Distribution of $^{137}$Cs in the South-west Caspian Soil

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**INTRODUCTION**

Cesium-137 is an artificial radionuclide, a product of nuclear fission reaction with a half-life of 30.2 years which decays to $^{137}$Ba by beta emission [principal modes of decay (keV): $\beta$ 510 (94%), 1180 (6%); $\gamma$ 662 (85%)] (Eisenbud and Gesell, 1997). The atmospheric $^{137}$Cs is derived from two main sources:

- Atmospheric testing of nuclear weapons; and
- Accidents in nuclear facilities as well as a limited amount during their normal operation.

Weapons tests in the northern hemisphere commenced around 1954, peaked in 1963 and the corresponding fallout fell to insignificant levels by 1986. Two major nuclear accidents released significant quantities of $^{137}$Cs into the atmosphere in 1957: Windscale reactor meltdown in the UK, and a chemical explosion in a Soviet plant treating active wastes, situated in the Urals. On 26 April 1986, however, a massive release of $^{137}$Cs and other radionuclides occurred as a result of the reactor meltdown accident at Chernobyl in the Ukraine. Winds carried away the radioactive cloud and as a consequence, considerable amounts of $^{137}$Cs as well as other radionuclides were deposited all over Europe and other parts of the northern hemisphere mainly by precipitation (UNSCEAR, 2000). Experience gained from the management of this accident showed the crucial importance of employing rapid and effective abatement strategies based on a valid estimation of levels and characteristics of deposited radionuclides.

When scavenged from the atmosphere, the $^{137}$Cs concentration in surface soil decreases under the influence of various processes like decay, mechanical removing with rain water, vertical migration and diffusion into deeper layers of soil. Around two decades after the Chernobyl accident and over four decades after the peak of testing nuclear devices in the atmosphere, we have studied $^{137}$Cs distribution in the surface horizons of soil in Guilan, an Iranian northern province located in south-western region of the Caspian Sea. This study has been carried out as part of a comprehensive program of environmental radioactivity measurement in the South-Caspian ecosystem, which included inventory measurements of natural radionuclides Radium-226 ($^{226}$Ra), Thorium-232 ($^{232}$Th) and Potassium-40 ($^{40}$K) as well.

**MATERIALS AND METHODS**

The study area, Guilan province, is located in Northern Iran, between south-west coast lines of the Caspian Sea (-26 m asl) and high mountain ranges of Talesh and Elborz (3000-4000 m asl) (see Fig. 1). The plains consist of mainly rice fields and the mountains are mostly covered with old natural forests. Average annual precipitation in the region is in the range of 1200-1500 mm.
Inventories of $^{137}$Cs have been measured for more than 800 soil and surface vegetation samples collected from almost 70 sites throughout Guilan Province. Care was taken in the selection of suitable sites, situated on land that had remained without major natural or man-made disturbances over about several decades. Split-level composite sampling method was employed in individual sites on 0-5, 5-10, 10-15 and 15-20 cm depth intervals. Samples were air dried and homogenized before being subjected to gamma spectrometry using HPGe detectors. Gamma spectrometry systems were calibrated against standard samples provided by analytical quality control services of the International Atomic Energy Agency (IAEA). Activity of $^{137}$Cs was determined by its gamma emission at 661.6 keV, and inventories were calculated by integrating activities in each of the cores over the entire core depth (Smith, 1997).

RESULTS AND CONCLUSIONS

The range in $^{137}$Cs deposition in the region of interest is estimated at 244-4083 Bq m$^{-2}$ with a mean value of 1984±99 Bq m$^{-2}$. Considering the range of Cesium-137 deposition in other parts of Iran at 28-3734 Bq m$^{-2}$, and world mean deposition of 1244 Bq m$^{-2}$, the higher deposition seems to be mainly due to high annual precipitation, orographic effect (seeder-feeder mechanism) and occult deposition (Fowler et al., 1998), and possible influence of Chernobyl depositions in the region. The range in specific activities of dried soil samples is 5-73 Bq kg$^{-1}$.

Figures 2 and 3 illustrate the typical depth distribution of $^{137}$Cs in collected cores and its deposition pattern in northwestern part of the study region, respectively. Fig. 2 shows a sub-surface maximum, which is a usual case for under-canopy samples.
Knowledge of the vertical migration of $^{137}\text{Cs}$ in soil is important and has been subject of research for a long time. Apart from the use of increasing accuracy in field gamma-measurements; a description of the vertical migration is also a key factor in predicting the fate of present and future fallout (Almgren and Isaksson, 2006). Several models have been developed to describe $^{137}\text{Cs}$ migration in soils and to explain its vertical distribution. Bunzl reports that the major contribution of observed uncertainty in $^{137}\text{Cs}$ gamma dose-rate above soil surface is primarily as a result of spatial variability of the total amount of deposited $^{137}\text{Cs}$ in soil and its vertical distribution and soil bulk density stand at the next importance levels (Bunzl et al., 2001). Inspired by these studies, in order to have a better understanding of $^{137}\text{Cs}$ deposition on, and distribution in soil, a proper distribution function is employed and Monte Carlo technique is applied to generate deposition pattern for a hypothetical radionuclide fallout scenario. A convection-dispersion mass transport model (Bossew and Kirchner, 2004) is also modified to predict concentration of the radionuclide in soil with respect to a single pulse deposition to the soil surface. Further measurements based on detailed split-level
sampling as well as in-situ gamma surveys are needed for the application of these model studies.

REFERENCES


