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The Effect of Physical Property Variation on Radio Iodine Adsorption in Soils

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ABSTRACT

The soil as a carrier of different vital factors for plants is an important source of sustainable physical property variation. However, the effects of thermal use on radio iodine 125 in soil with its characteristics are poorly understood. Here, we have assessed the impacts of temperature on six types of soil from nine different parts with alternative climate in Iran. The method of experiments was mini-column approach in which somewhat more realistic soil conditions than the batch sorption technique are maintained. Electrical furnace was used for providing temperature within 15 min 445 Bq of ^{125}I were added to soils. After shaking of 500 g soil sample in 140 rpm for 3 min, the radio iodine in soil sub samples was determined by gamma counting for 20 sec. Duplicate sub sample of soil show that the relative error due to homogenization and analysis is less than 10%. In order to elucidate the influence of the temperature itself on the ^{125}I values, sub samples soils were heated at different temperature by electrical heater but no radio iodine were added to them. The observed variability among soils was considerable. Yet, significant temperature impacts on radio iodine 125 abundance or reduction were observed in soils. Also, we observed that the radio iodine adsorption values decreased in 5, 10 and 15°C in humus. In contrast, it increased in clay soil, coarse sand - clay soil, loamy soil, fine sand-clay soil, salty soil, fine sand-coarse sand soil in 20, 30 and 40°C temperatures. These results demonstrate that soil thermal energy can affect radio iodine adsorption in the soil. Knowledge of physical property as temperature variation effect on radio-iodine adsorption of soils is particularly essential for estimating iodide group, especially I-129 transferto fluvial systems and for successfully measuring radio-iodine enthalpy and entropy in soil studies.

Key words: Thermodynamic, radiation, radionuclide, disease, enthalpy, entropy

INTRODUCTION

The worldwide operation of nuclear power and reprocessing plants leads to the evitable release of radioactive matter (Hou *et al*., 2009) which contaminates soil layer. Radio-iodine would be an important element in polluting soil surface layer and extremely efficient accumulation in the thyroid gland (Zonenberg *et al*., 2006). Special attention has been focused on ^{129}I with half life more than 15 million years, which leads to a permanent accumulation in the environment (Hou *et al*., 2009; Reiners, 2009). There are many factors which affect on radio iodine adsorption in soil. The contaminant concentration in soil usually decreases as a result of different chemical and transport mechanisms (Shan and Javandel, 2005). Adsorption generally occurs upon cooling, but assembly (equilibrium polymerization) may arise either upon cooling or heating (Dudowicz *et al.*, 2009). The roles of microorganisms in radio iodine adsorption or desertion from soils are studied by Amachi *et al.* (2003). Radioiodine in iodides form is more readily adsorbed on soil which is abundant in organic matter (Koch-Steindl and Prohl, 2001). Desertion pattern of iodine is influenced by the soil types. Deposition of iodide group is often assumed to be uniform, resulting from individual rainstorms occurring in a period of year (Seki *et al.*, 1984). Conversely, variations in local rainfall during individual rainstorms are likely effect in the radio nuclides deposition. The parameters such as contact time, stirring speed, initial pH, ionic strength, acid-activation and calcinations is investigated for other radionuclide (Muramatsu *et al.*, 1993) except radio iodine The interaction of radionuclide in soil with environmental factors, such as temperature is important on its behavior (Flores *et al.*, 2009). The total soil organic carbon content and its qualitative characteristics are the most important factors affecting sorption-desorption of radio iodine in soil (Schwehr *et al.*, 2009). Quantitative determination of radio iodine sorption-desorption is therefore essential for both the understanding of transport and the sorption equilibrium in the soil -water system and it is also an important parameter for predicting one of the radio nuclides fate using mathematical simulation models. The process of the thermodynamics highlights contributions of the problem. The thermodynamic maintain the equilibrium and ecosystems. The thermodynamic can be understood the meaning and worth of non-equilibrium system (Tournassat *et al.*, 2005).

The author used iodine in the form of iodide (as ^{125}I) which has been found to be the dominant species in rain water (Seki *et al.*, 1988). The effect of temperature on soil radio iodine should be important for understanding the adsorption of radio iodine as well as for the assessment of long-lived radioactive iodine (^{129}I) in the environment. Therefore, this study aims to test adsorption of radio iodine under different temperature variation in soils.

MATERIALS AND METHODS

The method of experiments was mini-column approach in which somewhat more realistic soil conditions than the batch sorption technique are maintained (Ashworth and Shaw, 2006a). The soils are collected from an area which they are confronted with different rain and covering. The soil samples of region are from topsoil to 20 cm depth during June and July 2007. Sampling points are located in clinic and hospital. These places have a heavy traffic by patients, patient helper and other responsible people daily. They are Zahedan Emam Reza Clinic (clay soil), Fasa Farstan Clinic 1 (coarse sand-clay soil), Gorgan Clinic No.1 (humus soil), Zahedan Emam Ali Hospital (loamy soil), Fasa Farstan Clinic 4 (fine sand-clay soil), Mirjaveh Clinic 1 (fine sand soil), Ladiz Clinic 2 (salty soil), Chahbahar Clinic 1 (fine sand-clay) and 2 (fine sand-coarse sand).

The soil sample is provided with a 50 mm-diameter stainless steel corer to a depth of 20 cm. Three soil samples are collected at each location in which they are mixed. They are put in a plastic bag for transportation to laboratory. In the laboratory, the samples are weighed, homogenized and sieved with a 2 mm sieve. The temperature variation is provided by electrical heater for 15 min. Both case and control sub sample soils are put on electrical heater.

In the experiment, 500 g of sub sample clay soil, coarse sand - clay soil and humus soil are put in 500 mL polyethylene containers as case sub sample soil. Electrical furnace is used for providing 5, 10 and 15°C temperature within 15 min. From clay soil coarse sand-clay soil and humus sample soil as control, 500 g sub sample soil is poured in polyethylene containers and then it is put on electrical furnace for the same time without using ^{125}I. A few drops of liquid containing 445 Bq of ^{125}I are added to them. This corresponds with atotal ^{125}I activity 26720 CPM in tube test if ^{125}I losses from the tube test due to passing time and putting in tube are neglected (Seki *et al.*, 1988). The polyethylene containers are put on temperature, 20, 30 and 40°C by electrical furnace for 15 min as case soil. Sub sample of soil in other polyethylene containers are not put on electrical furnace for the same time, but I^{125} was added to sub sample soil as control. The absorption of radio iodide is estimated at 20, 30 and 40°C.

After shaking in 140 rpm for 3 min of 500 g soil sample of case and control soil sample, 50 g of case and 50 g of control soil sub samples are put in test tube. The radio iodine in soil sub samples is determined by gamma counting for 20 sec. The counts are carried out for 20 sec for each sample. Model name is Automatic Gamma Counting system with Serial No.GM1 8335 S 307. Manufacturer name is KONTRON Location: in which it is made in Switzerland. This set is calibrated by a standard activate solution of radio iodine and compare the curve. This counting method is chosen considering that it is not so important to identify the radio nuclides involved into the reactions, since the objective is to shift all the isotopes producing significant doses of radiation. ^{125}I activity concentrations are corrected for variation in sample self-absorption (Slavik, 1990) and convert to area activities with the total weight of the sample fraction less than 2 mm and the total sampling area. Duplicate sampling shows that the relative error due to homogenization and analysis is less than 10%.

The absorption of radio iodide by soils is investigated under different temperature values. In order to elucidate the influence of the temperature itself on the ^{125}I values, sub samples soils are heated at different temperature 5, 10 and 15°C by electrical heater but no radio iodine are added to them.

Experiments on sub sample of humus soil, coarse sand-clay soil and clay soil have been undertaken. Iodine-125 is added sub sample of soil as case soil, but iodine-125 has not been added to sub sample of soil as control soil. Iodine-125 react with sub sample soils at 5, 10 and 15°C.

RESULTS

Type of sub sample soil affects on radio iodine absorption. The radio iodine adsorption by sub sample of soil materials in coarse sand-clay soil is ascending as case; it is not so for control sub-sample of soil with lower values (Table 1). Adsorption of radio iodine in clay soil as case is measured at higher amounts than in coarse sand - clay soil as case. Adsorption of radio iodine 125 is same as its control soil. Desertion of radio iodine in sub-sample soil of humus is more than coarse sand clay and clay soil as case (Table 1). The adsorption of radio iodine sub sample soil is same and less values for each three soil sample as control soil (Table 1). The average values of radio iodine adsorption under temperature 5, 10 and 15°C are decreased in humus sub sample of soil, as case, but are the same values of adsorption in control soil really (Table 1).

Average values of radio iodine adsorption in sub sample soil at temperatures 20, 30 and 40°C are increasing radio iodine adsorption is also increasing in salty soil and fine sand sub sample of soil as case (Table 2, 3). The control sub sample of salty soil and fine sand soil are same at 20, 30 and 40 centigrade temperatures. There are same figures in case and control of fine sand soil (Table 3).

The trend of adsorption of radio iodine is ascending under 20, 30 and 40°C temperature in loamy sand clay soil. The sub sample of soil in loamy sand clay as case at 20, 30 and 40°C are two times relative to each other. But figures is same in control sub sample of soil at the temperature

Table 1: Adsorption of radio iodine in coarse sand clay, clay soil and humus soils under various temperatures

Temperature of sample soil (°C)	Coarse sand clay soil in Fars-Fasa-farstan clinic Bq kg^{-1} dry soil		Clay soil in Zahedan-emam Reza clinic Bq kg^{-1} dry soil		Humus soil in Gorgan-clinic 3 Bq kg^{-1} dry soil	
	Case	Control	Case	Control	Case	Control
5	2.7±0.75	1.2±0.75	34±3	4±1	525±60	3±1
10	4.5±0.25	2.7±0.25	80±2	5±0.3	235±22	3±1
15	14±9.1	6.7±3.75	87±7	2.2±1.2	174±18	3±1

Table 2: Adsorption variation of radio iodine in salty soils under various temperatures

Temperature of sub sample soil (°C)	Ladiz clinic 1 (salty soil)	
	Case (Bq kg^{-1} dry soil)	Control (Bq kg^{-1} dry soil)
20	19±7.0	19±2.0
30	20±0.3	15±2.0
40	25.5±1	27±10

Table 3: Adsorption variation of radio iodine in fine sand soils under various temperature

Temperature of sub sample soil (°C)	Fine sand soil in Mirjaveh Clinic 1	
	Case (Bq kg^{-1} dry soil)	Control (Bq kg^{-1} dry soil)
20	20±2	19±0.75
30	28±5	16±16.0
40	38±1	14±58.0

Table 4: Adsorption variation of radio iodine in Fars- Fasa- clinic 4 soil under various temperatures

Temperature of sub sample soil (°C)	Loamy sand clay soil in Fars-Fasa-clinic 4	
	Case (Bq kg^{-1} dry soil)	Control (Bq kg^{-1} dry soil)
20	10±0.75	4.0±0.91
30	28±0.2	3.0±0.75
40	37±4	3.5±3.5

Table 5: Adsorption variation of radio iodine in loamy soils under various temperatures

Temperature of sub sample soil (°C)	Loamy soil in Zahedan-emam Ali hospital	
	Case (Bq kg^{-1} dry soil)	Control (Bq kg^{-1} dry soil)
20	34±3	4±0.42
30	79±2	5±0.36
40	87±7	17±12

20 and 30 and 40°C (Table 4). In loamy soil, the adsorption of radio iodine under 20 and 30, 40°C temperature is more than loamy sand clay (Table 5, 6). In fine sand clay soil shows that adsorption of radio iodine by soil material is ascending under 20, 30 and 40°C temperature. As control, radio iodine adsorption sub sample of soil in fine sand clay soil is same. The adsorption is same, but less values in its control sub sample of soil (Table 6). Adsorption in soil of fine - coarse sand under 20, 30 and 40°C is higher than humus soil at 5, 10 and 15°C. In control sub sample soil of fine - coarse sand is same, but is less figures (Table 1, 7).

Table 6: Adsorption of radio iodine in fine sand clay soil under various temperatures

	Fine sand clay soil in Chahbahar - clinic 1	
Temperature of sub sample soil (°C)	Case (Bq kg^{-1} dry soil)	Control (Bq kg^{-1} dry soil)
20	71±33	2±0.8
30	84±0.2	2±0
40	97±0.3	2±0

Table 7: Adsorption variation of radio iodine in fine coarse sand soil under various temperatures

	Fine coarse sand in Chahbahar-clinic 2	
Temperature of sub sample soil (°C)	Case (Bq kg^{-1} dry soil)	Control (Bq kg^{-1} dry soil)
20	16±14	3.7±1.0
30	49±4	2.9±0.42
40	100±0.3	2.0±0.36

DISCUSSION

Radio iodine adsorption in sub sample of soil changes with temperature variation and soil type. Humus soil sub sample is full of organic matter. Dai *et al.* (2004) found that iodine adsorption is significantly correlated with soil organic matter negatively and positively with free iron oxide contents (Table 1). He reveals there are not correlation between iodine adsorption and cation exchange capacity and soil pH is found. Radio iodine adsorption values decrease in humus soil by increasing temperatures at 5, 10 and 15°C (Table 1). Adsorption of radionuclide 125 in coarse sand clay soil and clay sub sample of soil is compared to humus soil. Its result reveal that organic matter effect on increased temperature leading to be decreased radio iodine adsorption, because there is more organic matter in humus soil than coarse sand clay soil and clay soil. Tournassat *et al.* (2005) reported iodine accumulation in the marine organic matter of the sediment that ranging from 2 to 3 ppm. According to Table 4, adsorption of radio iodine in salty soil under 20, 30 and 40°C temperatures is ascending. The figures of control subsample soil are same as each other. Due to the organic matter factor, the penetration depth of radio iodine into the soil will be changeable. The vertical ^{125}I distribution over the soil profile is usually approximatedby an exponential decrease with sub sample soil depth with most of ^{125}I in top few centimeters (Ashworth and Shaw, 2006b). Sorption exhibit consecutive steps ascribe to Humic Acids (HA) monolayer and bi layer formation, respectively. Increasing temperature changes site capacity in which suggest different HA molecular conformations on the soil. Linearly correlated enthalpy and entropy changes for HA sorption point to the importance of hydration and dehydration in the sorption mechanism (Ghabbour *et al.*, 2004).

Other factors affect on penetration of radio iodine in soils. Sheppard *et al.* (2004) found that radio iodine adsorption in mineral as well as sandy soil and organic soils has been linked to pH, organic matter and Fe and Al oxides. Radioiodine adsorption from the contaminated soil increases with increasing temperature 20, 30 and 40°C for loamy soil. The free energy of iodine exchange ion on the soil material have an enthalpy at 20, 30 and 40°C for the high- and low-affinity exchange sites (Liu *et al.*, 2003). According to scientist researches, thermodynamic requires chemical equilibrium. It enables us to compute the entropy and enthalpy of the adsorbed phase, the heat of adsorption, specific heat capacity and the adsorbed phase volume thoroughly (Chakraborty *et al.*, 2009). Adsorption of radio iodine-125 under the temperatures variation in fine sand soil and salty sub sample of soils are nearly the same. Increasing temperature of soil sub sample increase adsorption of radio iodine in salty-clay soil sub sample (Ashworth *et al.*, 2003).

The content and chemical characteristic of the Soil Organic Matter (SOM) is considered to be one of the important factors which affect on temperature of soil and lead to be differences in sorption capacity of soil. Meanwhile, the extent of radio iodine adsorption in soil is at rather descending level under low pH value conditions and ascending level with increasing pH value (Chakraborty *et al*., 2009). Besides, adsorption of radio iodine was observed in most of tested soils. It shows that organic matter in humus sub sample soil is more than salty soil and fine sand soil Available organic matter of sub sample soil could play a role on temperature. Radio iodine adsorption values also increase in 20, 30 and 40°C in salty-clay sub sample soil. From the view point of radio iodine adsorption, salty-clay sub sample soil is compared to coarse sand clay soil in 5, 10 and 15°C. It seems to be a suitable temperature that causes to increase the activity of biological system in soil. Radio iodine values for clay sub sample of soil increase in 5 to 10 and 15°C. As the temperature increase, the number of strong adsorption sites remain relatively constant while the number for the weak adsorption sites increase. These results indicate that the net gain in adsorption capacity and the decrease adsorption irreversibility at elevated temperatures are due to the increasing in available weak adsorption sites. Ashworth *et al*. (2003) showed that migration and accumulation of ^{125}I in the soil depend upon soil moisture and redox conditions.

The quantity of radio nuclide can be changed by microbial mass and food in soil sample (Bors and Martens, 1992). Therefore, some of factors in sub sample soil effect on the variation of temperature in which it change iodine 125 (Spalding, 2001). Microorganism biomass in the soil lessen the amount of iodine-125 in soil (Amachi *et al*., 2003; Bors and Martens, 1992). Bors and Marten (1992) showed the temperature ascend the adsorption of radio iodine if there are suitable condition in soil from the point of microorganism biomass and food. The ^{125}I activity concentration of sub samples soils decreases at 20 to 30 and 40°C. This shows temperature affect radioiodine adsorption in soil and increasing temperature decrease microorganism and then, it decreases soil radio iodine adsorption. The interaction of radionuclide behaviour in soil with environmental factors, such as temperature and humidity as well as farming practices are researched by Koch-Steindl and Pröhl (2001). He says that the physiological constraints of plant growth, appropriate soil conditions for growth affect soil conditions and present-day parameters may be considered appropriate for roughly estimating the behavior of radio nuclides in the soil-plant system.

Mixing operation on soil sub sample causes the ^{125}I of upper soil sub sample to be Trans located and the temperature is changed in soil sub sample. The intensity of sub sample of soil redistribution of radio iodine by mixing operations depends strongly on attribute sub sample of soil and management. Soil sub sample attributes and management in these soil sub sample vary less in comparision with the entire soil.

Mixing operation on soil result also in a reduction of the amount of radio iodine re distribution per successive mixture event. Although, this effect is less pronounced if mixing causes the ^{125}I to be more or less uniformly distribute over the soil sample layer, the radio-nuclides such as ^{125}I activity concentration of the topsoil change due to progressive lowering soil surface sub sample temperature and the incorporation of soil sub sample containing no radio-nuclide from below the mixing layer (Shan and Javandel, 2005). Also, the occurrence of different patterns of mixture and deposition are caused by different temperature depending on intensity of mixing and type of soil sub sample, cause complex the activity concentrations in the topsoil.

The ^{125}I activities is probably due to temperature during ^{125}I deposition, in which the ^{125}I is not able to come into contact with the soil sample particles and preferentially flows to the lower positions of the tube soil sample. Temperature during mixing events have resulted in a much greater proportion of ^{125}I being deposited in the average soil sub sample (salty soil and fine sand soil sub soil sample). Furthermore, it might be due to the effects of soil sub sample redistribution and mixing operations. However, this study shows that mixing and deposition affect temperature variation of soil sub sample and change the temperature of soil sub samples. Pacific Northwest Laboratory is developing methods for evaluating the effects of temperature and pressure on radionuclide distribution coefficients (Kd) in radio nuclides. Ames and McGarrah (1980) found that cesium Kd values for basalts decrease with increasing temperature. Other radio nuclides presently under investigation for temperature effects on Kd values include ^{125}I.

Soil sub sample temperature contributes to the variation in ^{125}I activity in sub sample soil of the central part of the study area. In the part of the study area humus soil, the large-scale of increased ^{125}I values is probably the result of variation in initial temperature of ^{125}I deposition over the soils following mixing. Apparently, the soil sample receives larger amounts of radio-nuclide, which has resulted increasing of values of radio iodine in comparison with the other soil sub samples. This suggests that the ^{125}I has probably been caused by local variability in the mixing the soil sub sample and will be improved with increase concentration in initial solution and depends significantly on SOM.

CONCLUSION

This study demonstrates a few factor change the temperature that affect on ^{125}I adsorption in some soil sample. The method provides a better understanding of the contribution of various temperatures that causes the ^{125}I adsorption in the soil sample.

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