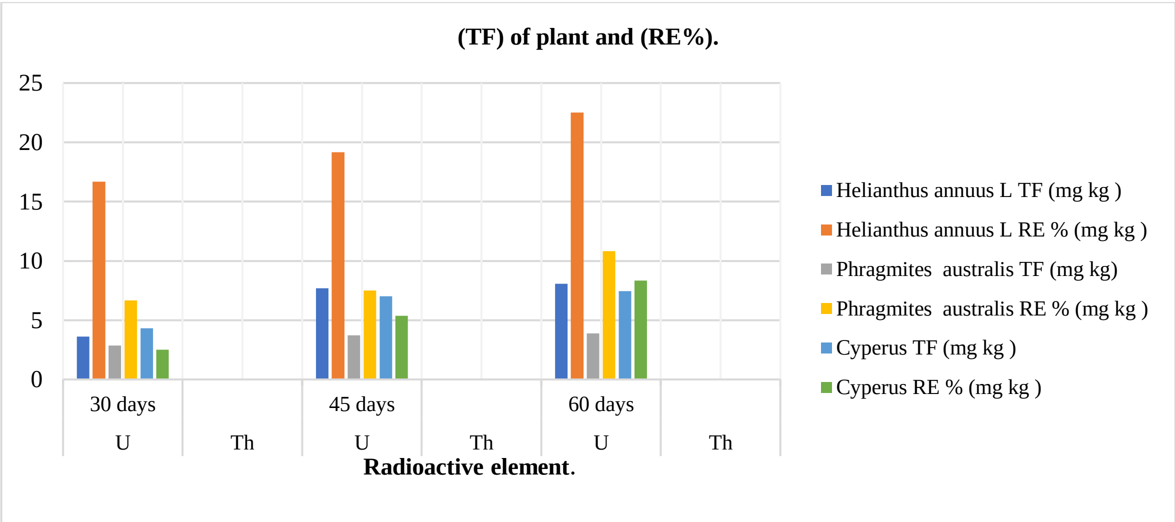

Fig. (7): Transfer factor (TF) of plant and Removal efficiency (RE%) in Bahteem

Table (5): Concentration (mg/ kg) of uranium and thorium of soil after harvesting plant a period at (30.45 and 60 days).

Location	(U) Initial Concentration (mg kg^{-1})	(U) Final Concentration (mg kg^{-1})	(Th) Initial Concentration (mg kg^{-1})	(Th) Final Concentration (mg kg^{-1})
Wadi Al-shaghb	70	21	18	4
Sebaiya	54	8	13	1
Bahteem	50	6	n. d	n. d

(n.d. means <10µg)

Table 5 and Figures (8 and 9 shows that, the high concentrations of uranium and thorium are considered the areas of Al-Nasr phosphate of East Nile, were 70 mg kg^{-1} for uranium and 18 mg kg^{-1} for thorium, of (West Nile) areas, uranium was 54 mg kg^{-1} and 13 mg kg-^{1} thorium.

According to [50] the maximum adsorption rate of thorium on clays, oxides and organic matter occurs at pH value of 6.5. These results indicate that in soils with high organic matter content, thorium complexes are probably going to dominate over inorganic complexes.

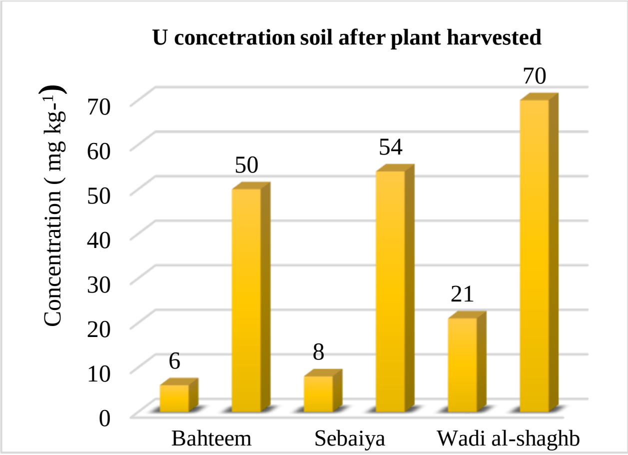

Fig. (8): The remaining uranium of soil after harvesting plants over period at (30.45 and 60 day).

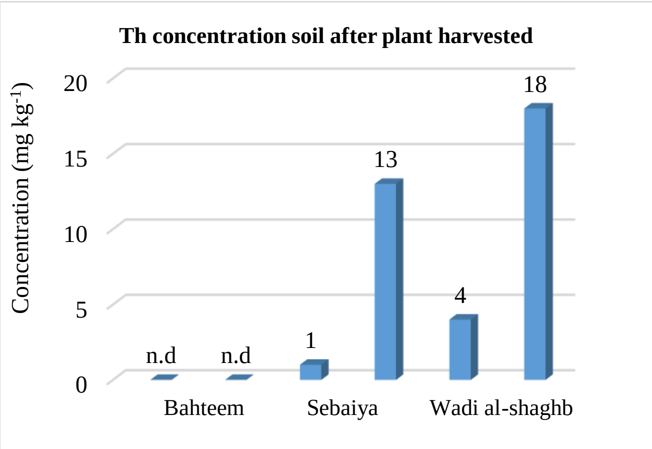

Fig. (9): The remaining thorium of soil after harvesting plants over period at (30.45 and 60 day).

Relationships between U and Th in soils and in different plant parts and Transfer factor of these radionuclides from soil to plants

Many radioecological evaluations are predicated on the idea that, under specific ecological and agricultural circumstances, the transfer of radionuclides from soil to plants follows a positive linear relationship [51].

Only sophisticated models that take into account a number of soil properties can be used to forecast uranium uptake by soil-grown plants, as it is not correlated with straightforward bioavailability factors [52].

The relationships between uranium and thorium may differ significantly depending on the soil type if we compare the relationships between uranium and thorium in three study areas, where it is noted that the correlation between uranium accumulation roots and shoots of Phragmites australis at age 30 days of Wadi Al-shaghb, as well as the Cyperus in roots and shoots of Sebaiya and roots and shoots of Helianthus annuusL in Bahteem all of which are statistically significant results, while no correlation was found between thorium and three plant species at the different three harvest periods, as shown Table (6)

Transfer factor of plant species was statistically significant for uranium in Wadi Al-Shaghb and Sebaiya, while it did not achieve statistical significance for thorium in Bahteem soil at different harvest periods, as shown Table (7).

U and Th have similar chemical properties. However, as we could see, behavior of these metals in soil and in plants (more exactly, in different plant parts) may be different, thus suggesting that there are probably additional factors affecting chemistry of Fig. 2. Relationship between U in soil and in roots of rye and wheat. these radionuclides in the soil–plant system.

Advantages and disadvantages of phytoremediation

Solidification, soil washing, and permeable barriers are some of the alternative common remediation procedures used to clean up radioactively contaminated environments. However, most of these technologies are costly to deploy and worsen the already contaminated environment. An increasingly viable substitute for expensive, high-energy traditional techniques is phytoremediation. In terms of cutting-edge cleanup technology, it is seen as a "Green revolution."

When compared to other remediation procedures, the phytoremediation systems have several prospective advantages, specifically.

is less expensive than conventional methods, both in situ and ex situ;

- The plants are plainly observable.
- The potential for businesses to recover and repurpose important metals focusing on "phyto mining";
- Because it uses naturally occurring organisms and maintains the ecosystem in a more natural form, it may be the least destructive approach.

However, using phytoremediation techniques has a number of significant drawbacks as well.

- Low biomass and slow growth necessitate a sustained commitment.
- Phytoremediation is restricted to the surface area and depth occupied by the roots.
- It's impossible to totally avoid using plant-based cleanup solutions.

the release of pollutants into groundwater (without the contaminated land being entirely removed, which by itself doesn't fix the issue of contamination.

- The toxicity of the contaminated land affects the plants' ability to survive, and

the overall state of the soil .

- The bioaccumulation of pollutants in plants, particularly radionuclides which subsequently go up the food chain from basic consumers or demands that the impacted plant material be disposed of safely.

CONCLUSION

In greenhouse pots, The mobility of uranium and thorium in soil, as well as their bioavailability to a variety of plant types, were examined.

The results of uranium absorption in the three soils examined were as follows: *Phragmites australis L* plant followed by *Helianthus annuus L* plant followed by Cyperus plant. Also the results of thorium uptake in three soils examined are as follows *Helianthus annuus L*, followed by *Cyperus*, followed by *Phragmites australis.*

The element thorium could not be detected, especially in old clay soil of particular. While it was found in the sandy loam soil.

The radionuclides uranium and thorium originate come from phosphate rock; can be slowed down to varying degrees in Phosphate fertilizers. This conclusion of this study indicates that, possible uranium accumulation in the soil over time is to be expected due to the high application rate of phosphate fertilizers in the harvested soil, especially Bahteem soil.

The connections between thorium and uranium of soil and plant depend significantly on the type of soil and the time at harvested. There is also a need to identify more plants that demonstrate improved resistance to radionuclides and better suited to radiation toxicity.

After reviewing previous research, we found that many plant species, especially model plants such as *Helianthus annuus L*., *Phragmites australis*, and *Cyprus*, are able to remove uranium and thorium from the soil.

RECOMMENDATIONS

1- Study the behavior of uranium and thorium in soil and assessing the radiation status allows solving many problems.

2-This research can be augmented by monitoring the activity concentrations levels of various chemical fertilizers and studying their effects.

3- The activity concentrations of uranium and thorium in soil samples should be tested periodically.

CONFLICTS OF INTEREST

The author declare that this study report is free of conflict of interest.

DATA AND MATERIALS AVAILABILITY

All the data's available in the manuscript.

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