EPR Dose Reconstruction of Two Kazakh Villages Near the Semipalatinsk Nuclear Test Site

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Received January 8, 2002

Abstract. Electron paramagnetic resonance (EPR) dose reconstruction has been performed on archived tooth samples from residents of two villages near the Semipalatinsk nuclear test site in Kazakhstan. The context of this work is a large multidisciplinary study of thyroid disease prevalence and radiation dose among long-term residents of villages near that nuclear test site, in which EPR is used for biodosimetric validation of the gamma-ray component of dose reconstruction algorithms applied to the data for various villages whose residents were exposed to radioactive fallout during 1949–1962, the period of above-ground atomic bomb testing. The tooth samples, nine from the village of Kainar and 23 from the village of Znamenka, were extracted in 1964 and 1967, respectively, and stored indoors in closed boxes in Semipalatinsk. According to provided information, some time in the past, the teeth from Kainar were heated to 80°C for one day. Experiments carried out on 12 teeth from US sources to determine the effects of long-term storage and heat treatment found that EPR assay findings were not compromised for storage times less than 35 years and annealing at temperatures below 200°C. For tooth enamel samples prepared from molars and premolars the average reconstructed gamma dose was 390±70 mGy for Kainar residents and 95±40 mGy for Znamenka residents.

1 Introduction

The Semipalatinsk nuclear test site (SNTS), an area of 19000 km² in northeastern Kazakhstan, was the location for over 450 nuclear test explosions during 1949–1989 with a total explosive energy of 17.4 Mt TNT equivalent. The majority of tests conducted before 1963 were on the surface or in the atmosphere, as opposed to the mostly underground tests conducted after that date. Surface tests,
in which the fireball interacted with the ground, were the main sources of radioactive fallout affecting areas downwind of the SNTS and were mainly to the east. It is estimated that 30000 to 40000 residents of nearby areas may be at risk of health effects related to radiation exposure from the tests. It is also estimated that the bulk of the radiation exposure to the population resulted from three tests, conducted in 1949, 1951, and 1953.

Determination of the radiation doses to residents of various areas downwind of the SNTS is important for estimating the likely health risks associated with exposure and for epidemiological analyses of radiation-related risks. Estimates of fallout deposition have been calculated from theoretical models on the basis of bomb characteristics (explosive power, location and altitude of detonation), the speed and trajectories of individual fallout plumes at different altitudes, wind and precipitation patterns, and measurements of radionuclides remaining in the soil at different times after detonation. Such models have been widely used to reconstruct fallout exposures from tests carried out by the United States, the former Soviet Union, and other countries. Considerable attention has been devoted to understanding and reconciling the different approaches used by Russian and American scientists, in particular, comparing methods used for dose reconstruction for areas downwind of the SNTS and the Nevada test site in the United States.

It is important that dose reconstruction models be validated by independent measurements. Biodosimetric methods on the basis of the measurements with tissues from exposed persons, such as electron paramagnetic resonance (EPR) assays of tooth enamel and fluorescent in situ hybridization (FISH) assays of chromosome aberrations in cultured lymphocytes, are the main methods in use today.

EPR biodosimetry is based on measurements of free radicals induced by ionizing radiation exposure in tooth enamel [6]. It has been successfully applied to dose reconstruction for the survivors of the atomic bombings of Hiroshima and Nagasaki [6, 7], victims of the Chernobyl reactor accident [6], Russian nuclear workers [8], residents exposed to radioactive discharges along the Techa River in the South Urals region of Russia [9] and, most recently, persons exposed to radiation from nuclear bomb tests at the Totskoye test site in Russia [10].

The EPR assessment of archival teeth collected from residents of two villages near the SNTS, Kainar and Znamenka, are reported. Tooth samples from other villages are presently being assayed, and it is intended that the results will be employed in a comprehensive validation of dose reconstruction models applied to several different villages in the vicinity of the SNTS.

An interesting aspect of the present analysis is that the Kainar teeth were subjected to heat treatment, whereas those from Znamenka were not, and additional experiments were required to evaluate the effects of heat treatment on EPR findings.

2 Materials and Methods

The teeth used in the present study were kindly provided by Dr. Boris I. Gusev from the Kazakh Scientific Research Institute of Radiation Medicine and Ecol-