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The vegetating of mine-residue deposits on the Witwatersrand

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SYNOPSIS

The paper briefly outlines the history of the successful development of vegetating techniques for mine-residue deposits. It seeks to place on record the major roles played by M.J. Mrost, who initiated and systematically developed the concept, and W.H. Cook, who continued the trials and successfully directed a stupendous large-scale project.

The vegetating techniques currently practised are outlined, and it is concluded that vegetating is still the only surface-stabilizing technique of any significance that is employed throughout the world.

SAMEVATTING

Die referaat gee 'n kort uiteensetting van die geskiedenis van die suksesvolle ontwikkeling van 'n beplantingstegniek vir mynresidu-afsettings. Dit wil die belangrike rolle van M.J. Mrost, wat met die idee begin en dit sistematies uitgebou het, en W.H. Cook, wat die proewe voortgesit en 'n ontsaglike grootskaalse projek suksesvol gelei het, boekstaaf.

Die beplantingstegnieke wat tans toegepas word, word in hooftrekke uiteengesit en die gevolgtrekking is dat beplanting nog steeds die enigste oppervlakstabiliseringstegniek van enige belang is wat oor die hele wêreld toegepas word.

Introduction

The success achieved by the gold-mining industry in South Africa during the past 25 years with the establishment of vegetation on residue deposits in the Witwatersrand area has been outstanding. The techniques used in the past have been well described by Chenik[1,2] and subsequently by James[3] and James and Mrost[4]. Mrost's initial concept of vegetating has not been described previously, nor has the work of Cook in any detail. This paper is intended to fill this gap. Mrost and Cook can justly be described as pioneer and consummator respectively of the vegetating project. The former was the team leader of the vegetating project initiated by the Chamber of Mines of South Africa through its Research Laboratory, and James was its Director. At the start of the project, Cook was the Horticulturalist for the Gold Fields of South Africa Group, and later he became Manager of the Chamber's Vegetation Unit.

The fact that gold-mine residue deposits cause both air and water pollution has been known for many years. In 1911, the Mines and Works Regulations stated that 'the mine manager shall cause any such dump ... to be sprayed ... so as to prevent the dissemination of dust or sand from it'[3].

In 1936, Thurlow[5] stated that many attempts had been made to prevent the dust nuisance that arose on windy days. Spraying with salt water and slime, oil and water, molasses, black mud, and other materials had been tried, but a satisfactory and economic solution was not available. He states that systematic spraying tests were started in 1914, and that in the same year vegetation was planted in holes dug in the side of a deposit and filled with soil, the growth of eucalyptus being considered successful. Cook[6] subsequently disagreed that success had been achieved.

As the years passed, towns expanded and housing approached more closely to the mines, while the residue deposits at the latter grew. Both these developments caused the dust nuisance to increase, and with it the public outcry. In the 1950–60 decade, the National Physical Laboratory of the Council for Scientific and Industrial Research (C S I R) investigated atmospheric pollution. Finally, in 1965 the Atmospheric Pollution Control Act was promulgated, Section IV of which deals specifically with dust from mine-residue deposits.

The first Rand Water Board plant for treating water from the Vaal River was commissioned in 1923, and from then on, if not earlier, systematic chemical analyses of the quality of the Vaal River were undertaken. With the passage of time it was noted that the quality of the water had deteriorated, and in 1948 Leslie, the chief engineer of the Water Board, stated[7] that 'Experts are now gravely concerned at the quantities of obnoxious effluents entering the Vaal Barrage ... by way of the Klip and other tributary rivers serving the Rand factory area. Both the Klip and the Suikerboschrand ... are contaminated from the development of the Witwatersrand, ... the most objectionable feature being the addition of sulphates'. Although not stated in the report, sulphate contributors included mine water pumped from underground, as well as that discharged from residue deposits on the surface in the rainy season.

The Chamber of Mines was well aware of the pollution problems caused by mines, and had been actively investigating these and pursuing solutions. In 1951, the Chamber negotiated with the National Building Research Institute of the C S I R for an investigation into the construction and stabilization of slime dams. Erosion and the control of water and air pollution were to be facets

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of this project, which was finally commissioned two years later.

The C S I R followed with a survey of river pollution in the Witwatersrand catchment area of the Vaal River in 1952 and 1953, and reported the presence of considerable pollution[8]. Similar results were obtained in an assessment of the extent of pollution by mine effluent in the Rietvleispruit catchment area (in the Krugersdorp–Randfontein area)[9]. This 2½-year study, which started in November 1953, was undertaken by the Chamber of Mines in consultation with the C S I R.

The degree of river pollution occurring in various parts of the country, but primarily on the Witwatersrand, led in 1956 to the passing of the Water Pollution Control Act.

In 1936, Professor John Phillips of the University of the Witwatersrand had reported[10] on the results of a literature study, which was supplemented by a survey of 'a good deal of representative dump area'. He concluded that vegetating of the deposits would not be practical unless they were first given a covering of soil.

Chamber of Mines' and Associated Investigations

Mrost, the team leader in the Rietvleispruit pollution investigation, noted during his site visits that, in adjoining regions and on the deposits themselves, there was some vegetative cover that both stabilized the surface and limited dust in windy conditions.

The remarkable stabilizing effect of plants is evident in Fig. 1. The mound in the foreground shows that there has been a build-up of approximately 150 mm of material around the grass growing on the slime, the grass being only six months old.

Mrost discussed the pollution problem and solution possibilities with Neethling and the other two members of the Chamber of Mines Research Laboratory Mycology Division. Neethling commented as follows[11]: 'It was suggested that, if varieties of grasses or plants would grow in the residue deposits, they could provide a viable solution. In January 1955, several species, including coastal and sand dune vegetation such as mesembryanthemums, were planted at the laboratory with the object of subsequently transferring them to deposits for growth monitoring. These tests went on for a long period using sandy, near-sterile soil, the addition of lime or fertilizer being deliberately avoided'.

Mrost and James were associated with the previously mentioned study by the National Building Research Institute on the best procedures for the stabilization of slime deposits[12]. By 1956 this study had indicated that processes such as bitumen or resin impregnation were unsuitable. A suggested alternative was stabilization with vegetation if growth could be sustained[4].

The Chamber of Mines discussed this possibility, and it was agreed that the Department of Agriculture should be approached for advice. As a result, Dr Dyer, Chief of the Division of Botany, accompanied by Mrost and James, inspected several slime deposits on the West Rand on 12th October, 1955, Dr Dyer reported that, since grasses, herbs, and trees were growing at one site, it was evident that the 'soil' was not toxic. The main problems appeared to be on the sides of the dumps, where there occurred severe exposure to wind, sun, and cold and violent scouring by rainfall. He recommended laboratory-scale testing in slime residues of several drought-resistant species.

So, in 1956, a year after Mrost's initial trials, the Chamber of Mines Research Laboratory was given the task of determining suitable vegetating procedures[4].

South African and overseas authorities on semi-desert vegetation were consulted, and a trip to the Kalahari to obtain suitable drought-resistant plant species was undertaken in September 1958. Twenty-four species were brought back and planted, along with other hardy species, on residue deposits at Crown Mines. In February 1959 it was reported that 103 species had been planted on the 'Club' slime deposit and 51 species on B sand dump. The test plots, 6 m by 3 m, were established on untreated residue material, no lime or fertilizer having been added[13].

After some hundreds of specimens had been tested, it

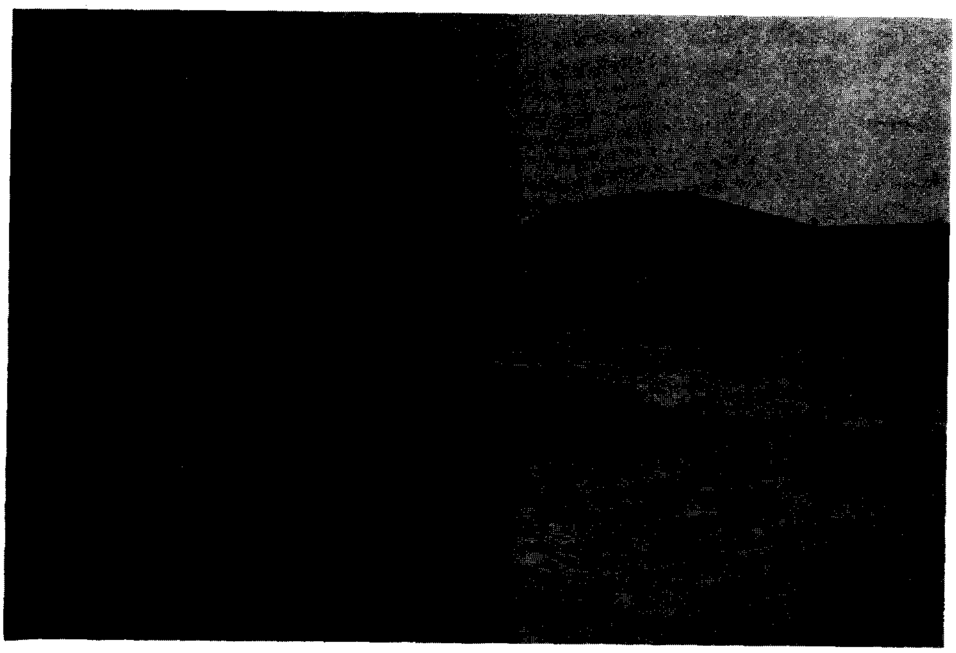

Fig. 1—Stabilizing effect of grass growing on a slime deposit

became clear that, since uncommon plants grew and spread slowly, there would always be difficulty in obtaining seed[14]. Consequently, it was decided to use commercially available varieties and to modify the growing environment with lime and fertilizer. By mid 1960, a reasonable idea of the requirements of these plants had been obtained[13].

Probably spurred by the imminent Water Pollution Control Act, which was finally promulgated in 1956, some of the mining houses were investigating the suppression of dust from residue deposits in the decade from 1950 on. In 1959, the Government Mining Engineer was informed that, in addition to the tests at the Research Laboratory, vegetating trials were being undertaken at Luipaardsvlei Estates, and to a more limited extent at Randfontein Estates and Rietfontein Consolidated Mines[13].

The trials undertaken at Luipaardsvlei have been described in detail[1,2,15]. In his first paper, Chenik[1] states that the project was guided by a committee chaired by the Consulting Metallurgist of Gold Fields of South Africa, H.E. Cross, and consisting further of W.H. Cook and himself, the first two supplying the technical and botanical expertise. Test plantings started in March 1958, both with and without the addition of fertilizer, and shortly afterwards, when the need became apparent, with lime. Before planting started, information was sought from public bodies and municipalities, and later a decision was taken to work in conjunction with the Chamber of Mines Research Laboratory. This liaison came into effect a year later[16].

M.H. Fennell, a recently retired Assistant Technical Adviser of the Chamber of Mines, was an official at Luipaardsvlei when the tests started. Because of his interest in farming, he frequently visited the trials and discussed their progress extensively with Cook, who was in sole practical control[17]. He has stated that there was no co-ordination with the Chamber of Mines in the initial stages of the tests, and he and Neethling[11] agree that no laboratory or plant-nursery tests initiated the Luipaardsvlei project. Therefore, it is evident that Mrost's tests preceded those at Luipaardsvlei by over three years, although Chenik's first paper appeared four years before those by James and Mrost.

The ultimate linking of the trials at Luipaardsvlei with those undertaken by the Chamber was probably associated with the fact that Cross was a member of both the Chamber of Mines and the Luipaardsvlei Steering Committees on vegetating.

The Progress of the Project

The progress of the Chamber's project, taken from the Chamber's air-pollution records, is as follows. By June 1960, the researchers had a fair idea of the species of plant that would survive, the quantities of lime and fertilizer needed, and the best methods of application. Reed windbreaks were being used to prevent wind erosion from destroying the vegetation on sand deposits. The introduction of these windbreaks on sand deposits and, later, the controlled leaching procedure were the major breakthroughs in the establishment of a completely reliable technique for the vegetating of residue deposits. The development of these two procedures by the research team is outlined later.

In July 1960, the recommendation was made that a mobile team equipped with agricultural machinery should be appointed to undertake operational-scale tests on slime deposits. This unit was to serve as a 'pilot plant' to throw light on problems not evident in the small-scale tests. The unit was to be capable during the planting season of preparing and planting 4 to 6 ha per day. The unit started operating at Crown Mines in September, and by December had completed the preparation and sowing of 148 ha on the tops of slime deposits.

In the initial phase of these operations, the dust that was raised caused severe wear of the engines in the equipment. After a considerable amount of testing, the problem was substantially reduced by the fitting of suitable air filters, which were serviced systematically and frequently[18].

By June 1961 the first sand deposit, viz the 8 ha B deposit at Crown Mines, had been completely grassed and a procedure for the vegetating of the sides of slime deposits was being developed. However, problems were being experienced with high acidity on the East Rand.

In March 1963, the scale of operations had become so great that it was agreed that the unit should be reconstituted into individual sections for slime, sand, services, and administration. Overall control would be vested in the Chamber's Biological and Chemical Research Laboratory. The change became effective on 1st January, 1964. In 1967, control of the Vegetation Unit was vested in the Chamber's Technical Adviser assisted by a committee of representatives from each mining group.

In 1973, it was reported that the Unit had a staff of 24 with 700 labourers, most of whom were in the field. In contrast, now that virtually all the old abandoned deposits have been vegetated, the present strength is 7, with 40 labourers in winter and 60 in summer.

With the consent of Gold Fields of South Africa, Cook in November 1959 was made part-time supervisor of the Chamber trials under the direction of Mrost and James[14]. When the Unit split into separate divisions in January 1964, he was made responsible for all the operations. At the beginning of 1968, he left Gold Fields to continue as a Chamber employee. In 1964, James wrote[3] that the Officer-in-charge, viz Cook, had conducted all the field experimentation during practically the entire course of the vegetating investigations. When he finally retired at the end of 1973, 3430 ha of residue deposits had been vegetated by the Unit. At the end of 1984, when virtually all except the deposits still in use had been vegetated, the total was 4263 ha. It follows that Cook was responsible for vegetating about 80 per cent of the Witwatersrand residue deposits that are no longer used.

The Solution of the Two Major Problems

The two major break-throughs in the establishment of vegetation on gold-mine residues were the decision to use *phragmites* reeds as windbreaks on sand deposits and the development of a mist-spraying technique that made possible the vegetating of excessively acid sites.

Shifting Sands

In 1960, Chenik[1] suggested that it might be necessary to rock clad the slopes of sand deposits to overcome the very real problem of shifting sands, which virtually sand blasted the young plants, covered them, or blew them away[2,6]. James observed that tests had shown that vegetation would grow on sand deposits, and that the main problem was one of sand movement[15].

When the Luipaardsvlei trials started, it was thought that windbreaks would be needed to protect young vegetation on the top of slime deposits. The species tested included cactus, eucalyptus, bamboo, napier fodder, pampas, and *phragmites* reeds[1,2,15]. The use of windbreaks made of 'solid' materials such as logs, plastic sheeting, and wood was also examined. The course of the windbreak trials at the sand test site at Crown Mines is given in Table I.

TABLE I
WINDBREAK TRIALS AT THE SAND TEST SITE, CROWN MINES

Source of Information	Information presented
Chamber records	Mar. 1959. Adequate windbreaks are needed.
Chamber records	Nov. 1959. Wind action severely scours away the sand in front of solid windbreaks.
Research report[19]	Jan 1960. Thousands of windbreak plants are being raised for use on shifting sands. (These plants appear to have been *eragrostis curvula*—see Neethling's observations in the text.)
Chamber records	Apr. 1960. *Phragmites* reeds with leaves had been woven between uprights of live silver poplar but, when the leaves dried, the windbreaks collapsed.
Chenik[2]	Jun. 1960. A photograph shows windbreaks of upright *phragmites* reeds erected by Cook at Luipaardsvlei. (Cook supervised both the Chamber and the Luipaardsvlei projects.)
Chamber records	Jun. 1960. Only small-scale vegetating trials had so far been undertaken.
Chamber records	Jul. 1960. The building of windbreaks on B sand deposit showed promise of success.
Research report[20]	Jan. 1961. A pattern of reedbreaks now covered the B sand deposit and was a success. Jun. 1961. Grassing of the deposit was complete.

Neethling[11] states that Cook initially tried cut-grass windbreaks but that these blew over. After that, *eragrostis curvula* was germinated in packets and then planted out. The *curvula* grew well, but the procedure was very labour-intensive and Cook agreed that a likely suitable species for windbreak use was the *phragmites* reed, which grew in abundance in vleis on the Witwatersrand. Reed stems were then erected to form upright windbreaks on B sand deposit, and they functioned very satisfactorily.

The success of these reed windbreaks in the form of small paddocks solved the problem of sand stabilization in mine residues and enabled the sand deposits to be vegetated.

High Acidity

The success of the vegetating trials on the tops of slime deposits at Crown Mines and Luipaardsvlei led to the formation, in September 1960, of a mobile unit to continue vegetating trials on a larger scale. Its operations were successful until slime deposits of high acidity were encountered during 1961 on the East Rand at New State Areas, Springs Mines, and East Rand Proprietary Mines. At these sites, plants either did not germinate or they died back.

The research team started investigating, but a year later James wrote that, although good cover had been established, fundamental problems remained to be solved in a number of instances. The Chamber of Mines air-pollution records and published papers include the following information on the intensive investigation that provided the solution.

The research team reported in August 1962 that limed trial strips had had to be laid at the acidic sites since the laboratory had determined that the addition of lime was insufficient to sustain the pH value of 5 that is required for plant growth. From such tests, it was eventually concluded that the direct adjustment of pH with lime was possible only where the lime requirement did not exceed about 7 t/ha. Such large additions were in any event costly.

In early 1962, trials were started at Van Dyk and Stilfontein on periodic rotavation of the upper 75 to 150 mm of the surface to determine how the exposure of fresh surfaces affected the acidity. In some of these tests, the lime needed to neutralize the initial acidity was added before rotavation, but it became evident that acid was rising from below the rotavated layer, probably owing to an upward movement of soil moisture in dry atmospheric conditions, to replace the near-surface moisture that had evaporated. Laboratory and field testing showed that, after rain, the acidic regions tended to move downwards[4]. Examination revealed that the acidic layer was confined to the first 2 m of deposit depth. Below this, the material remained in the original alkaline state[4]. Trials also confirmed that the slime was slightly permeable.

Mrost reasoned that the placing of water on top of the deposit would prevent the upward movement of the acidic content due to surface evaporation and would induce a downward flow into the alkaline layers below[4,18]. So, under his direction in late 1962, trials of shallow flood leaching were initiated on a slime deposit at Geduld and another at Venterspost. After a month, the trials were abandoned because, not only was it difficult to obtain a level surface, but the latter consolidated and became unsuitable for plant growth. Experiments with an agricultural spraying system at Venterspost delivered too much water and gave similar results.

Calculations and site tests by the research team confirmed that flooding could be avoided if the quantity of water introduced was regulated to give a downward flow through the slime of not more than 25 to 50 mm per day[4]. At Van Dyk it was found that, owing to the fine grind and consequent abnormally low permeability, even this flow was excessive[18]. Primus-stove jets mounted at intervals on plastic piping and used for 1 to 2 hours a day proved to be an adequate spraying system, and within about a week the pH at the surface rose sufficiently for seeding to be started.

By November 1963 successful vegetating had been accomplished on the lower, very acid slopes of the slime-deposit test site at Crown Mines. Mulch had been laid, followed by mist spraying through plastic jets for half an hour twice a day. The combination of mist spraying and mulching produced very good conditions for germination, and it was stated that, if winter-growing species were included in the seed mixture, the work could continue throughout the year, instead of only in spring and summer.

The Chamber records contain no information on the leaching trials conducted on sand deposits except a statement in March 1964 that, although difficulty was still being experienced with the removal of acid (by leaching) from highly acidic slime, no further work was being undertaken on sand as the procedures then employed were satisfactory.

The records give no information on the total period of leaching. However, R. Smith[21] reports the following.

(1) Initially, the mist-spraying procedure was continued for from 3 to 6 months. During that period, the pH values and pyrite content down to 1 m were monitored regularly. If the plant growth was good, mist spraying was discontinued when the pyrite content at 1 m decreased to 2 g/kg and the pH value was not less than 4. These limits had been established after extensive trials by the research team.
(2) Following instances of plant die-back when the acid level rose after leaching was stopped, it became the accepted practice to continue watering, using agricultural sprays. The length of the total leaching and watering period varied from site to site, always being monitored according to pyrite content and pH value. Approximately 2 years was the normal period.
(3) Because of the greater permeability of the sand deposits, it was normal practice to use agricultural sprays from the start of vegetating operations.
(4) During the time the leaching technique was being developed, the plastic hoses and sprays used were laid horizontally along the ground. As the plants grew, they tended to interfere with the mist spray. In about 1969, it was decided to raise the hoses onto 1 m stilts, which allowed sprays distributing through 360 degrees to be substituted for the 180 degree units previously used on the slopes. The change increased both the area covered by individual sprays and the evenness of the distribution.

A research report[22] dated August 1964 states that the problem of vegetating even highly acid slime deposits that could not previously be vegetated had finally been solved by the development of the mist-spraying technique. It pointed out that the rate of water application was critical: if it was too high, plants could not grow on the tops, and if it was too low, the acid did not sink. On the sloping sides, too high a rate of application could cause the material to slide.

Rotavation or Ridge Ploughing

The rotavation trials at Van Dyk Mine and Stilfontein in 1962 showed that the exposure of fresh near-surface material resulted in rapid oxidation and removal by rain of the acid constituents formed, and that the procedure could be of considerable value in dealing with dams where neutralization would be very costly and where time was not important.

In November, the technique was applied to a large, very acid deposit at the East Rand Proprietary Mines after a system of reed windbreaks had been installed to prevent the weathered material from being blown away. The windbreaks were an immediate success, and within a year the pH value of the surface layers had risen sufficiently to allow the normal dryland vegetating procedure to be followed.

The procedure of loosening and exposing fresh surfaces is still in operation at sites where the acidity is too high to allow successful plant growth. Ridge ploughs are now used, rather than rotavators.

Current Procedures

For completeness, an outline of current vegetation techniques is given below.

Engineering work such as the sealing off of gullies and the construction of perimeter and contour walls, if any, is undertaken. The tops of slime deposits that have lain undisturbed and have oxidized are vegetated by a mechanized, dryland procedure, i.e. without the use of irrigation. Agricultural lime is applied at a rate of about 10 t/ha, the actual quantity depending on the pH value at the surface. Superphosphate is also added, and the surface is then cultivated to a depth of approximately 75 mm. A cocktail of seed varieties, mixed with agricultural lime to assist distribution, is sown and the surface is rolled with a ridged roller. When the germinated plants have emerged, 2–3–2 fertilizer is spread and is followed, when the plants develop to the three-leaf stage, by a second application of 2–3–2 plus LAN (lime–ammonium–nitrate) fertilizer. Four to five weeks after germination, urea is applied lightly, followed a few days later by fertilization with urea, LAN, and potassium chloride.

Costly hand labour has to be used to vegetate the sides of slime deposits. The procedure involves the erection of reed and mulch-bale barriers in gullies, followed by the placing of leaching pipelines fitted with microjet sprays. Lime plus superphosphate is then raked into the surface with hand tines. A mulch of veld grass is applied, and irrigation starts. Normally within a week, when the pH value has risen, the lime–seed cocktail is sown. Two further additions of fertilizer are made within about fourteen days, with another, if necessary, 2½ months later. After that, both the sides and the tops are given further lime and/or fertilizer additions when considered necessary.

Deposit tops of low pH value may be mechanically vegetated using the same procedure as for the slopes, including leaching, but without the mulch application. On very acid tops, shallow ridge ploughing may be undertaken. The valleys between the ridges trap rainwater, thereby assisting leaching. One or two seasons later, after the acidity has been reduced, sowing is started using the dryland procedure.

The treatment of sand deposits is similar to that of the slime slopes with the omission of mulch. Sites of low pH are leached by use of agricultural rainbird sprays, and dryland sowing proceeds when the pH value is correct. To control sand movements, windbreaks of *phragmites* reed are erected in the form of 3 m by 4 m enclosures.

With both sand deposits and slime slopes, additional planting of the following is done by hand: deeprooting *pennesitum macrourum* (hippo grass), *stoloniferous cynodon dactylon, plectastachyus* ('kweek' and star grass), and *hyparrhenia hirta* (a hardy indigenous grass).

Fresh field trials[23] within the past two years have revealed several indigenous grasses and shrubs that propagate readily, are fire resistant, and grow well on mine-residue deposits. These species are currently being planted on a sand and a slime deposit. If the plantings prove as successful as the trials, the use of the new species may constitute a considerable advance in vegetating techniques.

The nil-cultivation technique is today the preferred procedure for vegetating the sides of slime deposits. The mulching, sowing, fertilizing, and irrigating procedures are similar to those described earlier for the sides of slime deposits. However, the surface of the deposit is left undisturbed before being covered with the mulch growth bed. The advantages are that the high cost of loosening and preparing the deposit surface is eliminated, and no acidic material is introduced from below into the deposit surface. It is stated that this change reduces the irrigating period from about 2 years to between 4 and 9 months. As irrigation is costly, the shorter time requirement helps to contain the expenditure.

Costs of Vegetating

It is appropriate to mention that there have been vast increases in vegetating costs due to inflation, increased wages in a labour-intensive operation, and similar causes. The cost of vegetating in the 1962–63 season is given in the Chamber of Mines records as follows per hectare:

Mechanized, dryland sowing	R60 to R75
Sand deposits (where hand labour is needed)	R300
Sides of slime deposits	Slightly less than for sand deposits.

The cost of these operations in 1985 was as follows:

Mechanized, dryland sowing	R1 700 to R1 800 and
Sand deposits (where hand labour is needed)	R20 000 to R23 000
Sides of slime deposits excluding irrigation	R12 000 to R14 000.

In 1984, the question arose as to whether vegetating is still the most effective procedure for the stabilization of residue deposits, particularly in view of the high costs. In a literature survey, 268 references were drawn from the Compendex data base (which abstracts from approximately 35 000 engineering and technological journals), and 215 abstracts were obtained from the Pollution Abstracts data base (drawn from 25 000 primary sources, journals, books, conference papers, etc.). The conclusion reached from the survey is that vegetating is still the only method that is utilized to any significant extent to control air and water pollution from residue deposits[24].

The Vegetation Unit has in recent years supervised or undertaken tests on stabilizing using cement, bitumen mixes, polymer products, etc. These materials have either cracked or dissociated, invariably within 1 to 12 months. Mrost had similar experiences in 1955–56. So, after a lapse of 36 years, there appears to have been little improvement in this field.

Aftercare Maintenance

Starting with the summer season after planting, 5 additional applications of fertilizer are made in the ensuing 10-year period. It was originally hoped that sufficient humic and organic residues would have formed to allow the growth to become completely self-sustaining. This objective has been attained at some sites, principally the tops of slime deposits, but at others it has been necessary to apply additional fertilizer. The interval between these applications is currently uncertain, but is generally 2 to 3 years. After fires occur, which are unfortunately frequent in the dry periods, it is advisable to re-fertilize.

From the latest field trials with fire- and drought-resistant plant species, an ecological system may be evolved that will succeed in reaching the ultimate objective of completely eliminating maintenance within 2 to 5 years from planting.

Conclusion

In conclusion, it is hoped that this paper will *inter alia* assist in placing on record the very major roles played by Mrost and Cook in the elaborate and successful project of establishing vegetation on gold-mine residue deposits: Mrost for the initial concept, the instigation of vegetating trials, and the understanding and conquest of the severe problem of acidity; Cook for both trials and the practical implementation of the project.

Acknowledgement

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References

1. Chenik, D. *J. S. Afr. Inst. Min. Metall.*, vol. 60. May 1960. p. 525.
2. Chenik, D. Addendum to previous paper. *Ibid.*, vol. 63. Jan. 1963. p. 212.
3. James, A.L. C S I R Conference S12, Implications of Air Pollution Control, Sep. 1964.
4. James, A.L., and Mrost, M.J. *J. S. Afr. Inst. Min. Metall.*, vol. 65. Apr. 1965. p. 489.
5. Thurlow, J.R. *S. Afr. J. Sci.*, vol. 33. Mar. 1937. p. 434.
6. Cook, W.H. *Clean Air J.*, vol. 1, no. 1. Aug. 1971. p. 21.
7. Leslie, J.P. *S. Afr. Std Bull.*, vol. 1, no. 12. Aug. 1948. p. 1.
8. Stander, G.J., *et al.* A survey of the river pollution in the Witwatersrand catchment of the Vaal River. *C S I R Spec Rep* W 22, Nov. 1963.
9. Mrost, M.J., and Hattingh, W.H. Investigation into mine effluents on the Witwatersrand. Johannesburg, Chamber of Mines of South Africa Research Laboratory, Jun. 1957.
10. Phillips, J. *S. Afr. J. Sci.*, vol. 33. Mar. 1937. p. 431.
11. Neethling, V.C. Private communication.
12. Donaldson, G.W. *J. S. Afr. Inst. Min. Metall.*, vol. 61. Oct. 1960. p. 183.
13. Chamber of Mines of South Africa. Air pollution records. Letter, 4th Feb., 1959.
14. James, A.L. *Endeavour*, vol. 25. 1966. p. 154.
15. Chenik, D. Discussions on reference 1. *J. S. Afr. Inst. Min. Metall.*, vol. 60. p. 744. Jul. 1960.
16. Chamber of Mines of South Africa. Biological and Chemical Research Laboratory minutes, 13th Mar., 1959.
17. Fennell, M.H. Private communication.
18. Grange, G.H. Private communication.
19. Transvaal and Orange Free State Chamber of Mines. Biological and Chemical Research Laboratory, *Annual report 1959*, no. 1. 1960.
20. Transvaal and Orange Free State Chamber of Mines. Biological and Chemical Research Laboratory. *Annual report 1960*, no. 2. 1961. p. 14.
21. Smith, R. Private communication.
22. Transvaal and Orange Free State Chamber of Mines. Biological Sciences Division report, Aug. 1964.
23. Gaynor, D.B. Colloquium: Mining and the Environment. Johannesburg, The South African Institute of Mining and Metallurgy, 18th May, 1985.
24. Greig, J.D., and Rees, D. Literature survey into methods of controlling pollution from tailing deposits. Johannesburg, Chamber of Mines of South Africa Research Organization, 1984.

Course on hydrocyclones

An intensive short course on hydrocyclones will be held in Oxford (England) on 28th and 29th September, 1987.

Hydrocyclones are widely used in industry for the separation of solids–liquid and solids–solids mixtures, and liquid–liquid and gas–liquid suspensions. They are now well established in the following industries:

- mineral processing
- mining
- chemical engineering
- petrochemicals
- waste-water treatment
- food processing
- pharmaceuticals
- textiles
- power generation.

The course is designed to bring delegates up to date on developments in hydrocyclone technology and industrial practice. The lectures will incorporate the results of recent experience and research with emphasis on

- basic engineering principles
- equipment selection and evaluation
- methods of testing and scale-up
- optimization and applications.

Aimed at engineers and scientists, the course will be of interest to anyone engaged in design, production, and development.

Modern teaching methods and computer graphics will be used on the course in order to achieve maximum efficiency of learning in the time available. All lecturers are actively engaged in hydrocyclone design and operation, and the lectures and the course manual incorporate the results of recent experience and research.

The course will cover the following topics:

- Introduction, elements of particle-fluid interaction
- Efficiency of separation
- Fluid flow and particle motion in a hydrocyclone
- Types of hydrocyclones available
- Installation and operation of hydrocyclones
- Operating characteristics
- The effects of design variables and internal finish
- Theories of separation
- Hydrocyclone selection and scale-up
- Hydrocyclones for liquid–liquid separation
- Degassing of liquids with hydrocyclones
- Combinations of hydrocyclones in series and with other separators
- Applications, economics, and safety
- Sorting of solids according to density with hydrocyclones.

All enquiries should be addressed to

Rosemary Pickford
Course Organizer, Hydrocyclones
BHRA, The Fluid Engineering Centre
Cranfield
Bedford MK43 0AJ
England.
Telephone: 0234 750422. Telex: 825059 bhra g.

Conference on hydrocyclones

BHRA is pleased to announce that the 3rd International Conference on Hydrocyclones will be held at St Catherine's College, Oxford, England, from 30th September to 2nd October, 1987.

Approximately 30 papers will be presented in a series of technical sessions with time allowed for questions and discussion. As in the past, this 3rd BHRA Conference on Hydrocyclones promises to be a truly international event. Offers of papers have been received from 13 countries. Delegates from overseas should find the opportunity to attend the Course (announced above) and the Conference during the same week particularly useful.

An exhibition is planned to enable participating organizations to bring their company products to the attention of potential customers.

Further details are available from

Rosemary Pickford
BHRA
Cranfield
Bedford MK43 OAJ
England.
Telephone: 0234 750422. Telex: 825059 bhra g.

PROTEC

As SAIMM members will know, the Institute supports PROTEC (Programme for Technological Careers) and encourages support from the mining and metallurgical sectors.

On 14th January, Sasol handed over a cheque of R100 000 to PROTEC. Mr Cliff McMillan, Chairman of PROTEC, said that the donation would be of enormous value to PROTEC. The objective of PROTEC is to ensure the career development of promising students from disadvantaged communities, with special emphasis on technology. PROTEC currently has about 2000 high-school students enrolled in its enrichment programmes.

Mr McMillan paid tribute to Sasol for its commitment to PROTEC, which has included financial and managerial support in setting up branches in Sasolburg, and now Secunda. He said the enrichment stemming from regular attendance outside of formal schooling makes it much easier for students to progress with their formal educational studies, and also gives them more insight into their career potential.

Mr Pieter Cox, General Manager of Sasol, said Sasol was well aware of the urgent need for more trained people, adding that the donation was in line with the Sasol mission, which recognizes the Company's responsibility in assisting people to develop and realize their career aspirations.

Mr Pieter Cox, General Manager of Sasol, handing over a cheque of R100 000 to the chairman of PROTEC, Mr Cliff McMillan, at a function held in Rosebank

Crystallization and precipitation

ISCAP '87, an International Symposium on Crystallization and Precipitation, will be held in Saskatoon (Canada) from 5th to 7th October, 1987.

Most hydrometallurgical, chemical, and pharmaceutical processes involve unit operations of crystallization and/or precipitation, either in the processing and purification or in preparation for tailings disposal. This Symposium is aimed at interfacing the basic and applied aspects of crystallization and precipitation.

The following topics will be included in the papers that will be presented at the Symposium:

- Crystallization and precipitation parameters
- Newer techniques for high purity
- High-tech applications
- Equipment used
- Operating problems and solutions
- Tailings disposal.

Further information is obtainable from

International Symposium on Crystallization and Precipitation 1987
P.O. Box 607
Saskatoon
Saskatchewan
Canada S7K 3L6.