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Section: SCIENTIFIC MARKETPLACE

IRRIGATING WITH GYPSIFEROUS MINE WATER

Coal mining in Mpumalanga is beset by a major problem, the generation of large quantities of mine water saturated with gypsum ($CaS0_4$) and high levels of magnesium sulphate ($MgS0_4$). Experience, gained at the Kromdraai opencast section of Landau Colliery, has shown that such water can be used in the short term for agricultural purposes and model predictions indicate that this may also be a sustainable practice.

These early results have led to a joint initiative between the University of Pretoria, the mining industry, the Foundation for Research Development and Water Research Commission at the Kieinkopje Colliery near Witbank to establish the long-term effects of this practice on soils, crops and the surrounding environment. The use of mine water for agricultural purposes came to the fore some three years ago, when the company Amcoal approached the Water Research Commission with a project proposal for the Department of Plant Production and Soil Science at Pretoria University to investigate the effect of irrigation with gypsiferous water on crop growth, soil properties, and catchment salt load. The immediate problem concerned Landau Collieries, but also applies to many other mines.

The investigation was of particular significance because, compared to the 12% arable and 4% high potential crop-land figures for the whole of South Africa, the Mpumalanga highveld (in the former eastern Transvaal) has an average of approximately 30-40% arable and 10-15% prime crop land. The area is therefore pre-eminently suitable for intensive agriculture.

Soils in the area are acidic, however, and rainfall is unreliable. This often leads to crop failure. It seemed obvious that irrigation with minewater, even containing high concentrations of gypsum, could become a major contributor to future agricultural development, and at the same time solve a large surplus water problem for the industry. The Department of Water Affairs and Forestry was concerned, however, that the salts would remain in solution within the soil and eventually land up in the surface and underground water systems.

The Kromdraai study

The Kromdraai open-cast mining operation is being undertaken in accordance with approved environmental practice, where overburden is removed to reveal the coal seam. When the coal has been mined, the overburden is replaced and the land rehabilitated.

A major problem at Kromdraai is acid mine drainage (AMD). By removing soil and blasting through rock to get to the coal, the existing strata are disturbed and, after rehabilitation, the system is then porous, allowing water to seep through. As the rock strata contain pyrite (FeS[sub 2), the percolating water is acidified to pH levels as low as 2.5, making it useless for irrigation and unacceptable for return to the environment. This problem was overcome by installing a liming plant where the iron precipitates out as 'yellow boy' slurry, which is periodically removed.

Water leaving the liming plant has a pH of approximately 7, but is saline, with an electrical conductivity of about 200 mS/m. The quality of this lime-treated mine water is acceptable for release to the Olifants River system and Loskop Dam catchment area, but the quantities are strictly limited by the Department of Water Affairs and Forestry.

The first WRC research project (199496) had three aspects to it. First, Professor Robin Barnard, working with a PhD student, Wilma Mentz, undertook a glasshouse screening trial, to ascertain the reaction of various crops to waters of different qualities. Simultaneously, Dr Nebo Jovanovic conducted a field trial where 20 different agronomic and pasture crops were irrigated with lime-treated AMD at Kromdraai. These field data were used to determine the required model parameters for the final phase, the simulation of the sustainability of irrigating with gypsiferous water.

Initially, a simple dynamic soil water-salt balance-generic crop growth model called SWB (Soil Water Balance) was developed under the leadership of Dr John Annandale. Using long-term generated weather data, 30 years of irrigation with gypsiferous water, followed by 20 years of dryland summer cropping was simulated to determine if the problem of salt disposal was merely being postponed. The soil appeared to act as an effective salt sink, with some 400 t/ha of calcium sulphate being deposited over 30 years, with negligible remobilisation thereafter.

The possibility of gypsum clogging soil pores was not seen as a problem as perennial pastures are often re-established at intervals and the consequent cultivation would, in all probability, open up the soil structure to alleviate the problem.

The study showed that drainage water quality was variable, depending heavily on rainfall. Peak salt levels were around 9 g/I, equivalent to a solution electrical conductivity of about 1300 mS/m. Depending on irrigation strategy, between 400 and 750 t/ha of salts was leached over 30 years. Once irrigation ceased, very little leaching occurred. As far as seasonal variations are concerned, it was observed that most gypsum precipitates in the dry winter season and most leaching occurs in the rainy summer months.

Based on the 50-year simulation, the team concluded that year-round, high frequency irrigation, with a leaching fraction in winter, would be an effective and economical way of utilising this water resource for irrigation without causing irreparable damage to the soil.

The Kleinkopje irrigation project

The Kleinkopje project was begun in January 1997 and is based on the preliminary results from the Kromdraai studies. It is being undertaken by the University of Pretoria (uP) on behalf of the Chamber of Mines, the participating parties being Amcoal, Goldfields of South Africa, JCl, Ingwe and Sasol Coal. The Water Research Commission, the FRD through THRIP (Technology and Human Reo sources in Industry Programme) and Kleinkopje Mine are co-funding the research.

The project leader is H.C. van Zyl (Amcoal), assisted by Dr ED. Tanner of Amcoal Environmental Services. Farming activities are carried out by Anglo American Farms. The UP research team is headed by John Annandale, an irrigation specialist. Annandale is excited about this truly multidisciplinary project, which has brought agronomists, soil scientists and a ground-water hydrologist from three universities together. The project currently has four graduate students on board, with the possibility of more to come. Annandale, together with a pasture science colleague, Professor Norman Rethman, is supervising a student who is looking at the feasibility, water use and economics of different cropping systems. Nebo Jovanovic, also from UP, is monitoring the water and salt balance in the field so that model validation will be possible. Dr Simon Lorentz, a process hydrologist from the University of Natal, is assisting a PhD student, Mbangi Nepfumbada, to quantify the effect of gypsum precipitation on soil hydraulic properties. A colleague of his, Dr Mike Johnston, is mapping soil salinity. Dr Andries Claassens, a soil chemist, is mentoring two master's students, one looking at plant nutritional aspects, the other at quantifying and understanding gypsum kinetics. Professor Frank Hodgson, a geohydrologist from the University of the Orange Free State, is monitoring groundwater levels and qualities to see if the practice of irrigating with gypsiferous water has a significant effect on ground-water quality.

The primary objective of this pilot farmscale agricultural project is to ascertain whether gypsiferous mine water can be used on a sustainable basis for the irrigation of crops and/or amelioration of acidic soils. This objective can only be achieved by developing predictive models for salt and water budgets, and this requires evaluating and refining these models over the three-year research period with summer and winter crops. The long-term salt and water budgets for different scenarios can be modelled once confidence is gained that the predictions are sound.

The Kleinkopje water comes from underground water in pillared workings where opencast mining cannot proceed if the water is not removed. The mine needs to pump around three to four megalitres per day and initially the research team thought that a liming plant would be needed. However, it transpires that, unlike Kromdraai, the water is not highly acidic but already contains gypsum and a fairly high level of magnesium sulphate.

As Annandale explains, the farm-scale activities have required the installation of three epoxy-coated, corrosion-resistant centre-pivot irrigation systems with various nozzle configurations. Two pivots are situated on rehabilitated soils and the third is on a site which will eventually be mined.

'Each centre-pivot system has six towers,' he says. 'The first two areas are over-irrigated, to give a leaching fraction, the second two towers give an optimum field capacity treatment, and the last two areas are under-irrigated. Crop planting is also done outside the irrigation area to provide a dry land control, so in effect we have four water treatments at each site.

'Under each of the three nozzle configurations we have an intensively monitored site with a data logger station. Water content and soil water tension are logged every 15 minutes at several depths. Soil water samplers are used to get soil solution samples and tipping-bucket rain gauges are used to measure rainfall and irrigation. Detailed hydraulic property measurements are also made at each site and soil chemical and physical properties are measured at several depths at the beginning and end of each cropping season.'

Apart from soil and water monitoring, detailed analyses are carried out on the crops themselves. Growth analyses, with crop parameters such as dry matter yield, leaf areas, rooting depth and radiant interception, are being correlated with micro-climatic data collected from an automatic weather station.

'All this is being done to validate and refine the model,' says Annandale. 'If we can predict changes in water potential, water content and conductivity, for example, then we can be reasonably confident in predicting what will happen if we irrigate for 40 to 50 years. The current pilot study is scheduled for completion in July 2000. If we are confident that our model is sound and the results look promising, the Department of Water Affairs and Forestry will in all probability sanction major irrigated farming operations on the Mpumalanga highveld with water of this quality. This will be a fantastic win-win situation, with agriculture in the region receiving a boost, and the mining industry solving a major problem of surplus poor quality water.'

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