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Retrospective dose reconstruction for an incident involving a concealed radium needle

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ABSTRACT

A historical radium (^{226}Ra) needle was found in a building in Prague. The needle was concealed in a wall under a window frame. Ambient dose equivalent rate measured in close proximity to the frame reached up to 2 mSv/h. The place was located between a corridor and a staircase where people normally did not stay; hence, any significant radiation exposure was not suspected. Because of a remarkable history of the building, our speculation was that the needle could have been concealed there during World War II. To verify this assumption, one adjacent brick nearest to the place of the find was removed. The brick was used for retrospective dosimetry based on optically stimulated luminescence (OSL) of quartz extracted from a chosen brick block. Dose rate values inside the brick block were determined by a laboratory reconstruction. The original exposure conditions were simulated using the needle and a brick wall containing thermoluminescence detectors (TLDs). We also performed a computational simulation with the Monte Carlo technique. The simulation provided us a more detailed dose rate distribution inside the brick block. Finally, we compared OSL quartz, TLD, and Monte Carlo results. A good agreement among the results supports the speculation that the radium needle was concealed during World War II.

1. Introduction

In August 2017, a historical radium needle was accidentally discovered in a hospital building in Prague. The place of the find was located in a wall between a corridor and a staircase. The wall had a window and a door. After removing the marble stool of the window and the thin mortar layer, the radiation source was found just under the window frame at a distance of a few centimeters from the left corner (Fig. 1). The needle was carefully pushed out using a thin spatula. Because the needle was not well visible during the process, its position was not known precisely. The presumptive uncertainty in the position was approximately ± 20 mm for horizontal and ± 10 mm for vertical directions in the plane just under the window frame. Ambient dose equivalent rate values measured in close proximity to the window frame reached up to 2 mSv/h. People normally passed through the corridor without staying there for long time. Investigation and measurements performed in the vicinity showed no evidence to believe that anyone could be irradiated significantly. However, interesting questions arose: how long has the needle been there and how did it get there?

The building has a remarkable history (Viktorin, 2015). It was built at the beginning of the 20th century to serve as a private hospital called Prague Sanatorium, which was opened in 1914 as a modern general hospital covering all medical branches, except infectious and mental illnesses. The Prague Sanatorium was conceived according to the idea of a prominent Czech surgeon, Professor Rudolf Jedlička, who was one of the pioneers of radiology. Among other research interests, he was engaged in the application of radium needles for cancer treatment. The Sanatorium achieved the greatest prosperity between the First and the Second World Wars. During that time, radium needles were used for the treatment of some malignant diseases. Following the German occupation of Czechoslovakia, the Sanatorium was confiscated and converted into a hospital for “Schutzstaffel” (SS) troops in 1941. The employees of the Prague Sanatorium had only 6 days to move out. In 1945, the Sanatorium was transferred under the administration of the International Red Cross. Shortly after World War II, the hospital was expropriated and reconstructed to establish a state maternity hospital. Radium treatment has not been performed at the hospital since the end of World War II.

Circumstances regarding how the needle reached the place of the find are not known. Considering the history, a predominant view is that it could have happened during World War II. Because the Czech radium

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Fig. 1. Position of the radium needle.

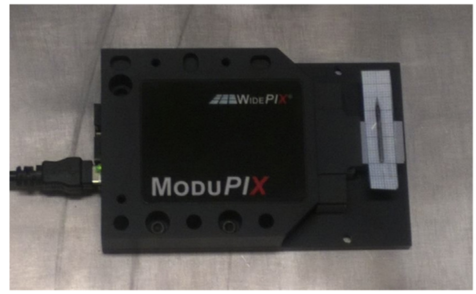
was a very valuable material, the German occupiers seized it and kept detailed records (Těšínská, E., 2017). The Czech employees might have had some reasons to hide a part of the material during the tense situation, especially in 1941. However, witnesses who could confirm or confute this speculation are no longer alive.

We got an opportunity to find out whether the needle really could have been concealed since World War II. Our colleagues from the National Radiation Protection Institute (NRPI) in Prague, who measured the radiation level at the place and removed the needle, provided us a part of the brick that was adjacent to the needle. We extracted quartz from a chosen segment of the brick. We then measured the radiation dose using optically stimulated luminescence (OSL) of quartz. We also performed a laboratory reconstruction of the irradiation conditions to determine the dose rate in various points of the brick segment. Dose rate inside the brick was measured using inserted thermoluminescence detectors (TLDs). In addition, we performed a computational simulation with the Monte Carlo technique. Subsequently, quartz, TLD, and computational results were compared for the considered time period.

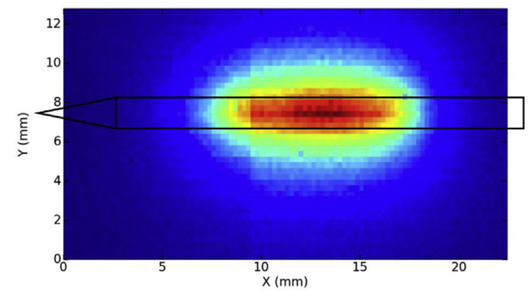
2. Material, instrumentation, and methods

2.1. Radium needle

The needle consists of a 25 mm long narrow-bore metal tube filled with a radium salt. ^{226}Ra disintegrates with a half-life of 1620 years to form radon. The product nucleus radon is a heavy inert gas that in turn disintegrates into its daughter products. As a result of the decay process from radium to stable lead, γ rays are produced with energies ranging



a. Radium needle fixed to a Timepix detector



b. Autoradiograph of the radium needle obtained using a Timepix detector.

Fig. 2. a Radium needle fixed to a Timepix detector. **b**. Autoradiograph of the radium needle obtained using a Timepix detector.

from 0.184 to 2.45 MeV. The average energy of the gamma rays from radium in equilibrium with its daughter products and filtered by 0.5 mm of platinum is 0.83 MeV (Khan, 2010). Activity of the found needle measured by a high purity germanium detector was 82.6 ± 8.3 MBq. Visually, the needle appears like a typical radium needle used for radium puncture in the past, but an eyelet hole is missing. The found needle and its autoradiograph are shown in Fig. 2a and b. The autoradiograph was created using a Timepix detector (Advacam). Because of the small detection area, the resulting image was created by joining two partial images. It is evident that the radium source is situated untypically only in the middle of the needle.

2.2. Quartz preparation

Quartz separation was done from segments of a part of the adjoining brick nearest to the needle (Fig. 3). For the purpose of a test OSL measurement, a segment from the top left corner of the brick was removed. Quartz was extracted by a common laboratory technique used in dating and retrospective dosimetry (Bøtter-Jensen et al., 2003; Fujita and Hashimoto, 2007). The brick segment was crushed, and the

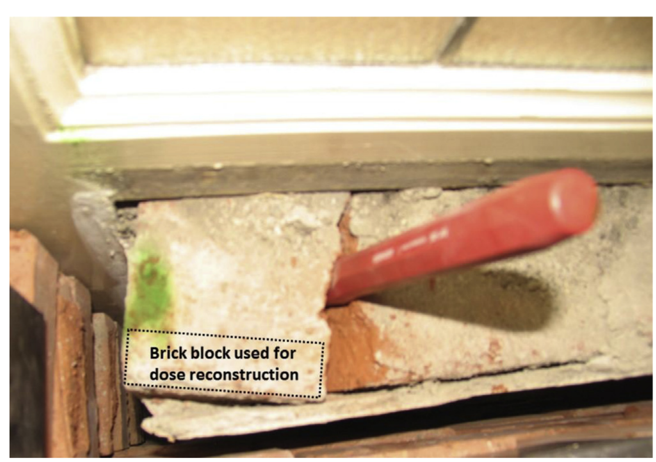


Fig. 3. Removed part of the brick used for dose reconstruction.