SERPENTINE TAILINGS RECLAMATION[1]

by
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Abstract. The serpentine formations in the Pretoria/Johannesburg region contains virtually no chrysotile fibre but those in the Eastern Transvaal (see figure 1, Paper Asbestos Tailings) contains large amounts of chrysotile. The tailings of those mines are therefore basically serpentine residues.

This paper deals with the rehabilitation of a closed down serpentine mine near Johannesburg and current research on chrysotile, sertpentine tailings, in the Eastern Transvaal. In the near future the programme will be expanded to also include Swaziland.

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Introduction

This Institute is the ecological consultant for the Department of Transport and various other Government Departments such as Minerals and Energy, Health, Water Affairs, etc.

The more or less twenty years exposure as reclamation consultant for the Department of Transport exposed the Institute to reclamation problems on a national basis; i.e. through all kinds of climatic conditions from desserts to sub-tropic's, from winter rainfall areas to summer rainfall areas, and gave us exposure to most kinds of vegetation types, soil and geologic formations.

Due to this wide exposure of ecological problems concerning rehabilitation (reclamation) of disturbed areas, the Institute developed a specific approach, i.e. that each problem area must be individually assessed and treated according to its own peculiarities.

The Individualistic Approach

The main aspects of the individualistic approach are the following:

1. A study of the vegetation in the vicinity of the disturbed area to determine the role of each species in the community with special attention to their rehabilitation potential, which includes:
   - potential to invade bare areas;
   - drought resistance;
   - seed production, germination and establishment under poor conditions;
   - recovery after fire, etc.;
   - unpalatable, if desired, for asbestos mines.
   - palatable where grazing can be controlled and where erosion is not a high risk.
2. Collection of seed and/or vegetative reproduction material.
3. Collection of representative soil samples.

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4. Physical and chemical analyses of the soil samples.
5. Chemical and/or physical amelioration of the soil based on the analyses.
6. Pot experiments in greenhouse and outside.
7. Establishment trials on site and a monitor programme of these, preferably for three growing seasons.
8. Seed production of the selected species on one of our seven seed production farms if they are not yet represented in our collection.
9. Drawing up a rehabilitation programme.
10. Act as consultant during implementation or physically do the implementation if the client so desires.
11. Implementation is normally followed up by two years of monitoring and, if needed, a light maintenance programme.

Rehabilitation of the Honingklip Mine

This serpentine mine closed down during 1987 because of a very low amount of asbestos fibre in the serpentine.

The quarry is about 13 ha in extent with an average depth of 5 metres. The walls were left vertical and varied between solid rock and partially weathered material with a thin layer of top soil which varied from 100 mm to 300 mm in depth. The floor was also solid rock but had been cracked due to the blasting.

The two tailings dumps and unsold ore were dumped over a ± 10 ha area. The average height of the tailings varied between 10-35 metres.

Another ± 7 ha in the vicinity was covered with a layer of tailings material and served as soccer field, parking area, roads, etc.

The reclamation programme was started in August 1987 with greenhouse experiments to determine tailings and quarry floor abnormalities and rectification procedures. This was followed by earthworks to flatten the vertical rocky slopes of the quarry to 15-18° and a ripping programme to break up the floor of the quarry.

The sides of the fine tailings dump were flattened to ± 18°, and that of the coarser tailings to 25°, as it was more resistant to erosion.

The greenhouse experiments in the mean time showed that the serpentine can be chemically rectified to sustain plant life and it was decided not to import topsoil.

Substrate amelioration and fertilizer was applied as follows:
Fertilizer and gypsum quantities per ha:

1. 3000 kg/ha calsium oxide
2. 750 kg/ha potassium chloride
3. 400 kg/ha superphosphate
4. 4 tons of gypsum/ha
5. After establishment 200 kg/ha 2:3:4(22) was applied.

Paddocks were constructed around the tailings and low lying areas to prevent rainwater from leaving the polluted area or carrying tailings to the nearby river systems or adjacent farms.

Hydroseeding and the planting of trees started in November 1987 and was completed in January 1988.

The seed mixture used contained ± 20 selected grass species and several *Eragrostis curvula* ecotypes, tree and shrub species. About 25% of the grass seeds were harvested locally through suction methods from the plants and soil surface. The advantage of the suction method is, apart from local seeds that are adapted to the local soil and climatic conditions; it also provides organic material, micro-organisms and a small quantity of topsoil, which are very important elements in rock quarry reclamation programmes.

The rest of the seed represents pioneer grasses and climax grasses selected for similar conditions as the Honingklip mine, i.e. drought resistant, good seed producers, etc.

The trees and shrub species mainly represent those that grow on local rocky outcrops, and were established from seed and seedlings.

The following grass species were represented in the seedmix:

Digitaria eriantha	2 kg/ha
Cenchrus ciliaris	3 kg/ha
Anthephora pubescens	2 kg/ha
Chloris gayana	3 kg/ha
Cynodon dactylon	1 kg/ha
Setaria sphacelata	2 kg/ha
Eragrostis tef	1 kg/ha
Eragrostis curvula (different ecotypes)	1 kg/ha
Pioneer mixture including: *Phynchelytrum repens*, *Eleusine indica* & others, *Enneapogon cenchroides*,	10-12 kg/ha
Chloris virgata	8 kg/ha
Total	33-35 kg/ha

The small deeper portion of the quarry is developed as a dam with islands and trees to attract bird life. The small lower lying part of the quarry will develope as a marsh and the rocky localities as habitats for small mammals and the rest would remain grassland (figure 1).

Final inspection took place on the 28th of January, 1988, at which time the release certificate from the Department of Minerals and Energy Affairs was handed over to the owner.

Revegetation on solid rock portions of the quarry

In order to rehabilitate the solid rock portions of the quarry, a project to investigate the use of plants which naturally grow on solid rock with very limited moisture and soil was started. These plants are the so-called resurrection plants. because they simply stop functioning when water is depleted, dry out and go into a type of hybernation until moisture is available again.

These plants have several very unique adaptations:

- They "invade" the soil "pillow" traces that forms around lichens and mosses from wind blown dust and/or soil particles in run-off water.
- They become dormant when they have depleted the moisture in the "pillow", their rootsystem on top of the rock surface gathers more wind-blown and washed down dust and soil particles (figure 2).
- It is known that they "resurrect" out of dormancy within a few hours after the next rain, and that they can survive droughts up to 8-10 years, while in hybernation..
- It is also on record that they can survive "artificial drought" (being left in a suitcase) for more than 20 years.
- The plants currently under investigation are:
  Myrothamnus flabellifolius (shrub)
  Coleochloa setifera
  Cyperus rupestris var. *rupestris* (both sedge like)
  Mariscus squarrosus
  Selagninella and mosses

Conclusion

The result of the rehabilitation was so successful that limited grazing was started within one year after establishment to prevent the stand to go moribund.

At present about 20 bird species, small vertabrates and three small game species have returned to the site. The island created in the dam and two large trees provided on the islands serves as a rest and sleeping place for birds, while several waterfowl species live permanently in the dam.

Rehabilitation of serpentine tailings at Msauli mine

Rehabilitation of serpentine tailings from chrysotile mining, is currently still in the research phase, but

Figure 1. (A)

Good vegetation cover on tailings (foreground) and on quarry floor to the right of the dam and quarry sides flattend to ± 20° in the back.

Islands has been constructed in the dam and mature trees transplanted to attract bird life untill the planted trees mature.

Figure 1. (B)

Vegetation cover on tailings dump and quarry floor.

Figure 2.

Myrothamnus flabellifolius lifted from solid rock. N e the soil pillow with all the roots confined to it. Sellaginella sp and Mariscus squarrosus are visible in foreground.

implementation will be started during the 1989/90 growing season.

Greenhouse experiments, based on physical and chemical analyses of tailings started during October 1984. The analyses revealed abnormalities in both physical and chemical properties. In all samples silt and clay particles were practically absent or very poorly represented. Magnesium was abnormally high, up to 2 000 ppm, with phosphate lower than 5 ppm. The pH of the slimes varied between 8,1 and 9,6.

Based on the results of the analysis, a pot experiment was designed in which various different soil treatments were included, as is indicated in Table 1. To lower the pH, three treatments of gypsum was used, i.e. 2,5 t/ha, 5 t/ha and 10 t/ha as is indicated in Table 1. Note that three levels of gypsum and three levels of potassium chloride were used along with the various amounts of organic material and soil moisturisers (water absorbing chemicals). The results varied but several tendencies were obvious. With the increase in gypsum application, the pH dropped from 8,8 to 7,6 and the number of seedlings that survived were somewhat higher than in the lower gypsum treatments. It is also evident from Table 1 that the vitality of the seedlings slightly increased with the higher gypsum application and that the application of organic material (compost) yielded slightly better results.

It must be mentioned that root development was generally poor and the vitality of the seedlings very low.

Due to the fact that no plants (not a single plant) naturally established on the various tailings dumps over a period of 30 years due to surface compaction and chemical abnormalities, it was decided to carry out a second set of pot experiments in which the surface and top 100 mm of the tailings was treated to change the physical and chemical properties. Larger amounts of organic materials and cow dung were used. Good results were obtained with higher applications of organic material and cow dung.

This was followed up by a field experiment. The lay-out, treatments and results are given in Table 2.

Seven plots of 11 x 11 metres in size were marked out (Table 2).
All seven plots received gypsum at 10 t/ha.
Numbers 2-6 received a 200 mm layer of coal ash (1 m^3 per plot).
Five plots received the same fertilizer mixture, except no 4 which did not receive potassium chloride, and number 6 which was not fertilized at all.
Plots 5, 6 and 7 received a 100 mm layer of cow dung (1,2 m^3 per plot).
Plot no 2 received the equivalent of 1,5 t/ha straw mulch.
The gypsum, ash, dung and mulch was mixed and worked into the top 250-300 mm slime, after which a 100 mm layer of topsoil was spread over all seven plots. The experimental area was fertilized and hand-sown. The following fertilizer and species were used:

NPK 2:3:2 (22) Zn	200 kg/ha
Superphosphate	500 kg/ha
Potassium chloride (KCl)	1500 kg/ha
Gypsum	10 t/ha

The seed mix consisted of the following:

Cynodon dactylon	3 kg/ha
Cenchrus ciliaris	5 kg/ha
Eragrostis curvula	2 kg/ha
Antephora pubescens	2 kg/ha
Panicum maximum	2 kg/ha
Digitaria eriantha	2 kg/ha
Aristida congesta *Aristida congesta* *Aristida adscenciones* *Hyparrhenia hirta* *Hyparrhenia aucta* *Rhynchelytrum repens* *Enneapogon cenchoides* *Themeda triandra*	±60 kg/ha

TABLE 1. VARIOUS SOIL TREATMENTS OF MSAULI MINE SERPENTINE TAILINGS

Gypsum application per ha	2,5 t/ha		5,0 t/ha		10,0 t/ha		Average of treatment	
	Average number of plants established	Average length of the tallest plant (mm)	Average number of plants established	Average length of the tallest plant (mm)	Average number of plants established	Average length of the tallest plant (mm)	Number of plants	Average height (mm)
Control	2,6	5,7						
Without potassium chloride (control)	7,2	12,8	11,0	20,2	8,8	15,2	9,0	16,0
+ 20 t compost	5,6	16,8	4,8	15,0	8,0	22,6	6,1	18,1
1000 kg potassium chloride (control)	5,6	6,8	6,2	11,2	12,0	15,2	7,9	11,1
+ 2 t gwanomix	11,6	12,4	6,4	9,6	11,6	16,6	9,9	12,9
+ 5 t gwanomix	7,8	11,4	9,6	14,8	8,4	16,0	8,6	14,1
+ 10 t compost	9,0	14,4	7,4	15,4	10,4	14,8	8,9	14,9
+ 20 t compost	7,4	14,6	10,2	20,2	10,2	16,8	9,3	17,2
+ 200 kg Aquastore	8,0	10,2	8,4	10,2	10,2	15,6	8,9	12,0
* + 200 kg Aquastore and * 200 kg Terrasorb	8,2	6,5	5,2	9,2	7,2	11,4	6,9	9,0
Total/average							8,6	13,8
2000 kg potassium chloride (control)	7,6	13,4	7,0	10,2	11,8	14,0	8,8	12,5
+ 2 t gwanomix	8,0	9,8	9,2	16,2	7,2	9,6	8,8	11,9
+ 5 t gwanomix	11,0	17,2	12,6	15,8	11,2	20,6	11,6	17,9
+ 10 t compost	6,8	9,0	7,6	10,0	8,4	18,0	7,6	12,3
+ 20 t compost	8,4	9,8	10,0	30,4	10,0	13,0	9,5	17,7
+ 200 kg Aquastore	4,0	7,4	6,4	7,8	8,8	14,4	6,4	9,9
+ 200 kg Aquastore and 200 kg Terrasorb	5,2	7,6	8,0	12,2	12,2	12,0	8,5	10,6
Total/average							8,6	13,3
Average for treatments	7,6	11,3	8,1	14,3	9,8	15,4		

* Aquastore and Terrasorb = soil moisture absorbents

TABLE 2. LAY-OUT, TREATMENTS AND RESULTS, 1988-89 SEASON

	1	2	3	4	5	6	7
	Gypsum	Gypsum	Gypsum	Gypsum	Gypsum	Gypsum	Gypsum
		200 mm ash	200 mm ash	200 mm ash	200 mm ash	200 mm ash	
		Mulch 1,5 t/ha			100 mm dung	100 mm dung	100 mm dung
	100 mm topsoil	100 mm topsoil	100 mm topsoil	100 mm topsoil	100 mm topsoil	100 mm topsoil	100 mm topsoil
	Fertilizer	Fertilizer	Fertilizer	No potassium chloride	Fertilizer		Fertilizer
A	16	17	22	23	29	29	27
B	1,0%	0,0%	0,5%	0,5%	5,5%	5,5%	4,5%
C	3,1%	0,0%	6,0%	6,0%	64,5%	56,8%	21,3%

A = Number of seedlings; B = Basal cover; C = Crown cover.

The results for number of species, basal and crown cover is clearly illustrated in Table 2. The results of plots 1-4 without cow dung are very poor in comparison with plots 5-7 which received cow dung (figures 3-4).

Conclusion

The inclusion of gypsum and organic material and cow dung is essential for the establishment of vegetation on chrysotile tailings.

Figure 3.

The results of plots 5 and 6 four months after establishment.
Serpentine tailings behind the experiment is plantless.

Figure 4.

Species selection trails at Msauli.
Hyparrhenia hirta (taller grass) and Cynodon plectostachyus (Rhodesian star grass) are doing well two seasons after establishment