Environmental and economic implications of slag disposal practices by the ferrochromium industry: A case study

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Abstract

A large volume of slag is annually produced by the ferrochromium industry and the slag has historically been dumped without any pollution prevention, control or remediation measures. The slag at the ASSMANG Chrome Machadodorp (ACM) plant in Mpumalanga (where this case study was conducted) contains elements that may pose a significant threat to human life and the environment. The objectives of this study were to assess the composition of the slag produced at the ACM plant and classify the slag in terms of the minimum requirements, as prescribed by the Department of Water Affairs and Forestry (DWAF), and to determine the economic implications of compliance with existing statutory requirements, and critically assess the implementation of the minimum requirements in practice.

According to leachability results for the ACM slag, aluminium (Al), iron (Fe) and manganese (Mn) have the potential to leach from the slag in excess of the acceptable risk levels. Using the minimum requirements' prescribed methods, the ACM slag was classified based on these three substances as Hazard Rating II. Total elimination of the production of slag is impossible at this stage and disposal on a permitted H:H landfill site is currently the final waste management option.

Permitting and construction of an H:H landfill site to accommodate all the ACM slag produced over a period of 55 years are conservatively estimated at between R 6.2 m. and R12 m. The cost to remove and dispose of 13×10^6 t ACM slag at the Holfontein landfill site is an estimated R5 900 m. If another permitted H:H landfill site becomes available at Nelspruit, the cost will be reduced to an estimated R4 600 m.

The DWAF minimum requirements document used for this case study is a useful guideline. However, the document was not compiled for use by a layman and the subsequent application requires careful studying and practice. Furthermore, a number of issues, for example, relevant usage of the two different methods for classification and ascribing a higher hazard rating to substances with high K_{oc} values, require clarification.

Introduction

Chromium reduction plants extract chromium (Cr) from chromite ore to produce ferrochromium. Ferrochromium is a mixture of Cr and Fe used in the production of stainless steel.

In South Africa, the submerged electrode arc-smelting process is mainly used for the production of ferrochromium. During the smelting process, an Fe-Cr rich melt (the ferrochromium product) and a slag (waste containing other residual materials) are produced. A large volume of this slag is produced annually by the ASSMANG Chrome Machadodorp (ACM) plant in Mpumalanga and historically this has been dumped without any pollution prevention, control or remediation measures.

The slag contains elements that may pose a significant threat to human life and the environment, for example, hexavalent Cr, Fe and Mn. It further has the potential to produce leachate and subsequent pollution of surface and groundwater resources.

The objectives of this study are to:

- assess the composition of the slag produced at the ACM plant and classify the slag in terms of the minimum requirements, as prescribed by DWAF,
- determine the economic implications of compliance with existing statutory requirements, and
- critically assess the implementation of the minimum requirements in practice.

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This study is limited to the slag emanating from the ACM plant and the statutory requirements pertaining to it in South Africa.

Literature survey

General background

Several different processes are used for the production of ferrochromium. In South Africa, the submerged electrode arc-smelting process is mainly used. During the submerged electrode arc-smelting process, the chromite ore is blended with carbon-rich material (reductants) and fluxes (coke, char and coal) to produce the feedstock. The feedstock is fed into an electric-arc furnace where it is melted (Papp, 2000).

The smelting process uses electrical energy to melt the feedstock, raising the melt to a temperature at which the mixture will chemically react. The net result of the chemical reaction is that carbon (C) combines with oxygen (O) from the ore to form CO and CO_2 gases that evolve from the melted mixture leaving a Fe-Cr rich melt (ferrochromium), as well as a slag (waste material) containing other residual materials. Once enough ferrochromium has been produced, the furnace is opened, permitting the ferrochromium and slag to flow out (Papp, 2000).

Variations in the process, depending on the relevant plant, affect the quality and composition of the product and slag.

ASSMANG Chrome Machadodorp Plant

The ACM plant is situated in Mpumalanga. Two 30 MVA furnaces and one 24 MVA open-arc furnace are currently used at the ACM plant.