Suspected Radioactive Contamination: Evaluation of 45 Israeli Citizens Potentially Exposed to Polonium-210 in London

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Abstract

The lethal poisoning of Alexander Litvinenco with the radioactive element polonium-210, and the risk that many civilians (including Israeli citizens) who were in the same location in London at the same time were exposed to radiation, was an unprecedented event in the western world. This was only the second known death due to ^{210}Po, a natural alpha radiation-emitting element. A task team was created to handle the event. The team comprised representatives from the Ministry of Health's advisory committee for radiological events (which includes the Israel Defense Force, the Israeli Atomic Energy Commission and the Ministry of Environmental Protection), the Public Health Services Central District, and a public relations expert. Forty-seven people were located and underwent an epidemiological inquiry, and urine samples for detection of ^{210}Po were sent abroad to a specialized laboratory. The radiotoxicological results were analyzed and evaluated by the expert team and follow-up recommendations were made. This unfamiliar and potentially stressful scenario was handled successfully by a multi-organizational multidisciplinary task team. The joint work of the task team was a real-life "exercise" simulating a radiological event in Israel. This team has recommended further evaluation of various vital missions in the event of any possible future radiological event, with special emphasis on a proactive communication approach to the media and the public.

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On 23 November 2006, Alexander Litvinenco, a former Russian intelligence agent who was residing in England, died after a 3 week illness presumably caused by the deliberate poisoning with the radioactive element polonium-210. The British authorities detected minute quantities of this rare material at various sites, including the Millennium Mayfair Hotel in London where the poisoning probably occurred by way of ingestion. There was uncertainty whether people who were present at those sites after 1 November – the date of Litvinenco's intoxication – were exposed to the radioactive contamination by inhalation or ingestion. In the course of the investigation the British health authorities conducted extensive efforts to locate potentially exposed individuals, interviewing more than 3000 people and testing almost 700 for the presence of ^{210}Po in urine. It transpired that more than 100 people had increased levels of ^{210}Po in their urine and therefore might have been exposed together with Litvinenco. Only 16 presented with levels high enough to cause a significant exposure to radiation, albeit very small [1].

On 14 December 2006 the British health authorities notified the Israeli authorities that Israeli citizens who had stayed at the Millennium Mayfair Hotel on November 1 should also be evaluated. Since the incident was considered very unusual, a task team of experts from various organizations and disciplines was created ad hoc on the same day. The team included representatives from the Ministry of Health's Advisory Committee for Radiological Events (which includes the Israel Defense Force, the Israeli Atomic Energy Commission, the Ministry of Environmental Protection), the Public Health Services Central District, and a public relations expert.

This article will review the potential effects of exposure to ^{210}Po, the activity of the Israeli polonium task team, the epidemiological investigation, the radiotoxicological tests performed, and some lessons learnt by health authorities in Israel as a consequence of this incident.

^{210}Po – characteristics and medical effects

^{210}Po is a natural radioactive element found in uranium ores and in the atmosphere as a decay product of uranium and radon. Due to its scarcity it is also produced artificially in nuclear reactors. It was used decades ago in the nuclear weapon industries, but its main uses today are in anti-static electricity devices and dust removers in various civilian industries. ^{210}Po emits alpha radiation, decaying into lead. Its physical half-life is about 138 days. Its

^{210}Po = polonium-210

specific activity (rate of radiation emitted per weight) of 4.49×10^3 curie/g is much higher than most other well-known alpha emitters like americium-241, plutonium-239 and uranium-235 [2].

Since the alpha radiation emitted by ^{210}Po is of very low penetrance, it is dangerous to the human body only following internal contamination. As such, it is an extremely potent toxin and only millicurie quantities, which weigh less than 1 µg, are sufficient to result in a lethal radiation dose of more than 10 sieverts (the LD50/60 of acute radiation exposure is about 3.5 Sv; $LD_{50/60}$ is the lethal dose for 50% of an exposed population in 60 days) [3]. Everyday exposure to ^{210}Po is a result of ingestion of ^{210}Po-containing foods and inhalation of ^{210}Po from the atmosphere, and is extremely minute.

Intoxication with ^{210}Po can be effectively caused by inhalation or ingestion. After entering the body ^{210}Po binds non-specifically to blood proteins, mainly to hemoglobin, thus irradiating tissues fairly homogenously [4]. Aggregates of ^{210}Po, created following inhalation, are engulfed by cells of the reticuloendothelial system, irradiating the bone marrow, liver, spleen and lymph nodes. The organs exposed to the highest doses of radiation are the liver, kidneys, bone marrow, spleen and skin [5]. ^{210}Po is cleared by excretion into the bile, and to a lesser extent by the urine [4]. The effective half-life of ^{210}Po in the human body is about 46 days [2].

45 Israelis were suspected of having been exposed to ^{210}Po during a contamination incident in London in November 2006. Three were found to have higher than expected ^{210}Po levels in their urine, but with no medical significance.

Acute exposure secondary to significant internal contamination of ^{210}Po leads to short-term deterministic effects, presenting in a similar fashion to the acute radiation syndrome of whole-body external radiation exposure. The main clinical effects will be hematopoietic suppression and mucosal damage in the gastrointestinal system. Unique effects of ^{210}Po exposure include fibrosis of vascular walls, and renal and cardiac disturbances [2,5]. Exposures to lower quantities of ^{210}Po will lead only to stochastic (probabilistic) effects, i.e., increased probability for long-term health effects, mainly malignant diseases in the irradiated tissues. Animals experimentally exposed to ^{210}Po have developed tumors in lymphatic tissue, bone, soft tissues and other organs [2]. The added risk for malignancy-associated mortality due to ^{210}Po contamination is calculated to be $7.3–140 \times 10^{-4}$/µcurie, depending on the solubility of the contaminating compound [6].

Sv = sievert

Data on human exposures are scarce, and only one published report previous to the recent one in London resulted in significant health effects [2,5,7]. In that case, a Russian worker accidentally inhaled an estimated 2700 µcurie of ^{210}Po and died 13 days later [5]. People who smoke tobacco are chronically exposed to inhaled ^{210}Po, originating from atmospheric fallout on tobacco leaves. Accumulation of ^{210}Po in the lungs leads to a significant radiation exposure to the bronchial epithelium [8].

Laboratory diagnosis of patients suspected of ^{210}Po contamination can be made by alpha radiation counting. Monitoring skin and clothes should be done when external contamination is suspected. Internal contamination can be diagnosed only by urine measurement of the specific radiation of ^{210}Po.

The treatment of persons with high level ^{210}Po intoxication is mainly supportive, and is similar to that for patients with acute radiation syndrome. In addition, ^{210}Po can be effectively chelated with dimercaprol (British Anti-Lewisite, BAL) [7]. Other chelators were developed but are not available for clinical use [9-15]. Chelation treatment of low level contamination should be carefully considered – weighing the prevention of potential future morbidity against the significant therapeutic toxicity.

The Israeli ^{210}Po task team performance

The worldwide scattering of radioactively contaminated people is a terrifying scenario. Following the first British notification accompanied by a list of the circumstantially exposed Israeli citizens, the Israeli Ministry of Health appointed a multidisciplinary team to handle the event. The team included members of the Ministry's Advisory Committee for Radiological Events joined by a group of epidemiologists and public health physicians from the Public Health Services. The task team included medical administrators, IDF experts for non-conventional warfare countermeasures, health physicists from the Israeli Atomic Energy Commission and from the Ministry of Environmental Protection, and a senior Ministry of Health public relations official. The team decided to handle the event in Israel rather than sending the Israeli citizens for consultation and further follow-up by the British authorities.

Challenges

The first task of the team was to consolidate a policy in response to the public and media reaction to the possibility that Israeli citizens had been radioactively exposed during the sensational poisoning of the former Russian spy. Such an unfamiliar and potentially stressful scenario for the Israeli population forced the task team to urgently discuss this issue despite the uncertainty and lack of clear information on the incident.

A proactive approach for communication with the media and the public was chosen. A list of potentially exposed people was obtained from the British authorities and an epidemiological

IDF = Israel Defense Force

investigation ensued. Personal phone calls by the district Health Ministry public health officers were made to the people on the "exposed list," summoning them for an inquiry regarding their potential exposure and for medical screening. Immediately afterwards the Ministry published a short statement that invited any person who was in London at the suspected locations on those particular days to come as well to the Central District Health Office for a similar meeting. It was also explained that although suspected exposure was negligible, a thorough evaluation of Israeli contacts was crucial.

Information on polonium and its major effects was available on the Ministry of Health website, together with frequently asked questions. In Israel all hospital emergency departments as well as the health management organizations received an extensive literature review about the hazards of polonium and recommended actions to be taken if approached by "worried well" or citizens who claimed to have been in London on those particular days.

The second issue that required a quick solution concerned the epidemiological questionnaire that should be used in the inquest of the incident. It was decided to adopt the British questionnaire, i.e., to use the same epidemiological and formal tool so that the data could be compared to the British data and in the event that a future liability suit regarding the poisoning will be issued.

Epidemiology

The epidemiological investigation was conducted by the public health officers of the Public Health Services Central District. The investigation was initiated 2 days after the British notice, about 6 weeks after the suspected exposure. The initial list of suspected people exposed included a list given by the British authorities, and a list obtained from the travel agency that was responsible for an event held at the Millennium Mayfair Hotel attended by a group of Israelis on the relevant dates of exposure. Every potential person exposed was contacted by phone and questioned regarding potential exposure, other possible people exposed, and potential clinical signs. Information about the event and potential consequences of ^{210}Po exposure was given, including a phone number for further questions. The place and dates for potential exposure were set between 30 October and 2 November 2006 for those residing at the Millennium Mayfair Hotel, London, focusing on those who had been in the hotel bar. Those who met the criteria for exposure were invited to the Central District offices to complete the epidemiological investigation and for urine sampling. The questionnaire included demographic details (age, gender, address, phone numbers, email address), data on exposure (time, place, possible contact with Litvinenco), clinical signs of significant ^{210}Po exposure (fever, nausea, vomiting, diarrhea, bleeding, sore throat) and smoking habits. In total, a list of 43 people was compiled. All of them were approached by phone. Our questioning revealed that one of them could not possibly have been exposed, one did not live in Israel (and thus was referred to the British authorities), and one refused to cooperate. Forty arrived at the Central District offices for further inquiry, and 38 of them gave urine samples. Their details are summarized in Table 1. None of the people investigated complained of any symptoms related to ^{210}Po exposure.

An important part of the inquiry was the urine tests for traces of ^{210}Po. Since only a few laboratories in the world have scientific expertise in this field – with huge differences in costs – the task team had to find a suitable laboratory. The British laboratories were too busy to present an option and we therefore approached a qualified recommended German laboratory. In accordance with the specific laboratory instructions, the recommendations of the health physicists and the environmental protection ministry regulations, a protocol for adequate urine collection, preservation, packing and shipping was prepared. Such a protocol for the collection of most other radiotoxicological tests does not exist in Israel. The team was confronted with numerous obstacles concerning the handling of the urine tests, most of them due to lack of experience and anxiety regarding radiation among laboratory workers.

Polonium-210 is a highly radioactive element, dangerous to the human body through internal exposure only. The hazards from exposure include radiation-induced damage to the bone marrow, gastrointestinal mucosa and other internal organs, and increased risk for future malignancies.

In February 2007 the British authorities discovered a teapot containing residual ^{210}Po, believed to be the instrument used for the poisoning. Two additional Israeli citizens were listed as having eaten in the hotel's restaurant at the time the teapot was in use, and one recalled drinking tea that had been poured

Table 1. Details of the 38 persons who completed the epidemiological investigation

Age (yrs)	
Range	21–68
Mean ± SD	40.6 ± 14.1
Gender	
Male	22 (57.9%)
Female	16 (42.1%)
Symptoms since November 2*	
Yes	0 (0)
No	38 (100%)
Smoking	
Yes	10 (26.3%)
No	28 (73.7%)

* Fever, nausea, vomiting, diarrhea, bleeding, sore throat

from a teapot and served at the table. The couple was contacted by the Public Health Services Central District and followed the same workup.

Test results and critical review of the data

The radiotoxicological evaluation of the 40 urine samples was done by alpha-spectrometry at the Julich laboratory in Germany. The measurements of ^{210}Po in the 24 hour urine samples from the Israelis who stayed in the Millennium Hotel on November 1 are shown in Figure 1. One measurement was below detection levels of the laboratory. Thirty-five measurements were in the range of 0.9–4.3x10^{-3} becquerel per day (average 2.52x10^{-3} Bq per day), which is below the upper limit of the normal range for the German population indicated by the laboratory (9.9x10^{-3} Bq/day). Two measurements were above the mentioned level: 11x10^{-3} and 18x10^{-3} Bq/day. The upper level for the British population is 15x10^{-3} Bq/day [15], thus only one person had levels exceeding what the British health authorities consider normal. The British Health Protection Agency has set the reporting level for ^{210}Po measurements in urine as 30x10^{-3} Bq/day, as this level is significantly above the normal background* [16]. With regard to the couple who stayed in the hotel in mid-November, one had levels within the normal range, but the person who recalled drinking tea from a teapot had 0.15 Bq of ^{210}Po in her urine measured more than 16 weeks after the exposure. This level was five times higher than the British Health Protection Agency reporting level, and exceeded the rest of the Israeli test results by a factor of 2.

Standards for ^{210}Po urine levels were never set for the Israeli population since no laboratory in Israel measures ^{210}Po. The results of three of the urine measurements were above the German normal background and two of them were above the British normal background. During their inquiry all three denied smoking. Only one sample was above the reporting level set by the British Health Protection Agency for the ^{210}Po incident in London. An assessment of the radiation dose received from the ^{210}Po was done by experts from the Israeli Atomic Energy Commission and the IDF. Since no known background levels were available for subtraction, we decided to assume that the entire amount of ^{210}Po measured in the urine samples originated due to exposure on November 1. This assumption is unrealistic, because continuous exposure obviously occurs in Israeli citizens too and resulted is an exceedingly higher level of exposure than in the event described here. Other assumptions were that the route of intake of the polonium on November 1 was by inhalation only, which is also associated with higher radiation exposure, that the contaminating aerosols had an activity median aerodynamic diameter of 1 μm, and that the committed dose equivalent of 1 Bq of ^{210}Po is 3.3x10^{-6} Sv [17]. The exposure of the "teapot" couple was considered to be from ingestion only. Using all these extreme assumptions, the committed effective dose equivalent

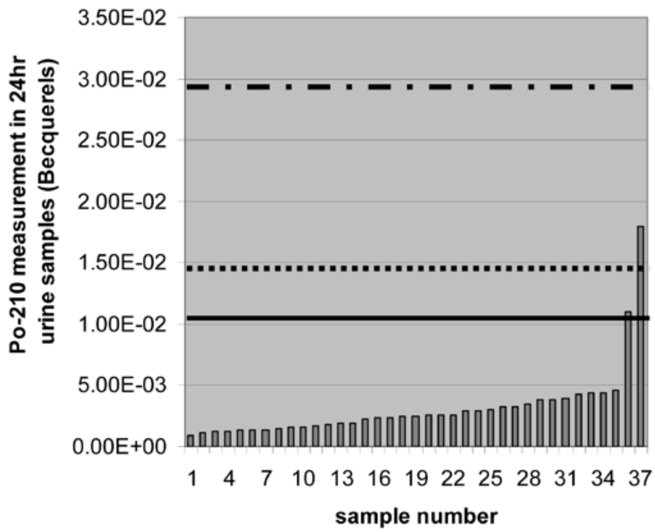

Figure 1. Measurements of ^{210}Po in 37 urine samples by alpha-spectrometry. The urine samples were from the Israeli citizens who were in London on 1 November 2006. The bold horizontal line marks the upper limit of the normal range for ^{210}Po measurement in Germany (9.9E-03 Bq per day). The dotted horizontal line marks the upper limit of the normal range for ^{210}Po measurement in Great Britain (1.5E-02 Bq/day). The dash-and-dot horizontal line marks the reporting level set by the British Health Protection Agency for additional workup of suspected contacts.

(the radiation dose that is expected from lifetime exposure to the contaminating radionuclide) for the three persons with the highest levels of ^{210}Po is calculated to be 0.54x10^{-3}, 0.33x10^{-3} and 0.66x10^{-3} Sv. Since normal annual background exposure to ionizing radiation from various sources in Israel is about 2x10^{-3} Sv, the doses that we calculated, even with the exaggerated assumptions, are negligible.

Since the three persons with the higher ^{210}Po urine measurements were non-smokers, there was no overt reason for their laboratory results. There is a theoretical possibility that they were among the people who were accidentally exposed to ^{210}Po contamination at the Millennium Mayfair Hotel. The calculated radiation doses had led the task team to refrain from any additional investigation or follow-up. All 40 people who gave urine samples were notified by phone and reassured that no further steps were required.

Comments

The polonium incident is the first "radiological event" in Israel, necessitating management of possibly contaminated people. Following a brief preparation period in which a specific task force was established, the evaluation of contacts was efficient and fast. Eventually, all the Israeli citizens evaluated did not have any clinical symptoms or urinary ^{210}Po concentrations necessitating further workup. Three of the subjects had higher urinary ^{210}Po concentrations than the laboratory's normal range. Since all three of them denied smoking and there was no overt occupational or environmental reason for ^{210}Po exposure, one could suspect that

Bq = becquerel

* The reporting level is set by authorities as a threshold for reporting in case of an accidental exposure. Background levels are normal levels of Po measured in the urine.

they had been exposed to ^{210}Po contamination during their stay in London. Since the normal range of urinary ^{210}Po is unknown, the test results of two of them could also be a normal variation. We could not find any other reason for the ^{210}Po urinary level of the "teapot" case, other than exposure to contaminated tea. In all three cases, the radiation dose that we calculated to arise from ^{210}Po contamination was negligible and no medical follow-up or further evaluation was recommended.

No anxiety or panic reactions were expressed by the possible contacts or their families. The media and the public interest were minimal, and the media coverage of the incident was fairly consistent with the team's directives. This might be attributed to the positive effect of the proactive strategy. Alternatively, this restrained reaction may result from the significant distance (days and mileage) from the actual scene in London. It should also be emphasized that we cannot extrapolate the behavior of the public and the media from this very limited event to a realistic radiological incident in Israel. Nonetheless, the main achievement from this event was the demonstration that multi-organizational multidisciplinary task teams are essential. The integrated capabilities of the team members provided solutions to problems encountered throughout the handling of the incident. The joint work of the task team was a real-life "exercise" simulating a radiological event in Israel. Such an event – whether due to an accident involving radioactive materials or due to the deliberate use by terrorists – should be dealt with by professional and well-prepared health authorities.

The task team has recommended further evaluation of various vital missions, such as mass radiological and epidemiological investigation, protocols for radiotoxicological laboratory investigation for various radioactive materials, and the capability to locally conduct them. Planning the logistic and financial aspects of a future intervention as well as the necessary experienced manpower to handle an event is also a serious consideration for policymakers.

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