

GOLD TAILINGS RECLAMATION IN

SOUTH AFRICA¹by
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Abstract. This paper deals with the history of rehabilitation (reclamation) on gold mine wastes since the beginning of research in 1932, to large scale experiments during the 1950's and implementation since the 1960's.

It describes the basic philosophy, techniques, methods and treatments followed by the Vegetation Units of the Chamber of Mines and that of Rand Mine Properties which establish vegetation on the tops of slime dams under dry land conditions, whilst using irrigation on the sides of slime dams for leaching, to raise the pH, for the establishment of vegetation.

It also elucidates some of the current research done by the Institute for Reclamation Ecology of the University of Potchefstroom with regards to the rehabilitation of the sides of slimes dams under dry land conditions on "old" slimes dams as well as newly constructed slimes dams due to recycling of "old" sand dumps and slimes dams.

Fairly successful dry land establishment experiments on a slime dam currently under construction from recycled material will be discussed.

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Introduction

Grange (1973) stated that more than 3 billion tons (3×10^9) of rock have been brought to the surface and crushed for gold extraction, and virtually all have been deposited on the

surface as sand dumps prior to 1921, and since then as slimes deposits. The combined area already exceeded 80 km² in 1973.

The advent of mines caused the development of cities and towns and the air-borne dust created a major nuisance and traffic flow problems.

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By 1932 the late Prof Phillips and the late Mr W H Cook started with basic research for the Chamber of Mines. According to James (1966) deposits were originally be considered to be similar to that in semi-desert regions. Seeds of plants used for desert reclamation were imported from various parts of the world. Only two species were found to be successful.

Consequently it was decided to try and modify the substrate to such an extent that more acid tolerating drought resistant commercially available species would grow.

Research during the early 1950's, using a cocktail of twenty-one species, yielded partially successful results. It was only since 1958 realised that the high pyrite content of the slimes caused vegetation growth failure despite large applications of lime.

Therefore a procedure was developed using fine water sprays for leaching the acidity from the surface layers into the more alkaline material below. Currently leaching is maintained for eighteen months to two years.

By 1968 the Vegetation Unit of the Chamber of Mines has grassed sufficient sand dumps and slimes and Rand Properties decided then on the formation of their own Vegetation Unit.

The Institute for Reclamation Ecology of the Potchefstroom University started with dryland establishment experiments using only native grasses and heavy liming during 1984 as will be discussed later in this paper.

Reclamation procedures of the Vegetation Units of the Chamber of Mines and Rand Mines Properties

Both Vegetation Units operate on fairly parallel procedures with substrate preparation, water control measurements, fertilizing, establishment, leaching, and maintenance.

The information with regards to the procedures followed by the two Vegetation Units is adapted from Cook (1985) and slightly altered and expanded by the second author.

Gold Tailings Reclamation in South Africa

Introduction

This paper is partially adapted from B J Cook (1985).

Under the guidance of the late Mr W H Cook establishment techniques evolved from:

- * The early 'seed bed preparation' method as originally developed for the vegetation of slimes dam sides, to
- * the 'minimum cultivation' method in which buttresses were 'split' and collapsed into adjacent gullies which in turn were blocked at intervals with bales of veld grass to prevent erosion, to
- * the 'no cultivation' method in which the surface of the slimes is not disturbed at all, except where gullies are exceptionally big.

Also under the guidance of Mr Cook, maintenance of vegetation has evolved from a general annual application of fertilizer to the situation where vegetation on the sides of a slimes dam and sand dump is fertilized by hand on a selective basis - Stoloniferous varieties only!

The need for rehabilitation

Slimes and sand dumps are rehabilitated to satisfy the requirements of the Air Pollution Act and the Water Pollution Act - as cost effective as possible and to the most environmentally satisfying aesthetical appearance, and by controlling the movement of all water on and around the dumps. The success of these efforts can be judged by the commercial and industrial activity and by the establishment of prime residential townships in areas which before 1960 (the leeward sides of very dusty mine dumps) were extremely hostile environments.

Rehabilitation methods as practised today

The rehabilitation of residue deposits proceeds as follows:

Prevention of water pollution - slimes dams

The first step taken is to prevent water pollution. While the mine is still operating any water on the surface of the dam is drawn off through the penstock pipe and discharged into the return water dam from where it is treated, if necessary, and recycled. Water falling on the side of the slimes dam is collected in paddocks at the base of the slimes dam where it is allowed to evaporate or is gravitated to the return water dam.

At closure, however, the procedure changes. A wall, one metre high and one metre broad at the crest, is pushed up by bulldozer around the perimeter of the dam. The slime used to construct the wall is lightly compacted by tamping the material with the bottom of the bulldozer blade.

Similar walls are constructed on contour on the top of the dam. These start at the penstock and proceed outwards at 0,5 m vertical intervals. The top of the slimes dam is thus divided into a series of paddocks - each one isolated from its neighbour by a one metre high wall. The walls are always constructed by pushing from the upstream side so that the resulting profile has the slime at the natural angle of repose on the downstream side and gently sloping at approximately 1:3 on the upstream side. Thus any water impounded does not rest hard up against the base of the wall.

Water movement within the paddock is further impeded by 'ridge ploughing' the floor of the paddock - on contour. This is done by means of a potato or tobacco ridger which leaves ridges and valleys about 50 cm high and about 50 cm apart. Rainwater thus stays where it falls and cannot start erosion by moving across the surface of the highly erodable slime.

The penstock is isolated only by means of the contour walls and by blocking the inlet. The downstream exit of the penstock pipe is never blocked and thus there is no possibility of a head of water building up

within the pipes and the side of the slimes dam being eroded when the pipe fails due to old age or corrosion.

After closure, rainwater falling on the sides of the dam is collected in paddocks around the base of the dam and evaporated. The paddocks are sized so as to contain and evaporate water resulting from a 1 in 100 year storm. Usually on the Witwatersrand this requires that the paddocks have the same area as the plan area of the sides of the slimes dam and that the walls are sufficiently high to enable 0,5 m depth of water to be stored within the paddock, plus 0,5 m freeboard.

Where breaks have occurred in the sides of a slimes dam they are isolated from surface water by the perimeter wall around the top. Another wall is thrown across the base of the break to impound rainwater that falls within the break.

Prevention of water pollution - sand dumps

On sand dumps the permeability of the sand is so great that rainwater can drain slowly down through the dump and flow out through low spots in the base, causing localised pollution problems. This is countered by impounding the seepage in paddocks as close to the dump as possible and allowing it to evaporate.

Prevention of air pollution

Generally all slimes dams, (tops and sides), and sand dumps are vegetated to prevent air pollution. As slimes oxidises it loses its cementing properties and becomes very susceptible to wind and water erosion. The oxidised material is easily vegetated. In fact, if this material remained in situ, slimes dams and sand dumps would probably be self vegetating. On sand dumps wind erosion is prevented by the construction of reed paddocks. On slimes dam tops ridge ploughing is most effective in preventing wind as well as water erosion. The oxidised slime collects in the valleys between

the ridges. On windy days the only dust blowing off a ridge ploughed top seems to come from the smooth access roads and not from the ploughed surface.

The oxidised material in the valleys between the ridges forms an excellent seed bed and vegetation of the top under dryland conditions is usually possible after a top has been ridge ploughed for two seasons.

Vegetation of the sides of slimes dams

The 'no cultivation' method is used to establish vegetation on the sides of slimes dams. Vegetation proceeds as follows:

- * Leaching equipment is erected. This consists of a number of 20 mm polythene water pipes, 100 m long, erected parallel to each other, on contour, 3 m apart. Micro jets are screwed into the pipes at 2,5 m intervals. The pipes are erected on stakes approximately 1 m high and each pipe is individually controlled by a valve.
- * Bales of mulch, or orange pockets in which a mixture of stoloniferous grass shoots which has previously rooted in soil, are placed in the erosion gullies at frequent intervals so as to impede the velocity of rain-water and prevent erosion until the vegetation is established.
- * Calcitic lime at 7,5 t/ha and superphosphate at 300 kg/ha is broadcast by hand over the area.
- * A mulch of veld grass preferably cut in the seed ripening stage in an area where a variety of grasses - particularly *Hyparrhenia hirta* - grow, is spread at a rate of 200 bales/ha. If the pH of the slime is below 3, the mulch is spread at a rate of 400 bales/ha.

* Leaching is started. Water is sprayed onto the surface of the slime from the micro jets at a rate that is just below the optimum rate of infiltration into the slime. In other words the water must all be absorbed into the slime with no run-off. On occasions washing powder is used to improve the penetration of the water into the slime.

* Handplanting. The seed of most of the grasses used for vegetation is commercially available. There are some species however that are so effective, and for which seed is not commercially available, that they are raised vegetatively in separate containers in a nursery.

Some of these varieties are:

Name	No of plants/ha
<i>Cynodon aethopicus</i>	1440
<i>Cortaderia selloana</i>	350
<i>Pennisetum macrorum</i>	350
<i>Pennisetum clandestinum</i>	700
<i>Populus canescens</i>	175
<i>Carpobrotus edulis</i>	80
<i>Coronilla varia</i>	100

* The seedmix is prepared and sown. Legume seeds are inoculated and all the seeds are mixed together into one large cocktail. Agricultural lime is used as a distribution and germination aid and approximately 100 kg of calcitic lime is thoroughly mixed with the seed before sowing.

The following seedmix is used:

Name	Quantity (kg/ha)
<i>Cynodon dactylon</i>	2,5
<i>Eragrostis curvula</i>	1,25
<i>Dactylis glomerata</i>	2,5
<i>Chloris gayana</i>	2,5
<i>Festuca elatior</i>	2,5
<i>Agrostis tenuis</i>	2,5
<i>Poa pratensis</i>	1,25
<i>Lolium perenne</i>	1,25
<i>Bromus catharticus</i>	1,25
<i>Atriplex semibocata</i>	1,0
<i>Trifolium repens</i>	1,25

<i>Medicago sativa</i>	1,25
<i>Melilotis alba</i>	1,25
<i>Brassica nupus</i>	0,25

- * Four days later 2:3:2(22) fertilizer is applied at 300 kg/ha and repeated when the seedlings reach the 3rd leaf stage - about 3 weeks after sowing.

Post germination treatment

Rape (*Brassica nupus*) is included in the seedmix as an indicator plant and gives early warning of phosphate deficiencies or of the return of acid conditions. Immediate corrective action to rectify conditions is always taken by applying either more superphosphate or agricultural lime. If it is possible to grow poor rape it is possible to grow good grass!

Leaching continues until a good grass cover has been established and then a 'toughening-up' process starts during which the application of water is decreased gradually. After no leaching has taken place for a period of at least two months, the leaching pipes are removed if no severe stress signs are apparent in the vegetation.

Vegetation of the tops of slimes dams

All vegetation is established on the tops of slimes dams under dryland conditions.

After water control measures have been completed on the top, the floors of the paddocks are ridge ploughed once per annum for at least two years.

Ridge ploughing usually takes place during the winter months just before the onset of the spring winds. After the second ridge ploughing is completed, trial plots, approximately 10 m x 10 m are established on the top at a density of roughly one plot/25 ha. These plots are fertilised, limed and sown using the standard seed mix during favourable weather conditions in early spring and if successful,

vegetation of the whole of the top proceeds during summer in the following manner:

- * During favourable weather conditions calcitic agricultural lime at a rate of 7,5 t/ha and superphosphate at 600 kg/ha is disced into the surface.
- * The seedmix is broadcast over the area and rolled using a land roller to corrugate the surface and to ensure a good seed/soil contact.
- * Four days after sowing 2:3:2(22) fertilizer is applied at a rate of 300 kg/ha. This application is repeated when the vegetation reaches the third leaf stage.
- * Once the vegetation is well established - 4 to 5 weeks after germination - urea is applied at a rate of 50 kg/ha and repeated about 10 days later.
- * The seedmix used is the same as is used on the sides of the slimes dams, with the addition of some tree seeds, particularly *Acacia baileyana*, *Acacia melanoxylon*, and *Gladitia tricanthos*. The *Acacia* seeds are boiled in water for two minutes to stimulate germination.

Aftercare -- maintenance

Slimes dams tops. The only aftercare provided for the tops of slimes dams is the annual discing of 5 m wide firebreaks around the top perimeter of the dam and across the top so that it is divided into paddocks approximately 2 ha in area. Bluegum (*Eucalyptus*) tree seedlings are also removed wherever they are found growing on residue deposits. They spread quickly and their presence rapidly leads to a deterioration of the other vegetation.

It has not been necessary, on any of the vegetated slimes dams tops under our control, in the last 15 years, to apply any maintenance fertilizer once the vegetation has been established.

Slimes dams sides. It was initially normal practice to fertilize the whole side where weak vegetation was apparent using a mixture containing 2:3:2(22) + 0,5% Zn at 150 kg/ha; urea at 50 kg/ha; and potassium chloride at 25 kg/ha. This was initially spread by hand, then by helicopter and eventually a fixed wing crop sprayer aeroplane.

The problem with giving a general application to the side was that the canopy cover grasses responded rapidly to the application and the stoloniferous varieties were suppressed. This resulted in a very lush growth of vegetation which consisted basically of very hungry grasses which required some form of veld management if they were not to go moribund. A fire during the winter was almost impossible to fight because of the lush growth. The fire tended to be a very 'hot' fire and usually severely damaged the vegetation. As a result of the damage the area would require fertilizing again the following season and this started a cycle of fertilizer, burn, fertilizer, burn, etc.

To overcome this a system was developed of applying fertilizer selectively by hand, to stoloniferous varieties only, instead of a general application. This obviously results in the promotion of the stoloniferous varieties at the expense of the canopy type varieties. It was found possible to change the predominant vegetation on the side of a slimes dam from one which is hungry, a fire hazard and susceptible to damage by fire, and which requires periodic management to prevent moribund conditions, to one which has low nutrient requirements, appears to recover well if burnt, and requires minimal attention.

Local grasses for which seeds are not commercially available also appear to move in more readily where they are not in competition with a heavy canopy-type cover.

There is also a considerable saving in fertilizer when applied selectively.

It takes a trained team consisting of a supervisor and 15 labourers about one month to selectively fertilize the sides of the 50 slimes dams representing 250 ha of sides.

Advantages of establishing vegetation on the sides of slimes dams using the 'no cultivation' method as opposed to seed bed preparation method

- * There is a significant saving in cost.
- * There is no storm damage.
- * Less leaching is required.
- * The 'no cultivation' method is not affected by the steepness of the slope of the slimes dam.
- * Reshaping costs are saved.
- * A 'permanent cover' is established more rapidly using the 'no cultivation' method.

Costs

Costs of vegetation vary from site to site but can be expected to fall within the following ranges if the work is done by the local workforce and the cost of water is excluded:

- * Slimes dam tops R1000 - R1500/ha
- * Slimes dam sides R800 - R1200/ha

For sides of slimes dams an amount of R200/ha/annum should be set aside for maintenance of vegetation for five years after establishment.

Conclusion

The well vegetated mine dumps on the central Witwatersrand bear testimony to the fact that South Africa's prominent gold industry need not have a dark side.

The mine dumps, those very visible relics of past mining activity, need not be considered liabilities in the city life. The challenge to overcome the environmental problems has uncovered an opportunity to bring nature back into the city (figure 1).

We have been able, at reasonable cost in financial, time and effort terms, to establish a vegetative cover on the dumps that is permanent, pollution free, aesthetically pleasing, cost effective and which is bringing wildlife back to an area from which it has been excluded for many decades.

Dryland rehabilitation
research on old slimes dams

Due to space limitation this presentation will be brief and to the point.

Dry land establishment on the sides of two still active slimes dams in the Western Transvaal is currently in the first and third season (figures 2 and 1) after establishment respectively.

Two of the six treatments yielded satisfactory results and will briefly be discussed.

Horizontal trenches, spade deep and spade wide, were dug at 1,0, 1,5 and 2,0 m vertical intervals starting at the top of the dam. Lime was applied in these trenches to the equivalent of 6 t/ha. The equivalent of 2 t/ha was evenly spread by hand.

The trenches were filled with grass straw from nearby seed production lands and therefore contained some seed. The straw was slightly compacted by walking over the surface.

Fertilizer and seed were applied by hydroseeding, after which a 100-200 mulch "blanket" was spread on by means of a hydroseeder. The mulch was tackified by means of butumen in the first experiment and with a local manufactured bonding chemical with a brand name of Multac Type 1 in the 1988/89 experiment (figure 2).

In all cases where the mulch blanket could be kept intact and in place for the first season a satisfactory, but not a uniformly even, cover developed. The stoloniferous grasses

are currently beginning to invade the bare buttresses where initial establishment did not take place satisfactorily.

The difference (rather fairly similar results) between dryland establishment, and establishment under irrigation (for leaching purposes) is obvious in figure 1.

It is not yet known if successful dryland establishment could be applied generally as some slime dams might have a higher pyrite content as the ones selected for these experiments. The cost of dry land rehabilitation is estimated at 50% of the establishment under leaching with irrigation.

Fertilizer

2000 kg/ha of lime was applied on the surface and 6000 kg/ha in the furrows. In addition 400 kg/ha superphosphate, 400 kg/ha KCl (Potassium chloride), 200 kg/ha 2:3:2(22) (NPK), and 100 kg/ha limestone ammonium nitrate was applied.

The seed cocktail (± 40 kg/ha) represent the following species:

Anthehora pubescens
Cynodon dactylon
Chloris gayana
Cenchrus ciliaris
Digitaria eriantha
Paspalum dilatatum
Hyparrhenia hirta
Atriplex semibocata
Atriplex numularia
Stylosanthus sp.
Trifolium sp.
Vicia sp.
Medicago sativa
Tritium sp.

Plus a mixture of pioneers and various *Eragrostis curvula* "ecotypes".

The exact amount of seed for each species cannot be determined as some of the seed was collected in mixed stands in natural veld by harvesting and by means of suction harvest from the ground.

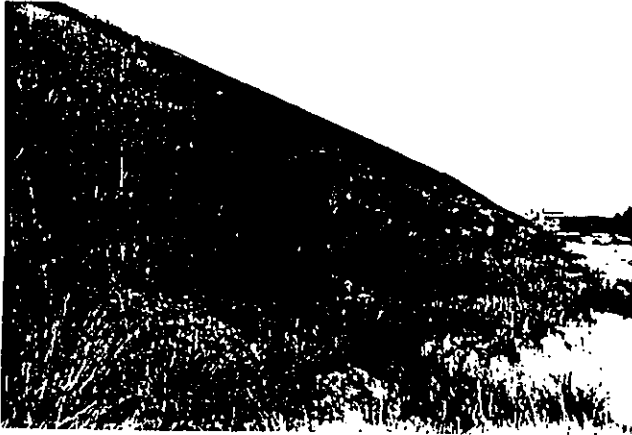


Figure 1. (A)

A permanent vegetation cover on the side of a slimes dam three seasons since establishment. Dry land establishment was used on the front 100 metres and irrigation on the rest.



Figure 1. (B)

A permanent vegetation cover on the side of a slimes dam three seasons since establishment. Dry land establishment was used on the left side and irrigation on the right hand side.



Figure 2.

Dry land establishment four months old. Establishment is good in the horizontal trenches and vertical gullies. Stoloniferous species only covers the buttresses from the second and third season onwards.

Dry land rehabilitation research
on freshly recycled slimes

The recycling of sand dumps and slimes dams has become a major industry during the last decade. It is estimated that about 50% of all existing slime deposits will be recycled for gold and acid extraction.

The Institute for Reclamation Ecology is acting as Ecological Consultant for one of the major recycling companies operating in the Eastern Suburbs of Johannesburg.

The slime after extraction of gold and sulphuric acid, is pumped as a slurry to a rural area some 50 kilometres distant from the downtown Johannesburg area.

The slimes dam will ultimately be about 2000 ha in size with a variable height due to undulating terrain on which it is constructed. The average height is expected to be 60 metres.

The construction method is by means of cyclones and the side slopes are $\pm 30^\circ$; not too steep to rehabilitate. Despite the recycling the pH varies between 4-4.5.

After three years of research, soil amelioration, species selection and establishment techniques have been worked out (figure 3), and implementation was started during the 1988/89 growing season.

Tailing amelioration and fertilization

Two tons of straw mulch was spread per ha, followed by the application of 400 kg/ha superphosphate; 400 kg/ha potassium chloride (KCl) and 200 kg/ha 2:3:2(30) + Zn and 6 tons of lime per ha. All the material was rotivated into the tailings to a depth of 100-150 mm. Hydroseeding was done immediately after the rotivating to ensure that the seed is placed on a freshly disturbed coarse seedbed. The same seed cocktail as already mentioned was used.

Pioneer grasses of which seed is produced by the Institute represent *Rhynchelytrum repens*, *Enneapogon cenchroides*, *Chloris virgata*, *Heteropogon contortus*, *Stipagrostis uniplumis* and various *Aristida* species. These species were originally collected in semi-desert conditions and are extremely drought tolerant.

The cocktail also contains 10-12 new genetic lines (not yet registered as ecotypes) of *Eragrostis curvula* (weeping love grass) specially selected by this Institute for rehabilitation purposes. They are in all respects superior to the commercially available *Eragrostis curvula* var. *Ermelo*.

In experiments, this cocktail yielded a very effective permanent cover (figure 3) and no maintenance had to be applied since establishment in 1985/86.

One of the recent "discoveries" was the observation that one of the "new" genetic strains of *Eragrostis curvula* was escaping from the experimental plots and invading totally untreated slimes (figure 3, right hand side of the road).

The vitality of these plants in treated and untreated slimes is exactly the same (figure 4).

Seed is currently produced of this new strain which will soon be registered as a new variety.

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reading materials

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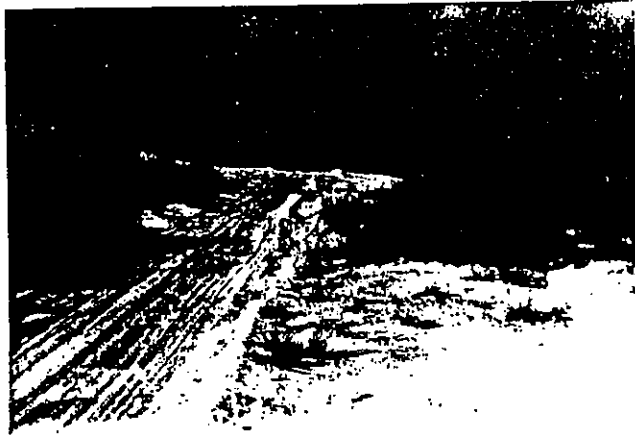


Figure 3.

Successful experiments left of the road side established in 1985/86. Invasion of a "new" genetic strain of *Eragrostis curvula* on untreated slime (dense stand) right side of the road.



Figure 4.

"New" genetic variety of *Eragrostis curvula*. Left, mature plant growing in totally untreated slimes. Middle and right young plants in treated (middle) and untreated slimes. The vitality of the young plants are basically the same.