Quantitive Dewatering of Mine Dumps by Vegetation—A Proposition

By E. A. N. GREENWOOD[1] and P. NETCHAEF

C.S.I.R.O. Division of Water Resources, Private Bag,
Wembley W.A. 6014. Australia, and BHP Engineering
P.O. Box 1237, North Sydney NSW. 2060

ABSTRACT

A rationale is presented for the use of vegetation on mine dumps to minimise runoff and infiltration which become vehicles for potential pollution.

The unique topography of mine dumps promotes high atmospheric advection which leads to extraordinary energy levels for evaporation discharge - the driving force of vegetation "pumps". This effectiveness is mainly a function of how well the vegetation will grow on a given site.

Recent advances in technology allow water discharge by vegetation to be measured semi-automatically, accurately and cost effectively. As a result the basis now exists for a thorough evaluation of the optimum mine dump vegetation cover.

This paper presents the current status of dump rehabilitation as seen by the mining industry. The significant prospects for use of vegetation to minimise mine water related problems with subsequent savings in capital and operational cost are also outlined. However, to examine the crucial questions of optimum hydrological ability, suitability and cost effectiveness of various types of dump vegetation a proposition is made to interested parties in the mining industry:

> The CSIRO needs potential study sites to evaluate the hydrological ability of vegetation under mine dump conditions.
>
> In return for such sites the CSIRO will provide expertise, assessment of the site and its hydrological ability and effectiveness.

As a result of this information the CSIRO and the Mining Company can jointly evaluate the cost effectiveness and feasibility of vegetation in minimising problems associated with water on dumps. The possible reward is a much improved mine dump with optimum vegetation resulting in minimal capital and operational cost.

It is believed that such work initially may be funded through the joint persual of research funds.

INTRODUCTION

Rehabilitation of mine dumps is today a common requirement for almost all mines and can be a significant cost item. Generally the spoil must be subjected to grading to prevent excessive erosion. Often selective placement of spoil is required where the general overburden is unsuitable for sustaining vegetation and retention structures are commonly required to prevent turbid runoff or polluted leacheates leaving the minesite in an uncontrolled manner. Apart from these statutory requirements, dumps may also have to be stabilised if excessive water infiltrating the dump gives rise to a destablishing piezometric head. This is particularly a concern where weak or slaking materials are present.

It is common to find that rehabilitation related work may cost upwards of $0.5 million per year. Apart from this direct cost, there is often a more significant indirect cost connected with the common practise of diverting production equipment to undertake the necessary earthworks.

The importance placed on proper rehabilitation is perhaps best illustrated by the fact that most mines carry an annual liability, which can be several million dollars, for each year that rehabilitation falls behind the agreed schedule. This money is payable to the responsible government body in the event that it becomes necessary for the government to step in and undertake the required rehabilitation works.

Since most of the reasons for which rehabilitation of spoil dumps is required are associated with the effect of water on these dumps, there is an obvious and considerable merit in trying to minimise the amount of water reaching and infiltrating the dump.

Traditionally vegetation has been used as cover on most dumps with varying degrees of success, mostly for its aesthetic value. Despite many efforts by the various mines, it would be fair to say that overall the approach to find suitable vegetation is still disjointed and to a large degree governed by a 'trial and error' approach. This has in some cases lead to notable successes, as at Moura coal mine where some of the best lemon trees in the region are grown on the spoil dumps. In other cases failures have caused disillusion with the entire concept.

The interaction of spoil dumps and vegetation is complex. Vegetation pleases the eye, will intercept rain before it reaches the ground, act as an evaporative "pump" on groundwater, and stabilise dumps through the root system. However, this same root system may open pathways for diffusion of oxygen which would cause easier oxidation of potential leacheates in the root system dump. On the other hand, roots are powerful consumers of oxygen. The dump composition obviously affects the health of the vegetation cover and thus its success in achieving the purpose.

Proper consideration of this complex interaction of factors are generally beyond the capability of the individual mine rehabilitation scheme.

The CSIRO has a long standing involvement with the relevant processes and in recent years considerable technological advances have been made which allows for comprehensive analyses of how vegetation interacts with its physical environment.

THE PARAMETERS

As in any other engineering problem little progress can be made unless the required parameters can be measured. It is with the ability to make those measurements now that the vegetation hydrologist has much to offer in the rehabilitation of mines.

The main parameters to be measured are:

* rainfall and throughfall - the difference between them being approximately rainfall interception by the leaf canopy (mm)
* The separation of throughfall into runoff and infiltration (mm)
* The transpiration, or pumping rate, of vegetation (mm^3 water per mm^2 ground area = mm)

Methods for measuring rainfall interception, runoff and infiltration or recharge, and their short-comings in practice, are well known and are not included in this paper. However, recent fully and semi automatic equipment is now available to measure transpiration from ground cover, shrubs and trees such as is used in mining rehabilitation projects.

BASIS FOR OPTIMISM

The reason why the revegetation of mine dumps is not always taken enthusiastically may well be because it is believed that its hydrologic effectiveness is small. And if vegetation is poor, that would be correct. What can be expected if revegetation is vigorous?

To illustrate the hydrological potential of vegetation let us first examine a non-mining example on a ridge site (some similarity with a dump) in a first order catchment on farmland in the lateritic - bauxitic region in the Darling Ranges in southwest WA (annual rainfall about 800 mm).

Originally, the catchment supported a eucalypt forest. In that state, total evaporation (E = rainfall interception plus transpiration plus evaporation from the soil surface) could not have exceeded the annual rainfall of 800 mm. And because there was surface and subsurface flow it would have been less than 800 mm.

CSIRO established a plantation of several eucalypt species along the ridge and when it was six years old E was measured from the three biggest species in the plantation and from the surrounding pasture at regular intervals over a year. Interception of rain was also measured. The values for E are shown in Table I. The trees evaporated six to seven times more than the pasture and three to four times the annual rainfall.

How could the plantation have a total evaporation rate greater than the rainfall? In this case there are three reasons: First, since the soil was fertile there was vigorous growth of roots (high water uptake) and leaves (high evaporation discharge). Second the plantation was well ventilated because of its structure and hill top position (the "clothes - line" effect). Third, an oxygen probe showed that the saturated zone was well oxygenated, which allowed roots to thrive and to take up water directly from the phreatic zone six to eight metres below. Under optimal conditions Morris and Wehner (2) showed that eucalypts can discharge 4000 mm yr, $^{-1}$ or nearly twice pan evaporation.

Table I

Annual rate of total evaporation (E) and rainfall interception (as percent of annual rainfall) from grazed pasture and three species of eucalypt trees (two replicates). The site is a lateritic ridge. After (1)

Vegetation	E (mm yr^{-1})*	Interception (%)
Grazed pasture	370 $\pm$ 50	-
Sugar gum	2660 $\pm$ 140	37 $\pm$ 1
Tasmanian blue gum	2690 $\pm$ 40	21 $\pm$ 4
Spotted gum	2330 $\pm$ 320	24 $\pm$ 0

* E was measured from November 1981 to November 1982 (684 mm rainfall): Interception was measured from February 1982 to February 1983 (499 mm rainfall).

An example of more direct minesite relevance is from the bauxite mining area of Dwellingup, WA. There, the jarrah forest has an understorey of banksia trees and ground vegetation. This understorey is able to evaporate 500 mm, or half of the annual rainfall (Table II) even though the tall trees compete with it for energy and water. In addition the soil is infertile (laterite over bauxite) and the watertable is some 20 m deep.

Table II

Annual evaporation (E) from the understorey of the jarrah forest prior to bauxite mining. Annual rainfall was 987 mm. After (3)

Vegetation	E (mm yr^{-1})	% of Rainfall
Ground vegetation	359 ± 1	36
Middle storey banksias	156 ± 6	16
Total understorey	515	52

Now the need arises to present comparable data from a rehabilitated mine site but none exist on an annual basis. Colquhoun (pres. comm.) gives some daily values of transpiration for eucalypts planted on rehabilitated bauxite mines at Dwellingup. From these conservative estimates of annual evaporation (Table III) have been made.

The estimates of Table III indicate that thorough rehabilitation of bauxite pits at Dwellingup (Alcoa has a good reputation for research and implementation) results in some species evaporating more than the annual evaporation while others will not. That is, species should be chosen for their ability as "evaporateurs".

The outcome of suitable revegetation is that net recharge is substantially reduced.

Table III

Estimated annual evaporation from 10 - year old Eucalyptus plantations in a rehabilitated bauxite mine pit at Dwellingup, WA. Average annual rainfall is 1250 mm (from Dr I Colquhoun, Alcoa Australia).

Species	Evaporation (mm yr^{-1}) Transpiration	Interception & Soil Evap.	Total
resinifera	1300	200	1500
wandoo	400	100	500

Given that bauxite reclamation in the Darling Ranges is relatively effective it can be argued that evaporation values would be higher than for vegetation established on less favourable mining materials. On the other hand the reclamation surface at Dwellingup is below the surrounding surface which is also forested. Therefore advective energy for evaporation could be relatively low. Dump topography in other situations could supply higher aerodynamic advection and so compensate in part for the poorer vegetation growing on it.

Mine dumps in arid regions may be incapable of supporting vigorous vegetation. Such vegetation would be quite ineffective against occasional heavy cyclonic rain. Interception would be low, and runoff would be high unless the material was very porous. In that case infiltration water would pass below the root system before any significant uptake of water could occur. It is therefore possible that revegetation is more effective in discharging water in more temperate and mediterranean climates than in the dry tropics and monsoon tropics.

MEASURING INSTRUMENTS

Presently available techniques for measurements of water use by vegetation are the automatic thermo-electric heat pulse logger (HPL) for trees, and the ventilated chamber (VC) for ground vegetation.

The HPL is based on the fundamental heat flow equation. It sends a heat pulse through the trunk of a tree and measures the rates of convective and conductive heat flow to thermistors located up and down steam of the heat source. Volume fractions of water, air and wood in the trunk are readily determined from core samples of the tree. Software in the logger provides stored output in lh^{-1} for each tree every 15 minutes. Power is from a 12V car battery. The technique is accurate, but for each new species that accuracy should be deomonstrated. The HPL is readily available commercially.

The VC is a transparent tent through which air is blown at a known rate. Vapour pressure is determined from samples of incoming and outgoing air by an infrared gas analyser. Sampling is automatic and the output is mmd^{-1}.

Water use from almost all vegetation on mine sites can be measured by either the HPL or the VC.

THE PROPOSITION

We would appreciate interaction at the conference with those who are interested in the new techniques outlined, the possible cost savings they represent and with those who may have appropriate information from mine sites.

Mine dumps vary greatly in ability to support vegetation because of wide ranges of climate and dump composition. How can the prospects of hydrologic and cost effectiveness be estimated for an individual site? The crucial questions in any particular situation will be:

* What are the sustainable values of rainfall interception and transpiration?
* What is the likely cost saving through improved vegetation?

We, the authors, coming from CSIRO and a mining company, are convinced that a partnership between vegetation hydrologists and individual mining experts is paramount. We have therefore devised a notional proposition.

The CSIRO needs potential study sites to evaluate the hydrological ability of vegetation under mine dump conditions.

In return the CSIRO will provide their unique expertise and quantify the ability of vegetation to dispose of rain water by interception and infiltrating water by transportation (reduction in runoff and of recharge).

The individual mining company in conjunction with the CSIRO may then assess the likely benefits and costs of vegetation as well as future applications of the study results.

Financial assistance may be sought from research funds both by the CSIRO and the mining company.

The proposals are skeletal and could vary with circumstances. We are open to suggestions. The main issue is to get started. CSIRO is ready, so it is in your hands!

REFERENCES

1. Greenwood, E.A.N., Klein, L, Beresford, J.D. and Watson, G.D. Differences in annual evaporation between grazed pasture and Eucalyptus species in plantations on a saline farm catchment. J. Hydrol., Vol. 78 pp. 261-278 (1985).

2. Morris, J.D. and Wehner, B.A. Daily and annual water use by four eucalypt species irrigated with waste water at Robinvale. Research Report No. 329, Victorian Department of Conservation, Forests and Lands, pp. 31 (1987).

3. Greenwood, E.A.N., Klein L., Beresford, J.D., Watson, G.D., and Wright K.D. Evaporation from the understorey in the jarrah (Eucalyptus Marginata Don Ex Sm.) forest, southwestern Australia. J. Hydrol., Vol 80 pp. 337-349 (1985).