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Natural and Fallout Activity in Mango Trees

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Abstract

In the recent years radiological studies are concentrated on the investigation of restoration possibilities of contaminated ecosystems and to develop methods for decreasing the bioavailability of the radionuclides released to the environment. In the present study the uptake of ^{40}K, ^{137}Cs, ^{226}Ra and ^{232}Th in the mango leaves of different towns of Bahawalpur, Bahawalnagar and Rahimyar Khan Districts were measured. The mean activity levels of ^{40}K, ^{137}Cs, and ^{232}Th in mango leaves present in the area under study are 279.63, 0.69, 4.19Bq kg^{-1}. The activities were found to be within the limits recommended by various agencies. The radium equivalent activity, external and internal hazard indices and absorbed dose rates were also measured to assess the health risks. The mean values of radium equivalent activity, hazard indices, and absorbed dose rates are 27.52 Bq kg^{-1}, 0.07 and 14.73 $nGyh^{-1}$ respectively.

Introduction

It is a well known that the radioactive elements are present in natural vegetation. Information on the existence and accumulation of radionuclides has recently gained importance because users of these products may develop a higher incidence of cancer and other health effects. Different radionuclides are always present in food samples from natural sources or as a result of discharge of radioactivity from industry, hospitals, and research laboratories or from nuclear weapon test fall outs. Most of the internal radiation sources received by human beings are due to the consumption of contaminated food. Therefore, it is necessary to check and estimate the activity of various radionuclides present in the food samples, in order to assess the radiation doses to humans the ultimate consumer of food.

Radioactive materials that decay spontaneously produce ionizing radiations, which have sufficient energy to strip away electrons from atoms creating ions or to break some chemical bonds. Any living tissue in the human body can be damaged by ionizing radiations due to decay of radionuclides present inside the body. The body attempts to repair the damage, but sometimes the damage is too severe or widespread, or mistakes are made in the natural repair process. The long-life health effect of ionizing radiations is cancer. Other effects include nausea, weakness, hair loss or diminished organ function. Fetus in the womb is also affected by radiation. These effects include smaller head or brain size, poorly formed eyes, abnormally slow growth, and mental retardation [1]. Studies indicate that fetuses are most sensitive between about eight to fifteen weeks after conception. They remain somewhat less sensitive between sixteen and twenty-five weeks old.

The nature of soil is a significant factor for the transfer of radionuclides. Usually the transfer factor is less in cases of sandy land [2]. It has also been observed that more activity is transferred from soil in tropical plants than in temperate plants [3]. The area under study lies between 27° 40' - 30°22' north latitudes and 60º 45' - 73º 58' east longitudes and 250 to 550 ft altitudes, which is a part of tropical zone. The land of area under study consists of (a) Riverine area (b) Canal irrigated (c) and Desert area including Cholistan and Thar [4]. Among other vegetation mango plantation is common in all these areas.

Experimental

From literature it can be seen that the concentration of radionuclides in leaves, fruit and bark is similar and is higher than in the core of wood and older parts of the plants [5]. Therefore, the leaves of mango trees were used in this analysis because of long lasting period as compared to fruits and contribute more to the exposure. Because of having similar activities in fruit this measurement can also help assess the ingestion activity due to mango fruit.

Materials and methods

The fresh leaves of mango trees (Mangifera Indica) from the areas Fort Abbas, Minchinabad, Hasilpur, Bahawalpur, Liaqatpur, Rahimyar Khan and Sadiqabad were taken and weighed. The samples were carefully washed to remove any dust and to ensure the uptake of activity from soil. The samples were then dried in oven at 110^{o}C till the weight became constant and ground and ashed in the electric furnace at 400^{o}C for the complete destruction of organic matter. Arbitrarily chosen vegetation samples were used and read. In order to prevent the escape of radioactive daughter products through gaseous diffusion, care was taken to avoid the contamination of the samples from the exposure to the environment. All ashed samples were kept in an enclosed, dark, airtight environment at room temperature. Each sample was carefully weighed and placed in a clean, pre-weighed plastic container having a diameter of approximately 2 inches. Each sample was properly labeled and catalogued.

Instrumentation

The samples of ashed mango leaves were analyzed by gamma spectrometry system. In this work, a high purity germanium coaxial detector model No. GC 3020 was used having a relative efficiency of 30% and active volume of 180 cm^3 with beryllium-end window. The detector had resolution (FWHM) 2.0 keV at 1332 keV of ^{60}Co and its peak to Compton ratio was 54:1. Spectral data from the detector was accumulated and analyzed by a PC using an MCA card Accuspec-B containing a commercial software Genie-2000 version 1.3 provided by CANBERRA, USA [6]. The operational voltage for the system was 3000 V. Each sample was read for 65000 seconds. The extended reading period was used to improve the statistical accuracy of the data. The date of each reading was carefully noted and the change in radioactivity levels of each sample was monitored over time. The activity of ^{238}U was replaced by ^{226}Ra due to disequilibrium set up between the two. The activity of ^{40}K, ^{137}Cs, ^{226}Ra and ^{232}Th were measured by considering 1460, 661, 186 and 911.1 energy peaks, respectively.

Results and discussion

Table-1 shows the radioactivity level in vegetation on dry weight basis in the area under study. It is obvious from Table-1 that the minimum activity of ^{40}K is 189.93 Bq kg^{-1} in Rahimyar Khan and its maximum level is 360.29 Bq kg^{-1} in Bahawalpur. ^{137}Cs is not detected in Rahimyar Khan and Minchinabad whereas its minimum level is 0.13 Bq kg^{-1} in Derawer Fort and maximum is1.39Bq kg^{-1} in Fort Abbas. ^{226}Ra is not found in detectable amount. The activity of ^{232}Th ranges from 2.96 Bq kg^{-1} in Rahimyar Khan to 7.20 Bq kg^{-1} in Fort Abbas.

Table-1. Natural and fallout radioactivity (Bq kg^{-1}) in vegetation samples.

Area	^{40}K	^{137}Cs	^{232}Th
Fort Abbas	250.14	1.39	7.20
Minchinabad	293.09	-	2.97
Hasilpur	275.28	0.74	3.72
Bahawalpur	360.29	0.37	4.99
Liaqatpur	231.89	0.74	3.72
Rahimyar Khan	189.93	-	2.96
Sadiqabad	347.20	0.74	2.98
Derawer Fort	289.22	0.13	4.99
Mean	279.63	0.69	4.19

Potassium-40 is the only nuclide which is found in greater amount in vegetation. Because of similar chemical properties of potassium and cesium and high content of potassium in soil, the soil's cesium may be replaced by potassium and absorbed by the plants.

The root uptake of ^{137}Cs usually decreases with time. The decrease has seen particularly in soil of high clay content due to fixation of cesium by clay minerals, however high organic matter enhances the root uptake of cesium but may also have the opposite effect; an excess of potassium dilutes the cesium ions, which decreases uptake, but may also cause the deposition of fixed cesium which increases uptake. Thus very little amount of cesium in present study may be due to large concentration of ^{40}K.

Radium-226 was not detected in these samples while the activity of ^{232}Th was found in detectable amount and absorbed more in vegetation.

The uptake of isotope from soil by plants depends upon various interrelated soil properties including texture, clay content, dominant clay minerals, cation exchange capacity, exchangeable cations, pH and organic matter content. It also varies with chemical and physical forms of radionuclides, plant species, plant part and stage of growth as well as experimental conditions [7].

To represent the specific activities of ^{40}K, ^{226}Ra and ^{232}Th by single quantity, which takes into account the radiation hazards associated with them, a common index has been introduced. It is called the radium equivalent activity (Ra_{eq}) and is defined as [8, 9]:

$$Ra_{eq} = A_{Ra} + 1.43\,A_{Th} + 0.077\,A_K \quad (1)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K respectively. In this calculation ^{238}U has been replaced by the decay product ^{226}Ra because there may be disequilibrium between ^{238}U and ^{226}Ra. While defining Ra_{eq} by Eq. 1, it has been assumed that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K produce the same gamma dose.

The objective of measuring radioactivities is to make an estimate of radiation dose likely to be delivered externally. To limit the radiation dose to 1.5mSv y^{-1} [10], a number of models have been suggested by various workers. One such model, proposed to serve as a criterion in the then Federal Republic of Germany at the beginning of 1980's, was [11].

$$\frac{1}{37}\left(\frac{A_{Ra}}{10}+\frac{A_{Th}}{7}+\frac{A_K}{130}\right) \le 1$$

This criterion, which considers the external hazards due to gamma rays, corresponds to a maximum radium equivalent activity of 370 Bq kg^{-1} can be written as Eq. 2.

$$H_{ex} = \frac{A_{Ra}}{370}+\frac{A_{Th}}{259}+\frac{A_K}{4810} \quad (2)$$

There is a radiation hazard to respiratory organs due to radon-222 and its short lived decay products. The maximum permissible concentration for radium must be reduced to half the normal limit, i.e.185 Bq kg^{-1} [8]. This restriction defines H_{in} (the internal hazard index) as Eq. 3.19 [9].

$$H_{in} = \frac{A_{Ra}}{185}+\frac{A_{Th}}{259}+\frac{A_K}{4810} \quad (3)$$

The external and internal hazard indices should be less than unity for safe amount of activity.

Absorbed dose rate in air is the dose that is received in the open air from the radiation emitted from radionuclides present in the soil. The absorbed dose rate (D) is the amount of energy absorbed by a body one meter above the ground, which is calculated by Eq.4 [12].

$$D = (0.662C_{Th} + 0.427C_{Ra} + 0.043C_K)\ \text{nGyh}^{-1} \quad (4)$$

where C is average activity concentration.

The radium equivalent activity, the hazard indices and absorbed dose rates are shown in Table-2.

Table-2. Radium equivalent activity, hazard indices, and absorbed dose rates in vegetation samples

Area	Ra_{eq}(Bq kg^{-1})	H_{ex}	H_{in}	D (nGyh^{-1})
Fort Abbas	29.56	0.08	0.08	15.52
Minchinabad	26.82	0.07	0.07	14.57
Hasilpur	26.52	0.07	0.07	14.30
Bahawalpur	34.88	0.09	0.09	18.80
Liaqatpur	23.15	0.06	0.06	12.43
Rahimyar Khan	18.85	0.05	0.05	10.13
Sadiqabad	30.99	0.08	0.08	16.90
Derawer Fort	29.41	0.08	0.08	15.21
Mean	27.52	0.03	0.07	14.73

Radium equivalent activity is minimum in Liaqatpur (23.15 Bq kg^{-1}) and it is maximum in Bahawalpur, i.e., 34.88 Bq kg^{-1}. The mean external and internal hazard index is 0.07 with minimum in Rahimyar Khan (0.05) and maximum in Bahawalpur (0.09). While considering the absorbed dose rate it is obvious from Table-2 that its value is minimum in Rahimyar Khan (10.13 nGyh^{-1}) and maximum in Bahawalpur (18.80 nGyh^{-1}).

Conclusion

In the present study ^{226}Ra was not found in the detectable amount. The mean activity levels of ^{40}K, ^{137}Cs, and ^{232}Th in mango present in the area under study are 279.63, 0.69, 4.19Bq kg^{-1} respectively. ^{40}K is the only nuclide present in significant concentration. The uptake of isotope from soil by plants depends upon various interrelated soil properties including texture, clay content, dominant clay minerals, cation exchange capacity, exchangeable cations, pH and organic matter content. From Table-1 it is obvious that no single reason can account for the trends of activity in the area. The mean values of radium equivalent activity, hazard indices, and absorbed dose rates are 27.52Bq kg^{-1}, 0.07 and 14.73nGyh^{-1} respectively. All the values of radium equivalent activities are under the recommended limit of 370Bq kg^{-1}. Similarly, the hazard indices are also within the safe limits, i.e., less than one

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