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The Contribution of Plant in Uptaking Radio Iodine from the Soil in Zahedan City, Sistan and Blouchestan, Iran

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Abstract: In order to determine contribution of plant in radioiodine uptake, soil-to-plant concentration ratios of radioiodine from soil to agricultural crops are needed and so we carried out radiotracer experiments. The mean values of concentration ratio (on a wet weight basis) of radioiodine from soil to edible parts of crops in podzol were as follows: lentil, 0.054; pea, 0.012; wheat, 0.040 and red bean, 0.068. The mean values of the radioiodine concentrations in plant parts of red bean, lentil, wheat and pea (on a wet weight basis) were 4.32, 3.43, 2.64 and 1.0 kBq kg^{-1}, respectively. We also studied the distribution of the radioiodine in the crops. There was a tendency for the concentration ratio of stem to be higher than those of root and leaves. A very high concentration ratio was found for root of red bean; because this plant was studied at a growth stage different from that of the other plants. The data obtained in this study should be useful in assessing the behavior of long-lived ^{129}I (half life: 1.57×10^{7} year) released from nuclear fuel cycle.

Key words: Concentration ratio, radioiodine, plant, wheat

INTRODUCTION

Radionuclides deposit into soil in various ways, subsequently they can transfer to plants from soil and may enter the human body through the food chain (Koch-Steindl and Pröhl, 2001). Amongst these radionuclides, the isotopes of iodine represent an important group because of their large fission yields, high volatility and extremely efficient accumulation in the thyroid gland. Most of the liberated radioiodine will eventually reach the soil (Ashworth *et al*., 2003) and its behavior and fate in this environmental component requires special attention. The uptake of radioiodine by plants can be affected by various factors (Cline and Betty, 1975; Tao *et al*., 2005). No previous studies on the transfer of radioiodine from soil to plants in arid parts of Iran have been performed. Hence this study on the plant uptake of radioiodine was performed to estimate soil-to-plant concentration ratios in different plant parts.

For this study, iodine in the form of iodide (as ^{125}I) was used as this has been found to be the dominant species in rain water after an accident (Seki *et al*., 1988). ^{129}I (half-life 15.7 million years) is a product of ^{130}Xe spallation in the atmosphere and uranium and plutonium fission, both in subsurface rocks and nuclear reactors. Nuclear processes, in particular nuclear fuel reprocessing and atmospheric nuclear weapons tests have now swamped the natural signal for this isotope. ^{129}I was used in rainwater studies following the Chernobyl accident. It also has been used as a ground-water tracer and as an indicator of nuclear waste dispersion into the natural environment. There are 37 isotopes of iodine and only one, ^{127}I, is stable.

In many ways, ^{129}I is similar to ^{36}Cl. It is a soluble halogen, fairly non-reactive, exists mainly as a non-sorbing anion and is produced by cosmogenic, thermonuclear and *in situ* reactions. In hydrologic studies, ^{129}I concentrations are usually reported as the ratio of ^{129}I to total I (which is virtually all ^{127}I). As is the case with $^{36}Cl/Cl$, $^{129}I/I$ ratios in nature are quite small, 10^{-14} to 10^{-10} (peak thermonuclear $^{129}I/I$ during the 1960s and 1970s reached about 10^{-7}). ^{129}I differs from ^{36}Cl in that its half-life is longer (15.7 vs. 0.301 million years), it is highly biophilic and occurs in multiple ionic forms (commonly, I^- and IO_3^-) which have different chemical behaviors. This makes it fairly easy for ^{129}I to enter the biosphere as it becomes incorporated into vegetation, soil, milk, animal tissue, etc. ^{129}I produced newly by the supernovas which created the dust and gas from which the solar system is formed. ^{129}I was the first extinct radionuclide to be identified as present in the early solar system.

It is important to recognize that ^{129}I (for which ^{125}I is used as a surrogate in this study) may enter soils from below in groundwater discharges as well as from dry and wet atmospheric deposition. Groundwater discharge is particularly relevant to solid radioactive waste disposal in subsurface facilities. The findings of this research could be used in assessments of the implications of I-129 deposition in soils. I-129 is not going to be of importance in a reactor accident because I-129 is too long lived therefore root uptake hastens. The results of Michel *et al.* (2005) showed that the isotope ratios in soils and ground water demonstrated a high mobility and an accumulation of iodine 129 in the water-soil zone and efficient migration into water saturated soil layer and ground water. Its transfer into food chain is related to the complex solution in the water-soil system

Since the development of awareness of pass ways of radioactivity from soils to crops via root uptake as a potential hazard to man so much experiments have been performed to determine appropriate transfer factors for crops, soils and radio nuclides. These have been a bewildering array of data, which is extremely difficult to interpret due to lack of standardization of experimental design. There is standardization in the region, it is occupied by those factors which are in the region. Those factors are limited and they seem not to be useful for other regions world wide. Therefore, these data in this soil type can help to find a realistic standardization.

MATERIALS AND METHODS

A podzol was used in this investigation. It was collected from the garden of Zahedan University, Sistan and Blouchestan, Iran. Samples were collected from the upper 20 cm of the soil profile and were homogenized as well as sieved before use. The soil samples are obtained from several locations and were bulked and homogenized before using the samples in winter 2005.

The grain sizes of the samples used were all below 2000 μm. The organic matter content of soil was large and well below that of an organic rich soil. Soil solution pH at 30°C was 6.1±0.2. The porosity of the soil was 40%. The soil color was light. It was also high in $CaCO_3$.

The adsorption of radioiodine by the soil was investigated in a batch experiment at 30°C. The investigation was carried out using ^{125}I as an alkaline solution of sodium iodide, provided from Ramzjoo Mougham laboratory.

For the experiment, the amount of dry soil per pot was 400 g (dry weight, d.wt.) of untreated soil sample which were poured into pots with dimensions 5×10×5 cm. This gave a dry bulk density at 0.6 g per cubic centimeter which is found the top end of the density rang that would be expected in the field. Four types of plants (wheat, pea, lentil and red bean) were grown for 2 weeks after giving them 150 mL water. This amount of distilled water was supplied in a single short administration. Fourteen days after planting, 0.15 kBq L^{-1} of ^{125}I at a concentration at more than 2 kBq L^{-1} were added to the surface of soil using a 5 mL syringe. Contamination of plant foliage was avoided during this administration procedure. The soils and plants were undisturbed after administration of the radionuclides of 14 days, except that 100 mL of distilled water was added to every 5 days. The pots were distinctively sampled separating the plant parts in roots, leaves and stem, using a knife, 11 days after the addition of radioiodine to the surface of the soil. The soil around the root was separated by shaking the root and hitting it toward the edge of container slowly. The character of the soil and adding of distilled water helped in detaching soil from the root material. Subsequently, samples were put in special container for determining their radioactivity by gamma spectroscopy. The gamma counting equipment was as follows: Serial No. GM1 8335 S 307, Counting system model: Automatic Gamma Manufacturer: KONTRON. The samples were too small for self-absorption to be a major issue and all samples were counted in the same geometry. The mass of material analyzed was 3 g. All experiments were carried out in too replicate.

RESULTS AND DISCUSSION

The amount of radioactivity concentration in the plants lentil, wheat, red bean and pea are decreased in first samples respectively. The greater amounts of concentration ratio of plant to soil in the first sampling are in lentil leave, lentil stem and red bean (Table 1).

The average amount of radioactivity concentration ratios in the plants red bean, lentil, wheat and pea are decreased (Table 2).

It shows the average amount of radioactivity concentration in lentil is higher than other plants. The compare of plants in first and second samples shows that concentration ratios in standing plant such as wheat is less than non-standing plants such as lentil, red bean and peas (Table 3).

Table 1: Concentration ratio in each parts of plant (1)

	Concentration ratio		
Plant type	Leaves	Stem	Root
Lentil	1.4×10^{-4}	9.5×10^{-4}	1.5×10^{-3}
Red bean	8.5×10^{-4}	3.4×10^{-4}	1.1×10^{-3}
Wheat	1.5×10^{-4}	4.4×10^{-4}	1.0×10^{-3}
Pea	2.1×10^{-4}	1.5×10^{-4}	1.4×10^{-4}

Table 2: Concentration ratio in each parts of plant (2)

	Concentration ratio		
Plant type	Leaves	Stem	Root
Lentil	1.8×10^{-3}	10.0×10^{-4}	1.6×10^{-4}
Red bean	2.8×10^{-3}	4.0×10^{-4}	2.2×10^{-4}
Wheat	7.6×10^{-4}	5.8×10^{-4}	2.0×10^{-4}
Pea	1.7×10^{-4}	2.3×10^{-4}	2.5×10^{-4}

Table 3: Concentration ratio in each parts of plant averagely

	Concentration ratio		
Plant type	Leaves	Stem	Root
Lentil	9.7	9.7	8.3
Red bean	1.8	3.7	1.3
Wheat	4.5	5.0	6.0
Pea	1.9	1.9	1.9

Table 4: The portioning of activity in the soil-plant system

Plant type	Plant part	Activity in soil (kBq kg^{-1} soil)	Activity in plant (kBq kg^{-1} plant)
Pea	Leave	1.00	1.77
	Stem	2.00	1.25
	Root	1.72	1.18
Lentil	Leave	2.30	1.15
	Stem	1.52	2.88
	Root	2.46	13.00
Wheat	Leave	1.56	1.42
	Stem	1.62	4.32
	Root	2.56	7.52
Red bean	Leave	1.32	2.00
	Stem	2.47	3.00
	Root	4.00	16.35

Table 4 shows the partitioning of activity in the soil-plant system. It reveals that the plant parts absorb 55.5 kBq kg^{-1} wet plant or 70% of activity while the soils absorb 24.5 kBq kg^{-1} dry soil or 30% of activity.

Considerable variation in the uptake of radioiodine into different parts of crop species is demonstrated by the data in Table 1 and 2. It shows that the greatest average concentration ratio is 5×10^{-4} in peas crop which is more than 15.9×10^{-4} in wheat (Colle *et al.*, 2005), 22.9×10^{-4} in red bean and 25.9×10^{-4} in lentil plant.

However, direct comparison between species should be viewed with care; because they have different growth rate (Koch-Steindl and Pröhl, 2001). It has often been noted that the uptake of radioiodine from the soil is considerably less in the leaves of red bean than leave of lentil crop (Table 3). All crops stem show activity more than lentil stem. Activity in wheat root is also more than root of other crops. Similarly, in all cases the radioiodine activity in peas is much less than other plants. These results suggest that there is translocation within the plant after the initial uptake (Collins *et al.*, 2004), because radioiodine is slowly mobile through the soil sample in comparison to some elements (Colle *et al.*, 2005). The experiment indicated that ^{125}I was mobile only within the saturated/low redox zone at the base of the soil column and accumulated in the zone of transition between anoxic and oxic soil conditions. The iodine can be easily transported in the calcareous soil and exceptionally organic matter contributed highly in iodine sorption (Collins *et al.*, 2004; Assem and Erten, 2005; Tao *et al.*, 2005). This finding contradicts some previous studies and will have implications for dose assessments (Colle *et al.*, 2005; Assem and Erten, 2005). A rather slow kinetics was observed for the adsorption of radioiodine on soil. The distribution ratio increased with increasing solution/solid ratio and the contact time In practice, contamination was highly dependent on factors such as growth form of the plant species and the condition of plant watering during the growing season (Koch-Steindl and Pröhl, 2001). It is very difficult to predict the effect of weather and the contamination by watering is likely to vary according to nature of the giving water, which could enhance or reduce its intensity of contamination (Tao *et al.*, 2005).

Concentration ratio in different crops for second sampling can be observed in Table 2. Concentration ratio of each crop has been calculated using amounts of activity for different depth of soil generally based on somewhat arbitrary assumptions concerning the rooting zone. The stem concentration ratio of lentil to soil is lower than other three plants; 5.8×10^{-4} in wheat, 4×10^{-4} in red bean and 10×10^{-4} in lentil; but the result of other research. The amount of radioactivity concentration in the plants lentil, wheat, red bean and pea are decreased respectively. The cause of it may be related to method of giving water. The different parts of a crop desorbs activity depend on the watering (Muramatsu *et al.*, 1996). The soil biomass showed a striking effect on the adsorption of radioiodine (Collins *et al.*, 2004). All values in podzol were however well below those of the organic rich soil. There was sensitiveness to absorption of radioiodine in plant type. This sensitiveness was observed by comparison of concentration ratio of plants in Table 3.

The activity of plant parts was 55.5 kBq kg^{-1} plants and soil 30 kBq kg^{-1} dry soil. This activity of plant parts was more than two times of soil activity (Table 4). One of the factors which decreases soil activity would be plant type. Uptake of ^{125}I by some plants was found to be low. The rates of uptake vary depending on soil parameters that are dependent on soil content, mineralogy, organic matter content, pH and rooting density. This range of uptake rates is compatible with results reported in the literature (Cawse, 1983). The effect of organic matter particularly requires investigation organic completing agents are known to increase the fraction of radionuclide in solution and would therefore increase the rate of migration. However, the mobility of such complexes and the effect the surface phase is unknown. The effect of the nature and concentration of the ions in the system are also unknown; such studies, from the point of radioactivity effects have not been made at this part of Iran.

CONCLUSION

This approach is suitable for predicting the fate of radioisotopes that are accidentally released into environment, though with a considerable increase in complexity for the elements because of their complex chemistry and redox behavior which would give rise to several species with differing mobilities.

The following point should commend to other users: When considering other radio isotope, the concentration profiles will be important if the isotope moves out of the rooting zone.

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