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Measurement of fertilizers induced radioactivity in tobacco plants and elemental analysis using ICAP–AES

Pooja Chauhan, R.P. Chauhan*

Department of Physics, National Institute of Technology, Kurukshetra 136119, India

HIGHLIGHTS

- The study is related to alpha radioactivity measurements in tobacco plants.
- The radon mass exhalation rates in various tobacco plants were also measured.
- Study is related to analysis of chemical elements in different fertilized tobacco samples.

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ABSTRACT

It is widely accepted that tobacco smoke is the leading cause of lung cancer worldwide. The alpha radioactive content present in tobacco smoke and increasing number of lung cancer cases explain the importance of investigation. The use of different fertilizers may cause alteration in the metabolism of plants causing different response towards uptake of different element and radionuclides. In the present study, the estimation of alpha radioactivity induced by use of different fertilizers in tobacco leaves was made using solid state nuclear track detector (LR-115) to identify the relative presence of radionuclides in the plants. The radon exhalation rates from the tobacco plant were carried out to confirm the presence of radium or emission of radon from plant. The elemental analysis of tobacco plant by inductively coupled argon plasma atomic emission spectrometry provides a way to understand the difference occurred in metabolism caused by the use of fertilizers. The alpha track densities were found to vary with nature of fertilizers added to the soil and an increase was also observed with time. The radon mass exhalation rates in various tobacco plants were found to vary with type of fertilizers used.

1. Introduction

Smoking is a leading cause of cancer and death from cancer. The transfer of metals and radioactive elements through tobacco smoke to humans is a serious health problem. It causes cancers of the lung, mouth, throat, kidney, bladder, pancreas and stomach as well as acute myeloid leukaemia (Sasco et al., 2004). Although there may be other cancer inducing mechanisms in human, one of the causative factor is the radioactive elements present in tobacco leaves used for manufacturing of cigarettes (Nain et al., 2008). Botanically, tobacco is one of the family Solanaceae, genus Nicotiana. Tobacco smoke contains several carcinogenic components; different radionuclides of natural origin (Martell, 1982) are present in a significant quantity besides the considerable quantity of toxic chemical compounds (Jenkins and Guerin, 1984).

Fertilizers have become essential to the agricultural field all over the world that helps to increase the crop production and to improve the nutrient-deficient properties of lands (Chauhan et al., 2013). Globally, the revelation that physical processing of phosphate ore does not alter the radionuclide concentration during the operational processes in fertilizer plants led to legislations concerning discharges in gaseous, liquid and solid forms (Mark et al., 2012). An investigation of pathway of radionuclides from fertilizers to tobacco plants and to humans is, therefore, very important from radiological protection point of view within the smokers to large extent. The radioactivity of tobacco leaves after the collection from tobacco fields and before cigarette production in order to find any association in the uptake of the naturally occurring radioactive nuclides (Papastefanou, 2001). 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

* Corresponding author. Tel.: +91 9468406020; fax: +91 1744238050.
E-mail addresses: mpoojarana@gmail.com (P. Chauhan), chauhanrpc@hotmail.com (R.P. Chauhan).

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of the alpha radioactivity in tobacco (Doll and Hill, 1956). The tobacco leaves are having large surface area and with their hairs sticky in nature. The properties and distribution of trichomes (hairs) on tobacco leaf surfaces suggest that they are effective collectors of small Aitken (nuclei) particles (<0.1 μm diameter) by means of diffusive deposition due to Brownian motion of the particles (Martell, 1974).

The primary sources of elements from the environment to plants are: air, water and the soil (Hamilton, 1995). The accumulation of heavy metals in environmental samples such as soils and sediments causes a potential risk to human health due to the transfer of these elements in aquatic media, their uptake by plants and their subsequent introduction into the food chain (Alonso Castillo et al., 2011). Heavy metals like Cu, Cd, Ni, Pb, Zn are major environmental pollutants, potentially considered to be toxic and carcinogenic though a few of them are essential elements for vital metabolic processes (Rama Devi and Prasad, 1998). Cadmium is cleared from the blood but it accumulates with age in the kidney and liver. Cadmium sources are either from atmospheric depositions or from the application of phosphate fertilizers and sewage sludge (Wagner, 1993). Tobacco is a cadmium accumulator (Wagner, 1993; Tsadilas, 2000). The deposition of ^{210}Pb by rainfall is the principal mechanism of ^{210}Po entry in plants (Parfenov, 1974; Francis et al., 1968). Tobacco fields containing higher concentration of Uranium also have large contents of ^{210}Po and ^{210}Pb due to the uptake of these radionuclides through roots of the plants (Abbady et al., 2005; Singh et al., 2005; Karunakara et al., 2000). Another source of ^{210}Pb and ^{210}Po is the phosphate fertilizers (Savidou et al., 2006).

The United States Environmental Protection Agency (US-EPA) has reported that inhalation of radon is the second killer from cancer (Tung et al., 2005). The radiological impact caused by nuclides is due to radiation exposure of the body by the gamma rays and irradiation of the lung tissues from inhalation of radon and its daughter (Nain et al., 2010, 2006). Exhalation of ^{222}Rn from these materials is of interest since the short-lived progeny of radon is the greatest contributors to the lung dose of inhaled radionuclides (Paredes et al., 1987). The radioactive half-lives of radon, thoron and their respective decay products are important in determining the exposure of people in work places and homes.

The physiology and metabolism of plants are altered by the use of different fertilizers in terms of the uptake of different element and radionuclide. The use of fertilizers in soil may cause an increase in the radionuclide content caused high uptake of radionuclide. The radionuclide (uranium, thorium, Radium, polonium) can be transferred from soil to root and translocate/accumulate in various parts of plants like leafs, grain and stem. Of the radionuclides, radium-226 appears to have the greatest potential for translocation and accumulation in plant shoot tissue (Knight, 1983). Since the starting materials of the fertilizers is phosphate rock used in wet process by attack of sulphuric acid in fertilizer industry contain varying amount of uranium. The ^{238}U remains concentrated into phosphoric acid while ^{226}Ra, ^{210}Po, ^{232}Th and ^{210}Pb precipitated out as sulphate salt concentrated in phosphogypsum as the byproduct (Mazzilli et al., 2000). The uranium either in form of $[U(SO_4)_2]$ or $[UO_2(SO_4)]$ in phosphoric acid is water soluble, remains in phosphoric acid which is used for the fertilizers production, thus the uranium content of fertilizers is expected to be high (Khater and AL-Sewaidan, 2008). The present work aims to the estimation of alpha radioactivity in tobacco plants grown using various fertilizers in different amounts before the plantation of the seedlings. Due to transfer of the uranium as a result of its dissolution in water, the presence of radium and hence emission of the radon gas is expected. The measurement of radon exhalation rates from the dry plant of tobacco grown with different fertilizer was performed with active techniques and reported here to assess a first order exposure risk for the persons working in the fields. The alteration of the metabolism by use of different fertilizers may affect the intake of various elements which was studied by an inductively coupled argon plasma atomic emission spectroscopy.

2. Materials and methods

2.1. Control growth of tobacco plants using different fertilizers

For the measurement of alpha radioactivity in tobacco leaves LR-115 Type-II solid state nuclear track detectors have been used. The LR-115 is a 12 μm thick cellulose nitrate layer deposited on the 100 μm thick polyester base which is most sensitive to alpha particle of energy 1.6–6.0 MeV. The alpha emitted by the various radionuclides having energy in the specified range produced a cylindrical track along the line of its trench. These have low sensitivity to beta and gamma radiations and hence suitable for detection of alpha particles in mixed radiation fields. In the present control study, the tobacco plants were grown by planting the seeds in earthen pots having equal amounts of same type of soil. Different amounts (15 g, 30 g & 40 g) of fertilizers like DAP (Diammonium Phosphate), NPK (nitrogen, phosphorus and potassium), potash fertilizer (PF), single super phosphate (SSP), zinc sulphate ($ZnSO_4$) fertilizers were added to the soil just before the plantation of tobacco plants in the pots. The growth of plants in all the cases was also recorded at regular intervals of time (Fig. 1).

The healthy leaves from different samples of plants at regular interval were plucked, dried in an oven at 40 °C and then sandwiched between two LR-115 detectors each of same size (2 cm × 2 cm) by wrapping a cello tape tightly to record the tracks for alpha radiations emitted from both upper and bottom faces of the leaves. The samples (Plants parts sandwiched between two LR-115 detectors) were packed into aluminium foil and were kept in the air tight plastic container having only 5–10% air volume. Thus, the environment radon contributions are considered negligible. Also the LR-115 detectors used in present study were checked for materials background. The background track density due to materials itself was 0.5 T cm^{-2} and less than that of rounding figures used in reporting the data. The alpha emitted from the surface of leaf and other parts of plant produced tracks on LR-15 detectors, which can be enlarged with chemical etching. The SSNTDs were etched with 10% 2.5 N sodium hydroxide solution in an etching bath at a temperature of 60 °C for 90 min time for developing the registered tracks. The etching process removes a bulk thickness of 4 μm leaving a residual detector thickness of 8 μm. The cellulose nitrate layer then removed from the polyester layer and used for track counting using spark counter. The removed layer was first pre sparked at 900 V and counted at 500 V twice. The spark counter system is calibrated by Polltech Inc., Mumbai.

Fig. 1. Tobacco plants grown using different fertilizers in earthen pots.