Straight Tox

Polonium-210: The perfect poison?

by Dwain Fuller, D-FTCB, TC-NRCC

It was July 5th, 2012, the Thursday of the Society of Forensic Toxicologists meeting in Boston. My cell phone rings, displaying a number with a Washington, DC area code. A little odd, but since I use my cell phone for my consulting work, I often get calls that I don't recognize. The caller identified herself as Kim Palchikoff, a producer with the *Voice of Russia* radio program, an English language station broadcasting out of our nation's capital. She wanted me to participate in a radio interview the next day regarding the news that Yasser Arafat's widow planned to exhume his body to determine if he had been poisoned with polonium-210. Ms. Palchikoff wanted me to discuss the toxicological aspects of polonium-210. Well, I had not yet heard the news of Arafat, and I knew little beyond the basics of polonium-210. I did, however agree to the interview, figuring that I probably knew more, or at least could learn more in the following 24 hours about polonium-210, than they or the general public likely knew. Never pass up an opportunity to look smart to the less informed masses, I always say. So, I did a phone interview sitting on the lawn across the street from the USS Constitution the next day. All appeared to go well, at least no one called in to tell me I was wrong.

While you, like me, may not have heard the news about Arafat, I'm relatively certain you did hear something about Alexander Litvinenko a few years back. Alexander Litvinenko was a former KGB agent, prior to defecting to London. Litvinenko fell from grace with Russian powers in 1998 after accusing his superiors of ordering the assassination of Russian tycoon and oligarch, Boris Berezovsky. Litvinenko was arrested on charges of "exceeding his authority at work" the following March, but was acquitted in November 1999.

Litvinenko was re-arrested and charges were again dismissed in 2000. Litvinenko fled with his family to London and was granted asylum in the United Kingdom. While in the UK, Litvinenko wrote two books, *Blowing Up Russia: Terror from Within* and *Lubyanka Criminal Group*, in which he accused Russian officials, including Vladimir Putin, of terrorism and the ordering of murder. It was later disclosed after his death that he was working as a consultant for the British intelligence services MI6 and MI5.

On November 1, 2006, after meeting with former KGB agents, Dmitry Kovtun and Andrei Lugovoi, Litvinenko fell ill with acute, severe, and progressive gastrointestinal symptoms. His health rapidly deteriorated with his hair falling out and the development of pancytopenia, a shortage of all types of blood cells, including red cells, white cells, and platelets.

Because his symptoms were consistent with either thallium or radiation poisoning, physicians collected a 24 hour urine and tested it for thallium as well as for gamma radiation. The tests yielded nothing of concern. When Litvinenko failed to respond to treatment, his urine was sent to Britain's Atomic Weapon Establishment for further testing. There tests revealed significant alpha particle radiation. Litvinenko died on November 23rd. His death was later attributed to polonium-210 poisoning, after the Health Protection Agency found significant amounts of this rare compound in his body.

Prior to proceeding, perhaps a refresher course in radiochemistry is in order. There are three types of nuclear radiation emitted by radionuclides: **alpha particles, beta particles, and gamma rays**.

Alpha particles are essentially helium nuclei, consisting of two protons and two neutrons. Alpha particles have a relatively large mass and high kinetic energy and can therefore cause direct ionization of other nearby atoms or molecules, but due to their size and 2+ charge have very little penetrating power; a few sheets of paper or intact skin effectively block them. As a result, alpha radiation is only a significant health hazard when ingested or inhaled, which places it in close proximity to sensitive tissues.

Beta particles are high speed electrons or positrons. Beta particles are produced when an unstable nucleus of an atom with an excess of neutrons converts a neutron into an electron, a proton, and an antineutrino. Because of the production of a proton during beta decay, an element of the next higher atomic number is formed in the process. Beta particles have a spectrum of energy levels. High energy beta particles can penetrate a few meters in the air and a few millimeters into tissue. Severe "beta burns" can be produced on the unprotected eyes or skin from exposure. Like alpha particles, beta particles pose a significant health risk from ingestion or inhalation of beta emitting material.

Gamma rays consist of electromagnetic radiation and are of high energy, similar to X-rays. Gamma rays pass easily through most matter including skin and clothing. Gamma radiation from all routes of exposure poses a significant health risk.

What is Polonium-210?

Polonium-210 is the predominant naturally occurring isotope of polonium. Polonium has over 25 isotopes, but only three: polonium-208, polonium-209, and polonium-210, have appreciable half-lives. Polonium-210 is a natural decay product of uranium-238 and radon-222. Polonium-210 has a half-life of 138 days. Uranium ore contains about 0.1 mg of polonium-210 per ton. Alternately it can be obtained from aged radium salts that contain polonium-210 at about 0.2 mg per gram of radium. However, most polonium-210 is produced by neutron bombardment of bismuth-209 which yields bismuth-210. Bismuth-210 subsequently decays by beta emission to polonium-210.

Toxicity

Polonium-210 is an alpha emitter, therefore it is reasonably safe to handle and transport, however it is extremely toxic when ingested. It is estimated that one gram of polonium-210 could kill 50 million people and sicken another 50 million. In perhaps more fathomable terms, it required probably no more than a microgram to kill Litvinenko, although indications are that much more was used.

Polonium-210 is readily absorbed and is deposited chiefly in the liver, spleen, bone marrow, kidneys, skin, and hair follicles. The half-life in the body (not radioactive half-life) is estimated to be one to two months, being eliminated primarily through urine and feces.

Polonium-210 when ingested does damage particularly to the epithelial lining of the alimentary tract and the bone marrow, the source of blood cells. The alimentary tract damage results in severe gastric distress in the form of nausea, vomiting, fluid loss, and bloody diarrhea. The bone marrow damage results in a rapid decline in white blood cells, red blood cells, and platelets causing a suppressed immune system, vulnerability to infection, impaired wound healing, and bleeding disorders.

Detection

Due to its radioactivity and typically low concentration, the preferred method for detecting polonium-210 is by alpha-particle spectroscopy, which identifies polonium-210 by its signature alpha particle emission with an energy of 5.3 MeV.

However, before we get over-confident, let's do some math. As previously stated polonium-210 has a radioactive half-life of 138 days and Yasser Arafat died in November of 2004. Therefore, as of July 2012, approximately 7.5 years, or 20 half-lives have passed. That means that the residual polonium-210 in Arafat's body, if indeed he were poisoned with polonium-210, would be approximately 1 millionth of what it was when he died. Furthermore, as discussed above, a lethal dose is estimated to be around 1 microgram, not to mention that he lived for several days after becoming ill. You see where I'm going with this? After all this time, I don't like the odds of finding conclusive proof of polonium-210 poisoning whether it happened or not. However, since polonium-210 is such a rare element in the environment, findings of polonium-210 significantly above background may indeed indicate poisoning.

Summary

So is polonium-210 the perfect poison? Polonium-210 possesses the "perfect poison" attributes of being lethal in small quantities, being relatively safe to handle by the poisoner, and rapid disappearance from the body and the environment. Additionally, its detection requires specialized instrumentation and an alert medical or forensic staff to even suggest its presence. However, it does suffer one major drawback: its availability. The production of a reasonable amount of polonium-210 requires a nuclear reactor, a fact that almost always indicates the collusion of a government entity. This alone violates one of the most sacred tenets of cloak and dagger work…plausible deniability.

References and Further Reading

Salma Abdelaziz and Schams Elwazer. *Arafat's widow wants body exhumed after test for radioactivity*. July 04, 2012. http://articles.cnn.com/2012-07-04/middleeast/world_meast_switzerland-arafat-polonium_1_body-exhumed-francois-bochud-suha-arafat?_s=PM:MIDDLEEAST Accessed 7/18/12

McFee RB, Leikin JB. *Death by Polonium-210: Lessons learned from the murder of former Soviet spy Alexander Litvinenko*. Response Guide for Chemical & Radiologic Threats. www.clintox.org/documents/WMDSIG/AACT-WMD-**Death_Polonium**.pdf Accessed 7/18/12

Alexander Litvinenko. Wikepedia. http://en.wikipedia.org/wiki/Alexander_Litvinenko Accessed 7/18/12

Polonium. Argonne National Laboratory. Human Health Fact Sheet, August 2005