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MATERIAL SELECTION AND THE IMPACT ON RECYCLABILITY, GREEN PURCHASING AND CORPORATE SOCIAL RESPONSIBILITY – THE MANGANESE METAL CASE

John E. Heinze[1], Karen Hagelstein[2]
[1]Environmental Health Research Foundation; 7521 Presidential Lane; Manassas, VA 20109, USA
[2]TIMES Limited; Sheridan, WY 82801, USA

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Abstract

Manganese metal is widely used as an alloying agent in the aluminum industry and is available from two distinct production processes. The environmentally preferred process uses sulfur as the catalyst and results in a typical purity of 99.9%. The other process, favored by almost all Chinese manufacturers, uses selenium as the catalyst with the result that the manganese metal contains up to 0.15% selenium but is produced at a lower cost. This has resulted in over 75% of the global market in recent years consisting of selenium-contaminated manganese. A case study demonstrates that use of this material has an impact on the recyclability of the aluminum dross and scrap, where recyclers face metal dust exposure issues and may not be aware of the selenium content that likely triggers hazardous solid waste disposal requirements. Downstream recycling is an important consideration of green purchasing and corporate social responsibility.

Introduction

Historically, supply-chain management for business has been primarily about logistics to ensure the financial bottom line. A more recent development is the realization that a business has the ability to influence the impacts of its suppliers on the environment. This "green purchasing" can take more than one form. Firstly, the contracts can be designed so that the suppliers must be 'environmentally friendly' in order to qualify for consideration. To give a simple example, it might be stipulated that all reports must be printed on 100%-recycled paper.

At the other end of the spectrum, the competing suppliers might be carefully audited for their environmental performance. Which company has had the fewest pollution incidents? Which produces the least waste? Which uses the least energy? These sorts of questions would be factored into the assessment of which supplier is most preferred. This process is already standard practice in government procurement, and its reach is spreading among companies who see strong environmental performance as a competitive advantage.

Corporate Social Responsibility (CSR) takes green purchasing a step further. CSR is about business being accountable for its impacts on all its stakeholders, both internal to the company and external. CSR considerations have led to companies reporting their 'triple bottom line'; that is, their financial, social and environmental performance responsibilities.

The potential reach of this consideration is extensive. For instance, if a business is serious about its impact on stakeholders, and one of its suppliers is using child labor, it would not be considered to be socially responsible unless it sought an alternative source for its materials. This is an especially clear-cut case, but other considerations might include whether or not it is worth spending extra on raw materials from a company that is ISO14001 approved, versus a supplier who is not.

We are now no longer talking about simply getting the cheapest product, or even the cheapest product that meets the specification. The simultaneous requirements to get on-spec, best value products without exposing the business to unnecessary risks (including adverse publicity) and while taking into account environmental and social impacts, lead to the search for a company that can offer the best overall 'service' to the buyer.

The Manganese Metal Case

As a case study of how the purchaser should seek to balance environmental, health and safety (EHS) hazards against costs, we have chosen the manufacture of manganese metal. In this example, two distinct manufacturing processes lead to marked differences in both costs and associated EHS hazards and risks. However, recent trends by producers and purchasers have resulted in a rapid rise in the production of selenium-contaminated – and cheaper – manganese, apparently without the full knowledge of potential EHS hazards and risks.

Manganese metal is made by an electrolytic process. The electro-winning of manganese metal results in a relatively low current efficiency, due to the low reduction potential of elemental manganese, and the subsequent high potential for the evolution of hydrogen. In order to increase the current efficiency and suppress the hydrogen evolution reaction, a catalyst is added to the electrolyte, and it is the choice of catalyst that differentiates the two processes.

On the one hand, there is selenium, favored by almost all Chinese manufacturers (only four of approximately 100 facilities do not use selenium). Selenium is a highly efficient catalyst in this process. The big improvement in current efficiency increases yields and results in a substantial saving in terms of production costs. However, the vast majority of the selenium added to the electrolyte will report to the cathode product, thus contaminating the manganese. The typical purity of manganese from this process is around 99.7%, with up to 0.15% selenium remaining in the metal.

On the other hand, other manufacturers prefer to use sulphur. Although less efficient than selenium, its reaction leads to the production of sulphuric acid at the anode. This acid can be recycled, and does not contaminate the manganese. Therefore, the manganese produced using this catalyst is of higher purity, at around 99.9%.

If it were just a case of the 0.2% difference in purity, it might be that all manufacturers would use selenium as their catalyst. However, selenium is toxic (see text box), and its handling and use have implications for workers, both at the facilities manufacturing the manganese and those handling the manganese product, during metals production and recycling of scrap.

Health Hazards of Selenium. Selenium is an essential trace nutrient with antioxidant characteristics, which is required in very low concentrations (0.070 mg/day) [1]. The margin of safety between the required daily intake and the safe upper daily intake level is relatively small (five times). Selenium compounds can be absorbed into the body by inhalation, through the skin and by ingestion. As odor warning properties are poor, occupational exposure limits are likely to be exceeded before one notices the characteristic garlic/decomposed horseradish odor.

Despite the fact that evaporation of selenium at room temperature is negligible, a harmful concentration of airborne particles can be reached quickly by dispersion [1]. The substance irritates the eyes, skin, the upper respiratory tract and the gastrointestinal tract. Inhalation of dust may cause lung edema. Inhalation of the fume may cause symptoms of asphyxiation, chills, fever, fatigue and bronchitis, although the effects may be delayed. Repeated or prolonged contact with the skin may cause dermatitis, nausea, vomiting, cough, yellowish skin discoloration, loss of nails, garlic breath and bad teeth [2]. Chronic ingestion of selenium compounds may result in cardiovascular, hematological, musculoskeletal, ocular and neurological effects [3].

Hazards at Manganese Metal Manufacturers

It is well documented that environmental controls are less well advanced in China than in developed countries [4]. A recent study documents the differences in the manganese industry.

In 2003, an Environmental Site Investigation (ESI) was conducted at several manganese manufacturing plants in China [5]. All solid waste samples contained high concentrations of selenium and other contaminants, and high concentrations of selenium were detected in all wastewater samples. In two out of five groundwater samples, selenium and other contaminants were at detection levels above Chinese standards. Heavy metals including selenium were also present in local drinking water sources.

It is also evident that it is not just the area of manganese metal processing where environmental performance is better in other parts of the world. A broader examination of manganese processing in South Africa, for example, as detailed in annual reports [6], suggests that overall performance is better, with effluent reduction and improvement programs and waste reduction programs all contributing to better environmental performance.

Implementation of environmental legislation and standards is becoming more of a priority in China, as evidenced by statements at the highest level of government, and also by the increasing frequency and robustness of environmental inspections there [7]. It remains to be seen whether these actions will lead to real environmental and occupational improvements.

Hazards at Manganese Metal Users' Facilities

A recent study has investigated selenium behavior during the alloying of steel with manganese additives [8]. It concludes that about half of the selenium present in the process reports to the gas phase, in the form of selenium dioxide. Small amounts of selenium dioxide (0.2 mg/m^3) released to the occupational work environment may be toxic and can cause health hazards, appropriate occupational protection measures (such as adequate ventilation measures) need to be considered for handling contaminated manganese additions [8, 10].

At secondary aluminum facilities where selenium-containing manganese alloys are processed in furnaces, selenium compounds can be present in dross and uncontrolled stack gas particulate emissions [3]. The baghouse dusts from the furnaces may also contain selenium compounds at concentrations that require hazardous waste disposal.

For example, the 2003 study [3] found that baghouse dust from the rotary furnace at an aluminum recycling site contained residual selenium compounds (105 to 121 mg/kg total selenium) from previous processing of materials. In 2001 and 2002, 36% of the baghouse dust samples were hazardous and 30 % of the total solid waste managed was hazardous waste. Hazardous waste transportation and disposal costs added about $40,000 per year to facility expenses.

Although concentrations of selenium were below the recommended occupational exposure limit, selenium compounds were detectable in the recycling facility workplace air and the combination of exposures to multiple metal fumes and dusts may produce adverse health impacts [1]. If operators spend the majority of their workday in the salt cake area, the US Occupational Safety and Health Administration (OSHA) Time Weighted Average (TWA) limit for total particulates (15 mg/m^3) [11] would be exceeded [1].

Other publicly available data on occupational exposures to selenium in the aluminum and recycling industries are sparse. For instance, OSHA has not conducted a single test for selenium exposure in these industries in over five years [12].

Discussion

Balancing EHS Hazards and Costs

Its superior efficiency makes selenium catalysis of electrolytic manganese production somewhat cheaper than its sulfur alternative, but the former leaves residual selenium in the metal. Both the production of selenium-catalyzed manganese, and its subsequent use in alloying and recycling facilities, liberate that selenium in the gaseous and particulate forms. Potential hazards both to the health of personnel and to the environment may result.

If costs were no issue, it is likely that all companies would readily opt for the lower hazard option – the sulfur-catalyzed material. By avoiding the selenium-catalyzed manganese, there are potential EHS hazards and associated societal costs at the manufacturers and the recyclers that can be diminished. In the absence of information on the magnitude of the potential hazards and costs, it would seem prudent business practice to use sulfur-catalyzed manganese.

Health and environmental impacts among the Chinese manganese suppliers are now well documented [4,5,7], and substantial improvements – to say nothing of employee compensation and resource reclamation – are uncertain. Consequently, purchasing selenium-catalyzed Chinese manganese poses a clear conflict with green purchasing and CSR policies, at least until such time as the Chinese manufacturers demonstrate adherence to generally accepted environmental and health standards, including the relevant regulations of their own country.

There are economic and liability risks to manganese metal users should health or environmental impacts occur at the company or its customers. It is difficult to estimate the magnitude of such risks, but the potential impact could be substantial as demonstrated by the continuing asbestos catastrophe.

Mitigating Risks and Potential Hazards

There is, then, a marked difference between the two manganese production techniques. However, rather than having to make the choice, there is a third way – to try to mitigate the risks.

In view of the documented potential for occupational exposures and hazardous waste disposal requirements [1,3], manganese metal users would seem to have a product stewardship responsibility to inform recyclers of the selenium content of their scrap and dross. An analytical method for determining the selenium content of aluminum has recently been published [13]. The potential impact of selenium content on recyclers illustrates that downstream recycling is an important consideration in green purchasing and CSR policy

At the manganese metal manufacturing and recycling plants, appropriate pollution control equipment and standards on the gas, liquid and solid waste streams can all contribute to a safer working environment for personnel as well as reduce environmental emissions.

The manganese metal user is clearly responsible for the safety of his staff, and should ensure that, if the selenium-contaminated manganese is to be used, that the appropriate safety equipment is available and used.

Air Pollution Controls.

Within operating aluminum and steel furnaces, selenium evaporates out to the molten metal as a metal vapor. It reacts with oxygen to form selenium dioxide gas which cools to form selenium-containing particulates. The gaseous and particulate selenium concentrations depend upon the temperature of the furnaces emissions [14].

The coal combustion industry has reported that selenium and arsenic have the highest variability in removal efficiencies via either baghouse or electrostatic precipitation methods. They are volatile metals and most likely to be concentrated on particulate matter, creating solid waste disposal considerations [9].

The typical control efficiency of fabric filters with lime injection for controlling particulate matter and metal oxides in secondary aluminum processing has been reported to range from 85% to 99%. However, emission factors and collection efficiencies have low confidence ratings due to the deficiency of quality air emissions source tests with accurate metal production rates [14].

Effluent Management. Managing industrial waste effluents containing selenium on a full scale basis usually involves co-precipitation with iron salts at an acid pH, with or without the use of reductants. Other treatment processes include reverse osmosis, anion exchange, and biological treatment. The problems with reverse osmosis and anion exchange are related to the production and disposal of a concentrated brine, which could be classified as a hazardous waste. In addition, these two processes are very expensive and require a high level of operator expertise. The overall performance or treatment efficiency of both these processes is greatly reduced in the presence of high total dissolved solids, which are commonly found in industrial wastewaters [15]. A review of selenium removal technologies indicated that although significant reductions in selenium were possible more than half the technologies did not attain an average effluent level of 0.05 mg/L [16].

Physical treatment processes involving adsorption on media such as granular activated carbon (GAC) or activated alumina, have not found widespread use since they are only partially effective in removing either selenite or selenate. There is an ongoing operation problem associated with regeneration and/or disposal of spent adsorbent.

Solid Waste Management. Solid wastes include solids, semi-solids, liquids and gases under the hazardous waste management regulations. Any waste that contains a specifically listed hazardous waste is regulated regardless of the concentration of any hazardous constituent. The type of hazardous waste is characterized by corrosivity, ignitability, reactivity, and toxicity. Generators, transporters, and treatment, storage or disposal facilities (TSDF) hold special permits to manage hazardous waste and all are required to obtain an EPA identification number. Additional provisions for the generator include proper onsite management of hazardous wastes, obtaining a manifest when hazardous wastes are shipped off site, as well as record-keeping and reporting requirements.

Since most metal producing facilities manage their hazardous wastes onsite, owners and operators of hazardous and solid waste landfills have financial assurance responsibilities. A written estimate of costs for closure, post-closure care, liability and sudden and non-sudden occurrences is required and is to be updated annually. The operation of a TSDF is subject to federal and state regulation and permitting which are both administrative and technical in nature. The administrative standards require that emergency plans be developed, waste received is properly identified, and operating personnel are trained to operate the TSDF and respond to emergencies. The technical standards include general standards which apply to all TSDFs, and specific standards which apply to various types of facilities, such as tanks, containment buildings, surface impoundments, waste piles, and chemical physical, biological treatment facilities. Containers of hazardous waste shipped offsite must be labeled to identify the waste and its hazard class. Hazardous wastes shipments to an offsite TSDF must be accompanied by manifests and are subject to the full hazardous materials transportation regulations.

Variances to hazardous waste land disposal regulations are infrequent for selenium-bearing wastes. In 1999, the EPA granted a site specific treatment variance from the land disposal restrictions treatment standards for two selenium-bearing hazardous wastes at a Chemical Waste Management, Inc. TSDF facility in Kettleman City, California. The final rule allowed stabilization treatment of two specific wastes to alternate treatment standards of 51 mg/L and 25 mg/L selenium TCLP (Toxicity Characteristic Leaching Procedure) as opposed to the land disposal restrictions standard for selenium of 5.7 mg/L TCLP [17]. In December, 2004, the land disposal restrictions site specific treatment variance was withdrawn for a selenium-bearing hazardous waste generated by a glass manufacturing company and disposed in Model City, New York. EPA received a comment on the treatment variance that it deems adverse, and therefore the site specific treatment standard variance will take effect in January, 2005 [18].

The Chinese Situation. In China, the specification and use of pollution control equipment is being enforced more rigorously [4,7], but it is uncertain if this will lead to substantial improvements. To better manage the supply chain and the associated risks, manganese metal users can require that suppliers apply the same EHS standards as they use. This has the additional benefit of reducing the company's own risks while helping to improve the EHS performance of the suppliers. This would seem to be the minimal activity required by green purchasing and CSR policies.

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