Ambiental dust speciation and metal content variation in TSP, PM$_{10}$ and PM$_{2.5}$ in urban atmospheric air of Harare (Zimbabwe)

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Abstract Levels of TSP, PM$_{10}$ and PM$_{2.5}$ as well as levels of Pb, Co, Ni and Cd in TSP, PM$_{10}$ and PM$_{2.5}$ have been determined in atmospheric particulates collected at Louis Mountbatten School (Harare). The samples were collected for a period of 6 months from July to December 2002. The average levels of TSP, PM$_{10}$ and PM$_{2.5}$ measured at the site are 106.11, 59.70 and 40.55 mg m$^{-3}$ respectively. The average level of TSP at Louis Mountbatten School is 106.11 mg m$^{-3}$, which is higher than the annual WHO guideline limit of 90 mg m$^{-3}$. The average level of PM$_{10}$ measured at Louis Mountbatten School is 59.70 mg m$^{-3}$, and is higher than the US-EPA and UK-EU guideline limit of 50 mg m$^{-3}$. The average level of PM$_{2.5}$ measured at the site are also higher than the WHO and US-EPA annual guideline limit of 15 mg m$^{-3}$. The analysis of metal concentrations in TSP, PM$_{10}$ and PM$_{2.5}$ was done using Graphite Furnace Atomic Absorption Spectrometry (GFAAS). The analysis showed the following average elemental concentrations: 0.157 mg Pb m$^{-3}$ in TSP, 0.166 mg Pb m$^{-3}$ in PM$_{10}$, 0.185 mg Pb m$^{-3}$ in PM$_{2.5}$, 0.009 mg Co m$^{-3}$ in TSP, 0.007 mg Co m$^{-3}$ in PM$_{10}$, 0.011 mg Co m$^{-3}$ in PM$_{2.5}$, 0.223 mg Ni m$^{-3}$ in TSP, 0.166 mg Ni m$^{-3}$ in PM$_{10}$, 0.180 mg Ni m$^{-3}$ in PM$_{2.5}$ and 0.005 mg Cd m$^{-3}$ in TSP, 0.006 mg Cd m$^{-3}$ in PM$_{10}$, 0.005 mg Cd m$^{-3}$ in PM$_{2.5}$. The levels of Pb and Ni were generally higher than those of Co and Cd and this could have been due to high traffic volumes and various industrial activities in the Workington Industrial Area.

Keywords TSP · PM$_{10}$ · PM$_{2.5}$ · Trace metal · Urban atmosphere · Particulates · Air pollution

Introduction

The increased exposure to air pollution is a major problem accompanying industrialization and the demand for improved quality of life in urban environments. Increased traffic fleets and higher demand for energy are the most notable air pollution causes (Barrat 1990; Melgarejo et al. 1986; Stephen 1981; Agrawal et al. 1980; Fuleka et al. 1983; Ho and Tai 1988; Dube 1992; Musonza 1996; Musekiwa 1998; Zvimba 1999; Zendera 2001). Research has shown that airborne particulates of small size can cause severe respiratory problems particularly in urban areas (Nriagu 1988; Barrat 1990; Pope et al. 2002; Stephen 1981; Mugica et al. 2002; Salma et al. 2002a; Morris 2001; Yamaguchi...
The effects can be magnified dramatically in certain weather conditions hence the need to constantly monitor the levels of pollution by particulates. Dust or Suspended Particulate Matter can be classified according to aerodynamic diameter into:

1. Total suspended particulates (TSP). These are particulates of all sizes that can be collected on a glass fibre filter by a high volume sampler.
2. Particles with aerodynamic diameter of 10 μm or less (PM$_{10}$). This roughly corresponds to the thoracic fraction of particles.
3. Particles with aerodynamic diameter of 2.5 μm or less (PM$_{2.5}$). This corresponds to the respirable particles fraction (WHO 2002).

PM$_{10}$ and PM$_{2.5}$ are considered to be responsible for most of the adverse health effects. Such particles have relatively long residence time in the atmosphere (Noller et al. 1981; WHO 2002; Lazaridis et al. 1999). Epidemiological studies show an association between a wide range of health effects and exposure to particulate matter (WHO 2002; Lazaridis et al. 1999).

Toxicological studies show that health effects seem to be determined by the size and chemical composition of the particles (Mugica et al. 2002; Salma et al. 2002a; Morris 2001; Yamaguchi and Yamazaki 2001; WHO 2002). Small particles (PM$_{10}$ and PM$_{2.5}$), may be inhaled and penetrate into the lungs causing inflammatory reactions in the respiratory system (WHO 2002; Lazaridis et al. 1999). Such particles have high concentration of metals such as lead and cadmium. EU air quality standards for particulates are based on PM$_{10}$ and PM$_{2.5}$ because of the impact such particles are likely to have on health (World Bank Group 1998).

Potentially toxic elements become part of the atmospheric particulates due to their emission from anthropogenic and natural sources. Lead is related to combustion of leaded fuels, smelter processes and other industries. It affects the nervous system, the haeme group syntheses and the vascular system with children being worst affected (Nriagu 1988; Barrat 1990; Melgarejo et al. 1986; Stephen 1981; Agrawal et al. 1980; Ho and Tai 1988; Valerio et al. 1988; Mugica et al. 2002; Akhler and Madany 1993; Folio et al. 1982; Dube 1992; WHO 2002; Lazaridis et al. 1999). Cadmium is a toxic metal for most living species and is emitted by electroplating and battery production industries. Chronic exposure to high levels of cadmium can result in respiratory illness. It is also a possible carcinogen (Nriagu 1988; Barrat 1990; Mugica et al. 2002). Nickel is emitted in vehicle exhaust because it is used as an additive in fuels. It is also used in electroplating. Continuous and prolonged exposure to nickel can produce dermatitis and disorders in the respiratory system (Nriagu 1988; Mugica et al. 2002).

The City of Harare, like other urban sites in the world faces severe air quality deterioration. Almost 1.8 million inhabitants are exposed everyday to pollutant emissions from hundreds of micro industries, from more than half a million vehicles and from natural sources like erosion of soils. The most industrialised area of Harare is the Workington area, in the west and southwest of the City Center. Heavy industrial activities ranging from manufacturing (Lever Brothers Pvt Ltd, Zimbabwe Sugar Refinery (ZSR), National Breweries, Zimbabwe Fertiliser Company (ZFC), Chibuku Breweries, Dairibord Zimbabwe Ltd) of various goods to generation of Thermal Electric Power (Harare Thermal Power Station) exist. Industrial activities also stretch from Willowvale area to Aspindale area. The Graniteside, to the south of the City Center is also a location of light industries which have their own share of toxic emissions in the form of panel beating and spray painting (Zvimba 1999). In the eastern part of the city, Masasa is another industrialised area with Zimbabwe Phosphate Pvt Ltd being a major pollution source. Further to the east, Circle Cement, a cement manufacturing company, affects a wide area, which can be identified by its characteristic dusty environments.

Problem statement

The legislation governing the control of air pollution in Zimbabwe is the Atmospheric Pollution Prevention Act (Chapter 318 of 1971) and the various regulations that come under it. The Act provides for setting of limits for pollutants but does not refer to particle size. There are no regulations for many other important pollutants such as O$_3$. 