

Development of Particulate Matter and Heavy Metal Emission Factors for Kerman Copper Industries

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Abstract

An emission factor is a tool that is used to estimate air pollutant emissions to the atmosphere. It relates the quantity of pollutants released from a source to some activities associated with those emissions. To determine the quantity of pollutant released from copper and its alloys smelting furnaces, 63 samples from emission gases were collected on cellulose ester membrane filters in three 8-hour-shifts within 24 hours during a week at three locations. Samples were weighed and analyzed to measure the heavy metal content by flame atomic absorption spectrometry. The emission factors for location 1, without control equipment, for total particulate matter (TPM), Cu, Zn, Pb, Cr, Ni, and Cd were 87.689, 2.076, 37.071, 0.917, 0.023, 0.074, and 0.021 g/Mg of products respectively. Emission factors for location 3, with dedusting unit as control equipment, were 8.139, 0.152, 3.921, 0.055, 0.003, 0.008, and 0.007 g/Mg for the above-mentioned parameters respectively. Finally those were 95.828, 2.228, 40.992, 0.972, 0.026, 0.082, and 0.028 g/Mg as a whole set respectively. Samples of location 2 were collected from inlet of dedusting unit and their results were used only for dedusting unit efficiency calculation.

Keyword: *Air pollution, Emission factor, Heavy metal, TPM, Copper-smelting industry*

Introduction

Emission factors have long been used as a cost-effective means to develop area-wide emission inventories. Emission inventories are fundamental tools for air quality management. They are used for identifying major contributors of atmospheric pollutants, developing emission control strategies, determining applicability of permitting programs, and other related applications (1). Metallurgical equipment has long been an obvious source of air pollution. The emissions from metallurgical furnaces are sub micron size dusts and fumes and hence are highly visible. Around the turn of the century, one of the most obvious effects of industry on the environment was the complete destruction of vegetation downwind from copper, lead, and zinc smelters (2). Present smelting systems go to pay great expense to prevent the uncontrolled release of

pollutants but in many areas the recovery of the ecosystem will take years and perhaps centuries (3). Main emission from copper and its alloys smelting activities is primarily particulate matter. The smelting process utilizes large volumes of air to oxidize sulfides, zinc, lead and other constituents of molting metals. This oxidation procedure generates particulate matter in the exhaust gas stream. A broad spectrum of particle sizes and grain loading exists in the escaping gases due to variations in furnaces design and in the quality of furnace charges (4). Another major factor contributing to differences in emission rates is the amount of zinc present in scrap feed materials. The low-boiling zinc volatilizes and is oxidized to produce copious amounts of zinc oxide as sub micron particulate (5). Zinc oxide fumes vary from 0.03 to 0.3 μm and are toxic. Lead and lead oxide fumes are extremely toxic and have

been extensively studied. Arsenic, cadmium, bismuth, and other trace metals can also be emitted from many metallurgical processes (2). Fabric filter bag houses are the most effective control technology applied to copper smelters. The control efficiency of these bag houses may exceed 99 percent (6).

Materials and Methods

Place of study This study was carried out at the Smelting Factory of Kerman Copper Industries (KCI). KCI has three separate factories, Smelting, Foiling and Extrusion, all work together and located near Kerman city in the south east of Iran. Smelting factory with three separate electric induction furnaces was the major source of emissions to the atmosphere. The major KCI operations together with emission control system are shown in figure 1.

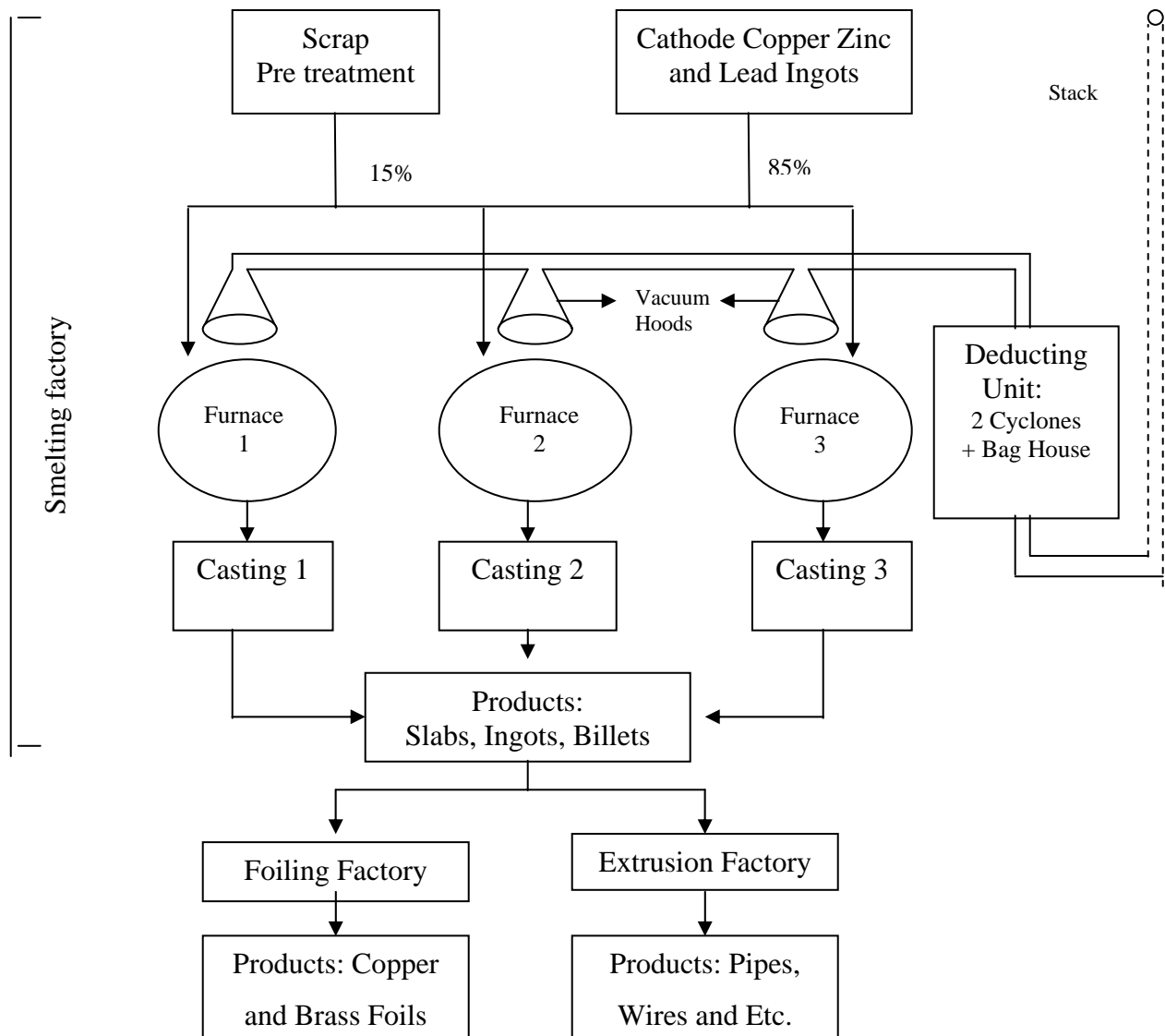


Fig. 1: Flow diagram of KCI operations.

Process description Copper smelting factory is divided into 4 continuous operations: Scrap pretreatment, Smelting, Alloying, and Casting. Pretreatment includes the cleaning and consolidation of scrap in preparation for smelting. Smelting consists of heating and smelting of scrap, and cathode copper in electric induction furnaces. Alloying involves the addition of one or more metals such as zinc and lead to copper to obtain desirable qualities characteristic of the combined metals. Fluxes are added to remove impurities and to protect the melt against oxidation by air (7). Casting of alloyed or copper products is the final step used by the copper smelting industry. The molten metal is poured into molds to produce ingots, billets, and slabs or other casting shapes which are used as primary materials in other copper industries to produce final copper and brass products such as wires, foils, pipes and etc. Mean production of all furnaces was 7 tons in one hour, consisting of about 85 percent cathode copper, zinc, and other metals and about 15 percent scrap of copper only. The factory was operated continuously in three 8-hour-shifts within 24 hours for about 20 days in each month, result an annual production of over 40,000 tons.

Emission and control Emissions from KCI occur during 5 processes include: handling of material, pretreating of scrap, charging the scrap into the furnaces containing molten metals, and transferring the molten metals from one operation to another. More emissions were released when the charging scrap wasn't sufficiently consolidated. Using charcoal as a lining in the molds also generated more dust. Emissions of the furnaces were collected by vacuum hood mounting above each furnace and transferred to the dedusting system consisting of two cyclones and a bag house. After dedusting, the flue gas was released to the atmosphere by a tall stack. During charging the scrap and zinc to the molten metal, the emission

usually exceeded the capacity of the vacuum hoods and entered to the workplace air.

Sampling and analytical methods Samples were collected from three different locations during three working shifts, in the morning 08-16, in the evening 16-24, and at the night 24-08. Sampling sites at the location 1 were under the roof (height 10 m) where the polluted air blew out of the workplace by axial fans and through the open windows. Twenty one samples were collected at this location during 7 days. Sampling sites at the locations 2 and 3 were at the inlet and outlet of dedusting unit serving all furnaces. From each one 21 samples were collected as the same procedure as location 1. Such sampling strategy allowed us to ensure that all changes in work styles, production types and rates in a week have been assessed. Three sampling trains were used in this study simultaneously. Each sampling train contained a vacuum pump, a calibrated Rota meter, a 47 cm open face filter holder for the location 1 and a 47 cm online filter holder for the locations 2 and 3 with the connecting tubes. Mounting a sampling probe on duct walls allowed sampling from inlet and outlet ducts of dedusting unit. Samples were collected on cellulose ester membrane filters. The heavy metals concentrations in the samples were determined following the corresponding ASTM method, D 4185 (8). The samples were first weighed and then treated with concentrated nitric acid to destroy the organic matrix and to dissolve the metal present. The extracts of samples, filter blank, and standards were then quantitatively analyzed for copper, zinc, lead, chromium, nickel, and cadmium by flame AAS using the Varian Spectr. AA-200 atomic absorption spectrometer. The samples of location 2, dedusting unit inlet, were not analyzed for metals but gravimetrically studied and the results were used to assess the dedusting unit efficiency.

Method of calculation There are several available methods for estimating emissions

from industries. Generally, methods that use site-specific data, such as stack sampling data, are preferred to the methods that use industry averaged data. Site-specific data include pollutant concentrations in the exhaust gas and the exhaust gas volumetric flow rate was used in this study to determine the emission factors. The emission rates were divided by the production rates to calculate the emission factors. An emission rate for a particular pollutant was estimated by multiplying the pollutant concentration in the exhaust gas by the volumetric flow rate (9).

Results

The levels of TPM, copper, zinc, lead, chromium, nickel, and cadmium in the samples are presented in tables' 1, 2 and 3. Table 1 shows the TPM levels and the concentrations of the heavy metals in the samples collected from location 1 while tables 2 and 3 show those from locations 2 and 3 respectively.

Table 1: TPM and heavy metal concentrations in the samples from location 1 ($\mu\text{g}/\text{m}^3$)

| Parameter | Min. | Max. | Mean | S.D. |
|-----------|------|-------|------|------|
| TPM | 350 | 3270 | 2725 | 987 |
| Cu | 32.4 | 85.1 | 64.5 | 24.2 |
| Zn | 757 | 1368 | 1152 | 342 |
| Pb | 2.5 | 156.8 | 28.5 | 42 |
| Cr | Ud* | 1.2 | 0.72 | 0.42 |
| Ni | 0.4 | 4.3 | 2.3 | 1.8 |
| Cd | Ud | 2.8 | 0.65 | 0.44 |

Undetectable

Table 2: TPM concentrations of samples from location 2, inlet of Dedusting unit, ($\mu\text{g}/\text{m}^3$)

| Parameter | Min. | Max. | Mean | S.D. |
|-----------|-------|-------|-------|------|
| TPM | 17348 | 31862 | 26824 | 4676 |

Table 3: TPM and heavy metal concentrations in location 3, outlet of Dedusting unit, ($\mu\text{g}/\text{m}^3$)

| Parameter | Min. | Max. | Mean | S.D. |
|-----------|------|------|------|------|
| TPM | 400 | 2105 | 1150 | 800 |
| Cu | 16 | 27.9 | 21.5 | 4.5 |
| Zn | 160 | 707 | 554 | 224 |
| Pb | 5.3 | 11.3 | 7.74 | 2.1 |
| Cr | Ud | 0.9 | 0.45 | 0.2 |
| Ni | 0.2 | 2.6 | 1.15 | 0.8 |
| Cd | 0.1 | 1.8 | 0.95 | 0.4 |

Table 4: TPM and heavy metal emission factors for KCI (g/Mg products)

| Parameter | Location 1 | Location 3 | Total |
|-------------------|------------|----------------|--------|
| Control equipment | None | Dedusting unit | - |
| TPM | 87.689 | 8.139 | 95.828 |
| Cu | 2.076 | 0.152 | 2.228 |
| Zn | 37.071 | 3.921 | 40.992 |
| Pb | 0.917 | 0.055 | 0.972 |
| Cr | 0.023 | 0.003 | 0.026 |
| Ni | 0.074 | 0.008 | 0.082 |
| Cd | 0.021 | 0.007 | 0.028 |

Discussion

TPM levels and heavy metal concentrations in the samples from location 1 were only about 2 times higher than those of location 3. One might expect even higher levels of TPM and heavy metals in samples from location 1, as there was no control equipment for emission at this location. Although the main fractions of furnaces emissions were collected by vacuum hoods and transferred to the dedusting unit for purification but the small fraction of those escaped from the vacuum hoods, while charging and pouring, entered the workplace air, diluted and then released to the atmosphere via the open windows and 8 axial fans, where the samples of location 1 were collected. The area of open windows in the roof above the furnaces was 22 square meters and the mean velocity of moving air through them, measured by vane anemometer was 0.95 m/sec result a

flow rate of $72 \times 10^3 \text{ m}^3/\text{h}$. On the other hand, eight $25 \times 10^3 \text{ m}^3/\text{h}$ capacity axial fans were mounted on the roof to blow out the polluted air. The flow rate of these fans was $2 \times 10^5 \text{ m}^3/\text{h}$. Hence the total flow rate from location 1 was $272 \times 10^3 \text{ m}^3/\text{h}$. This flow rate was then corrected as follow for mean temperature, 36.4°C , and barometric pressure, 871 mbar, of the field: Corrected flow rate (CFR) = $272 \times 10^3 (273 + 25) / (273 + 36.4) \times (871 / 1013)$ CFR = $225,255 \text{ m}^3/\text{h}$. The gas flow rate in the dedusting unit, which measured by using a standard Pitot tube and corrected for mean temperature and barometric pressure was $49540 \text{ m}^3/\text{h}$. The total TPM emission rate from the factory was 670.8 g/h (613.8 and 57.0 g/h from locations 1 and 3 respectively). Emission factors for TPM and heavy metals are presented in table 4. Emission factors in location 1 are about 10 times greater than those of location 3. This is also due to the lack of any control equipment for emissions from location 1. The calculated annual TPM emission from KCI to the atmosphere was $3,864 \text{ kg}$. It could be $11,188 \text{ kg}$ when no dedusting unit is used and it could be reduced to 481 kg in case of filtering the total emissions. The amount of furnaces emission, which escaped from vacuum hoods, was calculated to be about 32 percent. The mean efficiency of dedusting unit was calculated 95.7 percent as follows: Dedusting efficiency = $(26824 - 1150) / 26824 \times 100$

Improvement of ventilation system, designing more effective hoods, and passing the exhaust gases of location 1 through the dedusting system are strongly recommended to reduce the emission factor.

Acknowledgments

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