Air quality management in Botswana

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Abstract
This paper examines air pollution situation and the history of air quality management in Botswana. The current air quality management in Botswana is still largely underpinned by the Atmospheric Pollution Prevention Act of 1971, supplemented by the more recently enacted legislations such as the Environmental Impact Assessment (EIA) Act of 2010 and the Ambient Air Quality - Limits for Common Pollutants of 2012 published by the Botswana Bureau of Standards. Though commendable efforts have been made toward legislating against air and other forms of pollution, these have not yielded expected results in view of the prevailing levels of air pollutants like sulphur dioxide and fine particulate matters in the country's atmospheric environment. Legislation as a sole measure may not be effective in tackling this challenge. Rather, government should also address some root-causes of the problem by making policies and programmes that will reduce unemployment and increase the earning capacity of citizenry. This will, among other things, effectively check poverty-induced biomass burning in the country. The paper looks at some other challenges of air pollution management and suggestions are made to tackle the identified problems.

Keywords
Air pollutants, atmosphere, environment, carbon monoxide, mining, sulphur dioxide, nitrogen dioxide

Introduction
The environment refers to the totality of all the conditions that affect living organisms, including humans, in their habitat (Santra 2013; Girard 2014). Air is a component part of the environment that plays important life-sustaining roles, but in spite of this, it is still constantly subjected to pollution abuse. A report released by the World Health Organization (WHO) indicated that in 2012, about one in eight of global deaths was attributable to exposure to air pollution; this constituted a total of around 7 million deaths (WHO 2014). The importance of adequate air quality management cannot therefore, be overemphasized. The increasing rate of urbanisation without the proportional infrastructural development has worsened air pollution situation in Africa (Baumbach et al. 1995; Eliasson et al. 2009). Sub-Sahara African countries, of which Botswana is one, is especially prone to soil-derived particulate matter pollution because it is largely a dry continent.

Air pollution in Botswana
Botswana is a landlocked country with an approximate area of 582,000 km^2. It is located in the centre of southern Africa with geographic coordinates of 22 00 S, 24 00 E. Census figures showed that the population of Botswana in 2011 was 2,024,904; this figure was projected to rise to 2,230,905 in 2016 (Botswana Central Statistics Office 2016). Botswana climate is semi-arid with warm winters and hot summers. The land terrain is predominantly flat to gently rolling tableland with Kalahari Desert in the southwest. The country experiences periodic droughts and August winds blow from the west, carrying sand and dust across the country. The country is faced with natural and anthropogenic environmental issues including drought, overgrazing, desertification and limited freshwater resources. Mean monthly temperatures as high as 32ºC to 35ºC are recorded in the summer months of October to January (Shaikh et al. 2006; Shaikh et al. 2006; Eliasson et al. 2009). These invariably contribute to air pollution problems in the country. Outdoor and indoor air pollution problems in the country are brought about by biomass burning, vehicular emissions, smelting activities, and population growth (Jayaratne and Verma 2001; Shaikh et al. 2006; Eliasson et al. 2009; Verma et al. 2010).

Botswana has continued to witness steady technological and population growth in recent years. Citing figures released by the Central Statistics Office in 2004, Shaikh et al. (2006) indicated that the country witnessed an increase in maintained roads from 8,000 km in 1988 to 11,000 km in 2002, while the number of vehicles increased from 65,00 to 163,000 in the same period. Meanwhile, latest figures released by the same Central Statistics Office and accessed in 2016, showed that government-maintained road network increased from the 11,000 km of 2002, to 18,507 km in 2014; which corresponds to a 7,507 km (68 %) increase. Moreover, the number of visitors that entered the country increased from 1, 200,000 in 1998 to 1,800,000 in 2002. Latest figures put number of visitors at 2,082,521 in 2014. Such human and vehicular increases must have resulted in increased fuel usage and its attendant emissions.

Jayaratne and Verma (2001) carried out a study to investigate the impact of biomass burning on the environment of Gaborone, the capital city of Botswana, using two automatic laser scattering particle counters. The size range of the particles monitored was between 0.1 μm and 5.0 μm. The mean daily particle concentrations were found to vary from about 200 particles cm^{-3} on clear visibility days during the summer to a high of over 9000 particles cm-3 on cold winter evenings. The results also showed that the size and concentrations of aerosols were consistently higher in the highly populated areas relative to low density locations. They stated that due to the absence of proper legal restrictions, majority of the inhabitants use firewood for cooking and heating purposes. In many homes, logs of wood are used for indoor heating purposes during winter, leading to a pall of smoke hanging over the city in the evenings, with a marked influence on atmospheric visibility. Follow-up studies including those of Verma and Thomas (2007); and Verma et al. (2010) have reported increasing atmospheric concentrations of aerosol particles, CO, and particulate matter of size range of 0.3-5.0 μm especially in the low income residential areas.

In addition to biomass burning and vehicular emission, a major threatening source of particulate matter air pollution in Botswana is the mining industry. Ekosse et al. (2004) noted that the growth in mining activities in Botswana may have generated corresponding increase in particulate matter. One identified major site where mining activities pose environmental contamination challenge is the Selebi Phikwe mine area (Ekosse et al. 2004). The town of Selebi Phikwe was established in the early 1960s following the onset of copper-nickel mining activities. The first official activities related to the discovery of the Selebi Phikwe mineral deposits was in 1959, when surface prospecting started over an area of about 67,000 square kilometers. Geochemical exploration techniques were used to discover the Selebi deposit in 1963 and this gave an impetus to the commencement of robust mining activities in 1970. A large proportion (26 %) of the country's labour force, dominated mainly by males, is engaged in mining of Ni-Cu (Ekosse et al. 2006). However, over the past years, there has been growing concern over environmental pollution threat posed by mining activities in the town. Ekosse et al. 2004 carried out a chemical and mineralogical characterization of particulate matter (PM) at the Selebi Phikwe Ni-Cu area in Botswana. They reported that the air in the mining area was polluted by heavy metals including cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), nickel (Ni), selenium (Se), and zinc (Zn). The results of Ekosse et al. 2004 study were also indicative of traces of very fine quartz (SiO_2), pyrrhotite ($Fe1_{-x}S$), chalcopyrite ($CuFeS_2$), albite ($NaAlSi_3O_8$) and djurleite ($Cu_{31}S_{16}$). A consortium of the Institute of Environmental Management and Assessment (IEMA) carried out an Environmental Impact Assessment (EIA) of Selebi Phikwe mining area. They reported atmospheric sulphur dioxide (SO_2) concentrations of up to 100 μg/m^3 in the mining complex as against the critical level of 20 μg/m^3 set by the European Union. The IEMA consortium found a convincing correlation between the concentration of SO_2 in the air with the apparent plant growth reduction and foliar damage in the area (IEMA 2012).

Earlier, Ekose (2005) investigated the general health status of residents of Selebi Phikwe. Data generated revealed that the most frequent common health complaints in the area included frequent coughing, headaches, influenza/common colds and chest pains. These are respiratory tract related problems, suspected to be linked to the effects of air pollution caused by the emission of SO_2 from mining and smelting activities.

Criteria pollutants of concern in Botswana

Criteria pollutants are a set of air pollutants that are considered harmful to health and the environment, and that can cause property damage. They are typically emitted from many sources including industry, mining processes, transportation, agriculture, and electricity generation. The six criteria air contaminants that were the first set of pollutants recognized by the United States (US) Environmental Protection Agency (EPA) are sulphur dioxide (SO_2), particulate matter (PM), ozone (O_3), carbon monoxide (CO), lead (Pb), and nitrogen dioxide (NO_2) (Office of Air Quality Planning and Standard, OAQPS 2013). In Botswana, some of these criteria pollutants and their environmental and health effects have been reported. These include sulphur dioxide (SO_2), particulate matter (PM), carbon monoxide (CO), and nitrogen dioxide (Jayaratne and Verma, 2001; Ekose et al. 2004; Ekosse 2005; Ekosse et al. 2006; Shaikh et al., 2006; Eliasson et al., 2009; Verma et al. 2010). For instance, Ekosse 2005; Ekosse et al. 2006 associated some respiratory health problems identified among the residents of Selebi Phikwe to particulate emissions from mining activities in the region.

Though, many authors have, in the past, identified the sources of CO pollution in Botswana viz: vehicular emissions and biomass burning, especially among the low income group households (Jayaratne and Verma 2001; Verma et al. 2010), one potential source of CO pollution in Botswana that might not have attracted attention is emission from cattle and sheep. Methane (CH_4) is produced in the stomachs of ruminants and intestine of termites. As cattle digest food, methane is produced in their intestines. The methane enters the cow's bloodstream; and when the blood gets to the lungs, the methane is released and exhaled in the normal breathing process. Oxygen in the atmosphere subsequently oxidises the exhaled methane to CO via the equation: $2\ CH_4 + 3\ O_2 \rightarrow 2\ CO + 4\ H_2O$ (Girard 2014).

History of air quality management in Botswana

There has been very little development in air quality legislation in Botswana. The Atmospheric Pollution Prevention Act which came into effect from 14th May, 1971 was promulgated to prevent the pollution of the atmosphere through emissions from industrial processes. The act empowers the Air Pollution Control Officer, appointed by the minister, to sanction any unauthorised person who carries out an industrial process capable of causing or involving the emission, into the atmosphere, of objectionable matter within a controlled area. The penalty for any convicted person under the Act ranges from a fine of P500-1000 or a prison term of 6-12 months or both, depending on whether it is a first or second conviction.

The Department of Sanitation and Waste Management was established in April, 1999 under the provisions of the Waste Management Act, 1998. Prior to this, the government developed the Botswana's Strategy on Waste Management. The Department of Sanitation and Waste Management was merged with the Air Control Division of Department of Mines in 2005, with a responsibility of implementing the Atmospheric Pollution Prevention Act, 1971. The merger gave rise to the Department of Waste Management and Pollution Control. The Department of Waste Management and Pollution Control formulates and provides policy direction and leadership to all issues pertaining to waste management, while the implementation of the policies is done by the local authorities.

The Botswana Environmental Impact Assessment Act was passed in 2005, thus making Environmental Impact Assessment (EIA) mandatory for specified projects. The EIA Act, 2005 defines the Department of Environment and Conservation as the competent authority that is responsible for administering and controlling EIA activities in Botswana. This department was renamed as the Department of Environmental Affairs (DEA) and the functions previously assigned to the National Conservation Strategy Agency (NCSA) relating to EIA in the country were transferred to DEA.

The Environmental Assessment Act, 2010 passed by the National Assembly on the 12th April, 2011 and gazetted in June, 2011, is a consolidation of that of 2005. The Act provides for EIA to be used to assess the potential effects of planned developmental activities with a view to determining and providing mitigation measures for any significant adverse effects on the environment. The Act also provides for monitoring and evaluation of the environmental impacts of implemented activities. The Act stipulates sanctions ranging from a fine of P100,000 or a prison term not exceeding 5 years or both for anyone who undertakes a developmental activity without undergoing necessary processes as put in place by the Act. Moreover, such a convicted person shall rehabilitate the area affected by the adverse environmental impact of the implemented activities. Failure to comply will attract a further fine of P1,000,000 or a term of imprisonment not exceeding 15 years, or both.

The Botswana Bureau of Standards published Ambient Air Quality – Limits for Common Pollutants (BOS 498:2012). This Standard specifies limit values (Table 1) for common air pollutants to ensure that the negative effects of such pollutants on human health and the environment are prevented or reduced.

Limit values for common air pollutants in Botswana

Pollutant	Limit value (µg/m³)	Average period
Sulphur dioxide (SO_2)	350 120	1 hour 24 hours
Nitrogen dioxide (NO_2)	200 40	1 hour 1 year
Carbon monoxide (CO)	30,000 10,000	1 hour 8 hours
Particulate matter (PM_{10})	200 100	Monthly 1 year
Ozone (O_3)	120	8 hours
Lead (Pb)	0.5	1 year
Benzene (C_6H_6)	5.0	1 year

Source: Botswana Bureau of Standards (2012)

The Botswana limit values for common air pollutants as presented in the table above compares favourably with the limits in South Africa, a neighbouring country, except for PM_{10} one year limit value which is 100 % higher the South African value of 50 µg/m³ (South African National Standard, 2011). In spite of this, the Botswana government may still have to consider a downward review of some these pollutants, especially SO_2. This opinion is hinged on the earlier mentioned IEMA Environmental Impact Assessment of Selebi Phikwe mining area which found a correlation between the 100 µg/m³ SO_2 atmospheric concentration with the prevalent plant growth reduction and foliar damage in the area (IEMA 2012).

Challenges facing air pollution management in Botswana

Like in many other developing countries, air pollution management in Botswana is faced with several challenges, some of which have already been mentioned earlier in this paper. These challenges include increasing vehicle numbers and road networks (Shaikh et al. 2006), biomass burning (Jayaratne and Verma 2001; Verma et al. 2010), growing mining and smelting activities (Ekosse et al. 2004; Ekosse et al. 2006), inadequate data to monitor and appraise pollution levels, lack of cohesive air quality policies, and weak or no legal restrictions (Jayaratne and Verma 2001). The measures put in place to manage air quality; including the Atmospheric Pollution Prevention Act of 1971, the related but more recent Environmental Impact Assessment Acts of 2005 and 2010, and the Ambient Air Quality - Limits for Common Pollutants of 2012 published by the Botswana Bureau of Standards might not have yielded expected results in view of the prevailing levels of air pollutants like sulphur dioxide and fine particulate matters in the country's atmospheric environment. This conclusion is partly based on published air quality monitoring studies (Jayaratne and Verma 2001; Verma and Thomas 2005, 2007), some of which are outdated by a couple of recent legislations in the country. There is the need for regular empirical data to allow for proper evaluation of the policies and legislations put in place to combat air pollution in the country.

The future of air quality management in Botswana and ways forward

Air quality management in Botswana requires a holistic evaluation and review to bring about significant reduction in the level of atmospheric pollution in the country. Air pollution is already taking its toll on the health and, by extension, the economy of residents, especially around Selebi Phikwe Ni-Cu plant and in the highly populated areas where the level of pollutants is high (Ekosse, 2005; Ekosse et al. 2006). Apart from strengthening existing laws on pollution prevention, effective enforcement measures should be put in place. Some of the challenges facing air pollution management in Botswana and measures that government can adopt or put in place to mitigate them are enumerated hereunder.

Increasing vehicle numbers and road network

To reduce vehicular emissions to the atmosphere, government should be more concerned in investing in quality public transport system. This will discourage the use of personal vehicles and subsequently bring about a reduction in the average number of vehicles on the roads. Importation and use of vehicles should be limited to new and fuel efficient ones. The legislation that has been put in place to set emission limits for automobile, industrial and other engines should be strengthened to ensure compliance. The use of bio-fuels which are environment friendly should be encouraged.

Biomass burning

The prevalent use of firewood, cow dung, plastic bags, and Chibuku cartons for cooking and heating purposes is fuelled by poverty and inadequate legislation (Jayaratne and Verma 2001; Verma et al. 2010). Legislation as a sole measure cannot be effective in tackling this challenge. Rather, government should address the root cause of the problem by making policies and programmes that will reduce unemployment and increase the earning capacity of citizenry. This can then be complemented by mass enlightenment and legislation. In the interim, government should find ways of making liquefied petroleum gas (LPG) and electricity affordable to the masses, probably by subsidizing the costs of these products. Electricity and LPG are more efficient and environment friendly alternatives to biomass fuels. Uncontrolled burning of wastes should be tackled by the local authorities.

Growing mining and smelting activities

The Selebi Phikwe Ni-Cu mine area is one of the most reported sources of air pollution in Botswana (Ekosse 2004; Ekosse et al. 2004, 2006). In view of the reported and potential health and environmental consequences posed by the mining plant, government and other stakeholders should work in synergy to curtail atmospheric pollutants emanating from the plant. It has been noted that a whopping 26% of the country's labour force, dominated mainly by males, is engaged in mining of Ni-Cu. Steps should therefore be taken by government and relevant bodies to reduce the over-reliance on mining, by diversifying the economy of the country and of Selebi Phikwe. Government should set sustainable emission standards for mining activities, and more importantly, ensure compliance. The huge SO_2 generated in the mining process can be captured and channelled to other productive uses such as manufacture of fertilizers and reagents like H_2SO_4. It may not be out of place for government to consider the idea of resettling the residents of Selebi Phikwe. By so doing, Selebi Phikwe will become a dedicated area for mining.

Inadequate data to monitor and appraise pollution levels

It has been observed that urban cities in developing countries are likely to have fine particulate matter concentrations up to 10-fold higher than the US National Ambient Air Quality Standards. Meanwhile, proper assessment of air pollution in these countries is difficult because of lack of cohesive air quality policies, poor environmental monitoring, and paucity of disease surveillance data (Shah et al. 2013). These observations capture the situation in Botswana, where environmental monitoring is weak and data are not available for regular evaluation of air quality. Government, stakeholders, and policy makers should set reference threshold limits values for ambient air quality for pollutants in the country. In addition, a body should be designated to monitor air quality in the country and its report should be published yearly to allow for evaluation.

The adverse effects of pollution, especially atmospheric, are now known not to be limited to the immediate locality where pollutant level is high (Dada et al. 2016). Air pollution is therefore better tackled not in isolation, but in collaboration with other neighbouring countries. Air quality monitoring data and policies in Botswana should be compared and shared with neighbouring countries – South Africa, Namibia and others.

Conclusion

Efforts to monitor air quality and control atmospheric pollutants in Botswana have not yielded expected results in view of the prevailing high levels of aerosol particles and associated compounds in the country's environment. The air pollution problem is fuelled by vehicular emissions, poverty-induced biomass burning, and mining activities among others. Since the potential adverse effects of these air pollutants on the citizens and environment may be too grievous to neglect, government and stakeholders should, as a matter of urgency, take proactive and holistic steps to tackle the identified causative problems and ensure a cleaner atmosphere. Legislation as a sole measure cannot be effective in tackling this challenge. Rather, government should address the root cause of the problem by making policies and programmes that will reduce unemployment and increase the earning capacity of citizenry. This will effectively check poverty-induced biomass burning in the country. Failure to do these may amount to a time bomb, going by the pollution-associated health challenges already identified among the citizens.

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