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Legal and illegal uses of the ^{226}Ra isotope

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Abstract
The exposure of the population to both cosmic and nuclear radiation, particle accelerators, atomic physics institutes, nuclear weapon experiments in specially designed polygons, radioactive waste deposits, the use of radioisotopes in industrial or medical activities is carefully monitored, and as a result of major nuclear events such as Chernobyl, Tokaimura, Three Miles Island, Wind Scale and Fukushima, environmental dosimeter has gained unprecedented expansion and development. The monitoring of the natural radioactive level aims at achieving more practical objectives that are most often due to legal obligations or international commitments. The portal at the old iron base on a steel platform signaled a load of recyclable metallic materials as a radioactive suspect. The ^{226}Ra isotope was identified. A criminal case was filed for the offense of "non-observance of the nuclear material or other radioactive material regime".

Keywords: nuclear alert, metallic waste, Ra-226, criminal file

1. Introduction

1.1 Discovery and evolution of radioactivity

Radioactivity is the property of unstable nuclei of disintegration and spontaneous emission of radiation. To understand the notions of radioactivity it is useful to understand the structure of the atom. Matter consists of chemical elements that in turn are made up of atoms. The atom, the smallest particle of an element that cannot be divided by chemical methods and which retains all the chemical properties of the element, consists of: the nucleus consisting of p + (positive charge) protons and neutrons n (without charge) and electronic envelope - electrons with negative charge. Normally, the number of positive charges in the nucleus (protons) is equal to the number of negative charges (electrons) around the nucleus, the atom being electrically neutral. A chemical element contains atoms having the same number of protons (Z), but the number of neutrons (N) can be different. Atoms of the same element having a different number of neutrons are called isotopes [1]. Some isotopes are radioactive and are called radioisotopes or radionuclides, which means they have an excess of nuclear energy, being unstable. An unstable nuclide spontaneously transforms into another unstable or stable nuclide by emitting ionizing radiation, a process called radioactive decay. By decay the radioactivity of nuclides decreases. All radionuclides are uniquely identified by the type of radiation emitted, the radiation energy emitted and the half-life. The half-life ($t_{1/2}$) of a radioactive element is the time it takes for half of its atoms to disintegrate and is a constant property for a given radioisotope. Examples of half-life: uranium ^{238}U - 4.47 billion years, ^{235}U - 704 million years, thorium ^{232}Th - 14.05 billion years, potassium ^{40}K - 1,277 × 10^9 years, carbon ^{14}C -5730 years, radon ^{222}Rn -3.8 days, radium ^{226}Ra -1600 years, cesium ^{137}Cs - 30,17 years, tritium ^{3}H -12,36 years, cobalt ^{60}Co -5,27 years, iodine ^{131}I -8,02 days [2, 3].

1.2 Use of radioisotopes

The discovery of artificial radioactivity has provided scientists with new possibilities to broaden the field of research by using radioisotopes as tracers in biology, medicine, agro-technology, chemistry, metallurgy, mining prospecting or radiation sources in the above-mentioned fields. Tracers use isotopes that have a half-life long enough for their presence to be monitored during the study. Particularly important is the tracing of reaction mechanisms, such as oil chain reaction reactions, saponification mechanism or rubber vulcanization. Reaction rate measurements, absorption studies, specific surface measurements of solids are currently performed with tracers. The tracer is a radioisotope of a stable element which, along with the element in a certain system, allows radioactivity measurements to track the path of that element in the system and its evolution. In biology using ^{14}C * radiocarbon, the process of glycogen production in the liver was clarified. Radioiodine ^{131}I is used for the radio diagnosis of some disorders of the thyroid gland. Radio calcium (^{45}Ca) and radio static (are used for the investigation of mammary glands and physiological processes. Radiofosfor (^{32}P) is used to investigate protein metabolism, to diagnose cancer as well as to treat it, together with radiopharmaceuticals (^{60} Co) which tends to replace radiopharmaceuticals in the treatment of this disease.

In agriculture, radioisotopes are used as tracers in the study of chemical reactions taking place in the plant body such as: photosynthesis process and phosphate assimilation. In the metallurgical field with the help of radioisotopes it is possible to precisely monitor the diffusion of C atoms into the cast iron or steel mass or the absorption of gases into metals. The use of the radioisotope ^{59}Fe* allows the determination of the degree of wear of the iron parts. The isotope ^{60}Co* is often used in the defectoscopy of large metal parts.

In many cases, tracers can track the stage of oxidation, metal diffusion in alloys, or their homogeneity can be observed. With the aid of radiocarbon $^{14}C^{*}$, the age of some rocks, artifacts and organic substances can be determined.
Areas where radioisotopes are predominantly used are: *medicine,* diagnosis; radiotherapy of cancer; reducing pain in bone cancer; sterilization of medical instruments; medical and dental X-rays; magnetic resonance diagnosis; radioscopic detection of tumors; in biology and environmental protection: investigating ways of spreading pollutants; tracing of animals in the natural habitat; plant growth research; *in industrial processes*: polymerization of plastics; measurements of flow processes; non-destructive testing of the quality of metal components; density testing in oil production, *in security processes:* smoke detectors; sterilization of food; pest eradication; signaling in buildings, *in the energy field*: producing energy.

2. Materials and Methods

The portal from the scrap metal base on the steel platform signaled a load of recyclable metallic materials as a radioactive suspect. Scrap iron was transported by means of transport (truck with dump), the cargo being accompanied by a non-radioactive bulletin. The truck and the bay were passed 5 (five) times through the portal and an alarm was triggered every time in the back of the bay. As a result of these alarms, the cargo has been declared a radioactive suspect and it has been decided to unload in the specially designed space within the old iron base and check with portable equipment. During manual verification, 4 (four) metal boxes with a measuring device type indicator (Russian model) indicating radioactivity presence were identified, one with the glass window and 3 with the broken glass. Those with the broken glass gave a stronger signal.
The indication of radiometric equipment - Inspector type and type Victoreen (supplied by the Nuclear Technical Laboratory) indicated a dose rate up to max. 300 nSv / h (at Victoreen with the alpha - beta window) at a background of 0.15 μSv / h. We checked the truck without loading by portal and manual and the signal was no longer triggered, and the measured values are within the range of variation of the natural background radiation. The "clean" radioactive load has been reloaded in the truck and verified with the portal installation, which has not given any signal and has been accepted by the recipient. Radioactive material suspect was placed in polyethylene bags, sealed and stored temporarily, in custody, in the Nuclear Technology Laboratory's source repository, and the incident was notified to the Emergency Center of the National Commission for Nuclear Activities Control (CNCAN). On site surveys, measurements were made on about 1600 tons of metal contaminated contaminants such as the Inspector and Victoreen type (supplied by the Nuclear Engineering Laboratory) by workers from the Nuclear Technology Laboratory and CNCAN, with no values of the radioactive dose. Also at the above mentioned point of reference and at the Nuclear Technical Laboratory's sources warehouse that carried out dosimetric measurements with FH 40 type dosimeter, with values ranging from 5.86-6.10 μSv / h.
Following the dosimetric measurements with the IDENTIFENDER marker, the four radioactive suspect devices emitted ^{226}Ra [2]. Radioactive suspect devices were navigation systems from the T34-T85 series of military tanks (Russian military equipment made between 1945 and 1965).
From a constructive point of view, the devices in question were made of materials that ensured the shielding of the radioactive effect of the ^{226}Raluminous substance impregnated on the circular scales of the dials. This type of equipment equips several types of Soviet production tanks, including the T-34, T-55 and T-72 that are in the Romanian Army, as well as Antonov AN-2, Ilyushin, Yakovlev YAK-12. The identification of the gyroscopes was possible due to the fact that 3 of them had broken sight glasses.

3. Results

In connection with the identified Ra-226 isotope, it was shown to be the most stable of all isotopes in this chemical, with a half-life of 1,601 years, representing the period when the radioactivity of an isotope is halved. Disintegration of this isotope results in radon and alpha particles. Due to its instability, the radius is luminescent, the property of which has been used to label clock dials and other devices that need to be perceived at night or under other conditions where visibility is reduced.
According to art. 25 of the Basic Radiological Safety Norms (NSR - 01) issued by the National Commission for Nuclear Activities Control (C.N.C.A.N.), activity based on Art. 5 of Law no. 111/1996 on the safe conduct, regulation, authorization and control of nuclear activities, the actual dose limit for the population is 1mSv / year = 1000 μSv.
Starting from the values recorded by the specialists displaced on the spot, following the measurements made in this criminal file and recorded in the criminal prosecution documents, namely:

Table 1: Determining the dose rate equivalent to the ESM FH 40 G-L 10 dosimeter for X and γ radiation (μSv/h)

The place of determination	0 meter distance of the box	1m distance from the box
Metal box with glass unbroken	0.083 – 0.097	0.084 - 0.085
Metal box with glass broken	0.083 – 0.099	0.083 – 0.084
The lead-shielded box where suspicious objects are stored	0.083 - 0.099	0.83 – 0.084

Table 2: Determining the dose rate equivalent to the VICTOREEN type radiometric dosimeter (with the α window and the open β window) and the INSPECTOR dosimeter (μSv/h)

The place of determination	0 meter distance of the box
Metal box with glass unbroken	13.24
Metal box with glass broken	180-240

4. Discussion

To reach this effective dose limit for the population, a person should have been exposed to the following periods of time:

- In the area where the glass panes are unbroken:
  1000 μSv:0,085μSv/h = 11764,
  706 h=11764,
  706:24 = 490 days
- Near the windows where the broken glass boxes are located:
  1000 μSv:240 μSv/h = 4,16 h (1)
- For the maximum cosmic fund:
  1000μSv:0,15 μSv/h = 6666,6667
  h = 6666,6:24 = 277,7 days (2)

The degree of danger of exposure to ^{226}Ra is due to eventual internal exposure to radiation a, exposure that can be achieved by inhalation, swallowing or contact with ^{226}Ra with injured skin (wounds).

In the case of external exposure, the risk of exposure to ^{226}Ra would be increased in the case of exposure exceeding:

- in the area where the glass panes are intact: 490 days;
- glued to the windows where the broken glass cases are located: 4.16 hours.

As none of the above conditions were met, the degree of exposure to ^{226}Ra was low. In order to reinforce this conclusion, the value of 0 μSv recorded by the Canberra digital individual dosimeters with which they were monitored during the measurements of the professional exposure involved is also important. This value was probably determined by the fact that in the case of external irradiation of the ^{226}Ra isotope, the α radiation protection is very easy, the particles being absorbed by all the substances, which means that by the simple use of rubber gloves, clothing, paper sheets or any other material obstacle, ensure good protection against them. These particles (α) are only dangerous if they are produced by the disintegration of a parent compound ^{226}Ra incorporated by ingestion, inhalation or dermal absorption through the injured skin (open wound), a situation not found in the present criminal case.

5. Conclusions

With regard to all these aspects, it was concluded, beyond any doubt, that the danger of exposure to Ra-226 of persons who came into contact with directional gyroscopic devices, regardless of their concrete material state, was low and, implicitly, the concrete social danger had the same nature, inducing a lack of public interest in further prosecuting the offense of "non-observance of the nuclear material or other radioactive material regime", ruling out the solution to the abandonment of criminal prosecution.

The guiding conclusion is that this complex phenomenon of radioactivity (currently over two thousand isotopes being discovered) must be further explored as a perpetual source of novelty that can be made available to humanity but it must be very clear how radioactivity is manipulated in order not to give it free to its destructive character, especially nowadays in which the global geopolitical conjuction is confronted with the extremely dangerous and unconventional scourge of terrorism[4,5,6,7,8].

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