The Radium Girls —Dialing Up Trouble

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By Bryan Curtis

December 9, 1924, was a shocking day for the family and friends of a 25-year-old woman in Newark, NJ, who died under mysterious circumstances. Her death certificate listed the cause as "phosphorus poisoning—necrosis of the jaw". Only a year earlier, her dentist had discovered the necrosis, a term that refers to the death of living tissue. This necrosis resulted in a rapid decay of the jaw.

Her family was suspicious that the real cause of her horrific and untimely death was not phosphorus poisoning but rather something connected to her working conditions at a watch factory. There she worked as a dial painter and used luminescent paint. The paint was composed of a glow-in-the-dark radium compound that was used to inscribe the numbers on watch dials. Fellow employees became worried that the same fate might be in store for them.

Watch dial painters became collectively known as "the Radium Girls". These workers in an Ottowa, IL, plant during the 1920s used luminescent paint composed of a glow-in-the-dark radium compound to inscribe the numbers on watch dials.

The workers were issued about 1–2 g of paint base in small containers. The powdered base was a mixture of radium salts and zinc sulfide (ZnS). Each worker mixed her own paint, using glue, water, and the radium powder. However, the powdered base became an airborne suspension and drifted throughout the room, causing the contents of the workroom, including the painters' clothes and bodies, to glow in the dark. The watch dial painters became collectively known as "the Radium Girls".

Why radium glows

Radium in the radium salts decomposes spontaneously producing radiation in the form of alpha particles. The term *radioactivity* refers to the spontaneous emission of either particles or electromagnetic radiation of very high energy from the nucleus of an atom. Radioactivity is a natural phenomena and has many beneficial uses—it can destroy bacteria in food or eliminate cancer cells.

The three most common types of emissions from radioactive nuclei are alpha particles, beta particles, and gamma radiation. Alpha particles are helium nuclei. Beta particles are electrons (or in some cases, positrons, which are particles exactly like electrons except that they carry a positive charge). When these particles are emitted from a radioactive nucleus, they can cause damage to the human body, not because of what they are but because they are emitted with extremely high energy. When they strike human tissue, they can damage this tissue. Gamma rays consist of electromagnetic radiation whose photons are of extremely high energy. Like alpha and beta particles, they can also cause damage to human tissue (see Table 1).

Table 1. Summary of general information and changes from natural radioactive decay

Type	Symbol	Change in atomic number	Change in neutrons	Change in mass number
Alpha (α)	$^{4}_{2}He$	Decreased by 2	Decreased by 2	Decreased by 4
Beta (β)	$^{0}_{-1}e$	Increased by 1	Decreased by 1	No change
Gamma (γ)	$^{0}_{0}\gamma$	No change	No change	No change

The greatest danger from exposure to radium comes from the alpha particles it emits. Radiation in the form of alpha particles cannot penetrate even this piece of paper. However, when you swallow nuclei that then emit alpha particles, it can be fatal. This is dangerous precisely because of the poor penetrating power of the alpha particles: They deposit all of their energy inside the body. Alpha particles can have a ruinous effect on the body, especially on the blood and blood-forming centers like the liver and the spleen. In small doses, alpha particles stimulate red and white blood cell production; but after continual exposure, they destroy white blood cells and shrink red blood cells leading to severe anemia. To further complicate the radiation effects when radium is absorbed into the body, it gets deposited in the bones, because it substitutes for calcium—both being alkaline earth elements. Symptoms of people exposed to radium include changes to the skin and blood.

The radiation from the radium salts ionizes the surrounding atmosphere, producing a blue glow. The emissions are enhanced in luminescent paints by allowing alpha particles to strike a *scintillator*—a material that emits visible light in response to ionizing radiation. In this case, ZnS acts as the scintillator, and without it, the radium compounds would never have been as luminescent, (i.e., emitting light at low temperature).

Dial painting technique

The dial painters were unaware of the dangers of radium. They assumed the paint was safe; and many would paint their teeth and faces, turn off the lights, and hide in a closet as a type of game.

To paint the small watch faces, a dial painter had to have a steady hand and a sharply pointed brush. To give the brush this point, a painter may have put the brush in her mouth between strokes, using her lips as a tool to make the point. This made her work quicker and more precise but caused her to ingest radioactive material, further compounding her exposure. The amount of radium absorbed in a day could be from 25 to 50 mg, enough to be deadly.

By 1929, in the United States, 33 female dial painters died at an early age from symptoms associated with radium poisoning. They worked in dial painting rooms from a little more than 1 year to more than 12 years. Unfortunately, all had used the lip method to put a point on their brushes, at least until reform measures had been put into place in 1925 prohibiting this practice—too late to help them.

Protecting radium workers

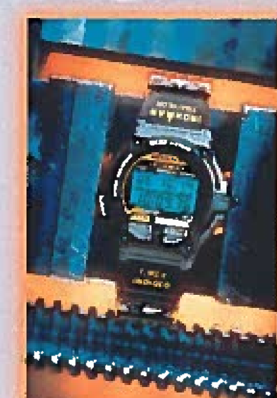
Early reforms to the workplace instituted many new safety methods, such as no eating in the work area; wearing rubber gloves to

$$^{226}Ra \rightarrow {}^{222}Rn + {}^{4}He \ (\alpha \text{ particle})$$

Figure 1. Measuring the amount of radon gas using a breathalyzer test determines the amount of radium to which a worker has been exposed. Radium-226 decays into atoms of radon-222 and helium-4 (α particle).

Glow-in-the-Dark Substitutes

There are now several substitutes for radium paints. One of these substitutes is promethium. The drawback to using this element is that it is also radioactive. However, promethium is less hazardous than radium because it decomposes to produce beta particles, which have a greater power to penetrate than alpha particles but less ionizing ability. Promethium ionizes the surrounding atmosphere producing an eerie pale blue or yellow-green glow. It is used when an object must be constantly luminescent with no extra energy added.


COURTESY OF TIMEX

Timex produces the most common luminescent watch called Indiglo Night-light. This product is a safer alternative to lighting a watch dial than using radium salts or other radioactive compounds.

Another substance that has been used for luminescent dials is phosphorus. A dial must first be charged with light energy before it becomes luminescent. However, there are a few problems with this method. The dial loses energy as it gives off light. Because of this property, it only glows for a short time, and it doesn't glow brightly.

Indiglo Night-light by Timex is currently the most common luminescent product. This is a very safe method of lighting a watch dial. The dial can remain lit as long as it can be supplied with power from the watch battery. The compound used in Indiglo Night-light is ZnS doped with copper (Cu). *Doping* is adding a small but controlled amount of an impurity to enhance certain properties. A microchip converts an electrical charge from the watch battery to a higher voltage. When this voltage is applied, electrons are excited in the ZnS and Cu. The microchip induces an alternating current that essentially turns the voltage on and off, allowing the electrons to return to the ground state. As electrons return to their ground state, energy is released in the form of light.

wash the painting equipment in water and dry it on a cloth rag; using lead containers to hold the radium; weighing and mixing the paint under a fume hood; limiting the time a worker was allowed to be in the painting department; and periodically examining the workers for radium exposure. Although there were improvements in employee health, the work environment was still unsafe—an unsealed container of the paint allowed radioactive particles to become airborne, even without the container being disturbed.

By the 1940s, when workers used radium paint for control panels in military airplanes, the National Bureau of Standards administered breath tests regularly to dial painters—an improvement over the tests of the 1920s. The breath test method was an improvement in that it detected radium exposure levels well before damaging symptoms occurred. This analysis determined the amount of radium exposure by monitoring the level of radon (see Figure 1) in a person's breath, an indication of the amount of radium in her body. When radon levels verified dangerous amounts of radium exposure (0.1 μg), the worker was permanently assigned to a different job with no exposure to radium.

Even though these more stringent safety precautions were implemented, dial painters were still being exposed to radium. The industry had to abandon the practice soon after the end of World War II.

Bryan Curtis is currently attending the University of Connecticut as a biology major and eventually plans to enter the medical field. The article was written last year with the aid of his chemistry teacher Amy Coan at Southington High School, CT.

The Marie Curie Connection

Marie Curie is best known for her work in the study of radioactivity. She was born in Warsaw, Poland, on November 7, 1867. Madame Curie held degrees in physics and mathematics. Her work led to the discovery of the elements radium and polonium in 1898. With her husband, Pierre, and Henri Becquerel, Marie was awarded the 1903 Nobel Prize in Physics for the joint discovery of radioactivity. In 1908, she became the first female lecturer at the Sorbonne, a university in Paris. Madame Curie won the Nobel Prize again in 1911, this time on her own, in chemistry. She received this award for her work in the isolation of radium.

Marie Curie and her two daughters, Irène and Eve. Her elder daughter, Irène, along with her husband Frédéric Joliot became Nobel Prize-winning chemists in 1935 for their discovery of artificial radiation by bombardment of alpha particles on light elements.

Radium is present in all uranium minerals. Of these various minerals, pitchblende is the most concentrated source of radium. For every 7 tons of pitchblende, only 1 g of pure radium can be isolated. Amazingly, Marie Curie was able to isolate a small amount of radium. To honor this legendary woman, one unit of measurement of radioactivity is called the *curie* (Ci).

Marie Curie learned about the problems encountered by the radium workers. She suggested that they eat raw liver to help with the anemia but indicated that they should not hope for a cure. Madame Curie encouraged a change in the methods employed by workers who used radium paint. Curie died on July 3, 1934, of a blood disorder, which was probably a result of her long exposure to radiation.

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