Environmental Risks of Beryllium, Selenium, and White Phosphorus Former Badlands Bombing Range

by

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The Technical Outreach Services for Native American Communities (TOSNAC) program has been providing technical assistance to the Badlands Bombing Range (BBR) Project Office of the Oglala Sioux Tribe by presenting fundamental environmental science information. The goal is to empower Native American community members and other stakeholders with an independent understanding of the underlying technical issues associated with potential environmental risks so they may participate substantively in the decision-making process to reduce risks, if necessary. One form of technical support provided is the review and summary of technical issues related to a site.

This report is in response to interest raised at the March 1998 Restoration Advisory Board meeting about health effects of beryllium, selenium, and white phosphorus in soil and/or groundwater at the BBR. Beryllium is a metal that is sometimes used in shell casing alloys, and although reportedly not used in the manufacture of munitions fired at this site, it is known to occur naturally in area soils in relatively high concentrations (1). Selenium is a chemical element not used in the manufacture of ordnance, but which is known to be naturally present locally in amounts sufficient to cause illness in animals ("alkali disease"). Another chemical element, white phosphorus, is used as an incendiary (burning) agent in some types of ordnance, and does not naturally occur at the BBR.

Beryllium

Beryllium is used in shell casings in the form of beryllium-containing metallic alloys, while natural sources of the metal are primarily beryllium silicate minerals (2). In practice, specialized laboratory procedures may be required to distinguish between the oxide weathering products of metal alloys and the clay weathering products of natural silicates containing beryllium. Because of relatively high local background levels of the metal, naturally occurring beryllium appears to be the main source of concern for this metal at the BBR.

Natural soil beryllium at the BBR has been measured in concentrations as high as 1.1 ppm (3), higher than the 1997 EPA Region III Risk-Based Concentration (RBC) of 0.15 ppm for the metal in residential areas, and almost as high as the 1997 EPA Region III RBC of 1.3 ppm for industrial (and agricultural) areas (4). The *average* concentration of beryllium in soils is 0.59 ppm at the BBR and 0.97 ppm for the western United States (3).

Airborne beryllium dust is considered a carcinogen, but reports of disease in humans (called berylliosis) caused by breathing beryllium dust are almost exclusively confined to enclosed workplaces. A recent calculation indicates that the maximum estimated airborne beryllium dust concentration at the BBR (0.000005 mg/cubic meter) is two orders of magnitude lower than the concentration that would cause concern about the health effects of breathing beryllium dust (0.0005 mg/cubic meter) (5). A special calculation of cancer risk at the BBR for a 154 lb. adult breathing beryllium-containing dust for 24 hours a day, 365 days a year over 70 years indicates that the resulting risk of cancer may be from one case in a population of 10 million to one case in a population of 100 million, which is one to two orders of magnitude lower than the one in one million risk of cancer that is the EPA has set as a level of concern at cleanup sites.

The recently released 1998 EPA Region III RBC for beryllium in residential area soil has been raised to 160 ppm, and the RBC for industrial (agricultural) area soil has been raised to 4100 ppm. The 1998 RBC's are calculated for ingestion only, rather than both ingestion and inhalation as the 1997 RBC's were. This is important, because beryllium weathering products tend not to dissolve in groundwater, and the major health risk is from inhalation of beryllium-containing dust (6), rather than ingestion.

Selenium

Selenium is an essential trace nutrient for animals, although it is toxic in excessive amounts (7). The semi-arid conditions of the Great Plains favor the formation of water-soluble forms of the metal (8) and it occurs naturally in local surface water and groundwater of the local area (9). In particular, groundwater from the nearby Niobrara Formation is potentially hazardous to humans and livestock because of elevated levels of selenium and other compounds, and selenium may be concentrated at toxic levels in the roots and leaves of plants. Selenosis ("alkali disease") is a selenium-induced disease that has caused livestock deaths in the region.

Selenium is not used in ordnance, so the selenium found at the BBR is likely to be from natural sources. Local bedrock formations such as the Carlile Shale, Niobrara Formation, and the Pierre Shale have reported selenium concentrations ranging from an average of 3.3 ppm to a maximum of 23.1 ppm (10). Natural selenium concentration in surface soil at the Black Hills Army Depot (BHAD) near Edgemont, South Dakota is reported to average 7.2 ppm, with maximum levels of 23.1 ppm (10). This is well below the EPA Region III RBCs of 390 and 10,000 ppm for soil in residential and industrial (agricultural) areas, respectively. However, maximum selenium concentration measured in groundwater at BHAD is 0.34 ppm, well above the EPA maximum contaminant level for drinking water (0.050 ppm). Selenium concentrations in water that pose risks to the environment are debated, but may range from 0.5 ppm for livestock (11) to anywhere from 0.020 ppm for acute effects and 0.005 ppm for long-term adverse effects in birds and aquatic animals in sensitive wetlands (12).

Accumulation of selenium in local plants can also create health risks to animals that eat those plants. Accumulator plants include goldenweed, loco weed, and princesplume. While selenium concentrations of up to 1.0 ppm are most commonly observed in plants (13) and meet dietary requirements for domestic animals, levels in forage above 2 to 5 ppm are potentially hazardous (14). Local areas in western South Dakota have accumulator plants containing over 50 ppm selenium (15).

White Phosphorus

White phosphorus is an unstable white, waxy material consisting of pure phosphorus, and which will burn on contact with air. It does not occur in nature, but can be refined from phosphorus minerals in rocks, and is used to manufacture incendiary weapons, pyrotechnics, fertilizers, and other industrial products (16). The EPA Region III RBC's for white phosphorus in residential and industrial (agricultural) area soils are 1.6 ppm and 41 ppm, respectively. The EPA RBC for white phosphorus in drinking water 0.00073 ppm.

Although evidence of incendiary weapons was discovered during a range clearance in 1964 (17), sampling work to evaluate the BBR for white phosphorus has not been conducted. Therefore, no statement can be made about the levels of white phosphorus at the BBR. However, it is only in soil, water, or sediment with very little oxygen that white phosphorus may persist for a great length of time and pose an environmental threat to wildlife and persons eating that wildlife. In oxygenated water, white phosphorus will react with oxygen and break down within hours or days, while white phosphorus in oxygenated soils will break down within days (18). The relatively great depth to groundwater at the BBR (40 feet) may result in relatively quick break down of white phosphorus that may be dispersed in the oxygenated soil. However, analysis of soil and water samples collected from areas where incendiary weapons may have been used (or disposed of) is necessary to determine risks due to white phosphorus.

General Comments

The goal of this paper is to present unbiased information consisting of, or derived from, generally accepted science and engineering principles. This information may help the community and other stakeholders gain a better understanding of natural or man-made environmental risks at the former BBR. The TOSNAC program can provide additional information on these or other topics upon request.

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