United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-84-016 Mar. 1984

EPA

Project Summary

Reclamation of Toxic Mine Waste Utilizing Sewage Sludge: Contrary Creek Demonstration Project, Addendum Report

Kenneth R. Hinkle

A demonstration project was undertaken to reclaim two abandoned pyrite mine sites with sewage sludge. Located in central Virginia, the mines had been inactive since 1923 and had caused severe acid mine drainage (AMD) in Contrary Creek. This small stream is virtually devoid of aquatic life and feeds into Lake Anna, which supplies cooling water for a nuclear power plant and has recreational uses as well.

Reclamation began in 1976 and included the use of sewage sludge as a soil conditioner. Severe droughts in 1976-77 and 1980-81 and the highly toxic nature of the mine waste required a continuing maintenance program to establish vegetation. By the summer of 1983, approximately 90 percent of the reclaimed areas supported a fairly-well-established grass cover.

A comprehensive monitoring program from 1975 to 1982 indicated a trend toward reduction in heavy metals, but no appreciable improvement occurred in the pH and acidity problem. More improvement is expected as AMD formation is reduced by the gradual development of a thicker soil layer and vegetative cover. Biologic surveys have revealed negligible improvement in the biota.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings in this research project that are fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Three abandoned pyrite mines containing some 12 denuded ha (29.5 acres) in central Virginia have been inactive since 1923 and have caused severe acid mine drainage (AMD) in a small stream known as Contrary Creek. The AMD, which included heavy metals, made the stream virtually devoid of aquatic life. The Virginia State Water Control Board (SWCB) was prompted to seek a solution to this problem when plans were announced in 1968 to construct a reservoir for a nuclear power plant downstream from Contrary Creek. This report describes the reclamation of two of the mine sites comprising about 8 ha.

The Contrary Creek Project is located in Louisa County, Virginia, approximately 65 km northwest of Richmond and 129 km southwest of Washington, D.C. Contrary Creek is approximately 8 km long and has an average annual flow of 197 L/s (7.3 cfs) at its mouth, where it empties into Lake Anna, an impoundment completed in 1972 as a source of cooling water for a nuclear power plant. The lake also has important recreational and fishing values.

The area is in the so-called pyrite gold belt of the Piedmont physiographic

province and was the scene of extensive mining activity in the 19th century. Between 1880 and 1923, more than 6 million tons of pyritic ore were produced from three deep-shaft pyrite mines known as the Arminius, the Boyd Smith, and the Sulphur along Contrary Creek. During this period, large volumes of wastes were dumped indiscriminately along Contrary Creek, denuding about 12 ha at the three sites and creating the AMD problem. The sources of AMD, which include heavy metals, are shown in Figure 1. The worst conditions prevailed at the Sulphur site, where about 6 ha were seriously affected.

The area remained essentially in this condition for more than 50 years after the mines were closed, until plans were announced to build the reservoir on the North Anna River, into which Contrary Creek drained. Concern existed that the continued influx of AMD would eventually cause a buildup of contaminants in the reservoir and could create major fish kills. Pre-impoundment biologic studies had shown aquatic life to be nearly nonexistent in Contrary Creek and to be adversely affected in the North Anna River for about 9 km below the confluence of Contrary Creek.

The SWCB conducted limited water quality studies of Contrary Creek in the early 1970's and determined that pH levels ranged from 4.8 to 3.3 in the most severely affected portions of the stream. Heavy metals, copper, iron, lead, manganese, and zinc were present in excessive amounts.

In 1973, the SWCB applied for an EPA demonstration grant to perform abatement measures under the provisions of Section 107 of PL 92-500. An EPA grant to reclaim the two downstream mine sites known as the Boyd Smith and the Sulphur was awarded to the SWCB in 1975. Deeds of easement were executed with the property owners concurrent with the grant application. A mining company assumed responsibility for reclaiming the third mine site (the Arminius). The Soil Conservation Service prepared plans and specifications for the construction and assisted throughout the project.

Procedures

Reclamation began in April 1976 and consisted of clearing debris, regrading and smoothing wastes, constructing diversions, excavating stream channels, riprapping stream banks, applying fertilizer and lime, incorporating wastewater sludge as a soil conditioner, seeding and mulching, and placing erosion controls.

Arrangements were made with the District of Columbia to deliver wastewater sludge from the Blue Plains Sewage Treatment Plant. Each day the plant generates approximately 275 wet tonnes of anaerobically digested sludge, which is concentrated to approximately 20 percent solids. Because of the high cost of sludge disposal in the Washington, D.C., area, the District agreed to deliver all sludge needed at no cost to the SWCB. This arrangement resulted in a tremendous cost saving to the project.

Droughts in 1976 and 1977 severely hampered efforts to establish vegetation on the reclaimed areas. A maintenance program was therefore developed and continued until 1982. The following elements were included:

1) Applications of additional fertilizer, lime, and sludge
2) Spot-seeding of persistent problem areas
3) Placement of riprap and straw bales for erosion control
4) Limited irrigation of the Sulphur site

A total of 2,118 dry tonnes (2,335 tons) of sludge was applied to the two mine sites from 1976 through 1979. Initial application rates ranged from 200 to 260 dry tonnes/ha (90 to 116 tons/acre). Lime application rates were determined from soil analyses and ranged from 4.5 tonnes/ha (2 tons/acre) to 33.4 tonnes/ha (15 tons/acre). Fertilizer (the 10-10-10 formula) was usually applied at a rate of 1,121 kg/ha (1,000 lb/acre). During the last years of maintenance, a higher potash fertilizer was used.

Conclusions

Vegetation and Soil Conditions

The first significant progress in the vegetative effort did not occur until 1978 and 1979, when near normal seasonal rainfall returned. Even then, irrigation water had to be applied periodically to critical parts of the Sulphur site. Abnormally low precipitation in 1980 and 1981 continued to impede vegetative growth. Despite the droughts that plagued this project and the very harsh conditions that existed before reclamation, about 90 percent of the reclaimed areas had a fair to good cover of vegetation by 1983. Some highly toxic portions of the Sulphur site still had sparse cover. Much of this site has a very thin soil layer supporting vegetation, and the susceptibility to drought is quite high. The Boyd Smith site appears to be well on its way to establishing a permanent cover. Without the use of sludge in this project, it is doubtful that a fraction of the vegetative cover would have been attained.

The most successful planting was Ky-31 fescue grass, which proved to be the mainstay of the vegetation. Weeping lovegrass exhibited high tolerance for drought and always made its best showing during the hot summer months when the Ky-31 became dormant. Korean and sericea lespedeza were both used in the seed formula, but neither of these legumes showed any appreciable success.

Regular soil analyses conducted by the Soil Conservation Service and the SWCB showed significant increases in pH (Table 1) and nutrient availability in the top layer of soil as the project progressed. But little improvement occurred in the deeper layers below the root zone. The heavy application of lime was undoubtedly a factor in raising the pH. Fertilizer formulas were adjusted according to nutrient requirements. A high potash fertilizer was used after soil tests began to show a relationship between potash deficiency and difficult areas to vegetate. Soil was also analyzed for water-extractable heavy metals. Sharp reductions in metal concentrations occurred within the top few centimeters over most of the reclaimed areas (Table 1).

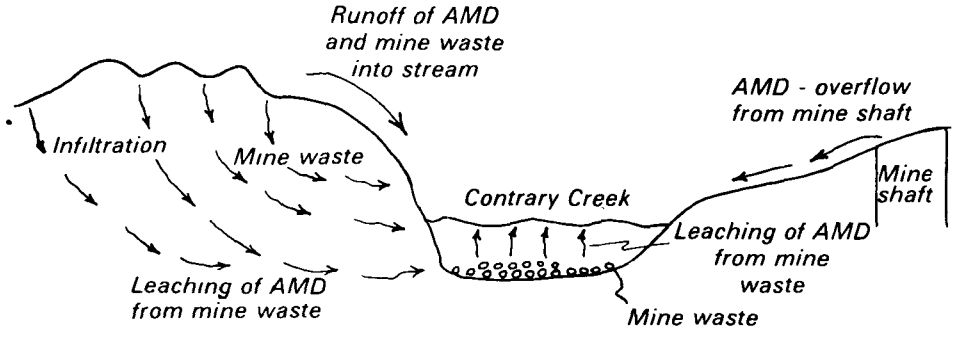

Figure 1. Sources of mine drainage into Contrary Creek. (Not to scale).

Table 1. *pH and Metal Content of Soil Collected from the East Side of the Sulphur Site Between 1976 and 1982 (mg/kg, dry weight basis)**

Date	pH	Cu	Fe	Mn	Zn
11-76	5.5	8.6	4.2	31.4	18.8
3-78	7.3	0.3	6.2	0.5	0.1
3-79	5.9	0.3	3.6	1.9	1.2
2-80	5.2	0.2	0.8	1.7	3.4
7-81	7.4	1.3	0.1	0.1-	0.8
2-82	6.4	0.4	0.1	0.6	0.5

*Each analysis is for one composite sample collection. All samples were collected at a depth of about 5 cm.

Water Quality

A comprehensive water quality program to evaluate the success of the project was implemented in October 1975 before reclamation. The program involved semimonthly samplings and flow measurements at five stream stations and sampling of two stations at surface, middle, and bottom depths in the Contrary Creek arm of Lake Anna. A stream-monitoring station was established below each mine site, with an additional one at the mouth of Contrary Creek and another above the Arminius site for control. Water samples from both stream and lake stations were analyzed for pH, acidity, sulfate, copper, iron, lead, manganese, zinc, suspended solids, and turbidity. Measurements of BOD (5-day) and fecal coliforms were included to determine whether any adverse effects of using wastewater sludge could be discerned.

The regular monitoring program continued until early 1980, when the lake stations were eliminated and the stream sampling was reduced to once monthly. Other monitoring included pH and conductivity transects along selected reaches of Contrary Creek and periodic analyses of tributaries. Monthly sampling continued until 1982.

In terms of concentration and load data, the 7-year monitoring program indicated a general trend toward reduction of heavy metals in Contrary Creek (Tables 2 and 3). But no appreciable improvement occurred in the pH and acidity problem.

The wide fluctuations in average annual flows had considerable bearing on the monitoring data generated. For instance, a severe summer drought in 1977 dropped flows drastically and raised concentrations sharply. When another more prolonged drought in 1981 reduced annual flows to about half those recorded in 1977, the rise in concentrations was much less pronounced indicating an improvement in water quality over that period.

Table 2. *Average Annual Concentrations in Contrary Creek Below the Sulphur Site**

		Concentration (mg/L)						
Year	pH	Acidity ($CaCO_3$	SO_4	Cu	Fe	Pb	Mn	Zn
1976	3.9	134	240	0.95	37.3	0.07	2.1	4.8
1977	3.8	238	376	1.73	54.9	0.13	2.5	7.9
1978	3.7	160	224	1.17	31.3	0.07	1.6	5.7
1979	3.6	217	196	0.79	25.5	0.07	1.7	4.3
1980	3.8	178	255	0.78	29.0	0.04	1.9	4.5
1981	3.7	211	250	0.90	32.0	0.05	2.0	7.3
1982	3.6	130	235	0.97	26.3	0.05	1.6	4.5

*Computed from average annual flows at a key monitoring station below the Sulphur site.

Table 3. *Average Annual Loads in Contrary Creek Below the Sulphur Site**

		(Load (kg/day)						
Year	Flow (L/s)	Acidity ($CaCO_3$)	SO_4	Cu	Fe	Pb	Mn	Zn
1976	147.8	1130	2188	8.4	313	0.6	18.5	46.0
1977	94.6	1080	1709	8.8	371	1.0	14.2	46.5
1978	206.5	2421	3242	18.9	493	1.4	26.2	87.5
1979	198.8	3186	2633	11.4	354	1.0	20.7	58.5
1980	153.1	1543	2300	7.7	281	0.4	17.8	46.3
1981	52.7	884	1106	3.9	133	0.2	8.7	35.0
1982	112.9	1116	1885	9.9	228	0.4	11.2	38.5

*Computed from average annual flows at a key monitoring station below the Sulphur site.

The water quality of Contrary Creek is still deteriorating as it flows past each mine site. The Sulphur site is the major contributor of AMD, but certain heavy metals appear to be peculiar to each site. Erosion and surface runoff of AMD have been reduced, but the continual leaching of AMD from the stream banks and the sudden flushouts during heavy rainstorms following extended dry periods are still problems. The downstream reach of Contrary Creek between the Sulphur site and Lake Anna, where a profuse amount of mine wastes have flushed downstream, is a major problem. No abatement work has been done on this part of the stream.

The monitoring program showed that the Contrary Creek arm of Lake Anna is degraded by AMD, but the main body of the reservoir has apparently been unaffected. No adverse effects on water quality and no health hazards are known to have resulted from the extensive use of sludge in this project. In view of the very toxic nature of the AMD entering Contrary Creek, improvement in the water quality will be slow. Several more years will probably pass before any appreciable improvement is noted.

Biologic Studies

As part of the monitoring program, the SWCB conducted spring and fall biologic surveys annually to determine the status of aquatic life in Contrary Creek. There have been slight improvements in the benthic communities between the Boyd Smith and the Sulphur sites, but much of the stream in the affected area remains highly toxic to all but the most tolerant organisms. Sensitive organisms do inhabit the unaffected tributaries of Contrary Creek. Thus, there is potential for benthic life to be restored in the main stream if the AMD problem is reduced.

Costs

Total cost of the entire project including Federal and State matching funds was approximately $327,000. Actual construction work and maintenance costs over the 7-year period were approximately $121,000, or $15,000/ha.

Recommendations

1) A project of this type will probably require several years of intense maintenance to assure permanent survival of vegetation. Soil tests should be conducted at least annually to evaluate progress and to determine soil additives needed. Close surveillance should be made of the reclamation sites for 5 to 10 years to observe progress and any evidence of damage that may reverse the project effort.
2) Whenever feasible, wastewater sludge should be used in the reclamation of lands severely affected by mine wastes. The positive effects that sludge has in promoting vegetation on highly toxic areas have been well

demonstrated in this project. Large urban areas that generate huge volumes of sludge and have problems obtaining disposal sites are the best sludge sources.

3) Water quality monitoring of the regular stream stations and key tributaries should continue on a limited basis. Biologic studies should continue biennially. All monitoring data should be evaluated for long-term changes.
4) The downstream reach of Contrary Creek between the Sulphur site and Lake Anna should be targeted if any additional reclamation work is conducted.
5) The vast amount of quantitative and qualitative data generated by the comprehensive monitoring program in conjunction with this project may have beneficial uses to other studies aside from AMD. Few streams of this small size have likely been monitored so intensely in terms of quality and flow.

The full report was submitted in fulfillment of Grant No. S-803801 by the Virginia State Water Control Board under the sponsorship of the U.S. Environmental Protection Agency.

Kenneth R. Hinkle is with the Virginia State Water Control Board, Bridgewater, VA 22812.
***Ronald Hill** is the EPA Project Officer (see below).*
The complete report, entitled "Reclamation of Toxic Mine Waste Utilizing Sewage Sludge: Contrary Creek Demonstration Project, Addendum Report," (Order No. PB 84-140 144; Cost: $10.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆ U S GOVERNMENT PRINTING OFFICE, 1984 — 759-015/7603

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Official Business
Penalty for Private Use $300