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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Mine Water Irrigation

Impact of Irrigation Usage on Groundwater Resources

Investigating the long-term sustainability of irrigating with saline mine water.

Gypsiferous mine drainage: From problem to resource

The disposal of mine drainage is a worldwide problem wherever coal and gold mines are found, whether these be operating mines, or closed underground or opencast workings.

Mining activities in the Mpumalanga coalfields currently result in the production of huge volumes of mine water impacted by acid mine drainage. These waters are mostly neutralised either naturally, during seepage through neutralising geological strata, or artificially, by the addition of lime. Mine drainage is, therefore, often saturated with gypsum.

If this highly saline water were to be released directly into the surface water environment, it would be responsible for unacceptable water quality degradation. As a result, large volumes of water contained in underground and opencast collieries are not being utilised at present. In a water-scarce country such as South Africa, optimal use should be made of all available water resources, saline mine water included.

A novel approach to the utilisation of mine water is irrigation farming. Field research at scales ranging from experimental to semi-commercial over a period of more than ten years has successfully demonstrated the potential of using gypsum-rich mine water for the irrigation of a range of crops without incurring soil salinity or crop production problems.

However, there is ongoing concern, especially among regulatory authorities, relating to the long-term impact that larger-scale implementation of this practice may have on water resource (particularly groundwater) quality and quantity. If irrigation with mine water could be proved sustainable over the long term, excess mine water could then be considered a national asset rather than a liability. Collieries closing down would be able to provide economic advantages for retrenched workers and also create opportunities for small farmers.

The quest for answers

After an extended period of experimental irrigation with mine water at a number of research sites, no significant deterioration of groundwater quality has, as yet, been observed. However, to allow reliable assessments of the longer-term impact of mine-water irrigation to be made, it has been necessary to acquire detailed knowledge regarding the subsurface behaviour of applied mine water. To this end, further research has been aimed at:

- Assessing the effect of mine-water irrigation on groundwater quality and quantity at rehabilitated opencast colliery spoils as well as on undisturbed areas, by first acquiring a better understanding of the hydraulic interaction of irrigated mine water with the underlying aquifers, as well as of migration and attenuation of salt from the irrigated areas.
- Establishing criteria for sustainable mine-water irrigation practice and management as part of integrated mine-water management.

The research has been conducted at five different pilot sites in Mpumalanga, both on undisturbed terrain and in coal-mining spoils. Soil conditions at the pilot sites range from sandy to very clay-like. As a means towards quantifying the impacts of irrigation on groundwater, a comprehensive groundwater monitoring programme at each site has been complemented by detailed on-site investigations of hydraulic and chemical characteristics and processes, further supported by laboratory studies and geochemical modelling.

Fresh insights

Irrigation on undisturbed terrain

Even though irrigation sites differ in terms of soil type, water quality and mining method, the results of soil water and groundwater monitoring as well as of detailed research have provided a convincing conceptual understanding of the general interaction between irrigation and the underlying soils and aquifers. Soils under centre-pivot irrigation with mine water display considerable attenuation capacity. Over the years of irrigation, a large proportion of applied salt has been retained in the upper portions of the unsaturated zones below each pivot.

Under irrigation, soils are generally high in water content throughout the profile, with some drying of the deeper layers during winter when efficient irrigation practice minimises leaching of water below the root zone. Clay-rich layers play an important role in allowing build-up of soil water above these layers.

Besides playing a major role in the vertical flux of the water, clay layers also have an influence on the salt distribution through the soil profiles. Most of the salt is contained in the top two metres of the profile. Geochemical modelling of the soil water indicates saturation of the water with respect of gypsum above one metre, implying gypsum precipitation.

Deeper down, the soil water is unsaturated with regard to gypsum. Analyses reveal that salt retention amounts to about 80% of salt applied over the years of irrigation. Of these retained salts, 40% to 45% is in the soil water, the remainder having been precipitated or adsorbed in the soil.

This implies that over the short to medium term, irrigation with coal mine water should not influence the aquifers to any great degree. Dissolved salts leach to the aquifers at a very low rate, where they are rapidly diluted because of lateral groundwater flux. As a result, salt concentrations detected through borehole sampling remain low, with no boreholes outside the pivot-irrigation areas having shown any meaningful change in water quality as a result of leaching from the irrigated area.

All evidence, therefore, shows that in the short to medium term, irrigation with mine water on soils undisturbed by mining does not hold significant threats to the regional groundwater quality.

Spoils irrigation

The cumulative understanding gained from laboratory and field studies, together with geochemical modelling, has also allowed the construction of feasible conceptual reaction models for predicting the eventual water quality response of the system when coal mine spoils are irrigated in various ways with saline mine water. Important considerations are the reactive nature of the spoils, the irrigation water quality and the way in which the irrigation is managed.

Overall indications are that irrigation on spoils is feasible and potentially desirable. Although the practice will give rise to further water quality deterioration under certain conditions, irrigation over periods of 20 years or less in a particular area will generally be associated with net positive effects on salt loads, particularly if gypsum-rich irrigation water is used.

Impact of larger-scale irrigation

There is no immediate opportunity for increasing the scale of mine-water irrigation in the Mpumalanga area. Excess storage is currently available and some of the water is being treated for potable supply to cities in the area. However, beyond the year 2040, up to 100 Mℓ/day of excess mine water will become available for use. At that point, expansion of irrigation with mine water may become desirable and would best take place on rehabilitated opencast spoils. These are areas already impacted by mining and it could be argued that salts being leached with irrigation water would be feeding into the same system as that from which they originated.

Considering that the amount of mine water available will only be sufficient for irrigating a small portion of the available spoils area, and that some of this water will in any event have to be applied on undisturbed terrain, it can be estimated that mine-water irrigation will add less than 7 500 t/year to the overall salt load. This represents an almost 80% reduction in the annual salt load that could potentially be added to the environment.

It needs to be borne in mine, however, that irrigation does not irreversibly remove the salts, and that the majority of these salts will be remobilised into the groundwater regime in the very long term. Nevertheless, if irrigation duration is limited to periods of about 20 years in each spoils area and if the spacing of the irrigation is such that resultant salinity plumes in the aquifers below each irrigation pivot do not interact, the effects on water quality will be minimal.

Criteria for mine-water irrigation

By combining research findings, fundamental considerations concerning mine-water irrigation, requirements of the regulatory environment and practical experience in implementing mine-water irrigation, it has been possible to define the conditions under which mine-water irrigation can be implemented and to draft associated operational and monitoring guidelines that need to be followed.

These conditions and guidelines have been included in a user-friendly software application called *Groundwater Impacts of Mine-water Irrigation* (GIMI). GIMI takes into account crop types, climate, water quality, soil properties, irrigation water quality, size of irrigation area, spoils geochemistry and aquifer properties in recommending whether irrigation is viable and what monitoring needs to be put in place. The GIMI program is currently available for application, testing and refinement, where necessary.

Further reading:
To obtain this report, ***Determination of the Impact of Coal Mine Water Irrigation on Groundwater Resources Conservation*** **(Report No: 1507/1/08)**, contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; E-mail: orders@wrc.org.za; or Visit: www.wrc.org.za