

The control of dust from mine dumps

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SYNOPSIS

This paper gives a resumé of the early attempts to control dust from mine dumps, leading up to the research project undertaken by the Chamber of Mines Research Laboratories to explore the possibilities of establishing vegetation on dump surfaces. The ultimate success of this work and details of the principles involved are outlined.

Also given are a brief history of the event that culminated in the introduction of the Atmospheric Pollution Prevention Act in 1965, details of the control of dust in terms of this Act, and a short summary of the dust-control work.

SAMEVATTING

Die referaat gee 'n oorsig oor vroeëre pogings wat aangewend is om stof vanaf mynhoop te bekamp en wat gevolglik aanleiding gegee het tot die daarstelling van 'n navorsingsprojek deur die Navorsingslaboratorium van die Kamer van Mynwese. Die hoofdoel van die projek was om die moontlikheid van begrassing van die hoop te ondersoek. Besonderhede oor beginsels wat toegepas is by die uiteindelijke suksesvolle uitvoering van die projek, word beskryf.

'n Kort opsomming van gebeure wat gelei het tot die instelling van die Wet op die Bekamping van Lugbesoedeling in 1965, met spesiale verwysing na die bekamping van stof kragtens hierdie Wet, word geskets. Ten slotte word 'n oorsig gegee van huidige toepassing van stofbeheer en hoe die verantwoordelike instansies dit hanteer.

EARLY ATTEMPTS

The history of the attempts to control dust from mine dumps in the comparatively dry climate of the Transvaal Highveld is almost as old as the mining industry itself. When mining first started at the close of the last century, it was on virgin veld. There were no towns, and the people living and working on the mines were the first to suffer from the dust nuisance.

The future could not be envisaged, and there was no basis for long-term planning. Towns came into being associated with the mines, and further development followed. The result is that today on the Witwatersrand practically all the present and past mines are within the areas of local authorities.

More than 3000 million tons of rock have been crushed for the extraction of gold, and practically all of this is in the form of sand dumps or slimes dams on the surface.

In the early gold-extraction processes, the residues were discharged as sand to the dumps, and it was the wind-borne dust from these that first created a nuisance. Tipping of rock on the sides of the dumps to cover the sand proved inadequate, for it was not long before the rock in turn was covered by sand unless

the rock had been tipped in depth, which was very expensive even if there was enough rock available. The spraying of dump surfaces with various substances such as molasses, salt, and hygroscopic materials was tried but without success. In 1913, a sludge made from black vlei soil proved comparatively successful, and this method was practised for many years.

In 1921, the 'all sliming' system for gold extraction was introduced. In this process, the residues are discharged as slurries onto what are known as slimes dams, which are built up from the drying residues and which took the place of the sand dumps. Where the surfaces of these dams are dried out, the wind picks up dust from the flat tops, but very little from the side surfaces, which usually become hardened by pyritic reactions. Rock tipping on the sides of slimes dams proved satisfactory but expensive. The 'all sliming' process superseded all others, with the result that, on the Witwatersrand today, there are 6800 ha of slimes-dam surfaces and 1200 ha of sand-dump surfaces.

In 1932, Professor John Phillips, Professor of Botany at the University of the Witwatersrand, gathered all the information on previous attempts to grow vegetation on mine dumps and carried out further experiments. In his paper¹ he stated:

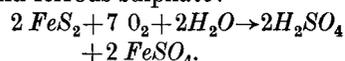
Soil moisture is sufficient during the rains and for some time after—but at this time the acidity is very high owing to the presence of the solvent, and plants are killed by the acids.

When the amount of water sinks, in the dry season, the amount within the reach of roots of plants recently established, is too small, and death from wilting takes place. On the whole, however, it could be said that the dumps are not so much severe upon very hardy drought-resistant plants, in terms of drought, as they are severe in terms of acidity.

and:

unless soil were transported to the dumps, little hope could be advanced for successful fixation, other than by awaiting the results of leaching. The authorities felt that the costs would be very great. Street refuse, old building material, etc., could be used with success.

It was known that pyrite in the mined ore reacts with oxygen and moisture to yield sulphuric acid and ferrous sulphate:



However, the reaction is by no means a simple one, and under most conditions in nature is accelerated significantly by bacterial agencies.

At that time, the Chief Metallurgist to Rand Mines Limited, Mr J. R. Thurlow, stated²:

To review in detail all the methods referred to would take more time and space than schedule permits, but to indicate something of what has been done, mention may be made of some, such as: Spraying with mixtures of salt water and slime from the reduction works; mixtures of precipitated mud resulting from the neutralisation of acid mine water with CaO; mixtures of oil and water; molasses and water; black mud comprising the overburden of fireclay deposits; 'clayey' or similar earths or soils. All these have been tried in turn, but the problem of dust allaying by these media remains, and still awaits a satisfactory and economic solution.

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For the next twenty years attempts to control dust from blowing off the dumps were confined to physical methods, none of which was entirely satisfactory.

By 1953 the problem of stabilizing dump surfaces had not been solved and, when the Chamber of Mines in conjunction with the Council for Scientific and Industrial Research was investigating the structural stability of slimes dams, the Steering Committee looking after the project recommended that the most satisfactory method of stabilizing the dump surfaces would be to establish vegetation on them if this could be achieved.

RESEARCH

The Chamber of Mines Research Laboratories undertook this task and set out to review, not only the problems involved, but other possible methods of stabilization. It is not intended to give a detailed history or record of this research, for the works of James^{3, 4} and Mrost⁴ in this field from 1954 onwards are well known, but the following details are extracted from their papers.

The slimes as deposited are alkaline in reaction, but the Witwatersrand ores contain iron pyrites in varying amount, and oxidation of the pyrite, often accelerated by bacteria, causes a gradual accumulation of acidity in the surface layers of the dump. Acidification occurs to depths of about 6 feet, with a zone of maximum acidity about 12 inches below the surface. The pH value of the material near the surface varies from dump to dump and place to place, depending on how much pyrite is present and the extent to which oxidation has occurred. Acidities up to 2 per cent and pH values as low as 1.5 are encountered, sometimes over areas many acres in extent.

There is some evidence that the acidity moves downwards, particularly during rain, but this movement is halted or reversed by evaporation from the surface. It was decided to try to maintain the downward movement until the acidity reached a depth at which it would enter the alkaline body of the dam, or at any rate not return to the surface during any combination of weather conditions that could be anticipated.

It is neither practicable nor desirable to flood the top of a slimes dam with water, since prolonged flooding compacts the material and produces conditions that are very unfavourable for plant growth.

Studies directed at establishing the practicability of leaching acidity from the surface layers of slimes dams into the more alkaline material below, were accordingly initiated. It was found that the downward move-

ment of the acidity can be encouraged by an extremely fine spray of water, which forms a mist over the surface and retards evaporation. The rate of deposition of water must not exceed the rate at which it can infiltrate into the slimes. The permeability of these is very low, and in practice no system could be devised which deposited water evenly over a large area at a sufficiently low rate. The nearest approach to the ideal was obtained by using fine jets surmounted by striker plates inserted at intervals along piping laid in parallel rows. Observations of the movement of acidity under these conditions confirmed the conclusions based on laboratory studies⁴, and showed that the zone of high acidity could be moved to a sufficient depth, usually within a period of three to four weeks.

Sand dumps still posed problems. This is because the surface moves in wind, and because it is difficult to work on the steep slopes of loose sand. Unless the surface is stabilised temporarily, work on the establishment of vegetation can be lost in a few hours by being buried under several feet of sand or by the surface being blown away. In addition, the abrasive action of ground rock blown across the surface will strip plants to a bare stem.

There are several ways of achieving temporary stabilisation, but the most effective and economic method is provided by a system of low windbreaks made with cut stems of reeds (*Phragmites communis*). The area is divided into small paddocks whose size is determined by the slope of the ground, the windbreaks are erected and the various procedures leading to seeding and mulching can then be carried out. The windbreaks afford excellent protection for the seedlings until they have grown sufficiently to become stable.

From these details it will be seen that the principles of dealing with acid in the sand and slime, and with wind erosion had been established to make it possible to plant vegetation on dump surfaces and thus reduce the dust nuisance.

During this period, experimental work carried out on individual mines, such as Luipaardsvlei⁵, added to the knowledge of techniques required for the establishment of vegetation on dumps. This work was undertaken on behalf of Gold Fields of South Africa, Limited, and was directed by a committee consisting of Mr D. Chenik, Manager at Luipaardsvlei Gold Mine, Mr H. E. Cross, Consulting Metallurgist, and Mr W. H. Cook, the Group Horticulturist.

The work by the Chamber of Mines under the guidance and control of Dr A. L. James and Mr M. Mrost had advanced to such a state that by

1961 a mechanized unit for planting vegetation on dumps had been brought into being. Early in 1963 Mr Cook was appointed Field Manager of this Vegetation Unit, which from 1st January, 1964, became fully operational under the aegis of the Chamber of Mines as an advisory and contracting unit for the planting of vegetation on sand dumps and slimes dams and for associated works.

Fig. 1 illustrates in a simple manner the relation between pyrite, acidity, and pH in waste sand and slimes as the pyrite is oxidized, and acid is produced and then leached out by rain or artificial means. When sand or slime is first delivered or exposed, there is virtually no acid present, the pH of the material being over 7 and the pyrite concentration depending on the amount in the original material. In the graph, values for the concentration of pyrite and acidity are given, but these should be regarded only as examples illustrating the principles involved. As oxidation takes place, the pyrite is reduced, acid is produced, and the pH decreases.

Depending on rainfall conditions, leaching down of the acid from the oxidized layers takes place and the pH begins to increase. During leaching, acid water may move down as much as 5 cm per day, but, if the spraying is stopped, the water, as a result of evaporation and capillary action, may rise up to 1 cm per day. When leaching is done by fine-spray irrigation, this upward water movement can be prevented by control of the spraying time. It is not possible for all the pyrite to be oxidized as some is well protected in the individual grains of the material, and this residue, which is determinable in the laboratory, may be as high as 2000 mg/l as shown in Fig. 1. This simplified explanation gives the basic principles of the actions and reactions, which are dependent on many variables.

As a guide to the conditions in sand or slime for the planting of vegetation, the following details are given.

- (1) If the pH is greater than 3.5 and the pyrite and acid concentrations are less than 3000 p.p.m., planting can be under-

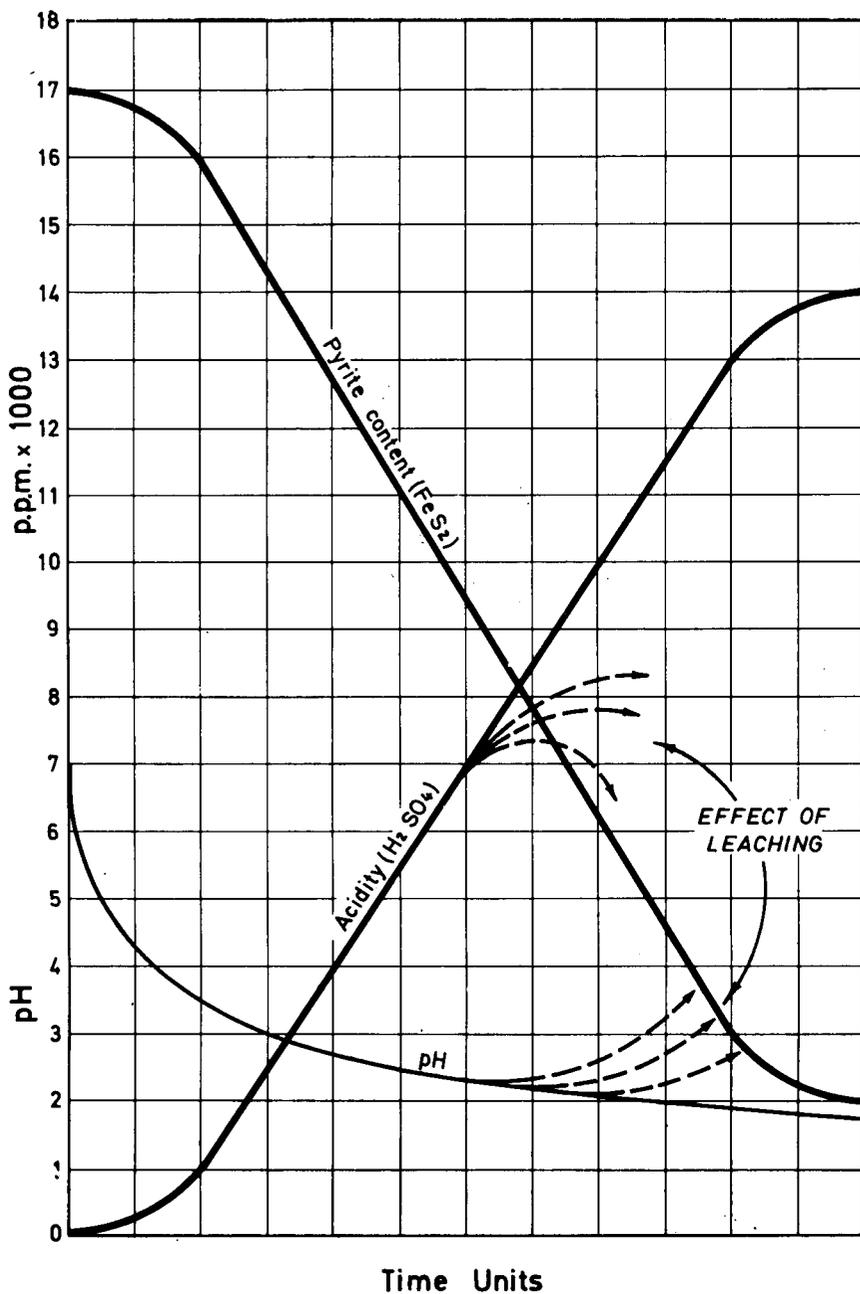


Fig. 1—Relation between pyrite, acid, and pH as pyrite is oxidized, and acid is produced and then leached

taken, provided appropriate additions of lime are given. The quantities required here have been found to be usually 1 ton per acre for every 800 p.p.m. of acidity. After liming and before planting, the pH and acidity values should be checked to ensure that conditions are favourable.

- (2) If the pH is less than 3,5 and/or the pyrite concentration less

than 4000 p.p.m., leaching by fine spray is undertaken.

- (3) If the pH is less than 3,5 and/or the pyrite concentration over 4000 p.p.m., the material should be left to lie fallow for further natural oxidation as it is uneconomic to undertake artificial leaching.

Fig. 2 shows that, from 1958 up to the end of June, 1972, the work

undertaken by the Chamber of Mines in establishing vegetation on dumps had amounted to R3 656 000. Approximately another R1 000 000 has been spent by mines carrying out vegetation-planting programmes on their own. Monies spent on rock dumping on the sides of dumps exceed R1 600 000, and the expenditure on sludge spraying has amounted to R333 388. This gives a total spent on dust suppression from mine dumps by the Mining Industry of over R6 000 000.

The details given so far concern gold-mine tailing heaps, but investigations into dumps on asbestos, coal, diamond, copper, and other base-metal mines and ash heaps have also been undertaken. The treatment of coal-mine dumps is difficult, as most of them burn spontaneously for years, but fortunately today very few new coal mines are near densely built-up areas. The chemical and physical conditions to be contended with on these dumps are usually manageable.

LEGISLATION

About the middle of this century, most countries in the world, including South Africa, became aware of mounting pollution and its attendant problems.

In 1955, the National Physical Research Laboratory of the CSIR began to study atmospheric pollution, including dust fall-out, and in 1956 Dr E. C. Halliday (then head of the General Physics Division of the National Physical Research Laboratory of the CSIR) spent six months in America and England surveying the overall pollution situation in those countries.

For many years the Chamber of Mines Research Laboratories had kept a record of mine-dump dust fall-out, and from 1957 a more detailed survey was undertaken and later reported on by Kitto⁶.

In 1957, at the request of the CSIR, a national committee (with a wide range of representation) was

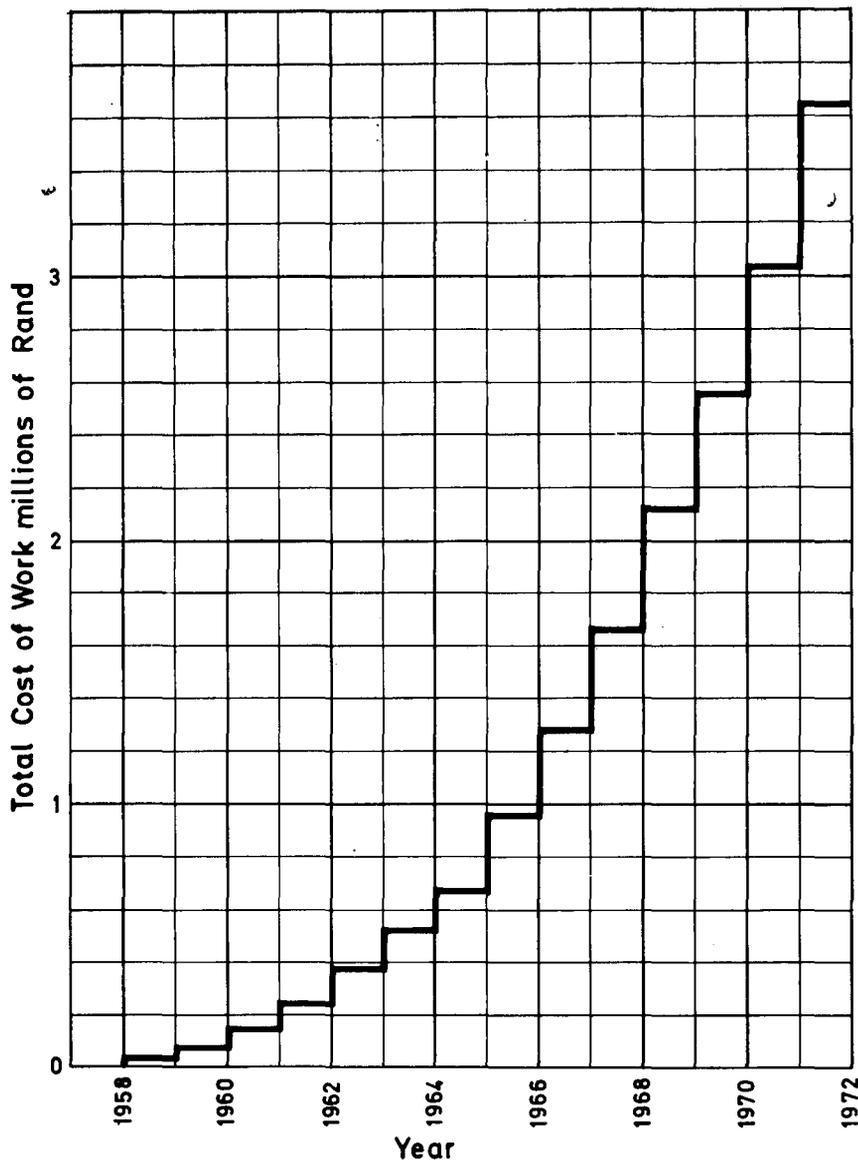


Fig. 2—Total overall cost of the work done by the Vegetation Unit, plotted for the end of June each year

formed to prepare a draft bill for the control of atmospheric pollution, and in April 1965 the Atmospheric Pollution Prevention Act was signed.

To give a general picture concerning dust control from mine dumps, the following is quoted from a paper, entitled 'The Control of Dust in Terms of Part IV of the Atmospheric Pollution Prevention Act 1965', presented in Cape Town at the 1967 Conference on Air Pollution by Mr T. L. Gibbs⁷, the Government Mining Engineer.

A provision in the Mines and Works Act empowers the Inspector of Mines to direct that dumps be dealt with

so as to prevent the dissemination of dust, but difficulty in applying this provision arises from the fact that the Mines and Works Act is confined to safety and health provisions and it has never been established that the health of the general public is endangered by the dust dispersed from mine dumps, which is rather too coarse to be a significant pneumoconiosis hazard. The Atmospheric Pollution Prevention Act has, however, facilitated the legal aspect of applying dust control measures as in terms of this Act such measures are necessary when the dust merely causes or is liable to cause a 'nuisance' and the discretion as to what constitutes a 'nuisance' rests with the chief officer.

The chief officer is the chief air pollution control officer, who, under

the directions of the Minister of Health, implements the requirements of the Act, and the Government Mining Engineer, in consultation with the chief officer, exercises the powers of the chief officer with reference to the mines.

Part IV of the Act concerns dust control, and the main requirements are as follows.

- (a) The control of dust in declared dust-control areas (section 27 (1)). The following magisterial districts were declared dust control areas under this section in January, 1967:
Heidelberg, Brakpan, Vanderbijlpark, Balfour, Boksburg, Oberholzer, Standerton, Germiston, Potchefstroom, Bethal, Johannesburg, Klerksdorp, Nigel, Roodepoort, Odendaalsrus, Springs, Krugersdorp, Welkom, Benoni, Randfontein, and Virginia.
- (b) Any person who in a dust control area has deposited on any land a quantity of matter that exceeds 20 000 yd³ and that causes or is liable to cause a dust nuisance shall take the 'prescribed steps' or adopt 'the best practicable means' (as defined in the Act) for preventing such nuisance.
- (c) Where the depositor is deceased or has (in the case of a corporate body) ceased to exist, or where (the Minister is of the opinion that) it would be impracticable or inequitable to require such person to take such action, the Minister may cause such action to be taken and direct that the cost involved shall be paid by the State, the appropriate local authority, and the owner in such proportions as the Minister may decide.
- (d) Whenever the Government Mining Engineer is of the opinion that a mine is likely to cease mining operations within a period of five years, he shall in writing advise the Minister of Mines and the owner of that mine accordingly and forward a copy of such advice to the Minister (of Health).

(e) The owner of any mine referred to in (d) above who, without the consent of the Minister, disposes of any asset of that mine before he has been furnished with a certificate by the chief officer to the effect that the necessary steps have been taken or that adequate provision has been made to prevent the pollution of the atmosphere by dust arising from any matter emanating from that mine, shall be guilty of an offence.

In requirement (e) the statement 'or that adequate provision has been made to prevent the pollution of the atmosphere by dust' means that the provision of an adequate sum of money shall be set aside by the company concerned as a fund to finance, as and when required, the taking of the 'prescribed steps' or 'adopting the best practicable means' for the abatement of such nuisance. The Mining Groups have established such funds, where considered necessary, with the approval of the appropriate Government Departments, thus removing attendant delays in the winding up of the affairs of a company when the mine has ceased to operate.

Not long after the Act came into force, the Government Mining Engineer asked that the rate of grassing be increased. This was arranged, and, from the information shown diagrammatically in Fig. 2, it will be seen that the rate of planting has increased more than three times since 1964.

DUST-CONTROL WORK

An accepted 'practicable means' of controlling dust from mine dumps has been developed, and the necessary legal machinery has been enacted to ensure that the dust from dumps is controlled. Much work has already been done; more than 2500 ha on the Witwatersrand have been planted and a great deal of experience gained.

Experience has shown that all foreseeable possible long-term developments for an area should be reviewed before the programming of mine dust-control work for that area

is undertaken. Development possibilities such as townships, motorways and railways should always be investigated. Cases have already occurred where a dump has been grassed, only to find that in a short while it will be removed or reshaped for some other development. This is not only a waste of effort but also of funds.

Water-pollution control measures are also required on mine dumps, and these should be co-ordinated with dust-control work in the original planning.

Rainfall run-off from mine-dump surfaces causes erosion (Plate I) and creates a certain amount of water pollution by taking some substances, including acid, into solution. The reduction, or prevention where possible, of this run-off is the basic operation in dealing with water-pollution control from dumps.

In most instances, this is achieved by the construction from slimes-dam material of a perimeter wall round the top of the dam and then internal contour walls so that rain water can be held in the paddocks so formed for ultimate solar evapor-



Plate I—Side of slimes dam showing typical erosion due to rainwater



Plate II—Westgate-Crown Interchange (Johannesburg M1 Motorway). Crown Mines A sand dump in background before dust-control work

ation. These walls, which are always grassed as an anti-erosion measure, also act as very efficient wind breaks. Where possible, holding paddocks are constructed at the toes of slimes-dam walls to hold the rainfall run-off from the sides for evaporation.

On some dumps, especially the older ones, considerable earthworks are required where erosion and/or structural failure has necessitated reshaping of the dump to permit the construction of pollution-control works and the planting of these surfaces.

For some years the Johannesburg City Engineer's Town Planning Department has had a special section dealing with, and co-ordinating, the overall planning of old mining areas, and this section has been of considerable help.

A major part in programming is establishing the priorities for the work to be done. Priorities are established for many reasons; naturally, those areas where dust nuisances create the greatest inconvenience to many are considered first. But these priorities are again modified for other reasons normally involving possible future development. In all cases of abandoned mines, priorities are established by the Government Mining Engineer, and in most other cases his guidance is sought.

One example will be given. Two large slimes dams in the middle of a

residential and industrial area created a considerable dust nuisance when the wind blew. The dust nuisance was created by the top surfaces being disturbed and turned into powder—the local youth used these areas as tracks for motor-cycle racing. Complaints had been received both by the Government Mining Engineer and by the Chamber of Mines. The future development and town-planning zoning of the land on which the slimes dams stood had not been determined, and therefore the owners had not taken any

steps to alleviate the nuisance. It was decided, in discussion by all the parties concerned, that, even in the absence of information on the future planning of the area, a high priority should be given to dust control and that the top surfaces should be divided into sections by throwing up steep banks of slime 4 ft or more high (to act as windbreaks) and grassing them. The paddocks thus formed could later be used as refuse tips, and in the meantime the motor cyclists were prevented from using the area. During the past three years no further complaints have been received, and the problem appears to have been solved at a low cost as an interim measure before town-planning zoning has been completed.

The example is quoted to illustrate the effective liaison that exists between the Government Departments concerned, the Local Authorities, and the Mining Industry, and this accounts for much of the success achieved.

In recent years, the Department of Health, through the Department of Mines, has been and is increasing the financing of dust-control measures on the dumps of mines that ceased to exist prior to the Act. The Department of Water Affairs is also financing work for water-pollution control measures in accordance with The Water Act (1956).

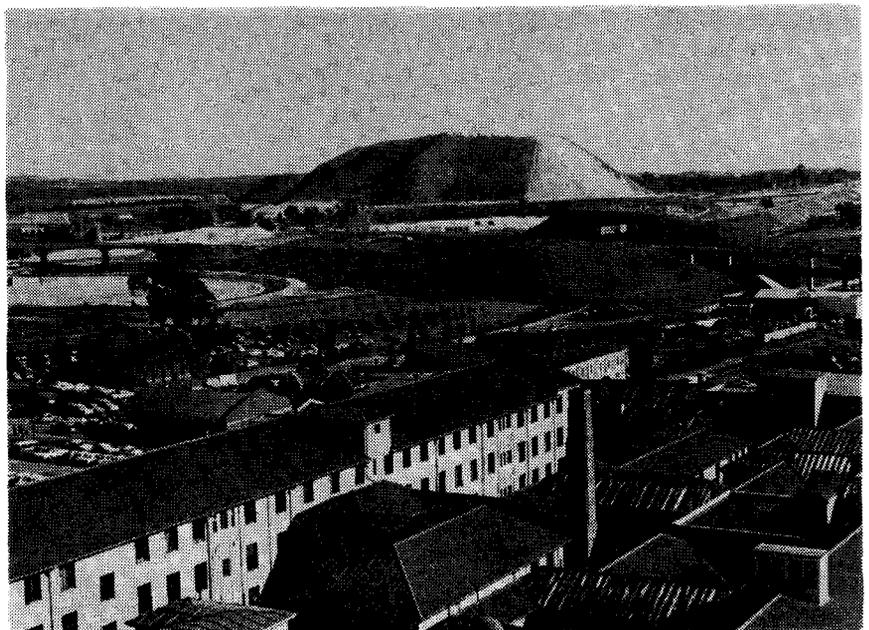


Plate III—Crown Interchange. Crown Mines A sand dump in background after dust-control work

When motorways have been cut through or taken over mine dumps, the Johannesburg City Council has spent considerable sums of money in establishing grass in cuttings or on embankments for dust control and for the prevention of water erosion.

ACKNOWLEDGEMENTS

I have quoted freely from the papers of those who have been intimately associated with the research

and development of this work, as it has not been possible to improve upon their wording. I wish to thank Mr H. T. Clausen, Effluents Advisory Officer of the Chamber of Mines, for assistance in preparing this paper, and the Chamber of Mines of South Africa for permission to present it.

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Plate IV—Reed windbreaks on embankment of Crown Interchange. Crown Mines A sand dump in background