

Risk assessment and remediation of historical mine waste – experiences from Sweden

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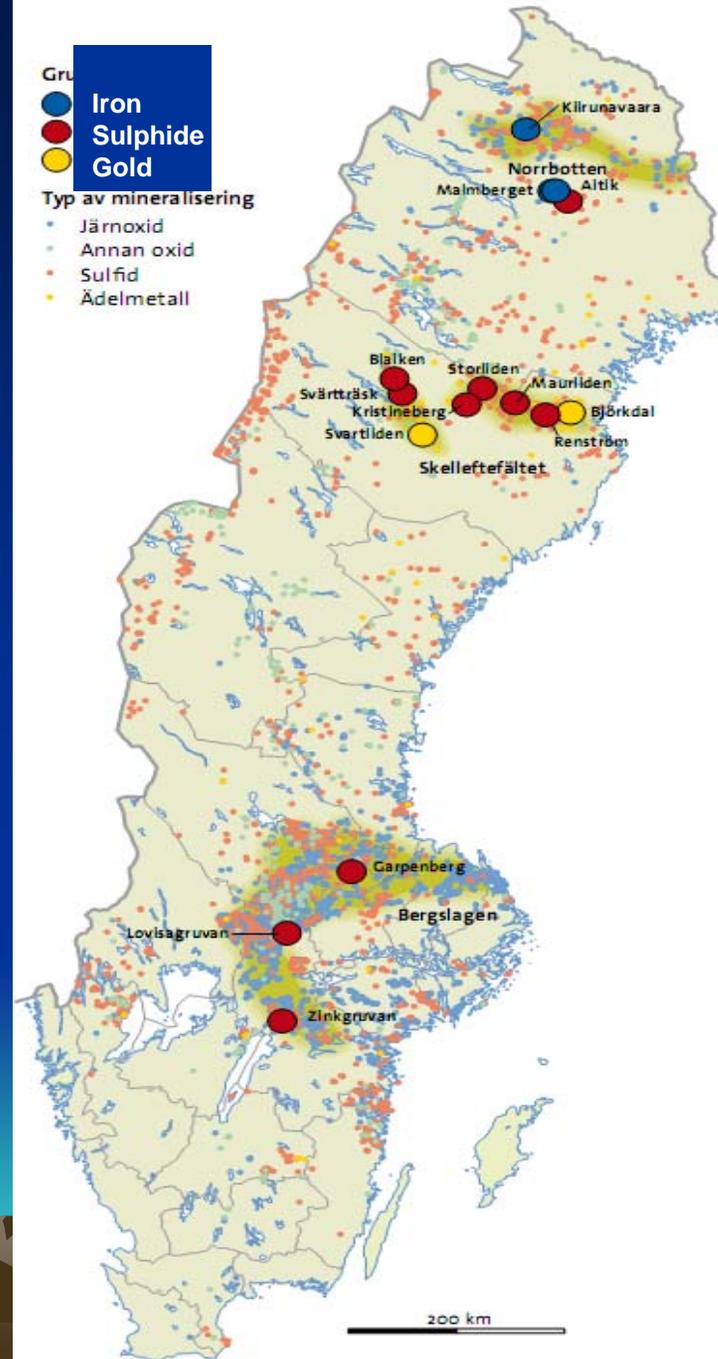
Mine waste

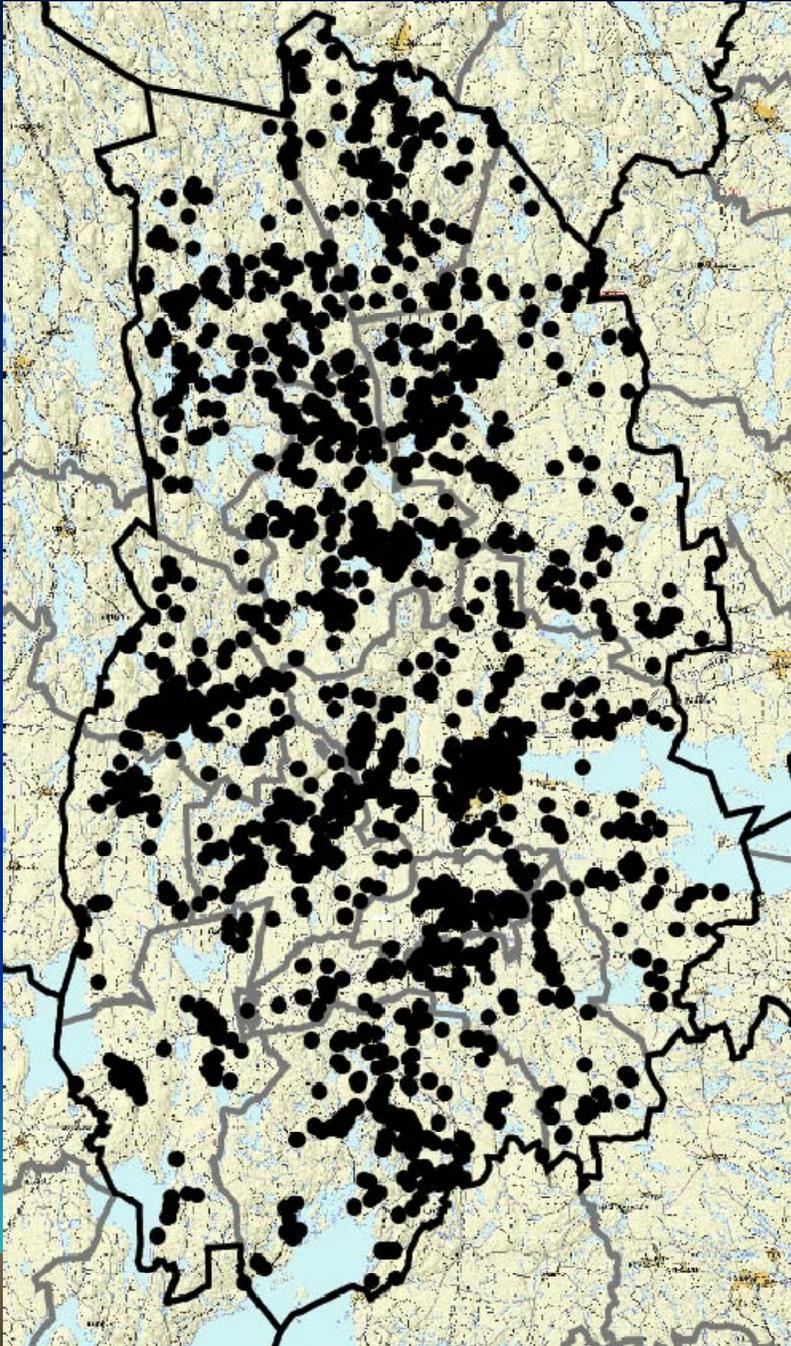
- Historically a very important industry in Sweden
 - Bergslagen region was a very important producer of copper in the world during the 17th and the 18th century
- Differences between modern waste and waste produced several centuries ago
- Modern waste
 - Ores with lower metal content are used today
 - Waste disposed of properly (e.g. water covers)
- Historical mine waste
 - Metal containing ores sorted as waste
 - Higher concentrations in the waste
 - Oxidized



Swedish mining regions

Swedish mines 2008





In only our county
nearly 900
contaminated sites
related to mining can
be found



Falun (UNESCO heritage site)

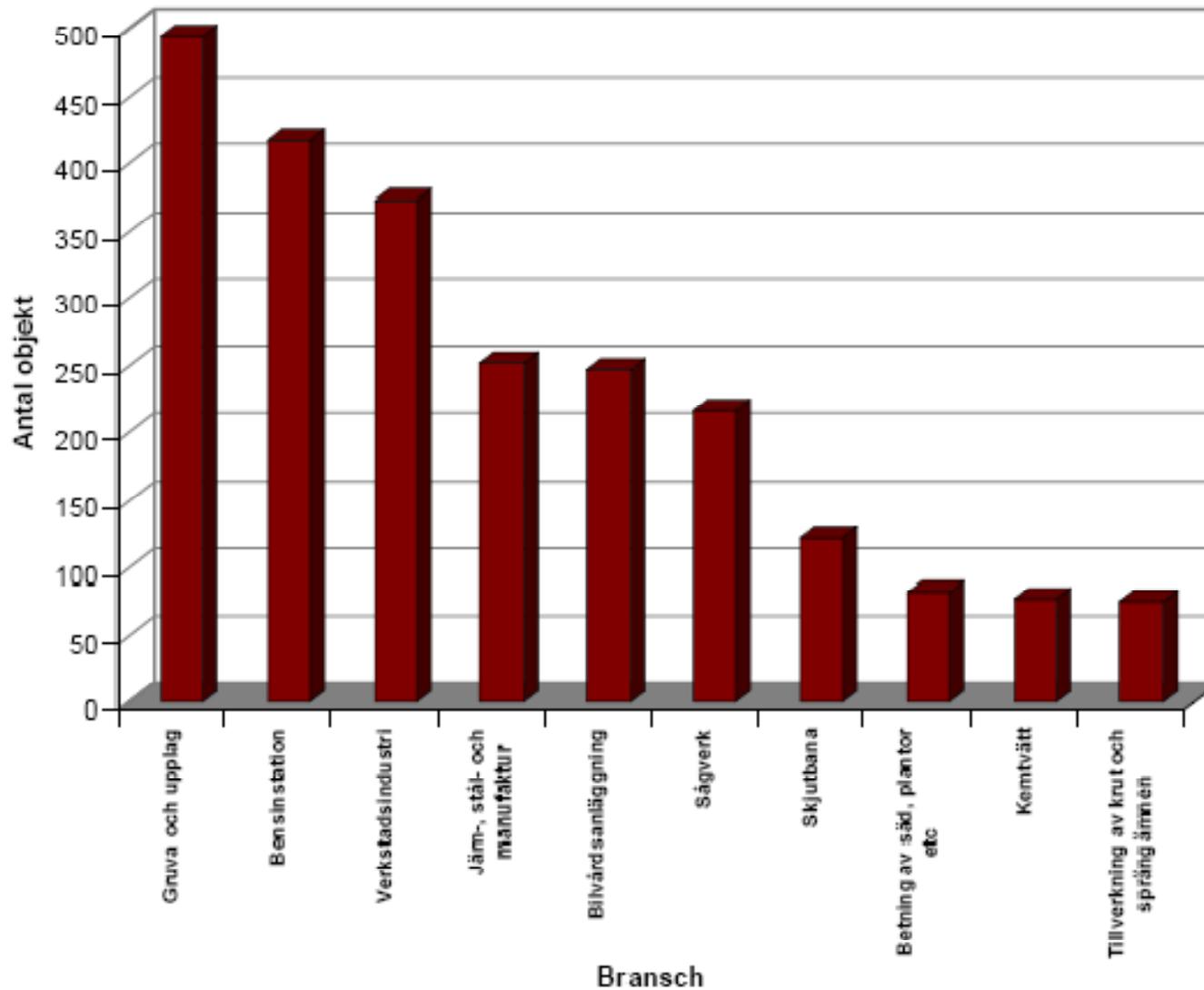










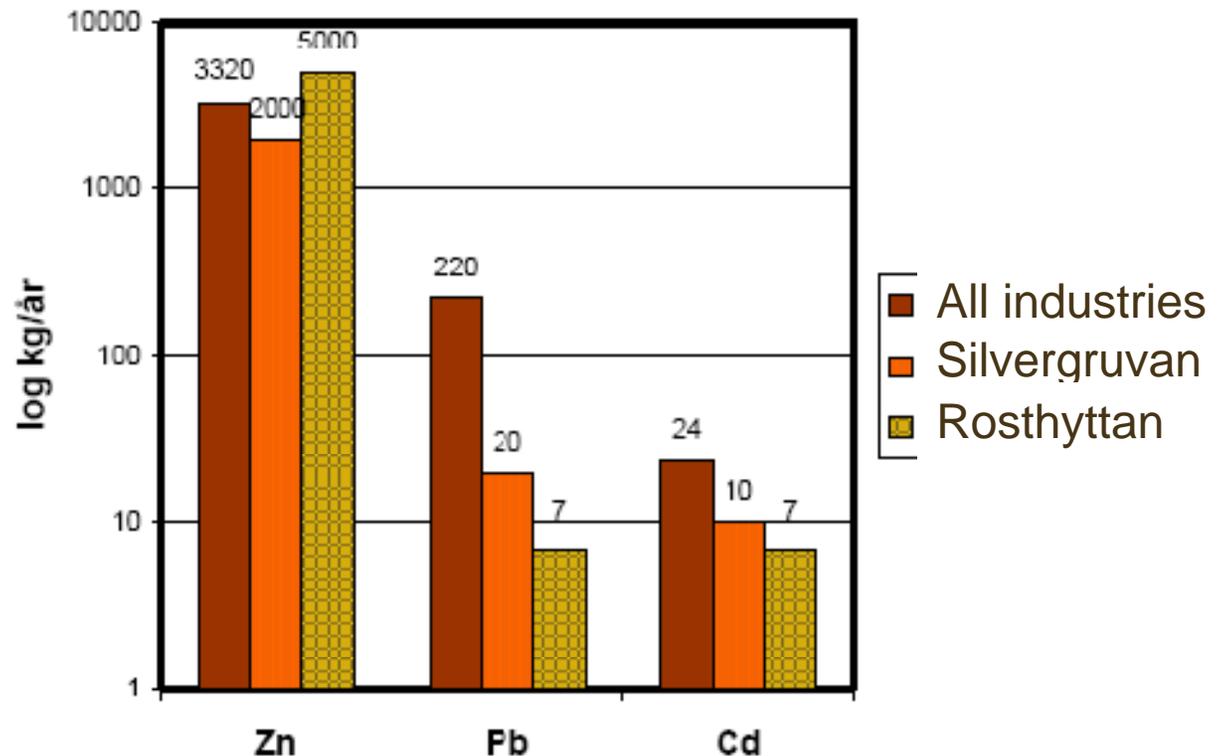


From an Örebro county board report



The relative importance of old mining sites

From an Örebro county board report



Figur 3. Beräknat/uppskattat utsläpp/läckage av zink (Zn), bly (Pb) och kadmium (Cd) till vatten år 2006 från Örebro läns A- och B-anläggningar och två av länets förorenade områden, Silvergruvans vaskverk och Rosthyttan. Observera den logaritmiska skalan. (Källa: EMIR 2007 och utförda undersökningar/beräkningar)

Total costs

- Total cost of reclamation (investigations, risk assessments and remediations) in the county of Örebro is estimated to about 150 to 500 millions US dollars until year 2050
- Mining related sites make up about half of the estimated total costs



Risk assessment procedures for orphan objects

- 1. Desk investigation by the county board
=> priority list
- 2. Minor field investigation (sampling etc)
=> priority list
- 3. Major field investigation (additional sampling, risk assessment) => reclamation



Risk assessment procedures for orphan objects

- Risk assessments to consider protection of both humans, soil organisms and aquatic organisms



Risk assessments

- Major conclusions
 - Arsenic and lead major problems for humans
 - Copper is mainly a problem for aquatic organisms



Selected objects

- Bersbo waste rock (reclamation completed around 1990)
- Silvergruvan jig tailings (reclamation completed 2009)
- Rosthyttan jig tailings (reclamation under way)
- Ljusnarsbergsfältet waste rock (risk assessment)



Bersbo waste rock

- History

 - Mining for copper started in the 14th century

 - Ceased in 1902

 - Maximum production 1850-1870

 - Minor reprocessing of the waste during WW2

 - Covered 1987-1989 (Illitic clay or cement stabilized coal fly ash)

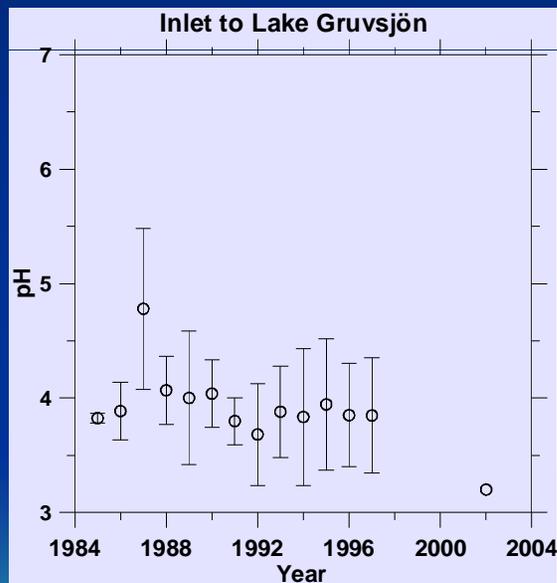
- Geology

 - Some 300 000 m³ of coarse waste rock (pyrite, chalcopyrite, sphalerite, galena) in two deposits

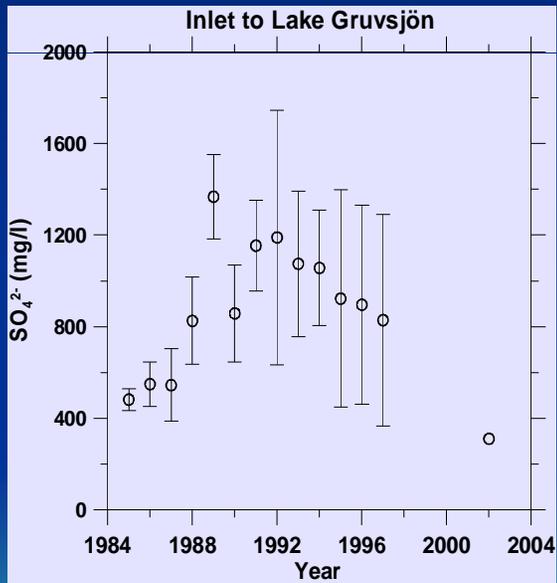


Bersbo waste rock - monitoring

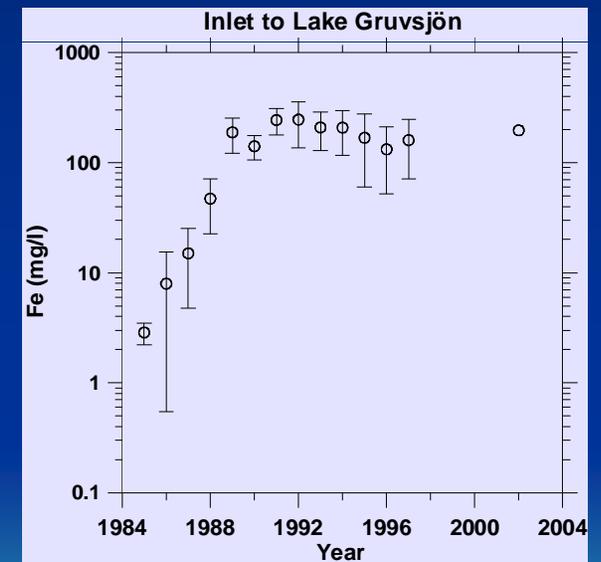
pH



Sulphate

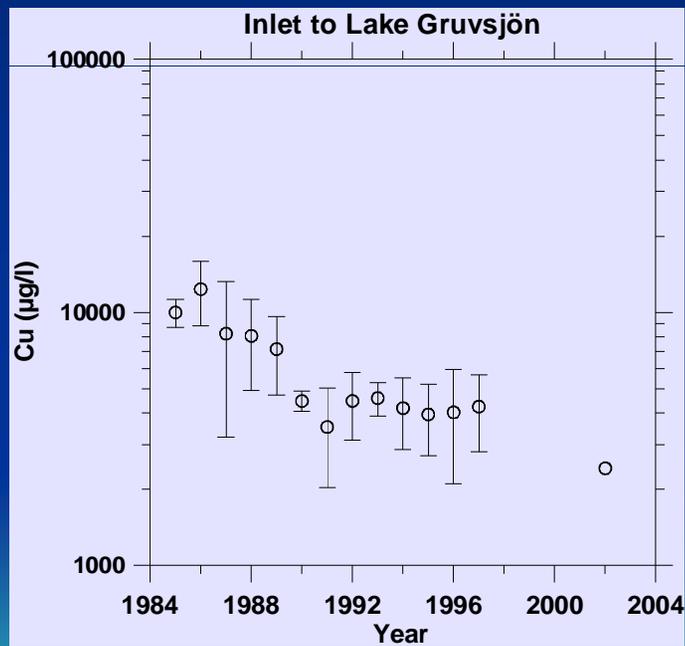


Iron

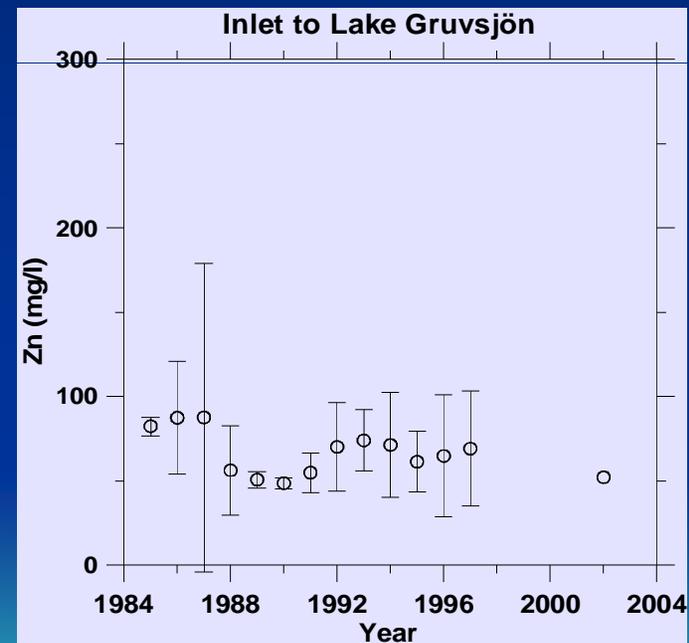


Bersbo waste rock - monitoring

Copper

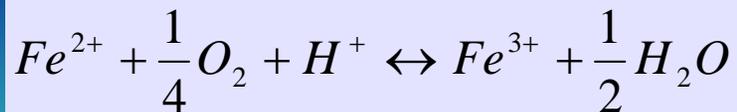


Zinc



Bersbo waste rock - summary

- Significantly lower volumes leachates has lead to lower mass transport from the deposits
- Autooxidation through ferric iron has increased the weathering



Silvergruvan jig tailings

- Jig along a river (late 19th century)
- Primarily production of lead and silver
- Significant leaching of zinc (2 ton/a), lead and cadmium. Also very high conc of arsenic (occasionally 1-2% or higher)
- Reclamation has been performed; dig and dump! 18 000-22 000 ton tailings have been removed at a total cost of around 6 million US dollars.



Silvergruvan jig tailings

- Risk assessment indicated significant threat to humans due to extremely high concentrations of arsenic and lead





Prior to the reclamation





During the reclamation (back filling in progress)





Distinct colours often indicated very high trace element concentrations



Rosthyttan

- Jig tailings (sphalerite and galena) and roasted zinc ore
- Large amounts of zinc are leached directly into the second largest lake in Sweden (about 5 ton/year)
- Considered to be a low risk for humans (due to lead concentrations) and a risk for aquatic life (due to leaching of cadmium and zinc)



Ljusnarsbergsfältet waste rock

- 100 000 m³ historical waste rock containing iron ore and a complex sulfidic ore
- High concentrations of Cd, Cu, Pb and Zn
- 20 % of the samples exceed concentrations (5 000 mg/kg dw) with possible negative health effects with respect to Pb





Ljusnarsbergsfältet waste rock

Risk assessment has been performed => it is indicated that the major portion of lead is associated with galena (PbS) and thus not available during ingestion



Summary

- Around 750 contaminated sites associated with mining only in the county of Örebro
- Jig tailings and tailings a far larger problem than waste rock and slags
- Jig tailings both high concentrations (toxic to humans and easily availability) and high leaching (problems for aquatic organisms)



Summary II

- Waste rock often high concentrations but low availability (in practice low risk for humans)
- Estimated total cost for remediation in the county of Örebro is between 150 and 500 million US dollars until year 2050



Summary III

- Weathering often continues in oxidized waste when covered due to the presence of ferric iron



Acknowledgment

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