Radiation Workers at the Idaho National Laboratory and Around the DOE Complex Need to Understand Blood Count Changes That Can Indicate a Significant Radiation Exposure

By Tami Thatcher
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A large external or internal radiation exposure can damage bone marrow and the damage is reflected by changes in complete blood count (CBC) results. A CBC is the determination of the number of red and white blood cells per cubic millimeter of blood. The following discussion would be relevant to a radiation worker with an above normal ionizing radiation external exposure or an internal exposure from intake of radioactive material.

After a significant radiation exposure, there is a sharp drop in lymphocytes which may remain depressed for several months. There is also a brief increase in granulocytes followed within a day by a decrease which reaches a minimum several weeks after exposure, and then returns to normal after several weeks or months. The depression in blood counts are due to destruction of the blood-forming stem cells in the bone marrow rather than to the destruction of the blood cells themselves. The red blood cell count does not reflect an overexposure until about a week after exposure. Then, depression in the red blood cell count continues until a minimum is reached between 1 and 2 months after exposure, followed by a slow recovery over a period of weeks.

Radiation workers with an internal exposure should be cautioned that much of the information available that describes radiation-induced blood changes is based on external exposure from penetrating gamma radiation. A disproportionately higher bone marrow dose may be received by internal exposure to bone seeking radionuclides such as plutonium taken into the body via inhalation, ingestion, or wound entry. The bone seeking radionuclides include americium-241, plutonium-238, plutonium-239, thorium-228, radium-226, radium-228, and strontium-90. When a radionuclide such as plutonium-239 is stored in bone, near the stem cells that produce white blood cells, these radionuclides deliver a chronic dose of radiation that can interfere with normal blood-cell production.

> **Why it matters**:
> When multiple Complete Blood Counts are conducted after a significant radiation exposure, trends in blood counts can be related to radiation dose.
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> **Radiation workers benefit by understanding the importance of trending their CBC results and sharing their radiation exposure history with their medical practitioners.**
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> Lost or falsified radiation exposure records may prevent proper radiation dose reconstruction and result in radiation illness compensation claim denial in the future.

The hematopoietic system is made of the bone marrow and other organs and tissues involved in the formation and functioning of blood elements. Human blood consists of (1) red blood cells (also called erythrocytes), (2) white blood cells (also called leukocytes), (3) platelets (also called thrombocytes), and (4) plasma.

There are five types of white blood cells: the lymphocytes and monocytes (which are agranulocytes) and the neutrophils, basophils, and eosinophils (which are granulocytes). The lymphocytes are produced in the lymph nodes and spleen and remain alive in the blood for about 24 hours. The granulocytes are produced in the bone marrow and remain alive in the blood for about 3 days. Neutrophils account for 50 to 75 percent and lymphocytes account for 20 to 40 percent of the cells in blood. The red blood cells are formed in the bone marrow and survive in the blood for about 90-120 days. The platelets are also made in the bone marrow and live about 8-12 days. The drop in the number of leukocytes can lower the resistance to infection. The drop in the number of platelets may lead to hemorrhage or profuse bleeding. Average concentrations of formed elements in human blood are shown in Table 1.

Table 1. Average concentrations of formed elements in human blood.

Formed elements	Concentration (per cubic millimeter) (Source: Mosby's Dictionary, 8th ed.)
Erythrocytes (red blood cells)	4,700,000 to 6,100,000 (adult males) 4,200,000 to 5,400,000 (adult females)
Leukocytes (white blood cells)	5,000 to 10,000
Lymphocytes	2,710 *
Neutrophils	4,300 *
Monocytes	500 *
Platelets	200,000 to 300,000

* Monocyte depletion is discussed and an estimate of the normal number of neutrophils, lymphocytes and monocytes per "microlitre" of blood is provided, and appears to actually correspond to milliliter. http://www.ccnr.org/bertell_book.html

Rosalie Bertell wrote that in addition of observing lymphocyte and neutrophil depletion that is typically described for assessing radiation exposure, [1] it is also important to observe monocyte depletion. The low number of monocytes and the lower variation in what may be considered normal levels allows the monocyte depletion to be a sensitive indicator of radiation exposure. Monocytes recycle 37 to 40 percent of the iron in the red blood cells when they die, so monocyte depletion is important to iron deficient anemia. Monocytes also secret the substance that activates the lymphocyte immune system and so monocyte depletion is important to depressed cellular immune system. [2]

[1] Radiation Emergency Assistance Center/Training Site (REACT/TS) Managed by Oak Ridge Institute (ORAU) for the Department of Energy, *The Medical Aspects of Radiation Incidents*, 4th Edition. https://orise.orau.gov/reacts/documents/medical-aspects-of-radiation-incidents.pdf and see more about REACT/TS at https://orise.orau.gov/reacts/index.html

[2] Dr. Rosalie Bertell, Gulf War Syndrome, Depleted Uranium and the Dangers of Low-Level Radiation, http://www.ccnr.org/bertell_book.html which references Bertell, R. "Internal Bone Seeking Radionuclides and Monocyte Counts", International Perspectives in Public Health, Vol. 9, pp 21-26, 1993.

Red blood cells can be deformed and are associated with chronic fatigue syndrome. This chronic fatigue syndrome has been observed both a Hiroshima and Nagasaki and at Chernobyl.

An elevated serum amylase provides a supplementary piece of information that may also be an early sign of serious radiation exposure involving the head and neck. The results of this test are nonspecific, however, and may also reflect alcohol intake, a stress response, trauma to the face or abdomen, or other factors. [3]

According to the Oak Ridge Associated Universities website, chelation with diethylene triaminepentaacetic acid (DTPA) accelerates renal elimination of radioactive materials from the body from plutonium, americium or curium. **The use of DTPA is indicated when individuals have been internally contaminated with a significant amount of radioactive plutonium, americium, and/or curium.** It should be noted that these radionuclides are also neutron emitters. [4] DTPA treatment may actually increase the deposition of uranium and neptunium into bone and thus is not recommended treatment for contamination with these radionuclides. [5] There are calcium or zinc forms of DTPA: Ca-DTPA and Zn-DTPA. Ca-DTPA is considered more effective in the first 24 hours but carries a higher risk of mineral depletion from the body. Zn-DTPA is considered as effective as Ca-DTPA 24 hours after exposure but carries less risk of mineral depletion if given over a long duration.

Chelation following plutonium intake is recommended to commence within one hour of the intake or wound entry. Actinides such as plutonium are rapidly taken up by bone within two hours. [6]

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[3] Anthony B. Wolbarst et al., Radiology, "Medical Response to a Major Radiologic Emergency: A Primer for Medical and Public Health Practitioners, February 8, 2010. https://pubs.rsna.org/doi/full/10.1148/radiol.09090330

[4] Environmental Defense Institute, July 2018 newsletter article "Neutron Exposure During Glovebox Work and Other Handling of Fissile Material at the Idaho National Laboratory and Idaho Cleanup Project." http://www.environmental-defense-institute.org/publications/News.18.July.pdf Note that Pu-239, which is fissile, is bred from U-238 by single neutron capture. Other transuranic radionuclides, which may or may not be fissile, result from repeated neutron absorption, usually in a nuclear reactor. Uranium and transuranic radionuclides such as plutonium, americium and curium may undergo spontaneous fission and emit neutrons. Some transuranic materials are created in spent nuclear fuel, while some transuranic radionuclides are created from target material exposed to high neutron flux in a nuclear reactor. Radiation workers who work around uranium and transuranic radionuclides such as plutonium are exposed to neutron radiation which is not stopped by metal shielding or lead aprons and which causes densely ionizing damage to the human body. The neutron dose may not be monitored or if monitored, the portion of the worker's radiation dose arising from neutron exposure may not be reported. The radiation workers most likely to have a plutonium, americium or curium intake may be chronically exposed to neutron radiation in their jobs. I suspect that the detrimental health effects of chronic neutron exposure such as infertility may be underappreciated in these radiation workers.

[5] Medical Countermeasures for Radiation Exposure and Contamination webpages at https://www.orau.gov/rsb/countermeasuretraining/#DTPA

[6] Nicholas Dainiak, MD, FACP et al., Radiation Emergency Assistance Center/Training Site, Oak Ridge Associated Universities, "REAC/TS Approach to Rapid Dose Estimation and Decontamination of Plutonium Following a Puncture Wound," Presentation May 10, 2017. https://radiation-medicine.de/fileadmin/user_upload/Praesentationen/Dainiak-ConRad2017.pdf Actinides (plutonium, americium and others) are absorbed through wounds rapidly, within 2 hours. The actinides are taken up strongly by bone and liver. "Early decorporation therapy (1-2 hours) with DTPA is required to reduce rapid translocation of actinides to tissues." In 2018, at a DOE site where a worker had a puncture wound involving 300

A blood sample can be analyzed for chromosome aberrations to estimate radiation dose. However, there are only two laboratories that perform dicentric chromosomal analysis, at REAC/TS and at the Armed Forces Radiobiology Research Institute. [7] Using this method to determine whether the number of chromosome aberrations in lymphocytes was elevated along with continued blood counts would provide important information about the radiation dose the worker received. The misrepaired chromosomes replicate; therefore, this damage remains years after the exposure.

disintegrations/minute on an alpha meter, the wound was flushed and treatment with Ca-DTPA was initiated within 1 hour.

[7] Anthony B. Wolbarst et al., Radiology, "Medical Response to a Major Radiologic Emergency: A Primer for Medical and Public Health Practitioners, February 8, 2010. https://pubs.rsna.org/doi/full/10.1148/radiol.09090330