AJEHS
African Journal of Environmental
Health Sciences
Volume 1, [1], November, 2014
pp 15-23

# An Assessment of Air Pollution Status in High Schools situated in Coal Mining areas of South Africa

A.C. Olufemi
Department of Environmental Health, Tshwane University of Technology, Pretoria, South Africa
E-mail: mukholams@tut.ac.za

A . Mji
Department of Environmental Health, Tshwane University of Technology, Pretoria, South Africa

M.S. Mukhola
Department of Environmental Health, Tshwane University of Technology, Pretoria, South Africa

Corresponding Author:
A.C. Olufemi, as above

**Abstract**

Globally, coal combustion and mining activities contribute to air pollution problems which could result in various adverse health effects. In South Africa, little is known about these effects especially among children. This study therefore assessed the levels of certain air pollutants which are commonly linked with coal combustion and mining activities. A cross-sectional study design was adopted. Five schools were purposively selected for this study. Air samples were collected from within and outside the classrooms. Radiello® samplers were used to measure the levels of Sulphur dioxide ($SO_2$), Nitrogen dioxide ($NO_2$) and Ozone ($O_3$) while filter pumps were employed for Lead (Pb). Standard laboratory analytical methods were employed for the. The results revealed that $SO_2$, $NO_2$, and $O_3$ were detected within and outside the classrooms at various levels. The concentration of $SO_2$ within the classroom ranged from 3.0 to38 µg/m$^{3.}$ As expected, the levels of $SO_2$ found outside the classroom were much higher ranging from 17 to 84µg/m$^3$. Incidentally, Lead (Pb) levels were generally < 0.007mg/m$^3$ and was only determined at one of the schools due to instruments' instability at other sampling. It is important to know that prolonged exposure to these harmful pollutants by the concerned school community may result in deleterious health effects. The elevated levels of these pollutants in the vicinity of schools investigated are a cause of concern to all the stakeholders in the education sector. Therefore, appropriate measures need to be urgently taken to safeguard the health of the concerned community.

Keywords:
Air pollution, Coal mining, Health risks, Students

## Introduction

The 21-st century has seen major developments in terms of industrialisation throughout the world. A resultant effect of this industrialisation has been the movement of communities from rural areas to urban centres. The sudden influx and concentration of people in different parts of the world has meant that a lot of resources are consumed. Also, the numbers have brought strain that has impacted negatively on the environment. As in other parts of the world South Africa has experienced similar problems.

Air pollution is one such environmental problem experienced in South Africa, especially in communities in the vicinity of industries. For instance, fossil fuel such as coal remains the main source of energy in South Africa and many other countries of the world.

Over the years, studies have consistently indicated that increased combustion of fossil fuel such as coal for electricity generation in most countries is majorly responsible for air pollution (Kampa and Carstanas, 2008).This fossil fuel combustion is reportedly the single largest pollutant accounting for 80% of anthropogenic greenhouse gas emissions (Quadrelli and Peterson 2007). These greenhouse gases are reported to be largely responsible for climate change and global warming (Moore *et al.,* 2008; Burnard and Bhattacharya, 2011) Climate change is expected to have widespread effects on physical, ecological and societal systems **(**Wardekker *et al*.,2012).

In South Africa in particular; coal burning is responsible for high levels of air pollution (Department of Environmental Affairs and Tourism 2005). This country in generating electricity releases 170 million tons of carbon dioxide annually, about 0.7 million tons of nitrogen oxides and about 1.5 million tons of sulphur oxides into the environment (Lloyd, 2002) .These are unsustainable levels of pollutants released into the environment which may have serious implications with regards to human health. For instance, a study conducted in Massachusetts, USA reported that short or long-term exposure to these air pollutants may be associated with increased risks of asthma and reduced lung function in schoolchildren (Brugge *et al.,* 2007).

In fact, it is reported that In South Africa children are major victims of air pollution and this invariably happens within their homes and schools (Mathee, 2003) This agrees with this statement made in a study in the USA that the most susceptible and overlooked population in the US subject to serious health effects from air pollution may be those who live very near major exposure routes (Brugge *et al*. 2007). About pollutants, it is estimated that more than 2 million premature deaths each year can be attributed to the effects of urban outdoor and indoor air pollution (WHO, 2005). In India for example, about 55 per cent of Delhi's population is reportedly directly affected by air pollution that can translate into 3,000 'premature deaths' annually due to air pollution related diseases (Centre for Science and Environment, 2012).

Other than carbon monoxide (CO) and carbon dioxide $CO_2$, coal contains pollutants that are released into the environment thereby causing air pollution which invariably affect human health and the general ecosystem (Sabbioni *et al.,* 1984). Examples of these pollutants are: Ozone ($O_3$), Sulphur dioxide ($SO_2$), Nitrogen dioxide ($NO_2$), Cadmium (Cd), Arsenic (As) and Lead (Pb). Several studies have indicated that exposure to these pollutants may be associated with serious diseases such as increased respiratory symptoms, reduced lung function, nervous system damage in children, cardiovascular diseases, cancers of various forms and increased number of deaths (Okonkwo *et al*., 2001; Brunekreef and Holgate, *2002;* Dockery and Pope, 2002; Stieb *et al.,* 2002).

These chemicals may also affect pregnant women. For example, a research study conducted at the University of Southern California revealed that pregnant women who breathe air heavily polluted with $O_3$ are at risk of giving birth to children afflicted with Intrauterine Growth Retardation [IUGR] (Salam *et al*., 2005). It is also reported that $O_3$ exposure is a major cause of absenteeism among school children in Southern California communities where about 83 percent experience upper respiratory illnesses (Gilliland *et al*., 2001).

For lead (Pb), a study conducted in New Orleans revealed that a high concentration of lead in the blood was responsible for 89% increase in deaths from cardiac diseases (Menke *et al*., 2006). Studies conducted in various places have also reported that exposure to Pb affect children's IQ levels (Schwartz, 1994; Schutz *et al*., 1997; Heinze *et al*., 1998). People who are near combustion sources such as coal fired plants as reported by the Agency for Toxic Substances and Diseases Registry (2002) may be exposed to higher levels of any of these pollutants. For example, a study conducted in Taiwan among children in schools located around coal fired plants revealed that exposure Arsenic may contribute to DNA damage, asthma and allergic rhinitis in children (Wong *et al*., 2005). In Oslo, Norway on the other hand, long term exposure to $NO_2$ has been reported to result in lung cancer among mine workers (Nafstad *et al*., 2003). Similarly in Japan, school children exposed to $NO_2$ were also found to have suffered from respiratory illnesses (Shima and Adachi, 2000).

Regarding $SO_2$, mine workers exposed to this compound in the United States are reported to invariably die from chronic lung diseases (Bridbord *et al*., 1979). Studies on school going children have also reported an association between exposure to $SO_2$ and illnesses resulting in absenteeism in Korea (Park, Lee, Ha *et al*. 2002) and in Europe (Sunyer *et al*., 2003).

## Materials and Methods

### *Study location*

The research site for the study was the town of Emalahleni. This town Emalahleni formerly known as Witbank means a place of coal. It is a city situated on the Highveld of Mpumalanga Province of South Africa. Emalahleni is a coal mining town that also supplies the coal to adjacent power stations for electricity generation.

### *Sampling procedures*

There are about 25 schools in this local municipality. In selecting the sample, the researcher contacted the local department of education who indicated that schools that were within the coal mining and combustion precinct would be the most appropriate to choose. In selecting the schools each school's name was given a unique number written in a piece of paper. The papers were put in a hat and five schools were drawn. When the schools were selected, the researcher approached the principal in each school to explain what she wanted to do. In order to maintain the anonymity of the schools, these were identified as School A, School B, School C, School D and School E.

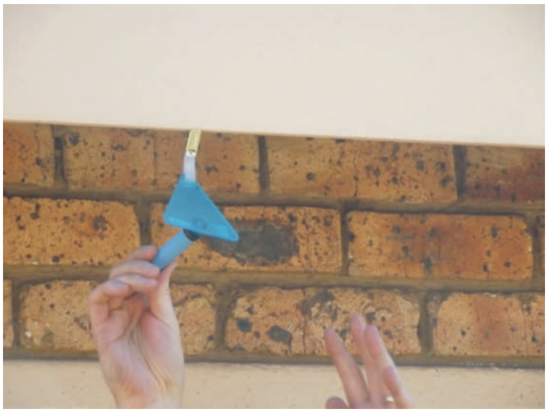
### *Collection of air samples*

The aim of collecting air samples was twofold. Firstly, we hypothesized that compounds such as $NO_2$, $SO_2$, $O_3$, and Pb would be readily available in the air. The hypothesis was based on the fact that the schools were in the proximity of the coal mines and the allied industries such as electricity generating plants. Also, this hypothesis is influenced by the 2005 WHO Air Quality Guidelines (AQGs) designed to offer global guidance on reducing the health impact of air pollution (WHO, 2005; WHO, 2011). Specifically, Radiello cartridges (samplers) measuring the presence of $NO_2$, $SO_2$, $O_3$ and filter pumps were used in measuring the presence of Pb (See figures below). Secondly, we established the levels or densities of each of the identified compounds in the air within the vicinity of the participating schools. Four samplers were put in each school. Two types of samplers were put within the classrooms and two were put outside the classrooms (in the school premises). One sampler was used to collect both $NO_2$ and $SO_2$. The other sampler was used to collect only $O_3$. The first setting up of equipment and sample collection for $NO_2$, $SO_2$, and $O_3$ commenced on June 5, 2012. The $O_3$ samples were taken for analysis after 7 days. Two weeks was allocated for the sampling of $NO_2$ and $SO_2$. So for these two compounds the collection period was June 05 – June 19, 2012.

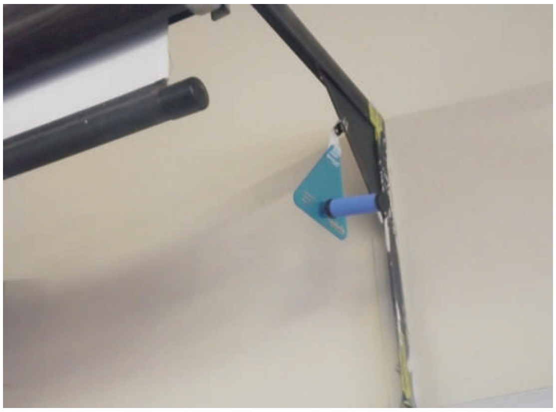
To collect Pb sample, sampling pumps with filters were used to collect this pollutant over a period of 7 days (June 12 - June 19, 2012). In this instance, two sampling pumps were put in two schools, School C and School E. The pumps were connected to an electricity power source and the filters were fixed in the mouth of each pump. The filters were then used to collect air particles from the school environment. On collection of the equipment at School E on the 7th day, it was noticeable that the pump had been touched or tempered with. The equipment at School C however was intact.

*Analysis of samples*

In all, ten Radiello cartridges were collected for the determination of $NO_2$ and $SO_2$. Also; ten cartridges were collected for the determination of $O_3$. Meanwhile, one filter was collected for the analysis of Pb (the other one was tempered with at School E). In analysing for the presence of $NO_2$ and $SO_2$, initially extraction of the cartridges was performed with diluted hydrogen peroxide ($H_2O_2$). The main analysis after the extraction involved the use of ion chromatography. On the other hand, $O_3$ was determined by spectrophotometric analysis according to the method published by Radiello®. Finally, to test for the presence of Pb the exposed filter was initially subjected to acid digestion followed by graphite furnace atomic absorption spectroscopy.



(i)



(ii)

**Figures:** (i) A depiction of how the Radiello samplers were installed (ii) A typical Radiello sampler inside the classroom

(iii)

(iv)

**Figures** iii and iv: A typical Radiello sampler outside the classroom at different schools

## Results

Before presenting the results of this present study, it is perhaps prudent to highlight South Africa's acceptable levels of the pollutants reported here. Table 1 shows the National ambient air quality standards for $NO_2$, $SO_2$, $O_3$ and Pb as proposed by the Department of Environmental Affairs (Department of Environmental Affairs [RSA], 2004)].

Table 1: National ambient air quality standards for $NO_2$, $SO_2$, $O_3$ and Pb

| | Averaging period | Density |
|---|---|---|
| $NO_2$ | 1 hour | 200 µg/m$^3$ |
| | 1 year | 40 µg/m$^3$ |
| $SO_2$ | 10 Minutes | 500 µg/m$^3$ |
| | 1 hour | 350 µg/m$^3$ |
| | 24 hours | 125 µg/m$^3$ |
| | 1 year | 50 µg/m$^3$ |
| $O_3$ | 8 hours | 120 µg/m$^3$ |
| Pb | 1 year | 0.5 µg/m$^3$ |

*Adapted from Department of Environmental Affairs, RSA (2004)*

For all intents and purposes it should be explained that it is difficult to argue for the actual benchmarking with the national ambient air quality standards (Department of Environmental Affairs 2004) and the (WHO 2011) values as the averaging periods differed. All one can do is to extrapolate, however a disadvantage of doing that would be speculative in nature. The compounds detected in the air were $NO_2$, $SO_2$, and $O_3$. In presenting the results, all the calculations in respect of the determination of $NO_2$, $SO_2$, and $O_3$ concentrations were based on an average ambient temperature that was obtained from the South African Weather Service. Table 2 shows the concentrations depicting of NO2, $SO_2$, and $O_3$ in the air in the vicinity of the schools. The values were provided here in order to give a better picture of how the pollutants may affect teaching and learning in schools.

It is observable from the table that the concentrations of $NO_2$ within the classrooms ranged between 19 and 28 µg/m$^3$ while the levels obtained outside the classroom ranged from 9.9 to 27 µg/m$^3$. In fact, the results show that $NO_2$ concentrations within and outside the classrooms were relatively constant. According to WHO (2011), the recommended values for exposure to $NO_2$ should be at a rate of 40 µg/m$^3$ on an annual mean and 200 µg/m$^3$ on a 10-minute mean. As a clarification, an x-hour mean is calculated every hour, and averages the values for x hours. So a 10-minute mean entails exposure to the indicated amount of 200µg/m$^3$ in 10 minutes. Both within and outside the classrooms, learners in this study were exposed to relatively low levels of $NO_2$ (see Table 2).

Table 2: Concentrations of $NO_2$, $SO_2$, and $O_3$ in each School

| School | Location | Sample ID | $NO_2$ (µg/m$^3$) | $SO_2$ (µg/m$^3$) | $O_3$ (µg/m$^3$) |
|---|---|---|---|---|---|
| School A | Inside | O-12-1680 | 19 | 4.8 | 40 |
| School B | | O-12-1691 | 20 | 3.0 | 10 |
| School C | | O-12-1693 | 20 | 6.0 | 30 |
| School D | | O-12-1695 | 26 | 38 | 26 |
| School E | | O-12-1697 | 28 | 8.8 | 18 |
| School A | Outside | O-12-1690 | 9.9 | 17 | 110 |
| School B | | O-12-1692 | 24 | 20 | 82 |
| School C | | O-12-1694 | 19 | 17 | 110 |
| School D | | O-12-1696 | 24 | 84 | 66 |
| School E | | O-12-1698 | 27 | 31 | 75 |

In terms of $SO_2$ the concentrations within the classroom ranged between 3.0 and 38 µg/$m^3$ while outside the classrooms, ranged from 17 to 84 µg/$m^3$. These results indicate that the amounts of $SO_2$ were extremely high within the classrooms of School D. The recommended exposure values to $SO_2$ should be at a rate of 20 µg/$m^3$ on a 24-hour mean and 500µg/$m^3$ on a 10-minute mean (WHO 2011). It may be observed from Table 2 that $SO_2$ levels within the classrooms were well below the recommended levels with the exception of school D. Outside the classroom however, the levels were at the threshold limit for School B while they were high for School E and School D respectively.

In terms of $O_{3,}$ the concentrations ranged between 10 and 40 µg/$m^3$ within the classroom while it was between 75 and 110µg/$m^3$ outside the classroom. According to WHO, (2011) it is recommended that the acceptable levels of exposure to $O_3$ should be at 100 µg/$m^3$, on an 8-hour mean. The results presented in Table 2 show that in all the schools, the exposure levels to $O_3$ were acceptable within the classrooms. However they were beyond the acceptable limit outside the classrooms in School A and School C.

As indicated previously, the filter for Pb placed at School E was found to be tempered with. In fact the filter did not take any particulate material, so no results could be reported from it. The filter placed at School C was actually the one which a Pb reading could be assessed from. With respect to the presence of Pb, atomic absorption spectroscopy was used after acid digestion of the exposed filter. The results indicated that Pb density was < 0.007(µg/$m^3$). It appears that this value would still be low over a period of a year from a South African perspective.

## Discussion

This study revealed that pollutants such as $SO_2$, $NO_2$, $O_3$ and Pb were indeed present in the vicinity of the schools. The reality about these pollutants is that they may result in harmful health effects. About $SO_2$ it is reported that it can affect the respiratory system and the functioning of the lungs. Problems from these are associated with coughing, mucus secretion, aggravation of asthma, and chronic bronchitis that makes people more prone to infections of the respiratory tract (WHO 2011). $SO_2$ is also reported to be the main cause of irritations of the eyes (WHO 2011). The fact that concentrations of $SO_2$ in some of the study Schools were high is a cause for concern. This finding is similar to a study conducted in Montreal, Canada where it was reported that an increase emissions of $SO_2$ resulted in the prevalence of asthma among children who live and attend school in proximity to petroleum refineries (Degar *et al.*, 2012).

With regards to $NO_{2,}$ we reported that the concentrations within and outside the classrooms could be at levels between 19 and 28 µg/$m^3$. This may look innocuous when compared to the WHO (2011) guidelines of 40 µg/$m^3$. The result of this study is in agreement with a study conducted in Helsinki, Finland where the levels of NO2 both within and outside the school were not that high compared with the recommended guidelines (Mukala, 1999). The authors went further to say that both short and long term exposure to this pollutant resulted in respiratory health problems such as cough among the children (Mukala, 1999). In this our study, the main issue though is prolonged exposure to the $NO_2$ by the concerned community. In fact Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase proportionately with long-term exposure to $NO_2$ (WHO, 2011).

The result of $O_3$ Show that in all the schools, the exposure levels were acceptable within the classrooms. However they were beyond the acceptable limit outside the classrooms in School A and School C. For instance $O_3$ is reportedly responsible for breathing problems. A study conducted in New York reported a similar finding where increased levels of ambient $O_3$ resulted in chronic Asthma and hospital admissions among exposed children (Lin, Liu, Le & Hwang 2008). However, it is generally reported that $O_3$ may trigger asthma, reduce lung function and cause lung diseases (WHO, 2011).

In this study, the amount of Pb measured at School C was found to be < 0.007 µg/m$^3$. This amount of Pb is reasonably low because in the US for example, the recommended air quality level for Pb is 1.5 µg/m3 for a maximum quarterly calendar average (United States Environmental Protection Agency 2012). In fact the WHO (2004) recommended value is 0.5 µg/m$^3$ to 1.0 µg/m3 on an annual mean.

A good aspect about the Pb content in this study is that it was extremely low. This is in contrast to a study conducted in inner city schools in the Western Cape Province of South Africa. In that particular study, it was reported that children were at risk of excessive exposure to environmental Pb because and over 90% of their blood had levels of 10 µg/m$^3$ (Mathee *et al.,* 2006). The Western Cape study was comparable with a South Western Nigerian study that reported high levels of Pb in the air in the school environment. Further, this Nigerian study reported high levels of Pb in the urine of children in both urban and rural schools which were above the recommended WHO air quality guidelines (Esimai and Awotoye, 2009)

It may be argued however that the concentrations of some of the air pollutants reported in this study were not that high. The problem here though is prolonged exposure. For instance, learners starting in Grade 8 in one of the schools are likely to be exposed to the pollutants for the next five years if they are to study there until Grade 12. What the compounded effect of this exposure results in, is a cause for concern. It is critical therefore that better environmental pollution management systems should be implemented by the mines and the allied industry. This could be achieved by these entities assisting in ensuring that there is a marked decrease in the amounts of the pollutants they churn out. Major reductions will certainly assist learners and educators breathing pollution free air. About this issue, it is argued that an important issue is the fact that health benefits accrue in the long run from improvements in environmental management (Remoundou and Koundouri, 2009). Also, in Europe it has been shown that considerable reduction in pollutants such as sulphur dioxide ($SO_2$) has been observable in the last decade (Devalia *et al.,* 1993).

## Conclusion

Based on the results of this study, it was shown that air pollutants are present within the selected schools. Prolonged exposure to these pollutants may result in chronic health problems especially in children whose developing bodies are more susceptible to the detrimental effects of these pollutants. It is recommended therefore that there should be provision for monitoring equipment in order to ensure early detection of these pollutants. Not only that, we want to recommend that learners and the educators should be medically checked from time to time. This is because while it may be argued that the levels of some of these pollutants as reported in this study were not that high, exposed members of the concerned community nonetheless spend most part of their lives in the schools. The presence of learners and their educators in this environment on a daily basis means that they are vulnerable to the pollution effects of these compounds. For instance, while it may appear that the level of Pb found in the air in this study was fine; this could still cause major health problems with children. The Pb content may be a problem with children because it is reported that "… even small exposures are associated with reduced IQ, increased ADHD and other health problems in children … No safe blood-lead level for children has been identified" (Young, 2012).The fact that a majority of the concerned community are children makes this issue even more urgent. The situation is urgent because the average age of the learners was 16 years; if they are to be exposed to the chemicals until adulthood then their health prospects are really threatened.

On the part of the mining industries, we recommend that they should adopt best environmental practices or best available operations so as to reduce the environmental problems resulting from their operations. The government also should adopt the "polluter pay policy" to serve as deterrent to unwanted pollution of the environment by the mining companies. All these are necessary in order to achieve a higher level of environmental equity.

**Acknowledgements**

This study was funded by the office of the Dean of Humanities, Tshwane University of technology, Pretoria, South Africa. We appreciate the effort of Brian Cowan and Andreas Trüe of the Consulting and Analytical Services of the Council for Scientific and Industrial Research (CSIR) for helping out with both the data collection and analysis of this work.

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