Radiation and Environmental Biophysics (2021) 60:383–387
https://doi.org/10.1007/s00411-021-00901-1

SHORT COMMUNICATION

Radiation levels following the Beirut seaport explosion: environmental survey and public dose exposure

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Received: 9 November 2020 / Accepted: 27 February 2021 / Published online: 8 March 2021

Abstract

On August 4, 2020, an explosion at the Port of Beirut, Lebanon, ripped the city to shreds, killing more than 200 people, wounding 6500 others, and leaving about 300,000 residents temporarily homeless. The explosion raised many concerns regarding the possible presence of radioactive material and the associated public health risks. Accordingly, and after opening the affected sites for public access, an external radiological survey of the hit area was conducted. The dose rate reading in Beirut's seaport (ground zero) varied between 58 and 100 nSv/h. The detected levels were within the average worldwide annual gamma dose rate of 50 to 53 nSv/h set by the United Nations Scientific Committee on the Effects of Atomic Radiation. The recorded values were not significantly different from those measured by the Lebanese Atomic Energy Commission (LAEC) at the National Council for Scientific Research (CNRS-L) in 2009 and 2010 at three locations in Beirut's seaport (minimum value 50 nSv/h and maximum value 140 nSv/h). Besides, in the surveyed area, radiological scans were conducted on 360 injured patients reported to the American University of Beirut Medical Center (AUBMC), showing no signs of radiation exposure due to the explosion.

Keywords Radiological survey · Exposure assessment · Beirut · Lebanon

Introduction

On August 4, 2020, at 06:06 p.m., a series of explosions rocked the city of Beirut, Lebanon, leaving in its trail a major disaster. In a matter of seconds, more than 200 people were killed, more than 6500 injured, about 300,000 others were left homeless, and large sections of the Beirut seaport, one of the largest and busiest ports on the Eastern Mediterranean (Area: 1.2 km^2), and its infrastructure were destroyed, including most of Beirut's grain reserves. Besides, billions of dollars in damages were inflicted across the city. Buildings within 1 km were badly damaged, including heritage houses located within 600 m of the explosion site. According to experts, the size of the Beirut blast was equivalent to 500–1100 tons of TNT, approximately 1/20th of the size of the atomic bomb dropped on the Japanese city of Hiroshima during World War II, placing it among the biggest non-nuclear explosions of all time (Rigby et al. 2020). It is ranked fifth in the strength of the explosion following the explosions in Oppau, Germany (1921), Halifax, Canada (1917), and Hiroshima and Nagasaki, Japan (1945) (Pickrell 2020).

The Beirut seaport explosion was so powerful that some observers feared the city had experienced a nuclear detonation of some sort, a fear exacerbated by the mushroom cloud, recorded by many, towering over the blast site after the explosion. Primary investigations into the accident's nature mentioned the presence of 2750 tons of ammonium nitrate stored in one of the port's warehouses. Theories were put forward about causative agents, the most plausible being the presence of weapons of unknown nature stored in the port in an unidentified dock, which were allegedly destroyed.

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In the aftermath of the explosion, footage of people measuring radioactive material in a polyclinic was circulated on social media, creating panic among those present in the disaster area. Besides, the information about the blast from authorities was not sufficient to dispel assumptions about the occurrence of an improvised nuclear device detonation or a radiological dispersal device (RDD), which can spread radionuclides to nearby areas knowing that signs of radiation exposure might not be immediate as health effects may take months to appear (CDC 2018).

Accordingly, an environmental survey was conducted to assess the radiation levels in the affected area within a 2.4 km radius from the explosion center, and the results are presented here.

Materials and methods

Instruments and calibration

Three devices were used to read the radiation and the exposure of people and environmental samples such as air and rubble. The first two devices were a Canberra Colibri survey meter VLD Mirion (Mirion Technologies Inc., San Ramon, CA, USA), and a digital survey meter Ludlum model 3000 (Ludlum Measurements, Inc., Sweetwater, TX, USA) used to measure any radiation dose rate in nano Sievert per hour. The third device was a G.M. Detector (Geiger-Mueller counter) Ludlum model 26 Frisker (Ludlum Measurements, Inc., Sweetwater, TX, USA) used to measure radiation in counts per minute. The instruments were calibrated by the respective equipment manufacturers using a ^{137}Cs source. The detection range for the Canberra Colibri survey meter VLD Mirion is a dose rate equivalent measurement of 10 nSv/h to 1 mSv/h. As for the Ludlum model 3000, the detection range is 0.00 µSv/h to 999 Sv/h, while for the Ludlum model 26 Frisker, the detection range is 1 cpm to 99.9 kcpm.

On the day of the survey, a background reading 20 km away from ground zero was taken. For comparison, the devices used by the Lebanese Atomic Energy Commission (LAEC) at the National Council for Scientific Research (LAEC-CNRS) during their survey of the Beirut seaport area in 2009 and 2010 included a portable NaI detector (3″ × 3″) and Graetz dosimeters for gamma dose rate measurements (Samad et al. 2012).

Sampling

On the night of the explosion, as per the American University of Beirut Medical Center (AUBMC) protocol, people from all over the disaster area walking into the medical center were checked for burns and/or other signs of radiation exposure, including nausea, fever, seizure (Mayo-Clinic 2019) and scanned for dose rate using the devices mentioned above. A certified radiation protection officer performed a triage to isolate contaminated persons if any were diagnosed.

On August 12, 2020, environmental samples were surveyed after the area was deemed accessible for nonmilitary personnel. Following sampling protocols (Snyder et al. 2020), measurement points were selected (Fig. 1) at 600 m radius from ground zero (yellow line), where ten sites almost equidistant from each other were scanned; at 1200 m radius (blue line), where eight equidistant points were chosen for the readings; and at 2000 to 2400 m radius (red line) from ground zero, where readings were taken at 11 locations (Fig. 1). Beyond the 2400 m radius, there were no evident cues for any impact of the explosion.

Measurements in the selected locations were done on waste, visible dust, rubble backfill, and air. The survey was conducted by slowly passing the detector over the area or objects to be surveyed at the height of 50 cm above the ground (the same height adopted by the previous survey conducted by LAEC-CNRS between 2009 and 2010). In the same location, background gamma dose rates were measured through the Colibri survey meter (VLD-Mirion).

Sampling was first accomplished for the closest radius. Global Positioning System data were recorded for future references and landmarks; the data are summarized in Table 1. The recording started at 06:00 and concluded by 11:00. Recordings were measured in CPM[1] and nSv/h. These readings were later compared to previous readings taken in 2010 by the LAEC-CNRC during the summer and winter seasons of 2010.

Results and discussion

The radiation exposure scanning results of the people who have reported/visited AUBMC on the night of the explosion, inclusive of those injured, first emergency respondents—the Lebanese Red Cross, the civil defense as well as the medical teams—did not show any immediate physical signs of radiation exposure (burns, vomiting, etc.) nor did the scan yield any reading above 195 nSv/h.[2]

[1] Geiger-Mueller (GM) detector is a pancake type with a facial diameter of approximately 2″. When the detector is connected to a standard portable ratemeter and calibrated to interpret equivalent dose rate (previously called dose equivalent rate, µSv/h) with 662 keV photons from ^{137}Cs the count rate is estimated at 5 cps per µSv/h. It should be noted that this correlation between count rate and exposure rate for ^{137}Cs (or any other gamma emitter that is used) applies only when the detector is viewing only the gamma radiation.

[2] 195 nSv/h is calculated as 3 times the average of 45 and 85 nSv/h which are the background gamma radiation levels measured the night of the blast around AUBMC.

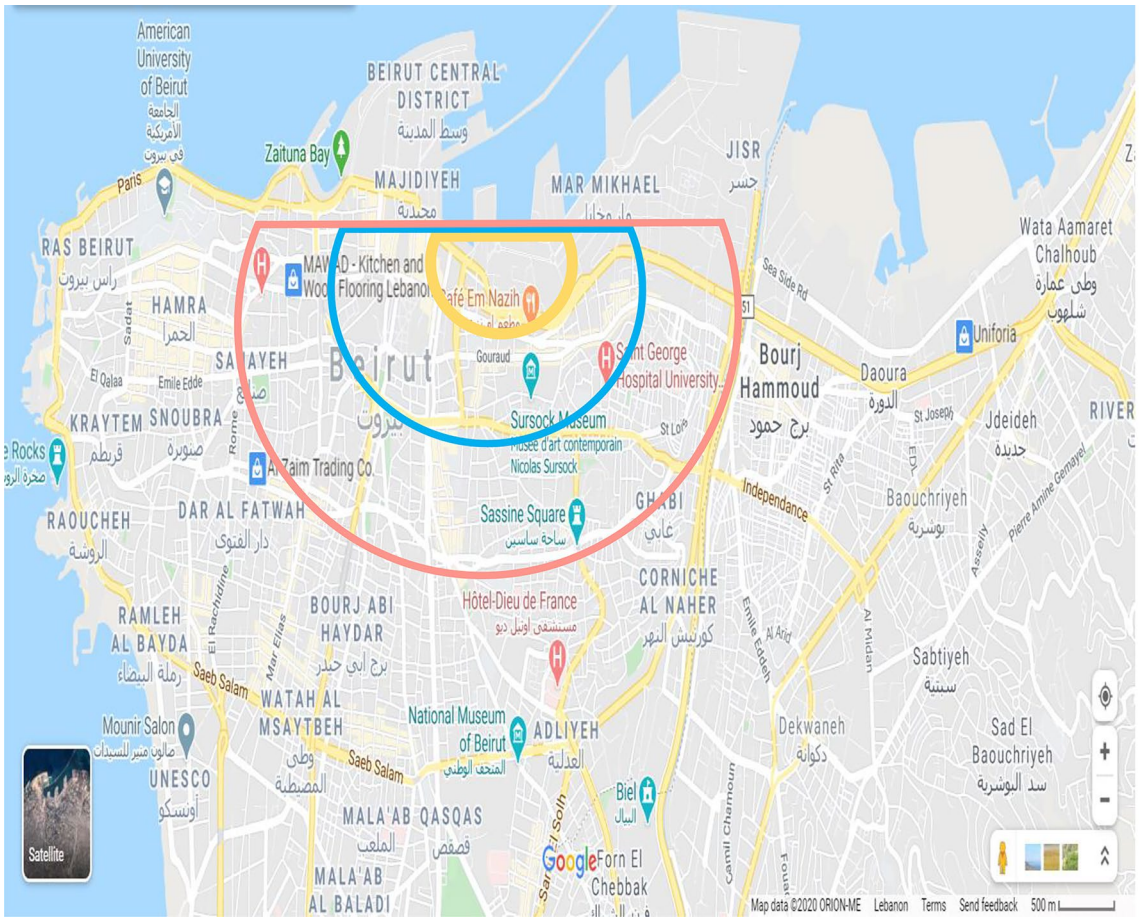

Fig. 1 Google map of Beirut showing the seaport and the selected sampling areas at radii 600 m, 1200 m, and 2400 m from the center of the explosion depicted by yellow, blue, and red, respectively (Google Maps 2020)

According to Lebanese regulations on radiation, decontamination is required for any area, where contamination levels exceed three times the background radiation level. Normal background reading is between 67 and 133 nSv/h using a G.M. detector (Chabot 2012). It is worthy to note that the background gamma radiation levels measured the night of the blast around AUBMC varied from 45 to 85 nSv/h.

The measurement levels recorded during the current survey using the Pancake G.M. detector (Ludlum, model 26) were within the normal background (117 to 183 nSv/h), knowing that the equipment safety levels are set by the manufacturer's between 83 and 250 nSv/h, and the alert level at 333 nSv/h (CNSC 2005).

Observing the radiation measurements obtained from the surveyed sites (summarized in Table 1), the recorded background gamma dose measured with the Colibri survey meter (VLD-Mirion) for the area extending 100 m to 600 m from ground zero (closest accessible locations) averaged at 84 nSv/h (ranging from 58 to 100 nSv/h) with a standard deviation of 16 nSv/h. The radiation readings in the area extending from 600 to 1200 m from the explosion epicenter averaged at 80 nSv/h with a standard deviation of 9 nSv/h, while readings in the area extending from 1200 m from the center of the explosion up to 2400 m averaged at 80 nSv/h with a standard deviation of 4 nSv/h. All the recorded readings in the selected areas fall within the normal range of 100 to 200 nSv/h (Curtis 1999, VISTA-Technologies 1999). It is worthy to note that a background level was taken on that day in an area 20 km away from the blast and measured 60 nSv/h.

Between 2009 and 2010, the Lebanese Atomic Energy Commission (LAEC) at the National Council for Scientific Research (CNRS-L) conducted a radiation survey across Lebanon and reported an average reading of 50 to 53 nSv/h at the Beirut seaport using a portable NaI detector ($3'' \times 3''$) and Graetz dosimeters for gamma dose rate measurements (Samad et al. 2012).

It is worthy to note that the absence of gamma-ray readings does not necessarily mean the absence of any radioactivity in total, because alpha and beta particles, along with low-energy gamma radiation, may be present but

Table 1 Readings in nSv/h at the different sites surveyed in the aftermath of the explosion that occurred at Beirut Seaport with GPS location, elevation, and distance from the blast

Distance from the center of the blast (m)	GPS North	GPS East	Elevation (m)	Dose rate (nSV/h)
100 to 600	33° 53′ 42″ N	35° 30′ 33″ E	60	58
100 to 600	33° 53′ 42″ N	35° 30′ 43″ E	40	94
100 to 600	33° 53′ 40″ N	35° 30′ 53″ E	50	94
100 to 600	33° 53′ 43″ N	35° 31′ 12″ E	50	61
100 to 600	33° 53′ 45″ N	35° 31′ 18″ E	30	61
100 to 600	33° 53′ 49″ N	35° 31′ 28″ E	30	97
100 to 600	33° 53′ 52″ N	35° 31′ 32″ E	10	67
100 to 600	33° 54′ 02″ N	35° 31′ 38″ E	20	94
100 to 600	33° 54′ 01″ N	35° 31′ 31″ E	10	100
100 to 600	33° 53′ 55″ N	35° 31′ 21″ E	30	97
100 to 600	33° 53′ 48″ N	35° 31′ 03″ E	30	100
100 to 600	33° 53′ 56″ N	35° 30′ 38″ E	20	80
100 to 600	33° 53′ 50″ N	35° 30′ 39″ E	20	86
600 to 1200	33° 53′ 50″ N	35° 31′ 46″ E	30	65
600 to 1200	33° 53′ 36″ N	35° 31′ 50″ E	50	84
600 to 1200	33° 53′ 41″ N	35° 31′ 27″ E	70	95
600 to 1200	33° 53′ 31″ N	35° 31′ 19″ E	50	91
600 to 1200	33° 53′ 17″ N	35° 31′ 12″ E	80	78
600 to 1200	33° 53′ 25″ N	35° 30′ 30″ E	50	76
600 to 1200	33° 53′ 44″ N	35° 20′ 24″ E	30	71
600 to 1200	33° 53′ 58″ N	35° 30′ 11″ E	30	83
1200 to 2400	33° 54′ 10″ N	35° 29′ 38″ E	10	84
1200 to 2400	33° 53′ 48″ N	35° 29′ 19″ E	60	79
1200 to 2400	33° 53′ 32″ N	35° 29′ 37″ E	80	83
1200 to 2400	33° 53′ 28″ N	35° 29′ 48″ E	90	84
1200 to 2400	33° 53′ 20″ N	35° 30′ 01″ E	80	78
1200 to 2400	33° 53′ 13″ N	35° 30′ 57″ E	80	84
1200 to 2400	33° 52′ 53″ N	35° 30′ 55″ E	60	76
1200 to 2400	33° 52′ 32″ N	35° 30′ 56″ E	50	77
1200 to 2400	33° 52′ 47″ N	35° 32′ 02″ E	20	85
1200 to 2400	33° 53′ 34″ N	35° 32′ 09″ E	50	79
1200 to 2400	33° 53′ 50″ N	35° 32′ 17″ E	0	74

cannot be detected by the surveying device used (VISTA-Technologies 1999).

It is clear from the obtained readings taken 1 week after the blast that the gamma dose rate level was close to the background and within limits set by LAEC (Samad et al. 2012). This is concurrent with the assessment conducted by an International Atomic Energy Agency (IAEA) team of experts who could not detect any elevated levels of radiation nor any presence of artificial radionuclides in the areas surveyed during their mission to Beirut in mid-September (IAEA 2020), even though the IAEA mission took place more than a month after the explosion.

On another note, the Beirut seaport's current readings were found to be twice as high as those measured in 2009 and 2010 by LAEC at the CNRS-L. It is unknown if this difference is due to an actual increase in gamma radiation over the last decade at the seaport or attributed to the investigators' use of different instruments back then (Samad et al. 2012). The difference may stem from several reasons: uncertainty of the measurements in that dose rate region, different response to the cosmic ray background, and different locations. Following the explosion, the surveyed sites may have been covered with other material than those originally present during previous measurements; for example, radioactive material used at hospitals damaged by the blast. Further studies are needed to explore the reason for this obvious difference in background dose rate.

Conclusion

When comparing the current measurements of the radiation levels at the Beirut seaport to those measured by LAEC-CNRS 10 years ago, the background range of 100 to 200 nSv/h remains acceptable. This might indicate that no radiation was spread over that area and that monitoring would be recommended at least twice a year to track the different activities at the seaport even though Lebanon has no nuclear power plants; Another reason for the proposed monitoring is that the country may be affected by nuclear activities from adjacent countries (Samad et al. 2012). It is also recommended that all clinics and hospitals damaged from the blast should census their instruments and devices and account for each one.

A more rigorous radiation survey should be conducted for all affected hospitals, clinics, and laboratories equipped with radioactive sources, radiation-emitting instruments or equipment, and around the explosion site to ensure no radiation leaks. Accidents with such sources may also involve contamination if the source is damaged. Besides, there is a need to strengthen nuclear safety and security across the country in addition to continuous monitoring to ensure the safety of radioactive materials for medicinal or military purposes received at the port.

Compliance with ethical standards

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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