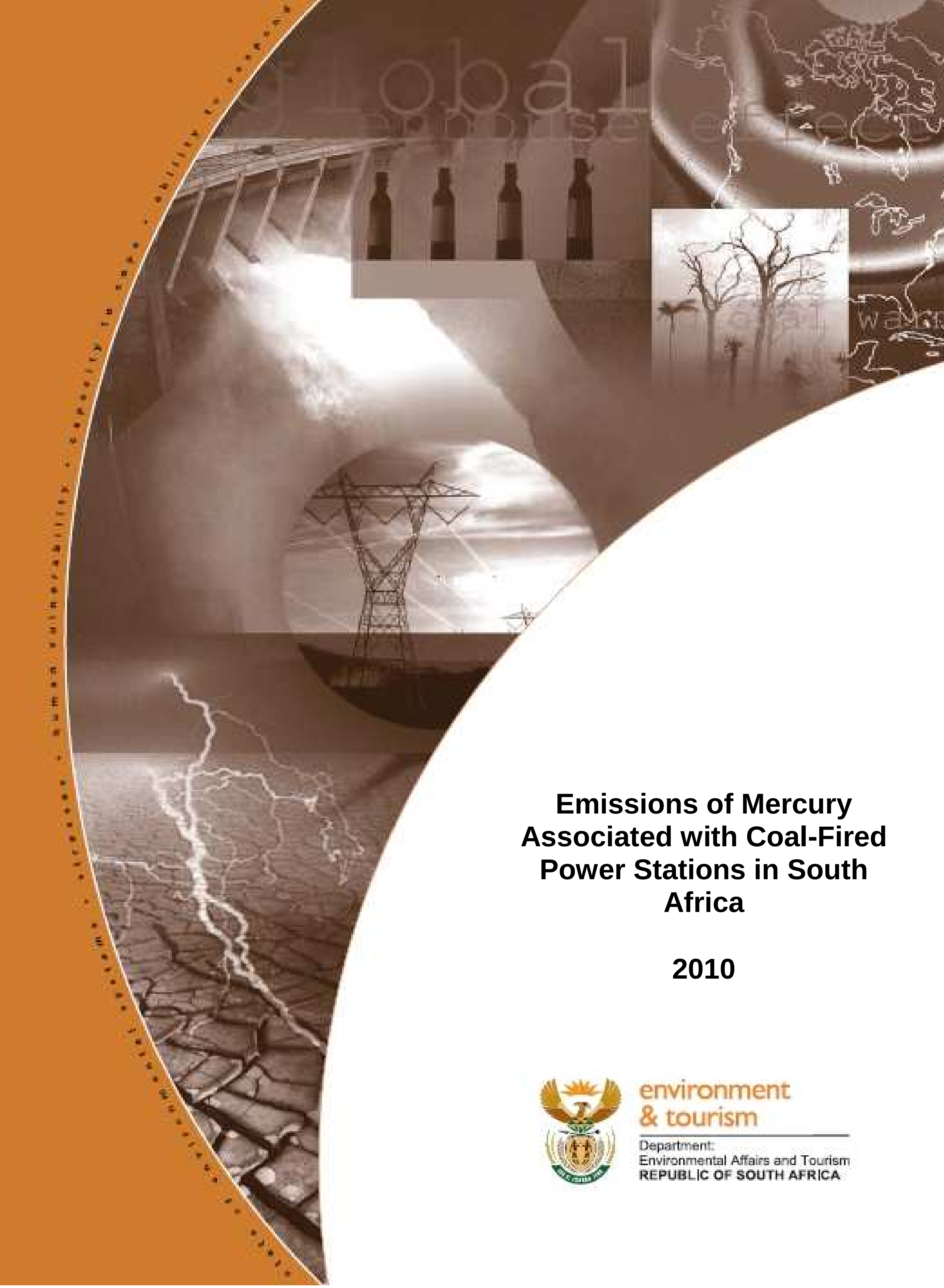

Emissions of Mercury Associated with Coal-Fired Power Stations in South Africa

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EMISSIONS OF MERCURY ASSOCIATED WITH COAL-FIRED POWER STATIONS IN SOUTH AFRICA

This document contains information on emerging issues that may affect the future state of the environment. The purpose of this paper is to draw attention to issues in preparation for the next state of the environment reporting cycle.

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Introduction

Mercury occurs naturally in the environment, and is generally bound in geological formations as a sulphide ore (cinnabar) or as a trace element in other naturally occurring ores (most notably coal). Like lead, it is a heavy metal and is a natural element of the earth. Elemental mercury is a shiny liquid at room temperature and has been commonly used in a wide variety of products, including batteries, dental amalgams, thermometers and more recently in energy saving compact fluorescent light bulbs. Mercury can occur in a variety of states and even at room temperature, metallic mercury can evaporate to form gaseous mercury vapours. Once released into the environment, mercury most commonly occurs as elemental mercury in a gaseous form or as inorganic mercury (combined with another element). When it combines with carbon, mercury forms organic mercury compounds, the most common of which is methylmercury.

Once released into the environment, mercury behaves as a highly mobile and persistent environmental pollutant that is particularly toxic towards humans and wildlife at low levels. The toxicity of mercury is dependent on the form, amount and pathway of exposure and methylmercury is particularly harmful towards the developing nervous system. Depending on local mercury pollution load, substantial intake of total (elemental and inorganic mercury) can occur through air and water. Methylmercury in particular, is of major concern, as it is considerably more toxic than inorganic mercury and accumulates in organisms and biomagnifies up the food chain, particularly in the aquatic food chain. In terms of human health, consumption of freshwater or marine fish with high methylmercury levels (mostly higher trophic level fish) is the most common pathway of exposure. Consumption of fish contaminated with methylmercury poses significant health risks to humans – particularly to the developing foetus and young children. Methylmercury easily passes from the mother's bloodstream into that of the foetus and its neurotoxic properties can adversely affect the development of the brain. Effects on adults include disruption to the nervous system, cardiovascular disease, cancer incidence and genotoxicity. A recent pilot study revealed that a number of commonly consumed marine fish occurring along the coast of South Africa, show high levels of total mercury, potentially posing a health risk to people who frequently consume fish (SANCOR, 2010). While most of the focus is on human health, it should be noted that mammals, birds and other wildlife can also be affected by high levels of methylmercury in their food, and the risk is highest for fish-eating animals.

Mercury is a natural element and can, therefore, not be broken down into less toxic substances in the environment. However, methylmercury can be degraded to the less toxic inorganic forms. As mercury is able to exist in a variety of forms (including as a gas) it can easily be transported to and detected in atmospheric, terrestrial and aquatic environments. The most significant releases of mercury are to the atmosphere, which results in it being easily transported to regions and environments far from the original source. The scale at which this transportation occurs is, however, both regional and global as elemental mercury is transported globally but inorganic mercury is deposited regionally. High levels of mercury have been recorded in the environment and in wildlife, even in pristine environments, completely lacking in human (anthropogenic) activity (e.g. the Arctic).

Global research has shown that environmental levels of mercury have increased steadily since the onset of the industrial age, particularly in the atmosphere and aquatic ecosystems. While natural releases of mercury to the environment do occur, these are small in comparison to those resulting from anthropogenic activities. As stated previously, mercury occurs naturally in the environment, usually associated with geological formations. However, numerous anthropogenic activities, especially the extraction and use of fossil fuels, result in the mobilisation of mercury, leading to increased levels in a variety of environments (i.e. atmospheric, aquatic and terrestrial) and potential exposure of organisms, ecosystems and humans to levels higher than would naturally be expected to occur. The persistent and harmful nature of anthropogenically released mercury emissions has resulted in it being the topic of numerous research projects in many countries, and substantial literature on its transport, fate and effects exists. At present, methylmercury is currently being considered for inclusion as a priority chemical in the Stockholm Convention of Persistant Organic Pollutants, which has been instrumental in banning other harmful chemicals, most notably several organochlorine pesticides, such as DDT.

The South African National State of the Environment Outlook (2006), identified (amongst other issues) the impairment of water quality, loss of biodiversity and human vulnerability through exposure to environmental hazards as key emerging environmental issues requiring urgent intervention and concerted focus in the immediate future (DEAT, 2006). Given the global importance of mercury as a high priority pollutant and its potential impact on each of the afore-mentioned issues, it is essential to determine the sources, environmental levels and likely impacts associated with mercury in the South African context.

Discussion

The majority of anthropogenically produced mercury emissions are released directly into the atmosphere via activities including coal combustion (e.g. power generation and residential heating), waste incineration, base metal smelting, large-scale and artisanal gold production and cement production. Of these sources, numerous country specific and global mercury inventories have identified coal combustion as the most important, both at a country and global scale (Pacyna *et al.,* 2006). Large quantities of coal are burned throughout the world, primarily for electricity and heat production. Coal commonly contains trace amounts of mercury and when it is burned at high temperature in the power generation process, mercury is released into the atmosphere in gaseous and particle associated forms.

Mercury emissions via coal combustion are particularly relevant in the South African context. South Africa is the third largest producer of coal in the world, and, in 2004, coal accounted for 68 % of the country's primary energy supply (DME, 2006). Electricity generation accounts for approximately 70 % of the total coal consumption in South Africa and more than 90 % of the country's electricity requirements are provided for by coal-fired power stations (DME, 2006). Coal use by Sasol is also significant, accounting for approximately 25 % of the total coal consumption in South Africa. Considering the world-wide importance of power stations as a source of mercury to the atmosphere, it is likely that the electricity generation sector may be an important source of emissions in South Africa. This was highlighted by a paper that listed South Africa as the second highest source of mercury emissions to the atmosphere on a global scale (Pacyna *et al*., 2006). The global concern of mercury in the environment and South Africa's estimated contribution to global emissions led to the development of the South African Mercury Assessment (SAMA) programme. One of the objectives of this programme was to compile an inventory of mercury emissions in South Africa, with particular emphasis on coal-fired power stations.

South African power stations

The main factors influencing the amount of mercury emitted to the atmosphere during the combustion of coal include the total amount of coal burned, the type and efficiency of emission control devices used to reduce atmospheric pollution and the mercury content of the coal itself. The South African power utility, Eskom, has thirteen coal-fired power stations located throughout the country, of which eleven are located in the Mpumalanga province, where 83 % of South Africa's coal is currently mined.

Combustion of coal results in the generation of large amounts of gaseous (particularly sulphur and nitrogen oxides) and particulate emissions (e.g. fly-ash). Most power stations have emission control devices fitted in their stacks, which are designed to reduce the combustion emissions from being released into the atmosphere. The most common devices installed in the stacks include electrostatic precipitators (ESPs) and fabric filters (FFs) (both of which are used to reduce particulate emissions) and flue-gas desulphurisation systems (FGDs), which are primarily used to reduce gaseous sulphur dioxide emissions. As the interest in mercury emissions and inventories has increased, so has more attention focussed on the efficiency of these devices in reducing mercury emissions.

ESPs installed in stacks consist of high voltage electrodes which impart a negative charge to particles in the air, which are then attracted to positively charged plates where the particles collect. FFs remove dust and particles by passing the gas through a fabric and leaving the dust on surface. While FFs are primarily designed to reduce particulate emissions, research has shown that interactions between chemicals in the bag itself reduce mercury emissions. Flue-gas desulphurization is designed to remove gaseous sulphur dioxide emissions but have also been show to be the most effective at reducing Hg emissions. Sulphur dioxide is produced during the combustion process and is a leading contributor in the formation of acid precipitation. Capture and removal of sulphur dioxide is accomplished by devices known as scrubbers, which combine the sulphur compounds with a calcium containing sorbent, generally lime (CaO) or limestone ($CaCO_3$), to create a slurry.

While a number of factors contribute to the speciation of mercury and its presence in particulate or gaseous form, due to the high temperatures in the boilers, the majority of emissions arising from coal combustion in power stations are gaseous (UNEP, 2005). However, all of the above mentioned control devices are able to reduce Hg emissions to various degrees. While the efficiency of devices vary over a wide range, ESPs are regarded as the least effective in reducing mercury emissions as they are designed more to trap particulate emissions. FFs are far more effective in reducing finer emissions of finer-sized particles and it has been shown that they are relatively efficient in reducing gaseous emissions. A combination of a particulate control device together with FGD results in the most effective reduction of total mercury emissions, as this combination reduces both particulate and gaseous mercury emissions. All of South Africas power stations are fitted with one or a combination of ESPs or FFs, however none are currently fitted with FGD systems. It is, therefore, likely, that the majority of gaseous emissions are released into the atmospheres with only particulate mercury being retained by the control devices, primarily because of the lack of FGD systems.

Mercury content of South Africa's coal

In general, low grade bituminous coal is used for combustion in South African power plants. Few studies are available on the Hg content of coal used in South African power stations. Mercury levels in South African coals indicate an average concentration that is equivalent to the global average value of ~0.2 ppm. Previous studies reported an average Hg content of 0.327 ppm for South African coals, while a more recent study (Wagner and Hlatshwayo, 2005) performed on highveld coals, reported and average Hg content of 0.15 ppm.

While, the mercury content of coal is relatively low, the large quantities of coal burned every year potentially results in high annual mercury emissions. In 2004, approximately 110 million tonnes of coal was consumed for electricity production. A more recent estimate for 2007 indicates an increase to approximately 125 million tonnes. Based on coal consumption data, emission control devices fitted in the stacks of the power stations and estimates of the mercury content of coal (using an assumed concentration of 0.2 ppm), it has been estimated that South Africa emits about 10 tonnes (ranging between 2.6 and 17.6 tonnes) of mercury to the atmosphere per year (Dabrowski *et al.,* 2008). The range in estimates is associated with the uncertainty in the actual mercury content of the coal used and in the efficiency of the emission control devices in trapping mercury. While this estimate is considerably lower than the 50 tonnes estimated in other studies (Pacyna *et al.,* 2006), when expressed as a ratio of the total population in South Africa, the per capita mercury emissions (0.24 g per person per year) are relatively higher than other leading industrialized nations such as Canada (0.15), China (0.13), Russia (0.16) and the USA (0.2). This would seem to suggest, that while our total emissions are lower than previously expected, South Africa does appear to emit high levels in relation to the number of people living in the country, suggesting that the potential for exposure to humans and the environment is relatively high.

Mercury levels in South Africa

Very little research has focussed on the levels and effects of mercury in the environment and on human health in South Africa. Recently a nation-wide survey of mercury levels in water, sediment and aquatic biota was conducted (CSIR, 2009). The study showed that nationally, mercury levels are not as high as anticipated, given our reliance on coal-fired power stations for electricity production. This does not mean that mercury pollution is not a problem or will not be a problem in the future. As highlighted in the beginning of this essay, Hg is highly persistent and even low levels of Hg will accumulate in organisms over time and biomagnify further up the food chain. Therefore, given the toxicity and associated health risks of mercury, constant monitoring of Hg levels in the environment is advisable.

More importantly, South African mercury emissions are not likely to decrease in the future. In fact, the exact opposite is true. South Africa has experienced a steady growth in demand for electricity on the back of increased economic development over the last decade. This demand has put South Africa's power generation under increased pressure, leading to the recent energy crisis experienced across the country. Consequently, demand currently exceeds available capacity and development of increased power generation infrastructure is essential. South Africa's coal reserves are estimated at 53 billion tonnes, and, based on the current production rate, are sufficient to last another 200 years. The current energy crisis in combination with the lack of development of alternative energy sources (such as nuclear, hydroelectric, wind and solar energy) indicates that the country's future primary energy needs will continue to be provided by coal.

This has been confirmed by Eskom's power generation development plans, which will result in an additional five fully functional power stations by the year 2017. By 2012 Eskom plans to reconnect three power stations (Camden, Grootvlei and Komati), which are currently moth-balled, to the country's national power grid. In addition, two large power stations are currently being built in the Witbank (Kusile) and Lephalale (Medupi) areas. These are planned to begin coming on line by 2013 and be completed by 2017, by which time a total of fifteen coal-fired power stations will be operational. Thirteen of these power stations will be located in the Mpumalanga region - an area that is already under severe pressure from both a water quality and water quantity perspective. These additional power stations will result in an increase in the amount of coal consumed and by 2018, Eskom forecasts that the total annual amount of coal burned will be approximately 200 million tonnes. It is certain therefore, that annual mercury emissions resulting from coal combustion will rise significantly.

In addition to the Medupi power station, another three power stations have been earmarked for the Waterberg region and environmental impact assessments are currently under way to gauge their feasibility. The overwhelming majority of South Africa's coal reserves (approximately 50 billion tonnes) are located in this region and as a result, considerable development is likely to occur here in the future. The location of current and future planned power stations in the Waterberg area is of concern considering their proximity to the recently proclaimed UNESCO Waterberg Biosphere Reserve. The name given to this region is paradoxical, as water is in fact not abundant in this area, as in so many other regions in South Africa. Development of power stations in the region will place the region's water sources under increased stress, from both a water quantity and quality perspective. Large quantities of water will be required to operate power stations and the associated development that goes with their operation (e.g. residential areas and increased urbanisation). From a water quality perspective, studies have indicated that the water quality in the mid to upper reaches of the Mokolo and Lapalala Rivers is good with few impacts and aquatic ecosystems are generally in a relatively healthy condition (in the upper reaches) (Oberholster *et al.,* 2009). Aquatic ecosystems in this region are largely characterised by impacts related to water abstraction and alteration of flow. Water quality is likely to be increasingly impacted through increased deposition of sulphur and other associated contaminants such as mercury.

Conclusion

Increased emissions of mercury into the environment is a global problem. Much of the current levels in the environment are due to combustion of coal. Eskom’s expansion programme will result in the consumption of approximately 200 million tonnes of coal by 2018, which is an increase of 60 % over current usage. Therefore, mercury emissions arising from this source can be expected to increase significantly to almost double the current emissions. Considering the potential impact on environmental and human health it is important that every attempt be made to mitigate the likely increase in mercury emissions in the future. Our current knowledge of the levels of mercury in the South African environment are constrained due to the limited number of studies on this topic. While a national survey has indicated that mercury levels in aquatic systems are not very high, it must be stressed that this survey measured single points in time. Therefore, it is not possible to determine the extent to which mercury levels have increased (or decreased) over time and whether there are temporal trends associated with different seasons (i.e. wet and dry season). Given the importance of mercury as a global contaminant and the potential effects on ecosystem and human health, it is important to monitor levels in the environment and mitigate against increased emissions now and in the future. In this respect the fact that FGD devices will be fitted to the new Medupi power station in the Waterberg is an encouraging sign as this will help in mitigating the quality of air in the region and reduce the potential for deposition of harmful contaminants into terrestrial and aquatic ecosystems.

Many people continue to live in poverty and are particularly vulnerable to exposure to environmental contaminants through use of water (and fish) collected directly from the rivers and dams. This reality, in combination with the anticipated increased levels of mercury in the environment will further increase their potential for exposure to mercury. In many countries throughout the world, health advisories specifying the number and frequency of fish consumption (on a daily or weekly basis) are commonplace and are specifically implemented in order to protect humans from excessive exposure to methylmercury in fish. South Africa currently has no such advisories or guidelines in place. It is, therefore, essential that continued monitoring and assessment of sources and levels of mercury in the South African environment takes place with the specific aim of assessing trends in environmental levels and identifying communities at risk of high levels of exposure, through consumption of fish or due to poor air quality.

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