Using color as a proxy to identify heavy metals in mine dumps;
Heavy Metals on Trails and Mine Dumps in Jacob City, Tooele Co, Utah

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Abstract

Jacob City is an abandoned mining town in the Ophir Mining District, near Stockton, UT. The area has many abandoned mines, waste rock and tailings piles that are part of a system of all terrain vehicle (ATV) trails with regular visitation. These mine dumps have high concentrations of heavy metals and may pose a health risk to ATV users. Soil samples were tested with an x-ray fluorescence analyzer and results show soils in the recreational area have high levels lead, arsenic, and cadmium exceeding the Bureau of Land Management risk-based screening criteria (BLM criteria; lead 1,000 mg/kg, arsenic 300 mg/kg and cadmium 950 mg/kg) for ATV users: lead (n=37, range 108 to 115,900 mg/kg, x 16,091 mg/kg), arsenic (n=36, range 0 to 6,732 mg/kg, x 1,166 mg/kg) and cadmium (n=25, range 0 to 1,626 mg/kg, x 87 mg/kg). Concentrations of lead, arsenic, and cadmium correlate with Munsell soil color system hue on tailings piles, waste rock piles and ATV trails: lead is elevated in soil with 5YR and 7.5YR hues, arsenic is elevated with 5YR and 7.5YR hues, while, cadmium is elevated with a 2.5Y hue. The data show that high concentrations of cadmium are inversely related to high concentrations of lead and arsenic. When cadmium is high, lead and arsenic are lower; and when lead and arsenic are high, cadmium is lower. Findings also show that average lead (x of lead in dumps 20,434 mg/kg, along trails 8,038 mg/kg) and arsenic (x arsenic in dumps 1451 mg/kg, along trails 642 mg/kg) concentrations are higher on mine dumps compared to ATV roads. Average cadmium concentrations (x cadmium in dumps 109 mg/kg, along trails 166 mg/kg) are higher on ATV roads compared to mine dumps. The cause of this pattern is still being explored. Since color hues correlate with elevated levels of heavy metals at the study area, color hue could be used as a proxy for elevated levels of heavy metals. This color proxy could be used to caution ATV users and assist future mapping and environmental remediation.

Background

Jacob City is a historical mining town that operated from 1870 until the 1971, Mining gold, silver, copper, lead, and zinc located within Dry Canyon and is considered part of the Ophir district. Starting in 2016 the abandoned mine reclamation program (AMRP) has backfilled abandoned mines using tailings and waste rock in the area, rebaring entrances closed and welding AMRP tags to mine entrances. The Oquirrh mountains ore occurs from bedded replacement deposits, irregular replacement deposits and fissure vein deposits. Ore is found within the limestone rock layers of the lower Cambrian to upper Mississippian including the Ophir formation, Madison Limestone, the Great Blue Limestone and the Long trail shale member (Gilluily, 1932). Formations include vertical calcite veinlets between 1-3" thick. Ore in Jacob city occurs as lead zinc deposits, the lead formed in part as replacement along fissures along with partially oxidized galena forming a cerussite. Lower in the rock, galena is encased by oxidized zinc and copper ore. Zinc carbonate ore occurred as a replacement of limestone prior to copper carbonates that would replace the zinc carbonate. Common ore minerals consist of ferruginous smithsonite, aurichalcite, malachite and azurite (Loughlin, 1917; Emmons, 1880). Primary ore bearing minerals include of galena, tennanite, chalcopyrite, sphalerite, pyrrhotite and pyrite (Ege, 2005). No environmental studies have been done to date but is frequented by ATV users for recreation especially after exposure from Utah Outdoor Activities website and Mojave Underground explorations viewable on YouTube.


Fig 1. AMRP tag outside a mine.
Photo by A. Shepherd


Fig 2. Calcite veinlet.
Photo by A. Shepherd


Fig. 3 Historical structure in Jacob city.
Photo by A. Shepherd


Fig 4. Vein of clay and calcite.
Photo by A. Shepherd

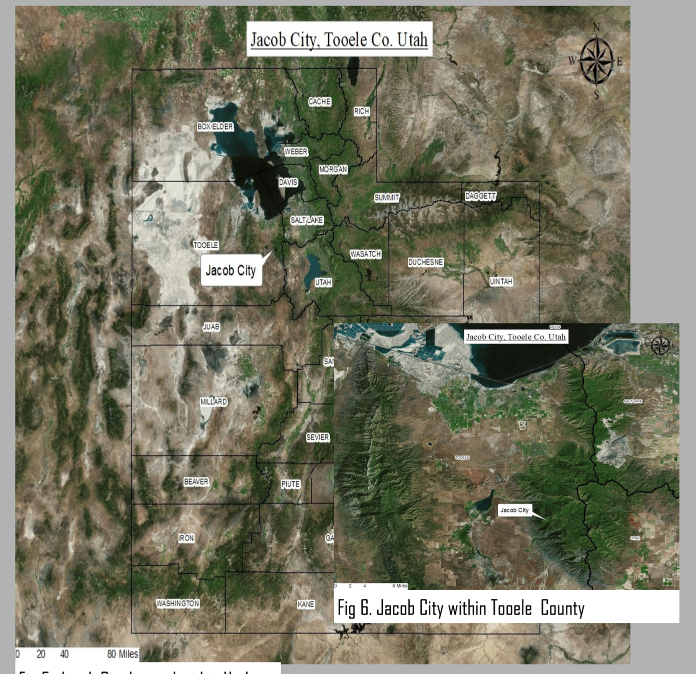


Fig 5. Jacob City located within Utah

Fig 6. Jacob City within Tooele County

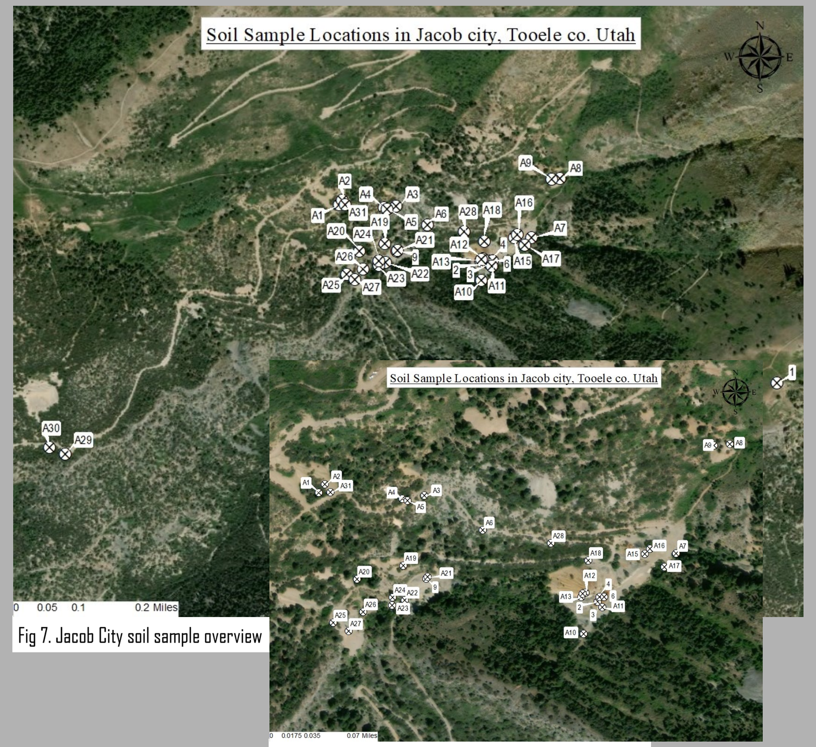


Fig 7. Jacob City soil sample overview

Fig 8. Jacob City soil sample zoomed into center cluster

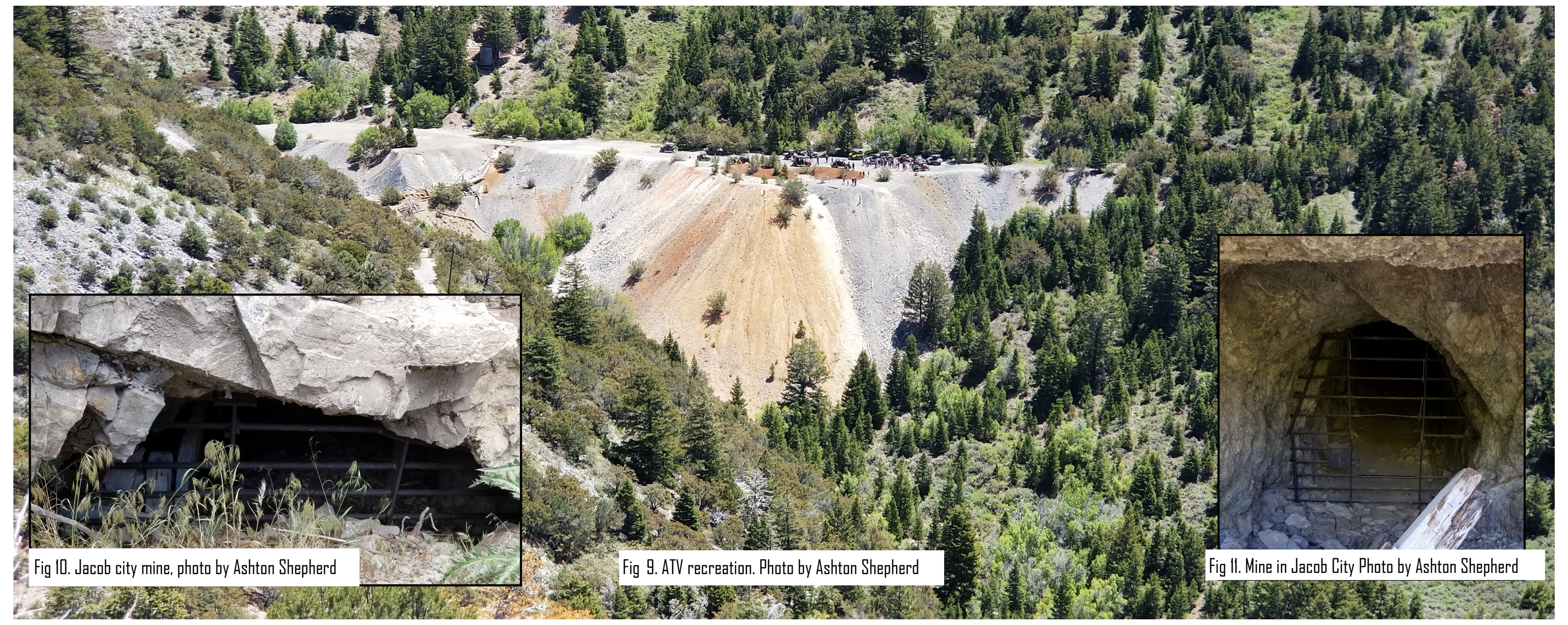


Fig 9. ATV recreation. Photo by Ashton Shepherd

Fig 10. Jacob city mine, photo by Ashton Shepherd

Fig 11. Mine in Jacob City Photo by Ashton Shepherd

Problem

Abundant abandoned mines at Jacob City have the potential for high heavy metal content and health exposure to recreational ATV users. According to EPA risk management criteria for metals at BLM mining sites the maximum amount of Arsenic (300 mg/kg), Lead (1000 mg/kg) and Cadmium (950mg/kg) is allowed for ATV driver exposure (Ford, 2004). The potential health risk would be ingestion and inhalation of vehicle dust with high concentrations of heavy metals such as lead, arsenic and cadmium. Recreational users may not know of the dangers of mine dumps and the high toxicity of metals in soils. The tailings in Jacob city have very distinctive colors. It could be helpful if soil color could serve as a visual proxy for high-concentrations of heavy metals. As of 2018, environmental studies have not been conducted at Jacob City.

Hypothesis

This study analyzed soil samples from mine dumps and the surrounding soil for heavy metals to address the following research questions:

- **Research Question 1:** Which mine dumps and ATV roads have the highest heavy metal concentrations and which exceed the BLM criteria for ATV user?
- **Research Question 2:** Do Munsell color chart hues correlate with concentrations of heavy metals on the roads and mine dumps? If color can be used as a proxy for heavy metal concentrations, then color could be used as a proxy to map high concentration areas and aid in remediation or notifications to recreational users.

Methods

- Collected 31 soil samples, homogenized five subsamples within a five foot area
- Dried and Sieved soil samples in lab
- Analyze soil samples with XRF using EPA 6200 method (EPA, 2007)
- Evaluate samples with Munsell Color chart

Fig 12. Munsell colors measured in soil samples.


Fig 13. Mine dump on main level pictured in fig 9. Photo by A. Shepherd

Fig 14. Analyzing soil samples in lab using XRF. Photo by A. Shepherd

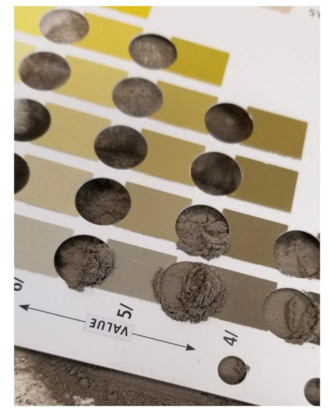
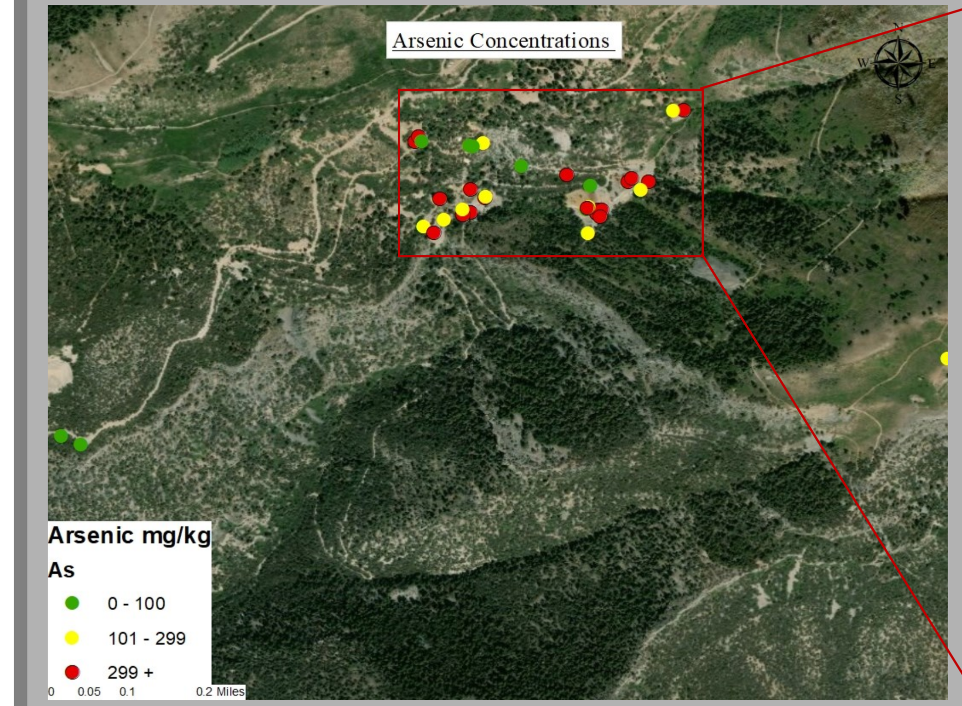
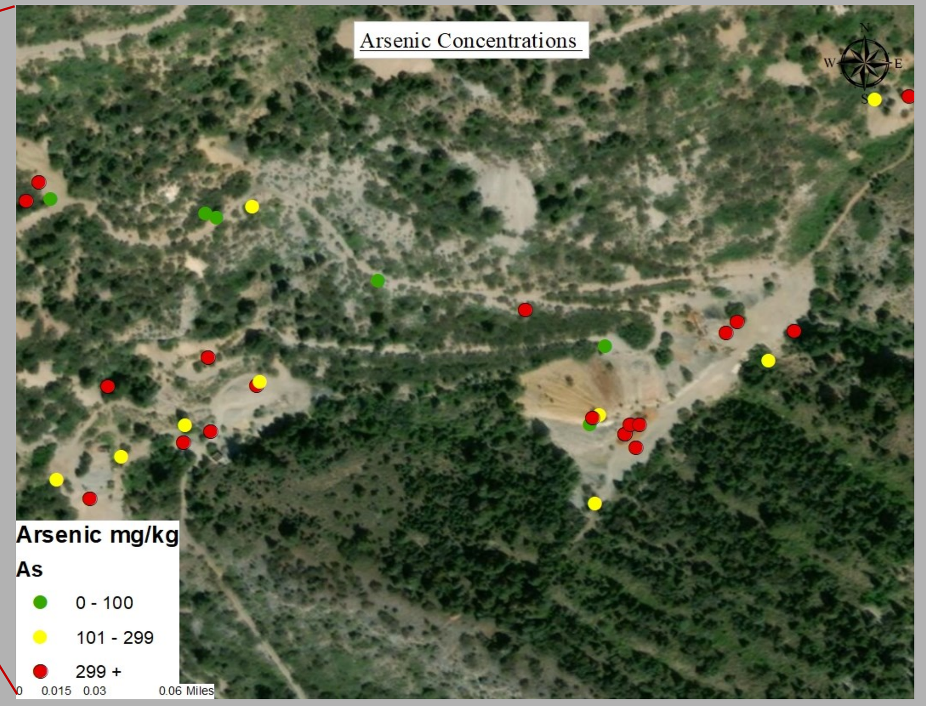
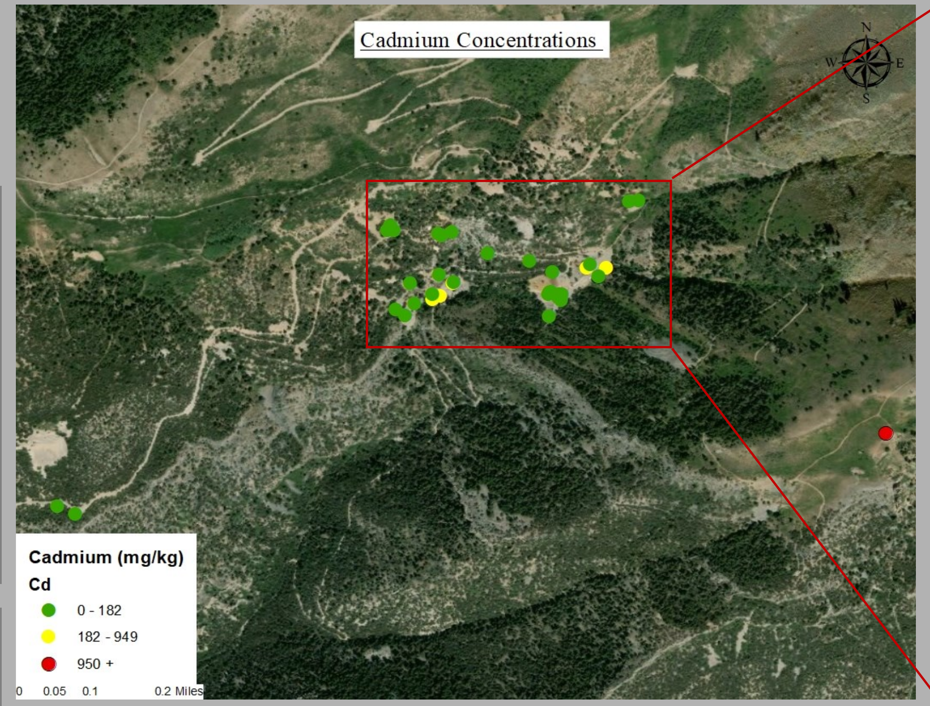


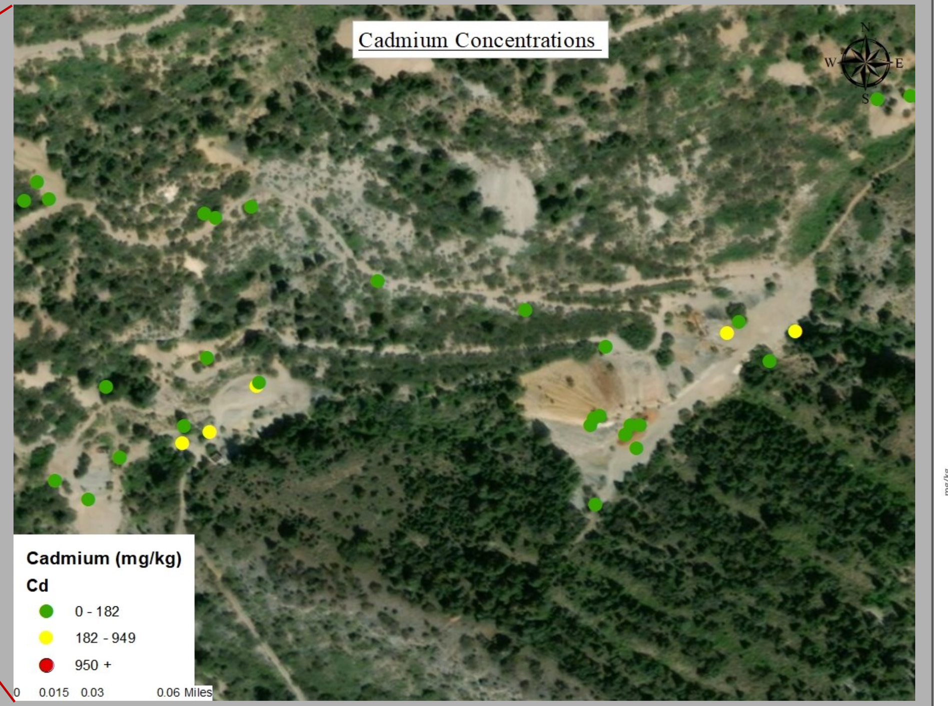
Fig 15. Comparing soil samples to Munsell color chart. Photo by A. Shepherd

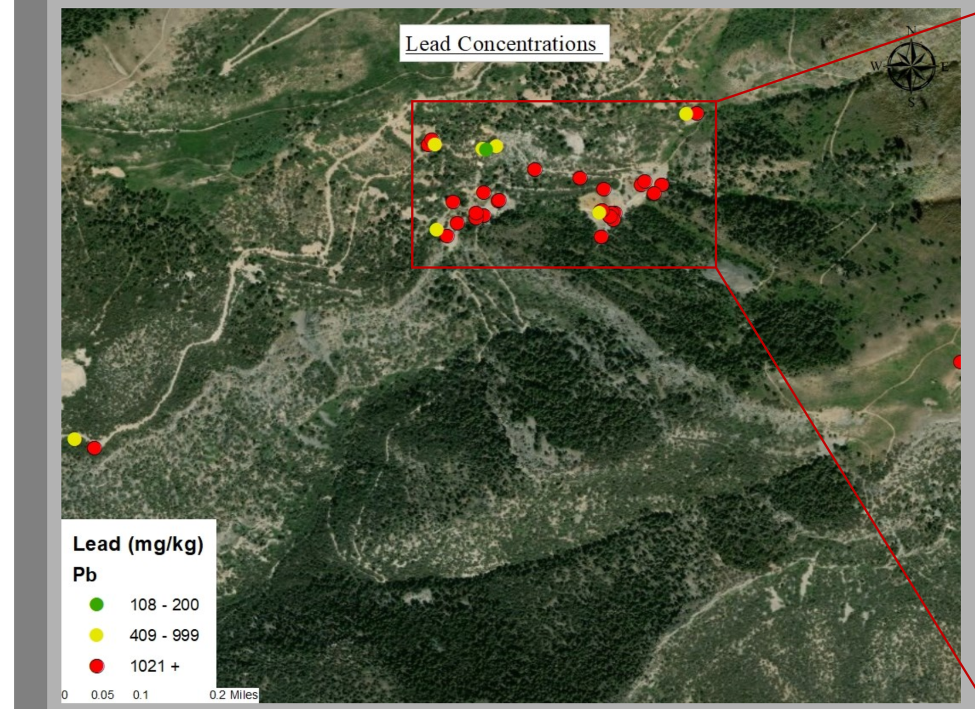
Results

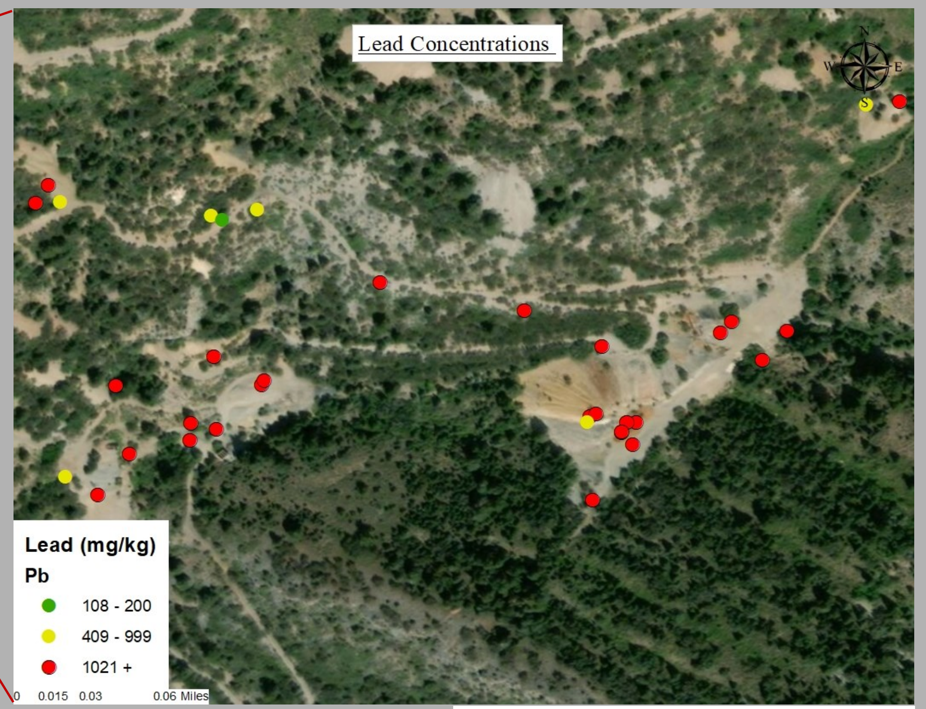


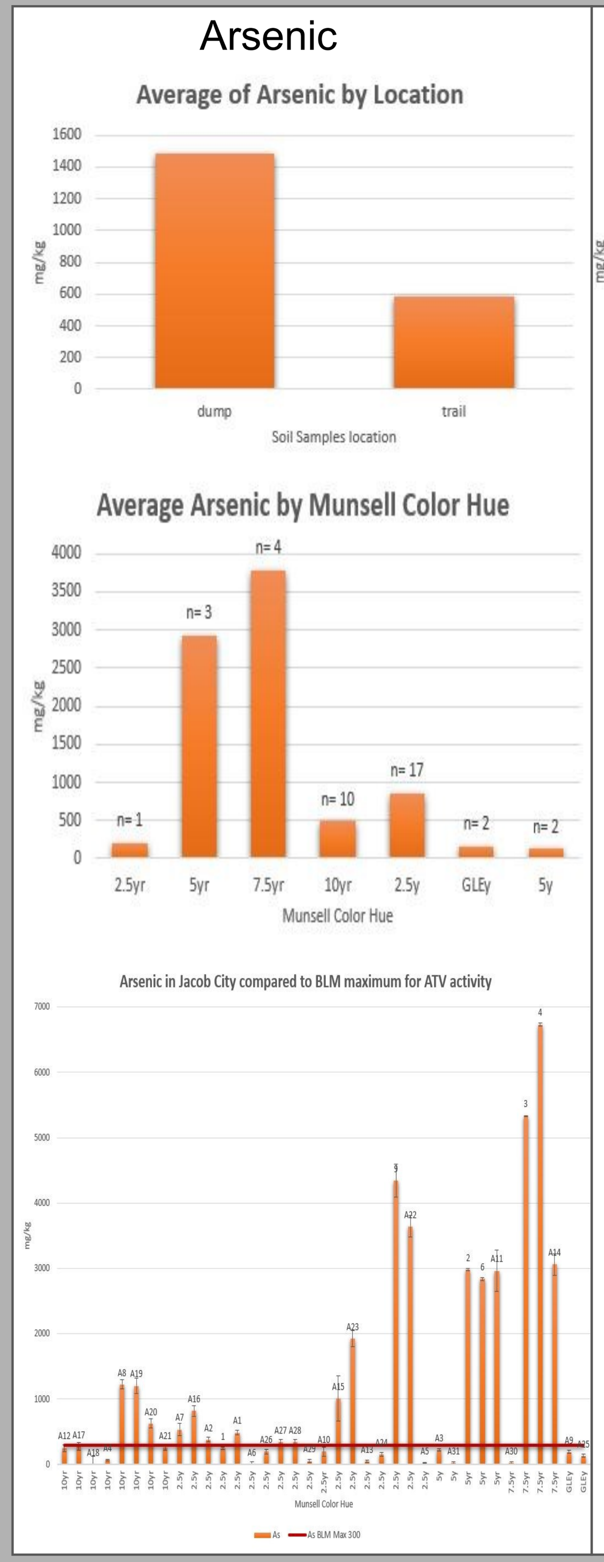


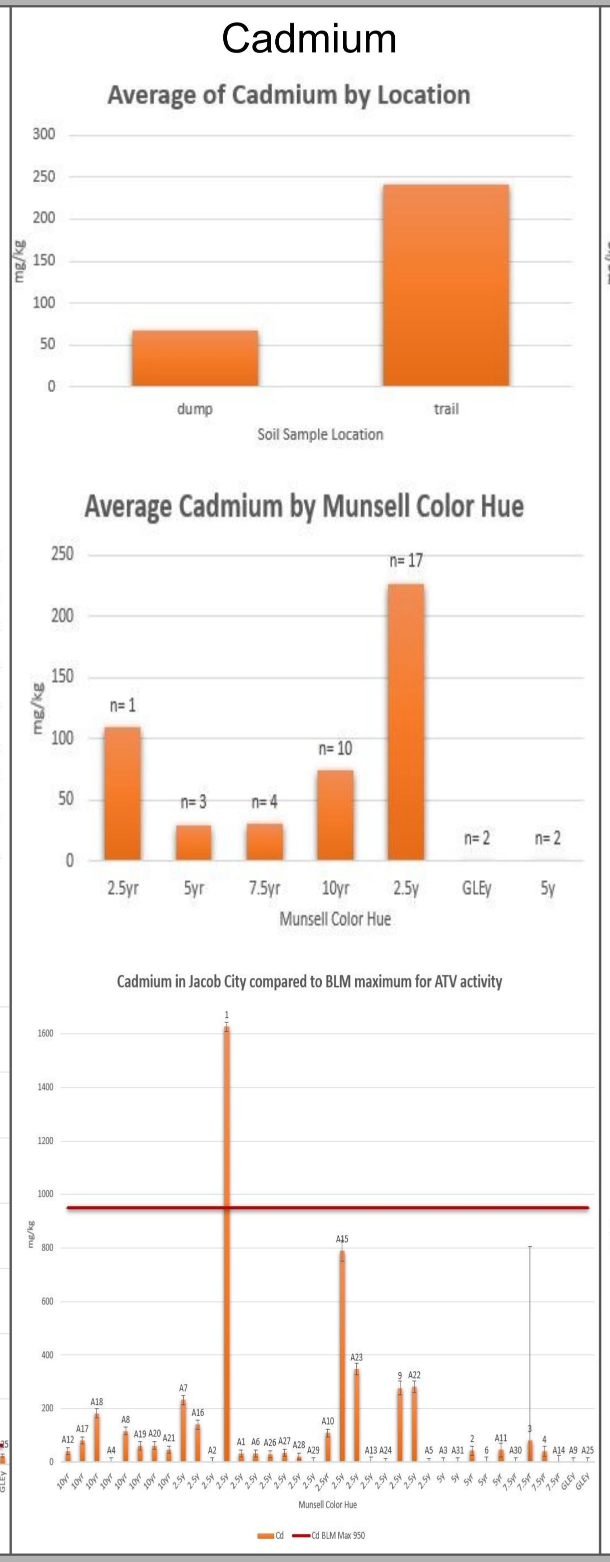












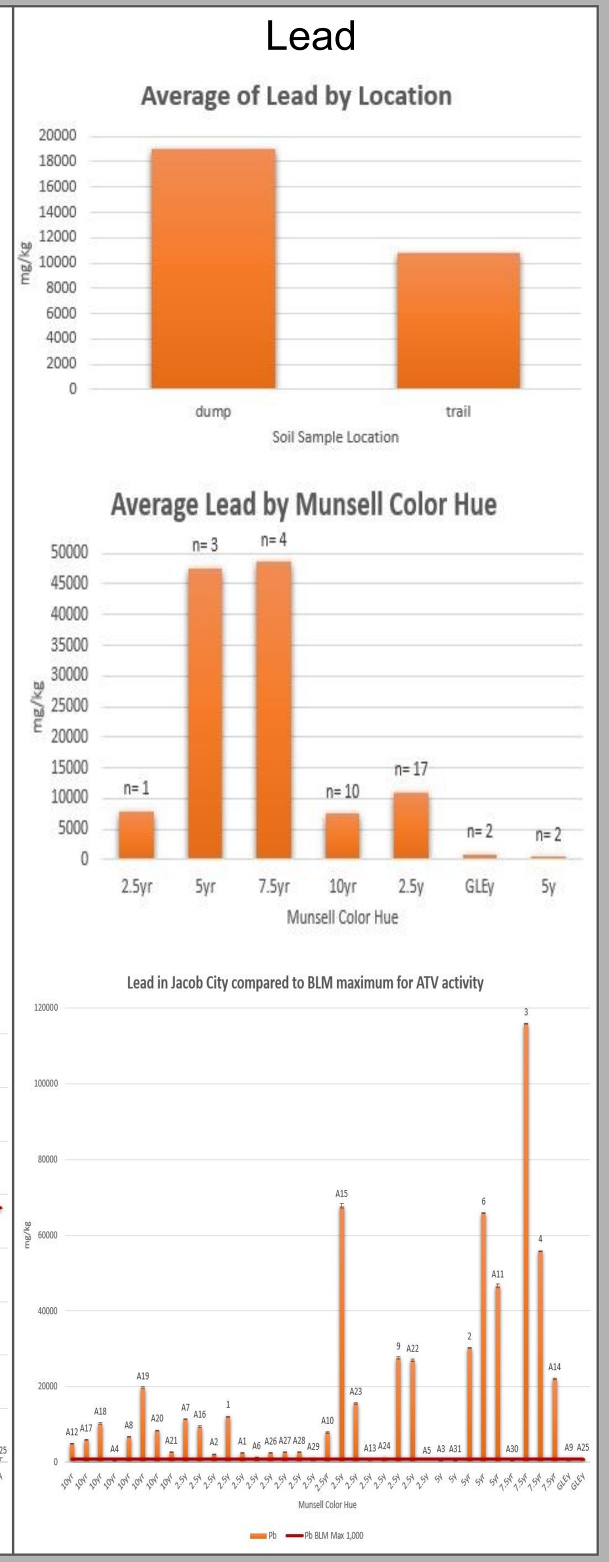


Fig 16-21. Heavy metal concentrations among trails and mine dumps.

Interpretations

Hypothesis 1: Cadmium is low in mine dumps and higher on ATV roads and highest at a point far from mining activity. Lead and arsenic are more concentrated among mine waste dumps than ATV roads possibly due to the process of mining metals such as mineral processing and metallurgical extraction. In future projects and studies it would be helpful to test this outcome on other mine tailings and waste piles to see if this observation can be used as an visual indicator. Future research should look at ratios of metals to other elements and if ratios of multiple elements are cause for the soil color patterns. And specifically for cadmium further readings from soil away from the mining site to determine natural cadmium levels in the area and to examine heavy metal content of the plants to determine if plant life effects cadmium levels in soils.

Hypothesis 2: Using the Munsell color system provides insight to heavy metals that may be present within soils surrounding mines. Munsell color hues correlate with lead, arsenic, and cadmium in soils at mine waste dumps in the study area. With Lead and arsenic concentrated at 5yr and 7.5yr hues where as Cadmium is concentrated within the 2.5yr hue.

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