Perspectives Learned on Superfund Clean up Actions For Mines  
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April 10, 2001

Full Text

Risk Range

The Superfund risk range is one in ten thousand ($10^{-4}$) to one in a million ($10^{-6}$), which means that Superfund clean ups should result in a residual risk in this range. Many people immediately gravitate to trying to protect to $10^{-6}$ without thinking about cleanup costs for different risk.

A rule of thumb that I found looking at the cleanup costs at many Superfund sites was that if it cost a certain amount ($A \times @$) to clean up to $10^{-4}$, it cost twice as much ($A \times 2@$) to clean up to $10^{-5}$, and ten times as much ($A \times 10@$) to clean up to $10^{-6}$.

With limited funds it is good to ask oneself: Is it better to clean up one site to a residual risk of $10^{-6}$ or ten sites to the level of $10^{-4}$?

Risk Discretion -- Carson River Mercury

It is important to understand the risk assessment model for mercury and where there is discretion. In a risk assessment you are concerned about the pathway for mercury to get to an environmental or human receptor.

At the Carson River Mercury Superfund site EPA was concerned about residential development in areas with mercury contaminated mine tailings. Our major concern was the soil ingestion by humans, especially children.

The risk assessment for mercury ingestion by humans is based on animal studies. To develop the mercury risk number the dose at which rats show an adverse effect to mercury ingestion is multiplied by three factors of ten in order compensate for uncertainty. These three factors of 10 are built into the risk assessment, no discretion to change.

There is, however, discretion on what species of mercury is assumed in a risk assessment. The EPA Superfund program preliminary remediation goal for mercury contaminated soils is 23 mg/kilogram. This clean up number presumes that mercury is in a highly bioavailable form such as mercury chloride or mercury oxide, rather than a less bioavailable form such as elemental mercury or mercury sulfide.

At the Carson River Superfund site EPA determined found that 95% of the mercury was elemental mercury or mercury sulfide. This meant the mercury cleanup level for soil could be much higher than if the mercury had been in a more bioavailable form. However, because there was uncertainty about the relative absorption of different forms of mercury in the human intestine, this risk assessment still contained a factor of safety to reflect this uncertainty. A soil cleanup level of 80 mg/kg was finally picked for this site.
Subsequent to EPA's Carson River decision a Department of Energy site near Oakridge, Tennessee was found to have mercury soil contamination similar to that in the Carson River. DOE performed comprehensive laboratory studies to simulate the absorption rate of mercury in the human intestine. Based on using this more precise information in the risk assessment, a final mercury soil cleanup number of 400 mg/kg was picked.

While I have discussed the ingestion pathway, some of you may be saying That is interesting, but not really that relevant to the pathway of methyl mercury to fish. But I content it is a pathway that will be of primary concern to Californian over the next few decades because of the amount of development that is happening in the Sierras in areas of old mine tailings. Flat spot for development.

Will Clean Up Change the Situation? -- Sulfur Bank Mercury

I went out to Sulfur Bank in 1992 know that one question that would have to ultimately be answered at this site was, should any remedial activity be taken in the lake itself. Two possible options were to dredge the Oaks arm or place a blanket of clean fill over the sediments in the Oaks arm. Which raises the question of what is your criteria for deciding if a remedial action is necessary.

As a preliminary thought before I visited the site, I stated that it would be hard to justify spending a lot of money if the net result was that fish would be posted for mercury consumption before the action and after the action, i.e. that the clean-up action had no impact on public health.

On the way up Greg Baker, the section chief looked at his fish licence and noticed that no only did Clear Lake have a fish advisory, but so did lake Berryessa. But the level of mercury in the sediment in the Oaks arm of Clear lake was 100 times more than that of Lake Berryessa. In response to this I came up with that thought, Does that mean one could clean up the sediment with 99% success, and still the Lake would be posted?

In the Carson River valley we were resigned to the fact that it would not be worth it to dredge Lahonton reservoir of reduce the level of mercury. What you have to hope for is for clean sediment to gradually be naturally placed on top of the contaminated sediments. This has been true nationally at almost all Superfund sites. It has almost never been a cost effective or environmentally preferable activity to dredge up contaminated sediment. One exception was United Heckathorn, another one of my Superfund sites. 100% DDT.

There is a lot more information that has been generated in the last eight years, and its up to the current management in the Superfund program to figure out what to do. But these types of questions remain.

Understand How Mercury Cleanup Decisions Affect Peoples Lives

In the Carson River valley there are some houses built on areas with elevated levels of mercury in soils. Whether a soil cleanup level for mercury is 20 or 80 mg/kg may mean the difference between people being worried about their health or not. Or it may make a big difference in the value of their house. And that has a big impact on their economic and social lives.
If we have data that the level of mercury in fish is high enough to trigger a fish consumption advisory, make sure you are prepared to answer questions which might be raised such as A Is it OK to drink the water? @ or A Is it OK to swim in the water? @ or A Is it OK to picnic on the beach?

Awareness of Mercury Background Levels B Greenhorn Creek

Greenhorn Creek is in a pristine setting. What if, on a side tributary, we discover 1000 cubic yards of placer mining debris with elevated levels of mercury and methyl-mercury? Should we remove it?

To answer those questions one must first be aware of the levels of mercury in the surrounding soils and sediments. For it turns out that the stream bed you see is not on bedrock. Due to intensive hydraulic mining between 1850 and 1890 the floor of this valley was filled with 200 feet of mercury contaminated hydraulic mining debris. The stream bed was raised 200 feet. In the last 120 years about 100 feet of this debris has eroded, resulting in the stream bed and valley you see here. It turns out those are not tree stumps you see. They are the tops of 100 foot tall trees that were buried when the valley was filled with placer mining debris. Greenhorn Creek, this entire valley, and all the trees you see in this picture are on mercury contaminated hydraulic mine debris.

We now know my hypothetical 1000 cubic yards of placer mine tailings sits on hundreds of thousands of cubic yards of similar placer mine tailings. Should we remove it? Perhaps. But the decision should not be made without a full understanding the background mercury levels in the surrounding area.

The Polar Star Clean Up

Lets go back to the Spring of 1999. As a result of the great work done by USGS, BLM, and the Forest Service we have identified the Bear River as an area with high levels of mercury in sediments and biota, we have identified abandoned sluice box tunnels as a high priority area for investigation, and we have determined the Polar Star Mine has high levels of mercury in sediment and elevated levels or methyl mercury in the stream that passes through it. Visible mercury could been seen in the tunnel sediments, and people were going into the mine tunnel to collect mercury in the hope it contained gold. In the last few years in California a few individuals have died from mercury vapor inhalation when they collected mercury from historic placer mining areas was then boiled off the mercury on a home stove. Now what?

EPA decided to evaluate the Polar Star mine to determine if it would be a good candidate for a removal action. The removal action turned out to be a mixture of perceived and actual environmental and human health risks, dreams, experimentation, contractors, site access, side shows, clean-up, and ultimately, a removal action that succeeded in removing all mercury contamination from the Polar Star sluice box tunnel. So what happened, and what did we learn that could instruct people considering removal actions in other sluice box tunnels.

Protection of Human Health Is A Primary Reason for the Cleanup of Mine Sluice Box Tunnels

The EPA Region 9 Superfund program performed a removal
action at the Polar Star to remove the mercury laden sediments. The primary purpose for this clean up action was to responsibly remove the mercury before someone else removed it in a way that could endanger human health. While the Polar Star clean up also had a secondary benefit of removing a source of methyl mercury to the environment, it was the site specific human health concern that drove this removal action.

Hopefully any cleanup actions for sluice box tunnels will be a benefit to both human health and the environment.

**Dreams:** The Gold Bug Whispered A Maybe a Removal Action Could Pay for Itself

With up to 3% mercury in some sediments that had been panned, thoughts of significant amounts of gold recovery began dancing in peoples heads. One gold mining enthusiast said his company would do the first 50 feet of the tunnel for free in order to determine if the removal could pay for itself. Hope springs eternal.

This dream ultimately affected the design of the removal approach, as mercury recycling and possible gold recovery was emphasized.

**Experimentation:** EPA Chose to Remove Mercury Contamination from the Tunnel as a Pilot Project

Alternatives to reducing the human health threat from human exposure to mercury and its improper disposal included securely gating the tunnel to prevent exposure; gating the site and routing water through a pipe through the tunnel would remove the human contact potential and also prevent methyl mercury discharges.

While removing all the material would be the most costly proposal EPA choose to use this site a pilot test to determine the economics and the cost-effectiveness of this approach. Since the EPA removal program has access to EPA Superfund money, the Federal and state agencies cooperating in the collaborative watershed study supported this pilot approach. It was hoped EPA could learn and share some valuable lessons by pioneering this approach...

**Contractors:** The Goal is a Quick and Safe Clean-Up, Not Recovering Gold

Perhaps some weekend recreational gold miners with some time on their hands a few six packs of beer could leisurely remove debris from a mine tunnel, pan for gold an mercury, take a few years, and make a few bucks from the gold (though their hourly rate of pay would be quite low).

When a government agency is using government contractors to clean up a tunnel the goal is to get in, quickly clean up, and get out. When you are paying for site security, quality assurance plans, a comprehensive site safety plan monitoring, health and safety equipment, geotechnical engineers, project management, workers with certified hazardous waste training, proper ventilation, OSHA compliant operations, improving roads to government standards, proper disposal of material, and all the aspects of a well run removal action, it is going to cost a lot more money than a local gold mining company might spend if they did the job.
Site Access  When You Use Heavy Equipment, There is a Row of Dominos That Goes With It.

The first six weeks of the response action was spent gaining access to the site. The mine tunnel cleanup activities used heavy equipment and standard size trucks to haul away material. This meant that extensive road improvements were made and large areas were leveled to provide pads for materials processing and site management. The improved roads required berms as high as the truck axle to comply with government requirements for mining roads. Blasting was needed for some of the road improvements.

Because of concerns that the vibrations from heavy equipment could cause a landslide above the mine portal the Geotechnical engineer recommended blasting the face of the cliff to remove loose material. Blasting subcontractors repelled from cliff top to manually clear loose rocks prior to drilling to set the explosive charges. After the blasting debris was removed trench boxes were installed to provide protection against landslides and/or falling boulders from the cliff adjacent to the upper portal of the tunnel.

Sideshow: The Land Owner Decides to Log the Area While The Removal Action Is Gearing Up

While the primary purpose of the removal action was protection of human health, a secondary benefit was elimination of a source of mercury and methyl mercury loadings to the Bear River.

While the removal action was being considered in the Fall of 1999 the land owner filed plans with the California Department of Forestry (CDF) to harvest the trees using drag line techniques. Because this could increase mercury sediment loadings to the watershed, EPA sent a letter to CDF asking them to identify areas, such as ground sluice areas and debris piles, where there may be elevated levels of mercury that should not be disturbed.

This letter raised a host of issues and concerns. The issues were mostly avoided when the land owner decided to helicopter log the area, but the issue of possible runoff and sedimentation from logging mercury laden soils is likely to be raised in other areas in the future.

Cleanup: Removal of Material From the Mine Was Easier Than Separating Out the Mercury

A standard operating method was developed for the actual removal of the tunnel's rocks, wood, debris, and sediments. Actual removal of material was rather straightforward. Material removed from tunnel was power screened to 2 2 minus and stockpiled fines on lined staging pad for amalgam separation. Large rocks were decontaminated and stockpiled on site. All decontamination water was collected.

Amalgam separation equipment problems stemmed from the trammel being inadequate to handle the feed rate and size of 2.5 inch - material. Screen repairs and modifications and enabled treatment of approximately 10 cubic yards of material, however the waste streams being generated, specifically the 1/4 to 1/8, and the 2.5" to 1/4", still appeared to be contaminated with significant amounts of mercury. A decision was made that it was not cost-effective to separate out elemental mercury using this equipment, and efforts to recover elemental mercury were abandoned.
Elevated levels of mercury were often detected in the tunnel during operations that disturbed the sediments. At times when no vapors were detected workers were normally at protection level D, with poly-coated tyvek, chemical protective boots, nitrile gloves, hard hats, and safety glasses. During periods of sediment disturbance mercury vapor levels normally ranged from 0.013-0.040 mg/m\(^3\). The highest level was 0.06 mg/m\(^3\). When elevated levels of mercury occurred workers went to modified level C with full-face APR with P100 cartridges.

The Finish: Successful Excavation of mine Debris and Sediments and Lots of Lessons Learned

The Polar Star tunnel has had all sediments and debris removed, and the bottom of the tunnel has been sealed. A source of mercury available for human exposure and improper processing and handling by humans has been eliminated as well as a source of methyl mercury discharges to the Bear River watershed. The removal action memo anticipated a mine tunnel cleanup cost of about $1.4 million dollars, and the final removal costs were about $1.5 million dollars.

One reason EPA took the lead on totally cleaning out a mine sluice tunnel was to learn the procedures and costs for this approach. The true value of a pilot project is to inform others of the lessons learned from the pilot project so that they can better decide if totally cleaning out a tunnel is an approach they want to take and what factors they should consider if they decide to clean up a tunnel. Attached is a summary of the lessons learned during the Polar Star removal action.

The Goldilocks Theory of Remediation for Mines

Superfund afraid of black holes like 100 million dollar cleanups. There were few new mines listed as Superfund sites for about 10 years. Mines are now being listed again, but they must be the right size: not too small and not too large, but just right.

The Sound Science Vrs. the Hand Waving Rationale for Spending Clean Up Money

It's best to have hard science and show a cause and effect relationship between a clean up action and its affect on water quality.

Sometimes this is difficult because the science is lacking, or you already know you won't have a significant impact and you will merely reduce a cumulative impact a little bit. Does this mean you don't do anything?

To spend really significant money for remedial activity you had better show a cause effect relationship and real results, such as:

- Iron Mountain hundreds of millions of dollars
- Huge groundwater pump and treat systems to meet MCLs
- But you can spend a modest amount of money with a more hand waving rationale if it is part of a priority list of problems.

Carson River B Homes for ingestion route. Bonus to environment.

Polar Star B Human health. Bonus to environment

BLM removing modest tailings piles in Clear Creek area.
Lessons Learned from Polar Star Removal

One reason EPA took the lead on totally cleaning out a mine sluice tunnel was to learn the procedures and costs for this approach. The true value of a pilot project is to inform others of the lessons learned from the pilot project so that they can better decide if totally cleaning sediments and debris out a tunnel is an approach they want to take and what factors they should consider if they decide to plan such a removal action. Below is a summary of many of the lessons learned during the Polar Star removal action.

The amount of soil disturbance for roads, mobilizations pads, and work areas should be minimized as much as possible. If it appears the environmental impacts of this disturbance are of greater concern than elimination of mercury sources then serious thought should be given to less intrusive removal actions.

A reclamation plan for disturbed areas should be developed prior to work activity. Part of this plan should anticipate the long-term after remediation site contours and drainage patterns so they can be considered when designing roads and work areas. State or Federal agencies that deal with these issues should be consulted and provide input in advance to the lead agency conducting the removal.

If mercury separation or gold recovery is a goal, make sure the equipment is sized to take anticipated loadings of materials taken from the mine tunnels. One reason for the failure of equipment designed to separate out the mercury may be that it did not have sufficient capacity to take the amount of muck that was loaded into it. In addition the screen size may not have been the optimum to use.

If mercury separation or gold recovery is a goal, make sure you take adequate sampling of sluice tunnel sediments to estimate in advance of the removal action the quantities of mercury or gold that might be recovered. This would allow one to evaluate whether these recovery efforts are worth the time, equipment, and cost.

When considering whether mercury recovery is worthwhile, be aware that mercury contaminated soil may not be a hazardous waste, and can be disposed of in a non-hazardous waste. This was EPA’s experience at the Carson River mercury site. Soil toxicity tests should be conducted during the removal assessment phase so an accurate estimate of disposal costs can be made.

It was difficult for local contractors with placer mining expertise to access EPA or their contractors with their ideas. However, EPA often has difficulty using local expertise because of how its contracting and sub-contracting activities are structured. Some individuals believe that there are local contractors with placer mining experience that could have successfully separated the mercury from the sediments. Similarly, EPA could have separated the mercury from the sediments had it decided to spend more time and money to do so when the equipment on-site could not do an adequate job of mercury separation. Unfortunately, the time and money to procure new equipment was deemed too costly. It became abundantly apparent shortly into the treatment process that the costs of on-site separation were not beneficial.
Small or local firms with mining expertise may state how cheaply they could clean out a mine tunnel. But with a Federal CERCLA cleanup that requires a comprehensive site safety plan (SSP) reviewed by the California Department of Industrial Relations (Cal OSHA), quality assurance plans, monitoring plans, site security, contractor mobilization areas, road improvements done to government standards, revegetation plans, personnel with hazardous waste training, and all the bells and whistles that go with Federal contracts, the cleanup costs turn out to be higher than a local firm may anticipate.

A Certified Tunnel Safety Representative was employed to review the scope of work and to be present during in-tunnel activities. A Geotechnical Engineer was employed to inspect the tunnel prior to any removal activity and make recommendations regarding stability concerns within the tunnel or other safety aspects.

Be careful where you get soil for building pads for removal operations. There may be mercury in unexpected places. There can also be pyrite present in the soil, and the water that collects in barrow pits could become acid through the work of sulfate reducing bacteria. At the Polar Star a small quantity of water that collected in the barrow pit was This water was neutralized and the pit was contoured to prevent future accumulation of water.

Make sure the sump at the top of the tunnel can withstand a 100 year storm and make sure there are provisions for who is responsible to periodically clean out the sump. The top of the tunnel and work pad areas were regraded, covered with rice straw and rip rap. Sumps installed in the tunnel were intended for the first year to minimized sediment runoff.

Make provisions for one year = s worth of quarterly sampling of water flowing from the tunnel so the water quality can be compared to the conditions before the removal action. Agencies that focus their efforts on studies as opposed to cleanup actions should address long term quarterly monitoring issues.