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Review

Biological treatment of precious metal refinery wastewater: A review

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Abstract

The refining of platinum group metals (PGMs) generates large volumes of wastewater which is highly contaminated by organic solvents and contains trace amounts of heavy metals. Treatment to reduce chemical oxygen demand and metal concentration to levels allowing reuse in refinery processes can help to alleviate the demand for clean water in arid/semi arid mining regions of the world. Traditional physicochemical treatment options have been favoured in the past for treatment of PGM wastewater but biological treatment is becoming increasingly popular. This review examines the need for treatment of PGM wastewater and various physicochemical technologies that are available for treatment of organic solvents and heavy metals. It also introduces various activated sludge technologies that have been shown to remove 99% of certain solvents, while biosorption has been demonstrated to be very effective in removal of heavy metals. A combination of biological treatment and biosorption can be a viable technology for the treatment of complex and potentially toxic wastewaters. Improved treated wastewater quality can allow for reuse in refinery processes which could lead to significant cost reduction and prove to be environmentally beneficial.

Keywords: Precious metal ores; Solvent extraction; Biotechnology; Reclamation; Wasteprocessing

Contents

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1. Water usage in South Africa

Water is considered to be a vital and limited resource; population growth, industrial developments and other pressures faced by developing countries have lead to structured measures to ensure sustainable management of this important resource. In a country that only receives an annual rainfall of approximately 480 mm – half that of the world average of 860 mm, South Africa experiences a large divide with regard to water quantity and quality that is accessible to rural and urban communities (Morrison et al., 2001). South Africa experiences an irregular distribution of rainfall distribution, with the western regions being more arid in comparison with the eastern regions. The alleviation of the discrepancy of rainfall between the regions was addressed by government with the creation of 19 Water Management Areas (DWAF, 2004). These Water Management Areas are defined catchment regions, 11 of which are faced with an overall water deficit where availability is exceeded by demand (Otieno and Ochieng, 2004). Industrial distribution and uneven evaporation rates compound the stress placed on the natural freshwater reserves, and with many major industrial hubs being clustered in the west, both industrial and domestic demands are high in a predominantly dry region (Mack et al., 2004). Activities involving industry, mining and power generation consume 12.5% of the total amount of water available for use in South Africa, making water the most extensively utilised raw material in a range of industrial processes and thus creating proportional volumes of wastewater (Schutte and Pretorius, 1997). The efficient utilisation of water and minimisation of wastewater generation is an area of increased interest, both for industrialists and environmentalists. Penalties for the discharge of untreated wastewater pose large financial pressures on industries and the pre-treatment of wastewater is becoming more popular and financially sustainable. These restrictions enforced by government along with other sustainable water management strategies ensure that this vital resource is correctly managed (Jooste, 2000).

2. Xenobiotics in the environment

Wastewater streams from metal refineries contain complex mixtures of xenobiotic compounds, many of which are solvents commonly used during the extraction of metals. Xenobiotic compounds including amines and amides are used in extraction of many metals from their ores. Intentional or accidental release of these compounds could be hazardous not only to the environment but also to humans, exhibiting acute or chronic toxicity (Rieger et al., 2002). These compounds are generally poorly degraded in the environment and there has been an increased interest among environmental biotechnologists to optimise existing catabolic pathways to degrade and detoxify these compounds more efficiently. The persistence of synthetically derived compounds is dependent on structure, determined by the sterical orientation and number of particular functional groups in comparison with naturally occurring organic compounds' functional groups (Rieger et al., 2002). Microorganisms have not been exposed to these compounds during evolution and so have not evolved the catabolic enzymes and pathways to efficiently utilise the compounds as a primary energy and carbon source, thus making persistence in the environment a lot longer. Aliphatic or aromatic compounds that carry methyl groups can be used to illustrate this persistence. Methyl functional groups are found naturally and many catabolic pathways and enzymes exist to degrade compounds containing these functional groups, but *ortho*-dimethyl or *vicinal*-trimethyl substituted aromatic compounds, or the branched *tert*-butanol and *tert*-butylmethyl ether aliphatic compounds, contain foreign structural elements limiting degradation and increasing persistence (Rieger et al., 2002).

Synthetic compounds can be biologically degraded more efficiently at high concentrations – such as industrial waste streams, but if intentionally released into the environment their lower concentrations prevent effective degradation due to the absence of readily usable energy sources and inducers (Rieger et al., 2002). Microorganisms have proved to be very useful in the degradation of xenobiotics due to their vast array of potential catabolic pathways and evolutionary potential. They are very easily manipulated genetically, allowing the creation of synthetic catabolic traits and pathways to degrade synthetic compounds (Timmis and Pieper, 1999). A fixed definition of a xenobiotic structure that will limit or prevent degradation cannot be given, but rare functional groups are seen as the primary reason for persistence and many strategies have been developed to degrade synthetic xenobiotics.

3. Extraction of platinum

Platinum group metals (PGMs) consist of ruthenium (Ru), rhodium (Rh), palladium (Pa), osmium (Os), iridium (Ir) and platinum (Pt) and are extremely scarce compared to other precious metals due to their low abundance and the complex processes that are required to extract these metals from ores (Bernardis et al., 2005). In the last few years there has been a dramatic increase in the production of these technologically important metals. These metals are separated using the unique chemistry that the PGMs exhibit. The first chemical characteristic exploited is their nobility, which refers to their extremely high inertia toward dissolution in media in which all other base metals dissolve. This is utilised during the selective leaching of base metals from the sulphide ores (Bernardis et al., 2005). Other chemical characteristics that are exploited include their chloro-complexes, ligand substitution reactions, volatile tetroxides, ion-exchange reactions and oxidation states (Bernardis et al., 2005). All of these chemical characteristics are used not only to refine the PGMs from other metals but also to separate the different PGMs from one another.