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Soil to plant Transfer Factors of Radionuclides in *Ficus racemosa* (L.), a Medicinal plant

Chandrashekara K.[1] and Somashekarappa H. M.[2*]
[1]Department of Physics, St. Philomena College, Puttur, 574202, INDIA
[2]University Science and Instrumentation Centre, Mangalore University, Mangalagangotri, 574 199, INDIA

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Abstract

Ficus racemosa (L.),a naturally grown medicinal plant, from malnad region of Kerala state in India, was analysed for natural and artificial radionuclides, ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K and ^{137}Cs, using a high resolution HPGe gamma spectrometer. The transfer factors (TF), average annual committed effective dose (AACED), and threshold annual consumption rate of medicinal plant were also estimated. The activity concentrations of ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K and ^{137}Cs were found to be 31.16±1.30, 31.49±4.20, 51.34±2.24, 225.00±12.91, and 3.65±0.60 Bqkg^{-1}, 1.28±0.17, 14.24±1.83, 1.34±0.27, 384.47±2.83 Bqkg^{-1}, and BDL, respectively in soil of the rooting area and bark of the plant respectively. In leaves of this plant activity concentrations of these radionuclides were BDL, 98.37±9.09, BDL, 1043.00±77.28 Bqkg^{-1}, and BDL respectively. The estimated values of AACED due to consumption of this plant were found to be far below the world average of 0.3 mSv/y. Thus present study shows that there is no radiological health risk of using this medicinal plant for treating the diseases.

Keywords: Medicinal plant, Ayurvedic system, radionuclide, radiological, therapeutic.

Introduction

The alluring collection of variety of plants and other biodiversity including human on Earth has made it to be a special planet in the Universe, not only in its natural beauty, but also in the standard of life on it. Moreover the dependence of the mankind on the biodiversity of Earth enhanced its multidimensional growth and progress. The role of medicinal plants which are abundantly available on Earth, in curing various diseases and ailments related to man, has become more instrumental and fruitful for several years. Ayurvedic medicine proved its efficacy for the treatment of various diseases and these medicines from plant origin are found to have minimum side effects. It is well-known fact that therapeutic use of medicinal plants in human health is in regular practice even from Vedic period.

The ancient Indian literatures such as Charak samhitha and Sushrutha Samhitha, the major documents of Ayurvedic system of medicine, have become the paramount authorities for the curative properties of medicinal plants[1,2], not only in past and present, but also may be in future. The Ayurvedic system of medicine with medicinal plants as the main ingredients has become more popular in medicinal therapy, not only in India, but also across the world. The availability of these medicinal plants for full of cheap, may be also the reason for its popularity among the other systems of medicine.

The soil on the earth contains radionuclides. The concentrations of these radionuclides vary from place to place. In some parts of the earth the radionuclides concentration will be more and less in some other parts. This radionuclide concentration in the soil might have occurred the moment when the earth is formed or there might be change of concentration due to deposition in later stages. A large number of radionuclides have shown their presence and significance in the soil and other environmental matrices, including plants, with their merits and demerits[3,4]. In addition to radionuclides like Radium Thorium, Potassium etc., there are many non-radioactive trace elements like Ca, Na, Co, Ni etc.[5]

The absorption of radionuclides by the medicinal plants depends on the activity distribution of these radionuclides in the corresponding soil. The transport of these radionuclides also depends on chemical form of the nuclide, its distribution coefficient, chemical breakdown of the complexes, the metabolic requirements of the plant, physicochemical parameters of the soil such as pH, organic matter, moisture content etc.[6-8]. *Ficus racemosa (*L.*),* which is commonly known as Athi, is a traditional medicinal plant with very high medicinal value, abundantly available and exclusively used for the treatment of different ailments, commonly in coastal regions of Karnataka, Kerala and also in some other parts of India. The detailed and systematic study of activity concentrations of heterogeneous natural and artificial radionuclides and the soil to plant transfer factors of this medicinal plant may help to estimate the average annual committed effective dose (AACED) to an individual, by the ingestion of naturally occurring radioactive materials (NORMs), due to its consumption. The study also may help to build up a documentary of the baseline radionuclide concentration and may help in radiological study related to this medicinal plant.

This study aims at the analysis of *Ficus racemosa (*L.*)* plant for the activity concentrations and transfer factors of the radionuclides ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K and ^{137}Cs. The study also intends to estimate the average annual committed effective dose (AACED) and the threshold annual consumption rate of this medicinal plant to gauge the radiological impact on human health due to use of *Ficus racemosa (*L.*)*. Present study also helps the general public to come out of the confusion, associated with use of this medicinal plant, especially in the present era of environmental pollution.

Material and Methods

Coastal and Malnad region of Kerala is associated with variety of medicinal plants and the practice of the traditional Ayurvedic medicinal system is well accepted by the general public of this geographical region. Vellarikundu taluk of Kasaragod district in Kerala state is commonly known for the cultivation of commercial crops like Rubber, Arecanut, Cashew, Pepper, Cocoa, Vanilla; food crops like Rice, Coconut, Ginger, Turmeric, Spices, vegetables etc., and for diverse medicinal plants of the region.

The bark and leaves samples of the medicinal plant, *Ficus racemosa (*L.*)*, and soil sample from its rooting area were collected from a location with GPS coordinates, N 12°39'197" E 75°28'250". The gamma background radiation level of this location was100 nSvh^{-1}. The bark of this plant is used in curing ailments like Oedema, Diarrhea, Dysentery, Uterine bleeding, Leucorrhoea and Pyroluria, wounds etc. whereas the leaves are used in Bilious affections[9]. The collected samples were processed using the standard methods given in EML procedure manual[10] and analyzed for ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K and ^{137}Cs activity concentrations, following the standard methods and procedures. All the above listed radionuclides have been estimated using gamma spectrometric method[11]. The detectable level (BDL) values for the activity concentration of ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K and ^{137}Cs are 0.62, 0.77, 2.46, 1.42 and 0.09 Bqkg^{-1} respectively. Activity concentrations of radionuclides less than the corresponding detectable levels are termed as below detectable level (BDL). The spectrometer was calibrated using standards obtained from IAEA. The soil-to-plant transfer factor (T.F.) is calculated using the formula;

TF = Activity of radionuclide in plant (Bqkg^{-1}dry weight)/Activity of radionuclide in soil (Bqkg^{-1}dry weight)[11]

The Average Annual Committed Effective Dose (AACED) to an individual, due to consumption of the medicinal plants by the ingestion of naturally occurring radioactive materials (NORMs) was estimated using the equation[7,12]:

$$E_{av}=C_r.\ DCF_i\ .A_i \quad (1)$$

Where, E_{av} is the average annual committed effective dose, C_r is the consumption rate of radionuclides, and DCF_i is the dose conversion factor for each radionuclide (2.8×10^{-7}, 6.9×10^{-7}, 2.3×10^{-7}, 6.2×10^{-9},and 1.3×10^{-8}Sv Bq^{-1} for ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Csrespectively),and A_i is the activity concentration of each radionuclide. Using the same equation, the annual threshold consumption rate for a medicinal plant is obtained;

$$Cr = \frac{5Eav}{\sum_{i=1}^{5}(DCFi\times Ai)} \quad (2)$$

Where, E_{av}=0.3mSv/y is the threshold average annual committed effective dose due to ingestion of NORMs in the medicinal plants, A_i is the activity concentration of radionuclide i, and DCF_i is the dose conversion factor for radionuclide i[13].

Results and Discussion

Table-1presents the activity concentrations of the radionuclides ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs in bark and leaves of *Ficus racemosa (L.)* and in the corresponding soil of its rooting area. Column 2 of the table-2, reports the activity concentrations of ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs in the soil of the rooting area and they were found to be 31.16±1.30, 31.49±4.20, 51.34±2.24, 225.00±12.91, and 3.65±0.60 Bqkg^{-1} respectively. The activity concentrations of above said radionuclides in bark of *Ficus racemosa (L.)* are presented in column 3 of table-1and were found to be 1.28±0.17, 14.24±1.83, 1.34±0.27, 384.47±2.83 Bqkg^{-1}, and BDL respectively. The activity concentrations of ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs in leaves of *Ficus racemosa (L.)* were found to be BDL, 98.37±9.09, BDL, 1043.00±77.28Bqkg^{-1}, and BDL respectively, as presented in column 4. The concentrations of radionuclides in soil, leaves and bark are also presented in the form of scatter plot in figure-1.

The activity concentrations of ^{226}Ra and ^{210}Pb in soil sample were almost in equal concentrations (31.16±1.30 and 31.49±4.20 Bqkg^{-1}). But the concentrations of ^{2226}Ra and ^{210}Pb in bark sample were about 1.28±0.17 and 14.24±1.83 Bqkg^{-1}respectively. In leaves, the activity concentrations of these radionuclides were found to be BDL and 98.37±9.09 Bqkg^{-1}.It is also found that activity concentration of ^{210}Pb in leaves is significantly higher than its concentrations in soil and bark. Thus the soil to leaves and bark to leaves Transfer factors (TF) of this radionuclide was found to be more than unity. This may be because of the fact that in addition to root uptake, ^{210}Pb is also largely available in the atmosphere and deposit as a fall-out of ^{222}Rn daughters on aerial parts of medicinal plant in the form of wet and dry precipitate and subsequent absorption[14]. The deposition of ^{210}Pb in this form will be proportionately more in leaves compared to other parts of the plants[15,16].

It is also found that the activity concentration of ^{40}K is very large compared to any other radionuclide in both bark and leaves. It was also found that the activity concentrations of this radionuclide in bark and leaves of *Ficus racemosa (*L.*)* are higher than its activity concentration in the corresponding soil of the rooting area. Consequently the soil to plant transfer factors of ^{40}K for this plant was found to be more than unity. This may be because of the fact that the Potassium is one of the important nutrients of the plants and ^{40}K being its isotope it is expected to be higher in its concentration. The higher concentration of ^{40}K in medicinal plant samples compared to soil sample may be due to the continuous accumulation of ^{40}K through root uptake over a period of time[5].

In spite of its significant activity concentration in soil, ^{232}Th is found to have the lower value for its activity concentration in bark and leaves of the medicinal plant. Because of its low solubility and specific activity, ions of ^{232}Th may be bound tightly to the soil particles, so that they are immobile and may not be transported to the medicinal plants[8]. This may be the reason for lower activity concentration of ^{232}Th in bark and leaves.

The columns 5, 6, and 7 respectively of table-1and the scatter plot in figure-2 represent the soil to bark, soil to leaves, and bark to leaves transfer factors (TF) of the above said radionuclides. It was observed in the study that the soil to plant transfer factors of ^{232}Th are lower than that of ^{226}Ra, in spite of the higher concentration of ^{232}Th in soil sample. This is because, the radium dissolves more easily in water than thorium; consequently it is transported to the plant through absorption of water through root. Radium exhibits similar chemical properties as that of calcium and magnesium, which are essential elements for the growth and nutrition of plants. In place of Ca and Mg, plants may take up ^{226}Ra depending on its availability in soil. The ^{137}Cs is found to be present in smaller quantity in the soil sample. The availability of this artificially produced radionuclide in the soils across the continents as a fall-out radionuclide is mainly due to open atmospheric tests conducted by some countries prior to the ban of open atmospheric tests [16].

Equations 1 and 2 are used to calculate the average annual committed effective dose (AACED), due to ingestion of naturally occurring radionuclides (NORMs) due to the consumption of this medicinal plant and its annual threshold consumption rate. The AACED values due to consumption of medicinal plant at the consumption rate of 1kg/y (Njinga et al., 2015) were 0.0128±0.0013 mSv/y and 0.0743±0.0067 mSv/y respectively for the bark and leaves. It was found that the estimated AACED due to consumption of leaves of *Ficus racemosa (*L.*)* plant as a medicine is more compared to that of bark of the same plant. This may be due to higher activity concentration of ^{40}K and ^{210}Pb in leaves of this medicinal plant. But the AACED values presented in this study are far below the world average of 0.3 mSv/y [13]. Thus there is no radiological health hazard due to consumption of this medicinal plant in treating the diseases. The annual threshold consumption rates were found to be 23.43kg/y and 4.03 kg/y respectively, for the bark and leaves of this medicinal plant.

Conclusion

The analysis of the medicinal plant, *Ficus racemosa (*L.*),* using HPGe gamma spectrometer for natural and artificial radionuclides has shown certain activity concentrations of natural radionuclides, ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K, in its bark and leaves. Out of the measured activity concentrations, the concentration of ^{40}K was maximum, both in case of bark and leaves. Consequently the uptake of ^{40}K is maximum followed by ^{210}Pb in both bark and leaves of this plant. The activity concentration of ^{210}Pb was more in leaves, compared to bark. The average annual committed effective dose (AACED), due to ingestion of naturally occurring radionuclides (NORMs) due to consumption of bark and leaves of this medicinal plant is far below the world average (0.3 mSv/y). Thus present study proved that there is no radiological health risk in using the bark and leaves of this plant in treating the diseases and may help the general public to come out of the confusion, associated with the use of this medicinal plant, especially in the present era of environmental pollution. This study also provides the baseline data of the activities of natural and artificial radionuclides associated with this plant and helps in the radiological safety study of this plant.

Table-1
Activity concentrations and transfer factors of radionuclides

Radionuclide	Activity Concentration ($Bqkg^{-1}$)			TF		
	soil	bark	leaves	Soil to bark	Soil to leaves	Bark to leaves
^{226}Ra	31.16±1.30	1.28±0.17	BDL	0.04	0	0
^{210}Pb	31.49±4.20	14.24±1.83	98.37±9.09	0.45	3.12	6.90
^{232}Th	51.34±2.24	1.34±0.27	BDL	0.02	0	0
^{40}K	225.00±12.91	384.47±2.83	1043.00±77.28	1.70	4.63	2.71
^{137}Cs	3.65±0.60	BDL	BDL	0	0	0

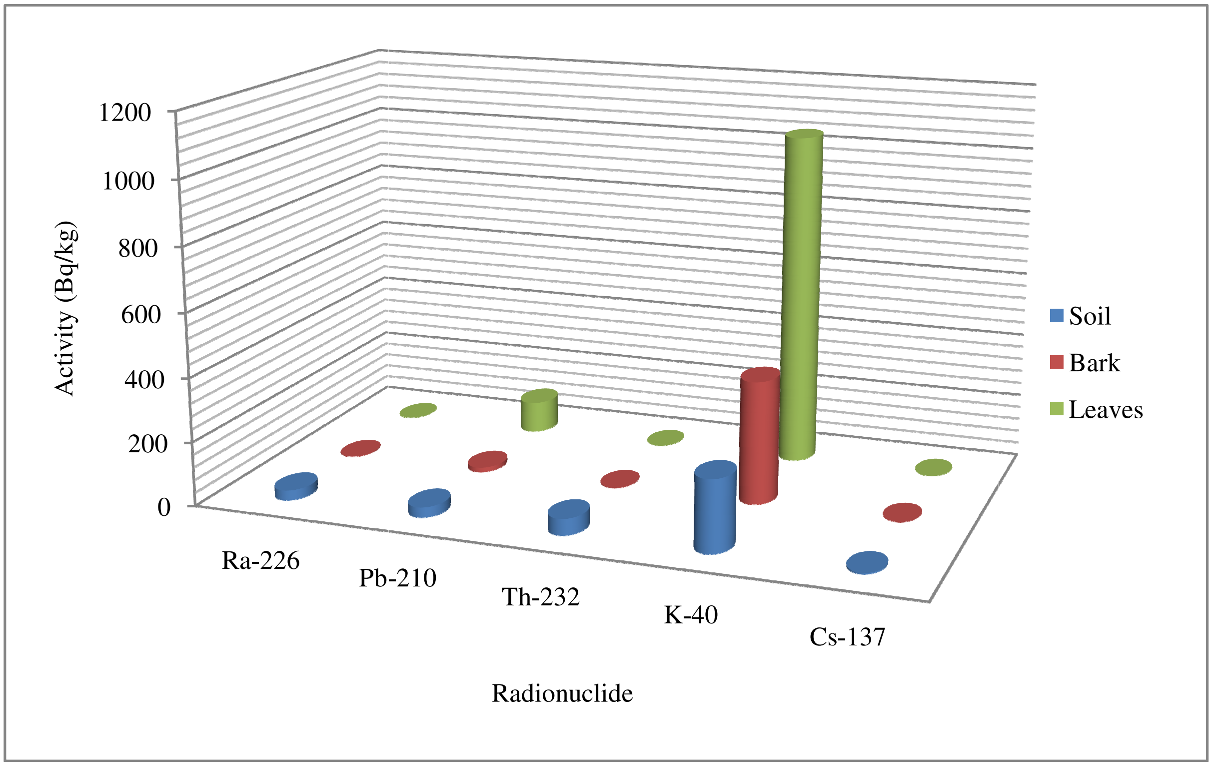

Figure-1
Activity concentrations of radionuclides

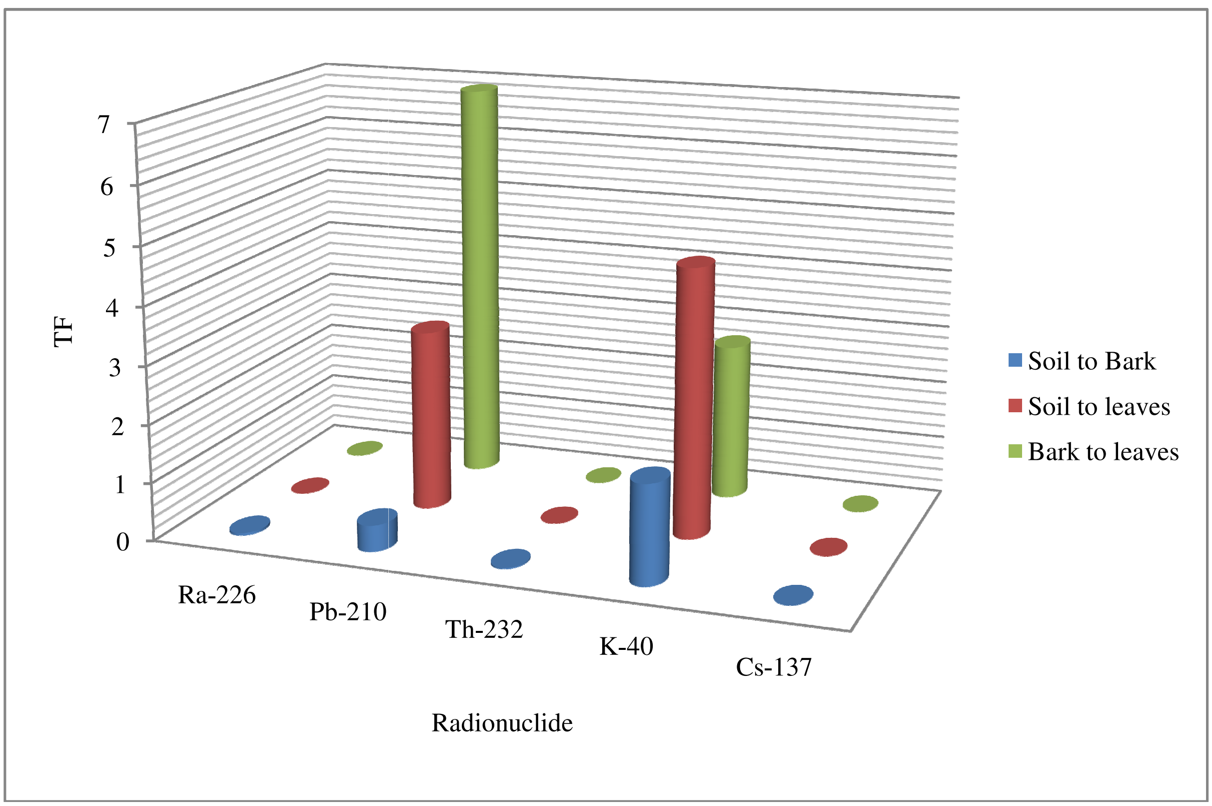

Figure-2
TF of Radionuclides

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