

EG0800289

Quantitative Mechanistic Description of Natural Radionuclide and Iron Sorption on phosphate Fertilizer Materials

N. H. M. Kamel

Radiation Protection Department, Nuclear Research Center, Atomic Energy Authority, P.

Box13759, Cairo-Egypt

Narimankamel@hotmail.com

ABSTRACT

The mean activity values of the radionuclide ^{226}Ra , ^{238}U and ^{232}Th decay series, and the radioactive isotopes of ^{40}K in Bq/kg dry weight of the phosphate ore (Pho-ore), single super phosphate granules, (SSP-G), single super phosphate powder (SSP-P), triple super phosphate (TSP), and phosphogypsum (CaSO_4) samples were determined. CaSO_4 sample was found to contain, 300 Bq/kg of radioactive ^{238}U which is less than the values found in other studied phosphate samples. CaSO_4 sample was found to contain the highest amount of ^{226}Ra concentration value of 850 Bq/kg. Phosphate fertilizer components are acidic character, therefore, the solid surfaces will in general acquire a surface electric charge when contact with polar solvent such as water. The net electric charge obtained through uptake or release of potential determining ions (e.g, H^+ or OH^-). Thus the solid surfaces tend to adsorb and/or release of different ions to maintain neutral. The aim of this study is to determine the electric charge and the surface electric potential at the phosphate fertilizer materials.

Key words: Phosphate/ Natural Radioactivity/ Leaching/ Electric Potential.

INTRODUCTION

Phosphate fertilizer materials is derived from the phosphate rock, it contains natural occurring radionuclides of the uranium (^{238}U), radium (^{226}Ra) decay series and the radioactive isotope of potassium (^{40}K). A wide variation in the uranium and radium concentrations in phosphate rocks was observed from various parts of the world^(1, 2). For uranium, a range from 3 to 400 ppm, corresponding to 37-4900 Bq ^{238}U /kg (1 ppm U=12.23 Bq ^{238}U /kg), and for ^{226}Ra a range from 100 to 10,000 Bq/kg. The industrial phosphate products are generally obtained by the reaction of sulphuric and phosphoric acids with the phosphate ore. Phosphate fertilizer materials provided soils by phosphorous, whereas, phosphate fertilizers hydrolyzed to soil solution. Phosphorous, uranium, iron and aluminum may be released by the phosphate fluid to soils-aqueous phases. Adsorption of uranium on soils depends on the composition of the soils, the cation exchange capacity, amount of fertilizers added to the soil, concentrations of uranium in the fertilizer material, the carbonate content, as well as organic⁽³⁾. The pH value of the soil type is the main factor determining uranium uptake by the soil. The pH of the soil has a great effect on the sorption of metal, where the sorption at the soil surfaces decreases at the low pH values of less than 3. Sorption^(3, 4) generally increase with increasing the pH values from pH 3 to 5 to reach a maximum adsorption in the pH range of pH 5.0 to 7.0-8.0 This is followed by a decrease with increasing pH values greater than 8.0.

In this contribution, the main natural occurring radioactive nuclides were determined in different fertilizer phosphate materials. The effective exposure dose for the presence of the naturally occurring radionuclides at the phosphate materials was calculated. Further leaching of radioactive material with water was carried out.. The surface charge density and the surface electric potential due to the remaining of phosphorous, iron and uranium at the phosphate materials are calculated⁽⁵⁾ and discussed

EXPERIMENTAL

Sampling

Phosphate fertilizers samples including; phosphate ore (Pho-Ore), phosphate products (SSP-G, SSP-P, and TSP samples), and CaSO₄ (by-product) samples were obtained from Abu Zaabal fertilizer chemical company in Egypt. About 200 g of the phosphate fertilizer samples were dried at 110 °C, for 24 hours, and sieved using sieves of the grain size distribution between 300 and 170 µm.

Chemical Analyses

The phosphate fertilizer samples were digested with hydrofluoric and perchloric acids. Concentrations of U(VI), Al³⁺, Fe³⁺, P³⁺ in the digested aqueous phosphate samples were determined as oxide percentage⁽³⁾, whereas, Al³⁺, and Fe³⁺ concentrations were determined using 1-iodo-2-naphthol-4-sulphonic acid (Ferron indicator)⁽⁶⁾. Phosphorous was determined by molybdate method⁽⁶⁾, and U(VI), was determined colorimetry using, 1-(pyridyl-2-Azo-Resorcinol) indicator, (PAR), in the presence of borate buffer solution at the pH value 3-10 at the wavelength 510 nm. Th (IV) was determined colorimetry using Arzinazo III indicator and measured at the wavelength 565 nm⁽⁷⁾. Spectrophotometer of model 7800, Jasco, UV/visible was provided with Microsoft computer was used for analyses. Carbonates was determined by back titration. The soil samples were digested in sodium hydroxide for the determination of silica content. Calcium and magnesium were determined by titrations, sodium and potassium were determined using flam photometer⁽⁸⁾. The specific surface area of the soil and the phosphate fertilizer samples were determined using ethylene glycol method⁽⁹⁾. The pH of the solid samples in distilled water was measured using a pH meter model, Inolab, WTW level 1.

Radiological Analyses

The radioactivity measurements were performed using a high-resolution gamma spectroscopic system employing a high purity germanium crystal (HPGe) coupled with multichannel analyzer (TENNELEC); it is a p-type co-axial detector (Nucleus Model No.CPVD530-10195). Radioactivity concentration of each sample was measured for about 24 hours .The background measurements were also measured. Activity measurements were made one month later to asses an equilibrium between ²²⁶Ra, ²³⁸U, and ²³²Th series . The gamma – transmissions used for activity calculations are 351.9 for Pb-214, 609.3, 1120.3, and 1764.5 kev, Bi-214 for the Ra-226 series, 338.4, 911.1 and 968.9 kev, Ac-228 for the Th-232 series and 1460 kev for K-40. The gamma spectrometers were calibrated using both uranium RG.U1, and thorium RTh.1 standard sources, and potassium chloride RGK1 standard solutions, obtained from IAEA in the same geometry as the samples⁽⁹⁾.

Dissolution

Known amount around 2 gm of the pho-ore, phosphate products (SSP-G, SSP-P, TSP) and CaSO₄ samples were shaken with 20 ml distilled water in 50 ml of polyethylene bottle using a solid to water ratio of 1: 20, 1:10, 1:5, 1:2, and 1:1. After various contact of time intervals, 1, 2, 3, 4, 5, 6 days, the pH of the solid-aqueous phases was measured, then the aqueous phases were separated, filtered and analyzed for UO₂²⁺, PO₄³⁻, and Fe³⁺ released.

RESULTS AND DISCUSSION

The mean activity values of ^{226}Ra , ^{238}U and ^{232}Th decay series, and the radioactive isotopes of ^{40}K in Bq/kg of the dry weight phosphate samples are given in Table 1. CaSO_4 sample was found to contain 300 Bq/kg of the radioactive uranium-238 which is less than the values of that observed in the other phosphate samples. For ^{226}Ra , CaSO_4 sample contained 850 Bq/kg which is the highest compared to other samples. Thorium-232 activity concentrations were found between 14 to 24 Bq/kg, and potassium (^{40}K) activity concentrations were found between 45 to 240 Bq/kg for the other different materials investigated. The variations in radium activity concentrations can be explained as follows; in the chemical production process ^{226}Ra is precipitated as an insoluble radium sulfate with other solid waste products of calcium sulphate, while ^{238}U remained in the liquid phase as uranyl complex⁽¹⁰⁾.

Radium equivalent (Bq/kg) concentrations are based on the following Equation⁽¹¹⁾ was calculated in Table 1

$$\text{Ra}_{\text{eq}} = A_{\text{Ra-226}} + (A_{\text{Th-232}} \times 1.43) + (A_{\text{K-40}} \times 0.077) \quad (1)$$

Where, Ra_{eq} , is the radium equivalent, $A_{\text{Ra-226}}$, $A_{\text{Th-232}}$, $A_{\text{K-40}}$ are the activity concentrations (Bq/kg) of the ^{226}Ra , ^{232}Th and ^{40}K in the investigated sample respectively.

Ra_{eq} was found between 330 and 881 Bq/kg. This value is lower than the values of radium equivalent values (148-1406 Bq/kg) of that reported for other countries^(12, 13).

The change of the radioactivity concentrations could be due to the separation of uranium into the phosphate products and by-products. The presence of ^{226}Ra activity concentrations at the phosphate materials was accounted by the following approach:

Four natural radium isotopes occur in the environment, of these ^{226}Ra and ^{228}Ra have relatively long half-lives, 1602 years and 5.8 years. The half-lives of the other radium isotopes ^{223}Ra , ^{224}Ra are only 11.4 and 3.7 days respectively. ^{226}Ra has the highest alpha emitter energy, while ^{228}Ra has a low-beta emitter energy. ^{226}Ra is a member of ^{238}U decay series. While ^{228}Ra is the second member of the ^{232}Th series⁽¹⁴⁾. ^{232}Th is found in low concentrations in phosphate fertilizers, it has insoluble properties. Therefore, ^{228}Ra was not detectable at the phosphate products. The highest radium content in phosphate rocks has the higher of the radioactivity impact for the radiation doses⁽¹⁵⁾.

Table 1.

The Specific activity (Bq/kg) of the ^{238}U , ^{226}Ra , ^{232}Th , and ^{40}K Radioactive Isotope and Radium Equivalent (Bq/kg) Values in the Ph-ore, SSP-G, SSP-P, TSP and CaSO_4 Samples.

Sample	^{238}U	^{226}Ra	^{232}Th	^{40}K	Ra.eq
	(Bq/kg)				
Ph-ore	840	700	30	28	745
SSP-G	400	219	20	14	248.6
SSP-P	512	300	20	20	330
TSP	740	594	25	24	631.5
CaSO_4	300	850	21	11	880.8

Chemical analyses of the phosphate samples are given in Table 2 show that phosphate sample contain 20 % of P_2O_5 while, SSP-G and SSP-P products samples were found to contain 15.2 and 17.4 % P_2O_5 , and TSP product analyzed sample contained 37 % P_2O_5 . These are within the range of P_2O_5 4 to 38 % observed in the phosphate ore samples by other investigations⁽¹⁵⁾. Chemical analyses of the phosphate ore sample was found to contain 3.93 % of Al_2O_3 , and chemical

analyses of Fe₂O₃ % was found between 3 to 9 % which are higher than of that reported between, 0.1 to 1.4 % in the literature⁽¹⁵⁾. Uranium (VI) concentration is 72 ppm in the pho-ore sample, and ThO₂ was found to be less than 1.0 %, in all the phosphate samples which are within the range of that reported^(15, 16).

Table 2: Chemical Analyses of the Commercial Phosphate Fertilizer Samples.

Sample	Phosphate Ore	SSP Granule	SSP Powder	TSP	Calcium sulphate
		Phosphate Products			By-product
P ₂ O ₅ %	19.86	17.4	15.2	37	18.75
Fe ₂ O ₃ %	5.3	4.96	3.24	8.9	5.07
Al ₂ O ₃ %	3.93	0.53	2.72	0.6	0.91
CaO %	20.16	8.96	14.78	9.41	16.6
MgO %	6.95	14.96	9.62	1.07	6.95
Na ₂ O %	0.38	0.12	0.32	0.48	0.12
K ₂ O %	0.34	0.15	0.39	0.58	0.15
SO ₄	3	17.8	11.2	22.6	3.6
CO ₃ %	16.94	0.12	7.2	Nil	Nil
U(VI) (ppm)	72	36	45	65	29
Th (IV)	0.79	0.49	0.49	0.62	0.52
PH	7.25	2.33	2.4	2.34	2.41

Surface Complex Reaction

Mineral present in natural system do not exist in pure form. Their surfaces are coated with thin layers of alteration products and secondary minerals which are often complex mixtures of meta stable amorphous microcrystalline (hydro) oxides⁽⁵⁾ of Fe, Mn, Al, and Si. The release of these ions is extremely dependent on the composition of the solid material, and the pH of the colloidal substance in water^(5, 16). Surface complex model was used to show how the major ions can be held by the solid phase. The ions were quantitatively described by the mass action (equilibrium constant) equation. Consider a system consisting of a single solid phase in water. The solid surface is electrically charged in water, the electric surface charge is calculated from the amount of ions that sorbed, and the specific surface area of the solid phase:

The pH values of the phosphate samples in distilled water was found between 3.3 to 2.3 , using the solid to aqueous phase ratio of, 1: 20, 1: 15, 1:10, 1:5, and 1 : 2.. Concentrations of the, PO₄³⁻, Fe³⁺ and U(VI) remained (mol/l) and that adsorbed (mol/kg) was determined, where the remained values (mol/kg) was calculated from an initial of ion concentrations and that released by the phosphate fertilizer samples are given in Table 3. Concentrations of PO₄³⁻ released was found between, 0.8 to 6 × 10⁻⁴ mol l⁻¹. Concentrations of Fe(III) released was found between 0.10 and 2.3 × 10⁻⁵ mol l⁻¹, and concentrations of U(VI) released was found between 0.1 and 2.5 × 10⁻⁶ mol l⁻¹.

The specific surface area of the phosphate samples were determined using ethylene glycol method⁽¹⁷⁾, and found to equal 18, 22, 17, and 20 m²/g for the SSP-G, SSP-P, TSP, and CaSO₄ samples respectively.

On the basis of the experimental data given in Table 3, and the SSA values, the surface charge densities at the phosphate samples were calculated as⁽¹⁷⁾:

$$\sigma_p = \frac{F}{S} [\{total[(\cong S - OH^o)]\}] \quad (2)$$

Where, σ_p is the surface charge density (coloumbs/m²), F is the Faraday constant, (96,490coloumbs/mol), S is the specific surface area (m²/g), and, $\cong S-OH^o$ is the sorption density of adsorbed ions (mol/kg) for the PO₄³⁻, UO₂²⁺, and Fe³⁺ respectively at the given pH value between, 3.2 and 2.3. Table 4, shows that, the net surface charge density at the phosphate surface materials was found almost independent on the solid to aqueous ratio, it was found dependent on the kind of the cation adsorbed.

Table 3
concentrations of PO₄³⁻, Fe³⁺, and U(VI) remained (mol/g), and released (mol l⁻¹) by the SSP-G, SSP-P, TSP, products and phosphogypsum by-product phosphate samples.

SSP-G phosphate product sample						
Solid: water ratio	Concentrations of PO ₄ ³⁻ , U(VI), and Fe ³⁺ (≅SOH ₂ ⁺) remained (mol/g) × 10 ⁻³			Concentrations of PO ₄ ³⁻ , U(VI), and Fe ³⁺ (≅SO ⁻) released (mol/l)		
	PO ₄ ³⁻	U (VI)	Fe ³⁺	PO ₄ ³⁻ × 10 ⁻⁴	U(VI) × 10 ⁻⁶	Fe ³⁺ × 10 ⁻⁵
1:20	0.32	0.01	0.03	2.9	0.84	0.1
1:10	0.39	0.01	0.02	2.2	0.13	0.5
1:5	0.46	0.01	0.01	1.4	0.11	1.4
1:2	0.48	0.01	0.02	1.3	0.10	0.80
1:1	0.46	0.01	0.02	1.5	0.08	0.79
SSP-P phosphate product sample						
Solid: water ratio	Concentrations of P, U, and Fe remained (mol/g) × 10 ⁻³			Concentrations of P, U, and Fe dissolved mol/l)		
	PO ₄ ³⁻	U (VI)	Fe ³⁺	PO ₄ ³⁻ × 10 ⁻⁴	U(VI) × 10 ⁻⁶	Fe ³⁺ × 10 ⁻⁵
1:20	0.28	0.02	0.04	3.8	2.5	1.4
1:10	0.41	0.02	0.05	2.5	2.1	1.1
1:5	0.47	0.02	0.05	1.9	1.6	1.1
1:2	0.46	0.02	0.04	2.0	1.3	1.3
1:1	0.48	0.02	0.05	1.8	1.0	1.2
TSP phosphate product sample						
Solid: water ratio	Concentrations of P, U, and Fe remained (mol/g) × 10 ⁻³			Concentrations of P, U, and Fe dissolved mol/l)		
	PO ₄ ³⁻	U (VI)	Fe ³⁺	PO ₄ ³⁻ × 10 ⁻⁴	U(VI) × 10 ⁻⁶	Fe ³⁺ × 10 ⁻⁵
1:20	0.61	0.03	0.08	1.8	1.7	0.18
1:10	0.61	0.03	0.08	1.8	1.7	0.25
1:5	0.66	0.03	0.06	1.3	1.3	1.8
1:2	0.64	0.03	0.06	1.5	1.4	2.3
1:1	0.63	0.03	0.06	1.5	1.3	2.0
Phosphogypsum phosphate by-product sample						
Solid: water ratio	Concentrations of P, U, and Fe remained (mol/g) × 10 ⁻³			Concentrations of P, U, and Fe dissolved mol/l)		
	PO ₄ ³⁻	U (VI)	Fe ³⁺	PO ₄ ³⁻ × 10 ⁻⁴	U(VI) × 10 ⁻⁶	Fe ³⁺ × 10 ⁻⁵
1:20	0.63	0.01	0.01	0.89	2.9	1.1
1:10	0.65	0.01	0.01	0.76	1.8	1.3
1:5	0.64	0.01	0.02	0.84	1.3	0.90
1:2	0.63	0.01	0.02	0.94	1.3	0.7
1:1	0.63	0.01	0.02	0.91	1.3	0.6

The, electric surface potential Ψ (Volts) is the potential that required for the transfer of one mol of ion from an aqueous solution to the solid surface. The electric surface potential is calculated from concentrations of the ions released (mol/l), and the surface charge density values as⁽¹⁷⁾:

$$\sigma_p = 0.1174 (C)^{1/2} \sinh (F\Psi \times 19.46) \quad (3)$$

Where, C is the aqueous og ion concentrations (mo/l), and F is the Faraday constant

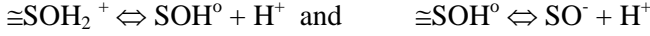
Table 4: the electric potential values for the leaching of P, U, and iron by distilled water

SSP-G phosphate product sample						
Solid: water ratio	Charge density (m2/columbs)				Electric Potential (volts)	
	PO₄³⁻ (SSP-P)	U (VI) (SSP-P)	Fe³⁺ (SSP-P)	PO₄³⁻ (SSP-P)	U (VI) (SSP-P)	Fe³⁺ (SSP-P)
1:20	1.74	0.08	0.14	0.205	0.197	0.220
1:10	2.09	0.08	0.12	0.223	0.185	0.172
1:5	2.46	0.08	0.07	0.241	0.189	0.118
1:2	2.58	0.08	0.10	0.247	0.191	0.147
1:1	2.44	0.08	0.10	0.240	0.197	0.153
SSP-P phosphate product sample						
Solid: water ratio	Charge density (m2/columbs)				Electric Potential (volts)	
	PO₄³⁻ (SSP-P)	U (VI) (SSP-P)	Fe³⁺ (SSP-P)	PO₄³⁻ (SSP-P)	U (VI) (SSP-P)	Fe³⁺ (SSP-P)
1:20	1.22	0.07	0.19	0.18	0.16	0.17
1:10	1.78	0.07	0.20	0.21	0.17	0.18
1:5	2.07	0.08	0.20	0.23	0.18	0.18
1:2	2.00	0.08	0.20	0.22	0.19	0.17
1:1	2.09	0.08	0.20	0.23	0.19	0.18
TSP phosphate product sample						
Solid: water ratio	Charge density (m2/columbs)				Electric Potential (volts)	
	PO₄³⁻ (SSP-P)	U (VI) (SSP-P)	Fe³⁺ (SSP-P)	PO₄³⁻ (SSP-P)	U (VI) (SSP-P)	Fe³⁺ (SSP-P)
1:20	3.45	0.15	0.44	0.25	0.21	0.27
1:10	3.45	0.15	0.43	0.25	0.21	0.26
1:5	3.74	0.15	0.35	0.27	0.22	0.19
1:2	3.63	0.15	0.32	0.26	0.22	0.18
1:1	3.60	0.15	0.33	0.26	0.22	0.19
Phosphogypsum phosphate by- product sample						
Solid: water ratio	Charge density (m2/columbs)				Electric Potential (volts)	
	PO₄³⁻ (SSP-P)	U (VI) (SSP-P)	Fe³⁺ (SSP-P)	PO₄³⁻ (SSP-P)	U (VI) (SSP-P)	Fe³⁺ (SSP-P)
1:20	3.1	0.05	0.07	0.27	0.14	0.13
1:10	3.1	0.05	0.06	0.27	0.15	0.11
1:5	3.1	0.05	0.07	0.27	0.16	0.13

1:2	3.0	0.05	0.09	0.26	0.17	0.15
1:1	3.0	0.05	0.09	0.26	0.16	0.15

The Correction of the Surface Charge Potential

Consider the ionization reactions of the variable charge as:



Where, $\cong\text{SOH}_2^+$, SOH^0 , and $\cong\text{SO}^-$ are the positively charged, neutral and negatively charged surface hydroxyl groups. The conditional of acidity coefficients of the surface species are assumed to be equal. The condition of acidity constants for the above reaction expressed are K_1^{app} , K_2^{app} in which dependent on the pH. Expressed as:

$$K_{a1}^{app} = \frac{[\cong\text{SOH}][\text{H}^+]}{[\cong\text{SOH}_2^+]} \quad (4), \quad \text{and} \quad K_{a2}^{app} = \frac{(\cong\text{SO}^-)(\text{H}^+)}{(\cong\text{SOH}^0)} \quad (5)$$

Permanently charged sites can be present on solid surfaces resulting from isomorphous substitution in a crystalline structural of the solid. (e.g Al^{3+} substitute for Si^{4+}) by the phosphate materials. Surface complexation adsorption treat the sorbent surface as a plane of hydroxyl groups, $\cong\text{SOH}$, where $\cong\text{S}$ is represented the structural of Al, Fe, and Si in the surfaces. Two types of surface complexes that can form outer sphere and inner sphere complexes. An outer sphere complexes involve electrostatic columbic interactions are weak compared to inner sphere complexes. the intrinsic equilibrium constants $K_{a1}^{int.}$ and $K_{a2}^{int.}$ are referred to the electrostatic or columbic correction factor, this term effects of surface charge on surface complexation reactions expressed as:

$$K_{a1}^{int.} = \frac{[\cong\text{SOH}^0][\text{H}_2^+]}{[\cong\text{SOH}_2^+]} \cdot \exp.(-F\Psi / RT) \quad (6)$$

$$K_{a2}^{int.} = \frac{[\cong\text{SO}^-][\text{H}_2^+]}{[\cong\text{SOH}]} \cdot \exp.(-F\Psi / RT) \quad (7)$$

Therefore, the corrected surface charge density can be equal to the diffused layer charge expressed as σ_d . the surface charge density calculated as:

$$\sigma_p = \sigma_d = \frac{F}{S} [\langle total[(\cong\text{SOH}_2^+ - \cong\text{SO}^-)] \rangle] \quad (8)$$

Table 5 shows the corrected surface charge and the surface potential values due to the permanent phosphorous, iron and silicon at the phosphate materials. The results are found within the surface charge densities of the Al, Fe and Si species of that reported^(18, 19). The intrinsic equilibrium constants values for phosphate, iron, and aluminum were calculated according to Eq. 6 and 7 are found $K_{a1}^{int.}(\text{PO}_4^{3-}) = -6.6$, $K_{a2}^{int.}(\text{PO}_4^{3-})$, $K_{a1}^{int.}(\text{Fe}_2\text{O}_3) = -7.25$, $K_{a1}^{int.}(\text{Fe}_2\text{O}_3) = -9.75$, and $K_{a1}^{int.}(\text{UO}_2^+) = -9$, $K_{a2}^{int.}(\text{UO}_2^+) = -5$

Table 5: The Corrected values of the Surface Charge and the Electric Potential of the remaining of , Phosphorous, iron and uranium at the phosphate fertilizer materials.

Parameter	SSP-G	SSP-P	TSP	CaSO ₄
Surface charge density for PO ₄ ³⁻ adsorption	0.004	0.031	0.002	0.002
Electric surface potential for PO ₄ ³⁻	0.27	0.49	0.22	0.18
Surface charge density for Fe ³⁺ adsorption	0.28	0.21	0.28	0.25
Electric surface potential for Fe ³⁺	0.72	0.69	0.71	0.70
Surface charge density for UO ₂ ⁺ adsorption	0.002	0.003	0.002	0.003
Electric surface potential for UO ₂ ⁺	0.19	0.24	0.19	0.26

The electric surface charge potential was found to decrease in the following order; Fe³⁺ > PO₄³⁻, > UO₂⁺, therefore, phosphate surfaces was retained hydrolyzed iron more than hydrolyzed phosphates, and uranium.

CONCLUSIONS

The study has been developed toward understanding and providing quantitative description for the sorption of iron, phosphate, and uranium at the industrial phosphate materials. SSP-G, SSP-P, TSP, and phosphogypsum samples. The pH of the solid to aqueous ratio 1 :10 was found between 2 and 3. the surface electric charge density and the surface electric potential at the phosphate materials were determined. The electric potential was calculated in order to determine of the retardation of PO₄³⁻, U(VI) and Fe³⁺ at the phosphate material surfaces. At all cases, the electric potential and retardation were found to decrease in the following order: PO₄³⁻ > U(VI) > Fe³⁺. The naturally occurring radionuclides of uranium, radium and thorium series, as well as the effective exposure dose due to the presence of the naturally occurring radionuclide at the industrial phosphate fertilizer materials were calculated.

REFERENCES

- (1) C. E, Rossler; Z. A, Smith; W. E, Bolch; & R. J, Prince. Health Physics, 37, 269 (1979).
- (2) International Atomic Energy Agency (IAEA). Gamma ray survey in uranium exploration. Technical Report Series No. 186 (1979).
- (3) A. J, Easten " Methods in Geochemistry Geophysics." New York, (1972).
- (4) Roger, W. Wong., Alexander, C., W., Judit, German Heins. " Remediation of uranium contaminated mine waste" Department of crop and soil science. U.S. Geological Survey. Washington 99164-6420 (2000).
- (5) W. Stum. " Chemistry of the Solid-Water Interface." John Wiley and Sons inc. New York, 74 (1992).
- (6) Galterman, H. L. " Methods for Physical and chemical analyses of fresh water." IBP Handbook. No. 8 second Edition (1978).
- (7) An. N, Nesmeynov. " A Guide to Practical Radiochemistry." V.2 Mir Publishers Moscow. 1984
- (8) Rand, M. C. " Standard Methods for examination of water and waste water". 14 th Ed New York (1972).
- (9) International Atomic Energy Agency, 1989. Construction and use of calibration facilities for radiometric field equipment. Technical Reports Series No. 309. IAEA. Vienna
- (10) E. Erdem; N. Tinkilic; T. Yilmaz v; O. F, Uyaink.. Fertilizer Research, 44; 129 (1996).

- (11) E, M. Ashraf.,, R, H. Khater, M, P. Higgy. J. of Environ. Radioactivity. 55: 255(2001).
- (12) A. Sam; and E. Holm. Science of the Total Environment. 16, 173 (1995).
- (13) R. Guimond. Technical Report. International Atomic Energy Agency (IAE) No. 310 , 113 (1990).
- (14) United Nation Scientific Committee on the Effect of Atomic Radiation (UNCEAR). Annex, New York1993).N. H. M. Kamel. J of TheScientificWorld, 2: 1514 (2002)
- (15) J. Hofmann., R. Leicht., H. J. Wingender., J . Worner. " Natural Radionuclide Concentrations in Materials Processed in the Chemical Industry and the Related Radiological Impact. Nuclear Safety and the Environment. Reporty EUR 19264 (2000).
- (16) Z. Chen., and G. Anderso. " Environmental Applications of Geochemical Modeling." Camberidge Unversity Press. (2002)
- (17) N. H. M. Kamel.,m M. Sohsah., M. Sadek and H. M. Mohamed. Proceeding, Environmental Physics Conference (EPC). 24-28 . 219-224 (2004)
- (18) D, A. Dzombak., F. M. M. More. Surface complexation modeling ; Hydrous ferric oxide. John Wiley and Sons. New York. 1990
- (19) M. D. Helman, D. I., Carter., C. L. Gonzalez. Soil Science. 100(6) 409 (1965).
- (20) K. B. Harvey. " Revie of Sorption Models and Their Suitability for use in Performance Assessments." AECL-10883, COG-94-621-1 (1997).