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# Estimation of radioactivity in tobacco

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The link between cigarette smoke and cancer has long been established. Smokers are ten times at greater risk of developing lung cancer than that of non-smokers. Tobacco fields and plants also have higher concentration of uranium and consequently large contents of $^{210}$ Po and $^{210}$ Pb belonging to uranium and radium decay series. These radio-nuclides have long association with tobacco plants. $^{210}$Pb and $^{210}$Po, decay products of the uranium series get dissolved in water and are first transported into plants and subsequently to the human being. Also, the uptake of radio nuclides into roots from the soils and phosphate fertilizers along with direct deposition of $^{210}$Pb by rainfall represents the principal mechanism of incorporation of $^{210}$Pb and $^{210}$Po into the tobacco plants. Uranium present in soil enters the plants through roots and gets distributed in various parts of the tobacco plants. This phenomenon may cause high intake of uranium and its radioactive decay products leading to harmful effects in human being. In the present work, Gamma spectrometry (HPGe detector of high-resolution gamma spectrometry system) has been used at Inter University Accelerator Center (IUAC), New Delhi, for the measurement of activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K in some tobacco samples. The alpha radioactivity of the leaves of the tobacco plants was measured using plastic track detectors LR-115 Type-II manufactured by Kodak. Measurement of track densities (track cm$^{-2}$ day$^{-1}$) shows variation on the upper face and the bottom face of the leaves for the plants. The track density due to alpha particles is higher at bottom face as compared to top face of the leaves.

**Keywords:** Track density, Plantation, Tobacco, Fertilizers

## 1 Introduction

Ever since studies on the relation of smoking to cancer particularly the lung cancer has been established, there had been a great interest in studies concerned with the monitoring of the alpha radioactivity in tobacco[1-3]. Although, there may be another cancer causing mechanism also in smokers but main harm caused in this case is by the radioactive environmental pollutants present in the tobacco leaves used in the manufacture of the cigarettes. The toxicity in tobacco was earlier considered mainly due to the presence of chemi-toxins like nicotine, tar, aromatic hydro carbons and many other materials leading to mutagenicity and carcinogenicity but there are many reports indicating the presence of naturally occurring radio nuclides like $^{210}$Po and $^{210}$Pb in the tobacco used in cigarettes[4]. All soils already contain uranium and radium to various extents but to get a huge profit in tobacco plantation by the farmers, the soil to grow tobacco is heavily treated with chemical fertilizers particularly with phosphate fertilizers, which are rich in uranium and its decay products[5]. It is because the phosphate for the manufacturing of phosphate fertilizers are derived from a rock mineral named ‘apatite’ containing radium and radioactive elements like $^{210}$Po and $^{210}$Pb. Therefore, tobacco fields containing higher concentration of uranium also have large contents of $^{210}$Po and $^{210}$Pb due to the uptake of these radio nuclides through roots of the plants[6,7]. Some of the daughters of $^{222}$Rn such as $^{218}$ Rn and $^{214}$ Rn become firmly attached to the surface and interior of tobacco leaves. The tobacco leaves having large surface area with their hairy and sticky nature, facilitates enhanced deposition of $^{210}$Po and $^{210}$Pb on the leaves during plant’s life[8]. The radioactive elements in phosphate fertilizers also make their way into our food and drink. Many food products, especially nuts, fruits and leafy plants like tobacco absorb radioactive elements from soil and concentrate them within themselves[9].

## 2 Experimental Details

For the measurement of alpha radioactivity in tobacco leaves the plastic track detectors L-R 115 types-II have been used. The tobacco plants were grown in earthen pots having equal amounts of same type of soils. Different types of fertilizers like D.A.P., zinc sulphate, potash, super phosphate, urea and their mixtures were added to the soil. The healthy leaves from different samples of plants were plucked, dried in an oven at $40^0$C for two hours and then sandwiched between two plastic track detectors each of same size (1 cm × 2 cm) by wrapping over a cello tape tightly across them to record the tracks for alpha radiations emitted from upper and bottom faces of the leaves. The LR-115 detectors have been used for these measurements because of low background noise and better contrast[10]. The exposure time of the detectors was 60 days. At the end of exposure time, the detectors were removed and subjected to a chemical etching process in 2.5 N NaOH solution at 60°C for one and half hour. The detectors were washed, dried and then, the tracks caused by alpha radiations emitted from the tobacco leaves were counted using an optical microscope using CCTV Camera and a monitor at magnification 600x.

For the measurement of radon exhalation rates, Can technique[10] has been used. A known amount of tobacco samples (crushed and oven dried) were placed in plastic cans. LR-115 type-II plastic track detectors were fixed on the bottom of the lid of each can with tape such that sensitive side of the detector faced the specimen. The cans were tightly closed from the top and sealed. The exposure time of the detectors was 100 days. At the end of the exposure time, the detectors were removed, processed and track density was calculated. The measured track density (track/cm$^2$/day) was converted into radon concentration in Bq/m$^3$ using calibration factor for LR-115. The equations used for radon exhalation rates[11-12] are:

$$Ex = \frac{CV\lambda/M}{T + 1/\lambda(e^{-\lambda T} - 1)} \times (\text{Bq Kg}^{-1}\,\text{h}^{-1})$$

for mass exhalation rate …(1)

$$Ex = \frac{CV\lambda/A}{T + 1/\lambda(e^{-\lambda T} - 1)} \ (\text{Bq m}^{-2}\,\text{h}^{-1})$$

for surface exhalation rate …(2)

where $C$ is the integrated radon exposure (Bq m$^{-3}$ h$^1$); $M$ the mass of sample (Kg); $V$ the volume of air in can (m$^3$); $T$ the time of exposure (hrs); $\lambda$ the decay constant for radon (h$^{-1}$) and $A$ is the area covered by the can or surface area of the sample (m$^2$).

Using HPGe detector of high-resolution gamma spectrometry system U, Th and K activity in the samples was measured at IUAC, New Delhi. The detector is a co-axial *n*-type high- purity germanium detector (Make E G & G, ORTEC, Oak Ridge, USA). The detector has a resolution of 2.0 keV at 1332 keV and relative efficiency of 20%. The output of the detector is analyzed using a 4 K ADC system connected to PC, the spectrum is analyzed using the locally developed software CANDLE (Collection and Analysis of Nuclear Data using Linux nEtwork). The samples were crushed into fine powder by using mortar and pestle. Fine quality of the sample was obtained using a scientific sieve of 150 -µm mesh size. Before measurement, the samples are dried in an oven at about $110^0$C for 24 h. Each sample is packed and sealed in an airtight PVC container and kept for about 4-week period to allow radioactive equilibrium among the radon ($Rn^{222}$), thoron ($Rn^{220}$) and their short lived decay products. An average of 300-400 g of sample in powder form was taken for each material. The samples were counted for a period of 72,000 s and the spectra are analyzed for the photopeak of uranium, thorium daughter products and K-40.

## 3 Results and Discussion

The calculated values of track densities for various samples taken as tobacco leaves collected from tobacco plants were grown using different types of fertilizers with their varying amounts just before the plantation of the seedlings of tobacco, are presented in Table 1. The variation in track densities at the upper and bottom faces of the leaves are also there for the same leaf. Also, there is a variation of track densities for the leaves of various plants grown using different fertilizers in varying amounts. The track densities show variation from 5.5 to 37.2 track cm$^{-2}$ day$^{-1}$ on

Table 1 — Alpha track density measurement at the leaves of tobacco plants with effect of different fertilizers

| Sr.No | Name of Fertilizer | Amount of Fertilizer (g) | Track density on top face of leaves (Track cm$^{-2}$ day$^{-1}$) | Track density on bottom face of leaves (Track cm$^{-2}$ day$^{-1}$) |
|---|---|---|---|---|
| 1 | No Fertilizer | - | 5.5 | 12.4 |
| 2 | DAP | 50 | 20.7 | 24.8 |
| 3 | Super phosphate | 50 | 20.7 | 26.2 |
| 4 | DAP + Potash | 50+50 | 27.5 | 35.8 |
| 5 | Zinc sulphate +Urea | 50+50 | 37.2 | 42.7 |

Table 2 — Measurement of uranium, thorium, potassium and doses from tobacco samples using gamma spectroscopy

| Samples | U-238 (Bq/kg) | Th-232 (Bq/kg) | K-40 (Bq/kg) | Raeq (Bq/kg) | D ($nGyh^{-1}$) | Indoor (mSv) | Outdoor (mSv) |
|---|---|---|---|---|---|---|---|
| TC1 | 61± 8 | 42 ± 3 | 2232 ± 25 | 293 | 147 | 0.72 | 0.18 |
| TCJKU | 89± 13 | 28±2 | 1009 ±12 | 208 | 101 | 0.49 | 0.12 |
| TCSFG | 153 ± 22 | 36±2 | 750 ± 10 | 261 | 123 | 0.60 | 0.15 |

Table 3 — Measurement of radon exhalation rates from tobacco samples

| Samples | Codes | Radon conc. ($Bqm^{-3}$) | Mass exhalation rates ($mBqkg^{-1}h^{-1}$) | Surface exhalation rates ($mBqm^{-2}h^{-1}$) |
|---|---|---|---|---|
| | TC1 | 669 | 41 | 457 |
| Tobacco | TCSFG | 590 | 73 | 403 |
| | TCJKU | 551 | 62 | 381 |
| AM ± SE* | | 603 ± 35 | 58 ± 9 | 414 ± 23 |

the upper face and 12.4 to 42.7 track $cm^{-2}$ $day^{-1}$ at the bottom face. The alpha track density increases due to use of different chemical fertilizers.

The average uranium, thorium and potassium concentration in tobacco samples varied from 61±8 to 153±22 Bq/kg, 28±2 to 42±3 Bq/kg and 750±10 to 2232±25 Bq/kg, respectively. The average indoor and outdoor annual effective doses were also measured as presented in Table 2. The average radon concentration in these samples was found to be 603 ± 35 $Bqm^{-3}$, the mass exhalation rate 58±9 $mBqkg^{-1}h^{-1}$ and surface exhalation rate 414±23 $mBqm^{-2}h^{-1}$ (Table 3).

## 4 Conclusions

1. The alpha track density at the bottom faces is higher as compared to upper faces of the tobacco leaves.
2. There is an increase in alpha radioactivity with the use of fertilizers, the track densities vary with the nature of fertilizers used and its amount added to the soil. Therefore, for healthy growth and reduced level of radioactivity in tobacco leaves, optimum use of phosphate fertilizers may be made.
3. The higher concentration of uranium, thorium, potassium and radon exhalation rates in tobacco samples enhances the radiation dose received by the worker working in tobacco fields and the smokers are at a higher risk of lung cancer.

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