The environmental impact of seepage from gold mine tailings dams near Johannesburg, South Africa

by

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SUMMARY

Gold mining in South Africa resulted in vast volumes of waste material, mainly in the form of tailings material. Poor management of most of the tailings dams resulted in the release of acid mine drainage that in some cases caused soil degradation and water contamination underneath and around these sites.

Although many tailings dams have been partially or completely reclaimed, their contaminated footprints pose a serious threat to the water quality of the underlying aquifers (e.g. dolomitic aquifers). This study investigated the geotechnical, mineralogical and geochemical parameters of eleven selected partially or completely reclaimed sites situated near Johannesburg. The main objective of the field and laboratory experiments was to assess the pathway of contaminant migration resulting from acid mine drainage from tailings materials through the unsaturated zone into the groundwater system.

Comparing extractable contaminant concentrations with a soil standard from literature represents the environmental short-term impact. In contrast, total element concentrations in the soil compared with background values were used to describe the long-term impact or worst-case scenario. Extraction tests have shown that only a minor portion of contaminants (i.e. Co, Ni and Zn) is mobile in acidic soils. This implies that plant growth could be limited because of phytotoxic elements occurring in the topsoils, complicating rehabilitation measures. In addition, the soils often

contain anomalous trace element concentrations, providing a pool for future contamination. Buffer minerals will eventually be depleted and the subsequent acidification of the subsoil, could result in the remobilization of contaminants from the subsoil into the groundwater system in the long term.

It is important to understand the parameters, which control the balance between retention and mobility of contaminants in soils. Therefore a risk assessment approach would be required for all tailings dams and reclaimed sites to identify those sites, which need rehabilitation and to define the type and extent of remedial measures. Minimum rehabilitation requirements at reclaimed sites could consist of soil management measures such as liming and the addition of organic material and fertilisers to minimise the contaminant migration from the topsoil into the subsoil and groundwater as well as to provide suitable conditions for vegetation growth and future land use. Removal of remaining tailings and excavation of those portions of the soil, which are excessively contaminated, are necessary. Tailings dams which pose a high risk to the environment would require a well-engineered soil and vegetation cover to limit rainfall infiltration into the impoundment, and thus to reduce the oxidation of sulphide-bearing minerals such as pyrite. Long-term monitoring is an absolute prerequisite to ensure the success of rehabilitation, and therefore the safe use of land and water.

(432 words)

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LIST OF ABBREVIATIONS

Abbreviation	*Full word*
AMD	Acid mine drainage
AVG	Average value
CEC	Cation exchange capacity
CIP	Carbon-in-pulp
DWAF	Department of Water Affairs and Forestry, South Africa
EC	Electrical conductivity (usually expressed in mS/m)
EPA	Environmental Protection Agency, USA
ExC	Extractable concentration
ICP-MS	Iductively coupled plasma mass spectrometry
Igeo	Geochemical load index
M	mol
MAX	Maximum value
MIN	Minimum value
MOB	Mobility
n	Total amount of samples (or population)
n. a.	Information not available
n. d.	Not detectable
P & T approach	Pump and treat approach to decontaminate groundwater
PI	Plasticity index
STDEV	Standard deviation
TC	Threshold concentration
TDS	Total dissolved solids (expressed in mg/l)
TER	Threshold excess ratio
TotC	Total element concentration
U.S.C.S.	United States Classification of Soils
WHO	World Health Organisation
XRD	X-ray diffraction
XRF	X-ray fluorescence spectrometry

Some common elements used in this study

Chemical	*Symbol*	*Chemical*	*Symbol*
Aluminium	Al	Manganese	Mn
Arsenic	As	Molybdenum	Mo
Barium	Ba	Nickel	Ni
Cadmium	Cd	Nitrogen	N
Calcium	Ca	Oxygen	O
Carbon	C	Potassium	K
Chlorine	Cl	Radium	Ra
Chromium	Cr	Sodium	Na
Cobalt	Co	Sulphur	S
Copper	Cu	Tin	Sn
Iron	Fe	Uranium	U
Hydrogen	H	Vanadium	V
Lead	Pb	Zinc	Zn
Magnesium	Mg	Cyanide	CN (radical)