

ASSESSMENT OF CONCENTRATION OF AIRBORNE HEAVY METALS
IN THE WORKPLACE AND OF OPERATIONAL EFFICIENCY OF A
SCRAP IRON AND STEEL SMELTER.

By

Oyediran Kayode OWOADE

B.Sc. Ed (Physics), 1992

M. Sc. (Engineering Physics), OAU, 1999

A THESIS SUBMITTED TO THE DEPARTMENT OF PHYSICS,
FACULTY OF SCIENCE,
OBAFEMI AWOLowo UNIVERSITY, ILE-IFE, NIGERIA IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D)

IN ENGINEERING PHYSICS

2006

Abstract

Energy and material audit, measurement of concentration of suspended particulate matter (SPM) and elemental analysis of the SPM were carried out in a scrap iron and steel smelter in Lagos, Nigeria. This was with the view to assessing the operational efficiency and the occupational exposure of workers in various production processes of the industry to toxic heavy metals.

Data were obtained through questionnaire served on operation engineers on mass and energy usage, and from purposively selected workers on exposure to toxic heavy metals in the workplace. Estimate of the input and output was computed using equation (1):

$$\sum M_i = \sum M_S + \sum M_f \quad \text{and} \quad \sum M_o = \sum M_p + \sum M_{sl} + \sum M_w \dots \dots \dots (1)$$

(where $\sum M_i$, $\sum M_S$, $\sum M_f$, $\sum M_o$, $\sum M_p$, $\sum M_{sl}$ and $\sum M_w$ were total weight input, total scrap weight used, total output weight, total weight of the product, total slag weight and total weight of the waste rod respectively). Size segregated suspended particulate matter-PM₁₀ (respirable fraction), PM_{2.5} (inhalable fraction) and TSP (Total suspended particulate matter) were collected at the two electric arc furnace sections (EAF-1, EAF-2), the continuous casting section (CC), the rolling mill (RM), a mechanical workshop, (MW), a quality control laboratory (QL) and air-conditioned administrative office (AQ) using Gent PM₁₀ and Negretti 1000 samplers once a month from April, 2003 to March, 2004. A combination of Total Reflection X-Ray Fluorescence (TXRF), Polarized Energy-Dispersive X-ray Fluorescence (EDXRF), Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) and conventional EDXRF techniques were used for the elemental analysis of the collected samples.

The result showed that the average energy input per ton of scrap iron processed in EAF-1 was 15500 ± 150 MJ, while the average energy consumed in melting a ton of the

scrap was 8060 ± 57 MJ with an average energy efficiency of 52 %. The average efficiencies of EAF-2 and CC were similarly estimated to be 59 % and 63 %. On the average $527.9 \pm$

28 MJ of energy was used in rolling one tonne of rod at the RM section. Average mass efficiencies of 91 % (EAF-1), 89 % (EAF-2), 91 % (CC) and 97 % (RM) were obtained using equation 1. The mass concentration values for TSP were 2306 (EAF-1), 3335 (EAF-2), 2534 (CC) and 646 (RM) $\mu\text{g}/\text{m}^3$; for $\text{PM}_{2.5}$ were 190 (EAF-1), 153 (EAF-2), 148 (CC) and 93 (RM) $\mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$ and for PM_{10} were 2051 (EAF-1), 4570 (EAF-2), 3319 (CC) and 687 (RM) $\mu\text{g}/\text{m}^3$. The highest concentrations of toxic heavy metals measured were Cr $6.4 \mu\text{g}/\text{m}^3$ at EAF-2, Ni $1.8 \mu\text{g}/\text{m}^3$ at EAF-2, As $0.4 \mu\text{g}/\text{m}^3$ at EAF-1 and Cd $2.3 \mu\text{g}/\text{m}^3$ at EAF-2. The average concentrations of Zn measured in the $\text{PM}_{2.5}$ samples were 38.0 ± 2.8 (EAF-1), 21.0 ± 1.6 (EAF-2), 40.0 ± 3.1 (CC) and 3.7 ± 0.09 (RM) $\mu\text{g}/\text{m}^3$ while the average concentration of Pb were 5.2 ± 0.13 (EAF-1), 5.9 ± 0.17 (EAF-2), 9.7 ± 0.27 (CC) and 1.4 ± 0.03 (RM) $\mu\text{g}/\text{m}^3$. Also, the average concentrations for Zn measured in the PM_{10} samples were 312 ± 4.2 (EAF-1), 2348 ± 28 (EAF-2), 482.0 ± 5.1 (CC) and 39 ± 1.9 (RM) $\mu\text{g}/\text{m}^3$ while the average concentration of Pb were 59.0 ± 2.9 (EAF-1), 160 ± 5 (EAF-2), 104 ± 3.8 (CC) and 11.0 ± 0.9 (RM) $\mu\text{g}/\text{m}^3$. Exposure concentrations per hour measured at EAF-1 and EAF-2 sections for Zn were $87 \mu\text{g}/\text{m}^3$ and $6.4 \text{ mg}/\text{m}^3$ while for Pb were 15.6 and $178 \mu\text{g}/\text{m}^3$

The study concluded that TSP was above the WHO guidelines of $40 \mu\text{g}/\text{m}^3$ and the Federal Ministry of Environment (FMEnv) Nigeria for industrial environment at all location. Also, average elemental concentrations for Pb and Zn were above the United States Environmental Protection Agency limits of 1.5 and $50 \mu\text{g}/\text{m}^3$. The study also concluded that workers' exposure to heavy metals was higher than Occupational Safety and Health Administration (OSHA) limits.