Environmental and Social Impact Assessment
27.5 MTPA Expansion Project

Assessment of Health Risks to Nearby Communities and Workers due to Emissions from Compagnie des Bauxites de Guinée

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Executive summary

This assessment of health risks covers the emissions generated by CBG (Compagnie des Bauxites de Guinée). With operations in Kamsar (processing plant and port) and Sangarédi (mine), CBG generates particulate matter (PM) and combustion gases that could pose risks to nearby communities. CBG operations also contribute to increased sound levels and may affect surface or ground water quality. Finally, the Expansion Project could also contribute to increased disease transmission due to the expected influx of workers.

As part of the Environmental and Social Impact Assessment (ESIA) for the CBG Expansion Project, a sampling campaign was carried out at selected points from February to June, 2014, in order to estimate the contribution of CBG to baseline conditions. The present assessment covers the processing plant and port in Kamsar along with the mining area in Sangarédi.

In general, the results demonstrate moderate levels of SO_2 and NO_2 in relation to the guidelines of the World Health Organization (WHO). These gases are emitted primarily by CBG operations (80-90%). As for particulate matter (PM), CBG's estimated contribution to all the PM collected, while moderate, is significant in light of WHO guidelines. The air quality we observed in Kamsar does not meet WHO guidelines and could increase the risk of health effects on the respiratory system, for example. These would be accentuated in more vulnerable individuals, such as infants or the elderly. The expected noise increase is marginal in Kamsar but, in Sangarédi, it calls for careful management to prevent annoyance complaints from nearby communities. Finally, the Project poses a risk of increased HIV/AIDS transmission in an already vulnerable population.

CBG will have to address these results in its Environmental and Social Management Plan in order to minimize the impact of emissions from its current operations and future expansion. It should also work with nearby communities to identify strategies for improvement.

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1 INTRODUCTION

CBG (Compagnie des Bauxites de Guinée) is a mining company owned jointly by the Government of Guinea and Halco Mining (Alcoa, Rio Tinto Alcan and Dadco). In operation since 1973, CBG is now planning to increase its bauxite production from 13.5 million tonnes per annum (MTPA) of shipped material, to a production capacity of 22.5 MTPA (at 3% moisture content) by January, 2017, followed by a further increase of 5 MTPA to a production capacity of 27.5 MTPA by 2022.

A socioeconomic study was carried out for this Project. The populations consulted for the study perceived that CBG activities contributed to the development of numerous ailments that are widespread in the town and surrounding villages. The processing plant and its emissions are often seen by local populations as being responsible for symptoms associated with respiratory illnesses (i.e., asthma and sinusitis) and vision problems. Many suggest that the dust is corrosive because it eats away at metal roofing and therefore consider it a toxic health hazard. The public consultations revealed that the inhabitants of Kamsar and the surrounding areas have little information on the composition and health impacts of the plant's emissions. Over time, a set of beliefs has been forged about the health impacts of the emissions, fueled by recurrent observations of certain symptoms and ailments and by a set of fears generated primarily by a lack of information[1].

In 2005, CBG invested US$17 million to reduce the dust emissions from the Kamsar plant's main stack, visible from several kilometers away, by 80%. The locals say the fumes have diminished but insist that more needs to be done. In this context, the Environmental and Social Impact Assessment (ESIA) for the CBG Mine Expansion Project recommended that an assessment of human health risks be carried out.

2 OBJECTIVES

The overall objective of this assessment was to identify the different CBG emissions, put them into perspective and assess their environmental health impacts. This allows us to:

- establish baseline data;
- provide the communities with transparent information on the contribution of CBG to total emissions; and
- establish a structure and strategies for implementing necessary mitigation, control and monitoring measures.

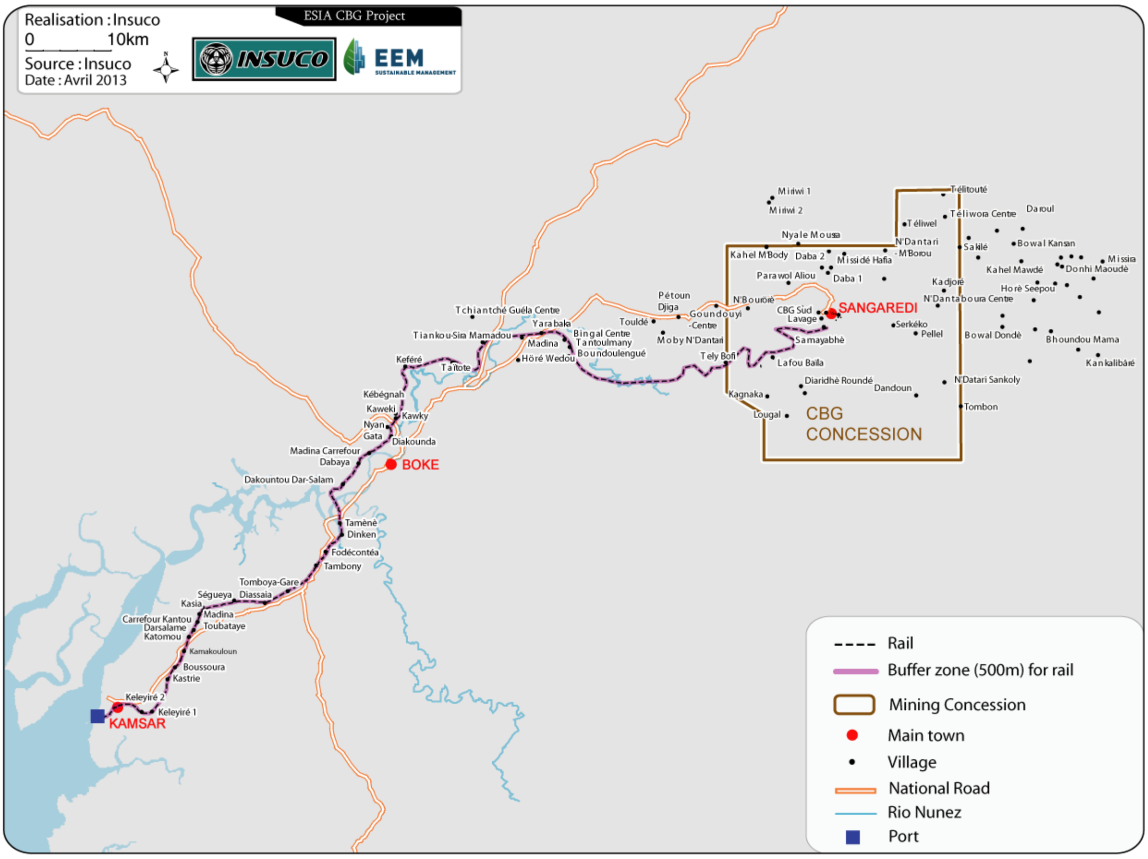
This assessment is considered a chapter of the ESIA of the CBG Mine Expansion Project.

[1] EEM (2014). Environmental and Social Impact Assessment of the CBG Mine Expansion Project – Social Impact Assessment (Chapter 7)

3 DESCRIPTION OF THE COMPANY AND ITS OPERATIONS

At present, CBG extracts, transports by rail, processes and ships some 13.5 MTPA of 3%-moisture-content bauxite (plant nameplate capacity) from its facilities, located in Kamsar and Sangarédi in northwestern Guinea, as shown in the figure below. These facilities have been in operation since 1973.

The Expansion Project involves major improvements in four separate project zones: the port and the processing plant in Kamsar, the mine near Sangarédi and the rail line that transports the ore from mine to plant.



Source: EEM and Insuco, Environmental and Social Impact Assessment of the CBG Mine Expansion Project, revised terms of reference, p.1.

Figure 1: Map of Project area and CBG facilities

Processing operations begin with the arrival of the ore by rail. At present, an average of five 120-car trains per day supply the plant's crusher. After crushing, the ore is transferred by conveyor either to a wet stockpiling area or to the dryers. The ore, which enters with 12.5% to 16% moisture content, must be dried to 5% to 7% moisture content. At present three (3) horizontal rotary dryers are used for this operation, each operating at a nominal capacity of 900 to 1,000 metric tonnes/hour. After drying, the bauxite can be stockpiled in a shed or sent directly to the loading quay, where one Panamax carrier is loaded approximately every 24 hours (about 54,000 tonnes/carrier).

At the crushing station, the cars are elevated and then overturned, dumping the ore into a chute that feeds the crushers. The unit is equipped with a dust suppression system. The rotary dryers are connected to scrubbers to control smoke emissions. The recovered sludge is stored in ponds, transferred during the dry season to drying beds and then reintroduced into the process.

The energy needed for the operations is produced by a 34-MW power station equipped with 12 generating sets burning fossil fuel.

The Expansion Project includes the construction of a new car dumper and an upgraded crushing station. The cars will be dumped into a hopper. Another stockpiling shed is also planned, along with two (2) additional rotary dryers, a loading quay extension allowing two carriers to be docked and the addition or modification of conveyors. On project completion, the plant will be able to receive an average of nine 130-car trains per day (capacity of 27.5 MTPA). The construction of closed conveyors is planned, and all chutes and transfer points will be equipped with dust suppression or collection systems. The dryers will also be equipped with scrubbers similar to those already in use.

4 DESCRIPTION OF HEALTH RISKS

4.1 Atmospheric emissions

The emissions generated by CBG operations stem from its industrial process as well as the use of heavy machinery and vehicles in Kamsar, in the mining area and along the rail line linking Kamsar to Sangarédi.

Most of the emissions are generated at the Kamsar plant from CBG's use of fossil fuel (fuel oil) to generate power and to dry bauxite. The fuel used to run the generating station and rotary dryers represents about 90% of CBG's total fuel consumption for Kamsar operations, or about 58 million liters per year (CBG, 2012).

The type of fuel oil used for these two operations is No. 6 residual fuel oil, more commonly referred to in the industry as Bunker C. This thick, viscous fuel oil is produced by mixing heavy residual fuel oils with lighter ones (usually No. 2 fuel oil) to meet certain criteria. Lower in quality, it is generally delivered with a higher sulfur content than diesel. The Bunker C currently used by CBG, delivered with a sulfur content of 2.36%, is an inexpensive fuel oil used primarily in the maritime industry.

CBG's other fuel-burning operations include its Sangarédi power station and its road, rail and maritime transportation. CBG operates a fleet of light and heavy vehicles used for various activities including ore extraction, railroad maintenance and earthworks. Rail transportation is used to haul the bauxite from the mine to Kamsar. For the purposes of this study, maritime transportation includes only fuel used by tugboats and shuttles, excluding that used by bauxite export ships. The Sangarédi power station and the entire machinery and vehicle fleet, including the locomotives, all run on diesel.

The principal gases emitted by fossil fuel combustion are sulfur dioxide (SO_2) and nitrogen oxides (NO_x, NO_2). Particulate matter (PM) is also emitted, including elemental carbon generally smaller than 2.5 µm in diameter. Volatile organic compounds are also found in trace amounts.

Nearby communities may be exposed to particulate matter emitted by the bauxite transport, crushing and drying activities of CBG.. Although dust suppression and control systems are in place, there are still visible emission sources. This dust can be carried outside the industrial zone by the wind.

One of the primary emission sources is the main dryer stack, where concentrations between 141 and 266 mg/m^3 and emission rates from 50 to 103 kg/h have been measured at the scrubber outlet (Ecoserv, 2006).

Given that no chemical reactions occur during the extraction, transport, crushing and drying of bauxite at the mine or processing plant, the composition of the dust emissions would be similar to that of the ore shipped to customers (Safety Data Sheet, Annex I).

Table 1 – Composition of bauxite ore shipped by CBG (one example)

Compound	Approximate concentration (%)
Silicon dioxide (SiO_2)	2-3
Titanium dioxide (TiO_2)	*2-3*
Iron oxide (Fe_2O_3)	19-25
Aluminum oxide (Al_2O_3)	46-49
Organic matter	25-27

Source: Minesight, CBG Long Term Mining Plan 2014-2042

Several common community activities also constitute emission sources. Vehicles, many of which are relatively old, are a substantial source of pollution due to exhaust fumes as well as the dust they stir up along the roadways. This dust is deposited on the main paved roads by vehicles coming from secondary, unpaved roads or by runoff during rainy periods. Particulate matter generated by cooking fires, trash burning and controlled brush fires are other identified emission sources.

4.1.1 Sulfur dioxide (SO_2)

SO_2 is a colorless, non-flammable gas with a pungent odor (sulfur), like the smell of a match being lit. Its presence can therefore be detected by smell, starting at a concentration of 0.4 parts per million (ppm). It is classed as non-carcinogenic for humans and is not considered a skin sensitizer.

As mentioned above, SO_2 is mainly generated by fossil fuel combustion. Thus the primary sources of SO_2 at CBG are the power stations, the dryers and the fleet of heavy machinery and vehicles (i.e., mining machinery, trucks and locomotives).

It is estimated that sulfur oxides (SO_2, SO_3) at about 500 ppm are directly emitted at the dryer outlet (Drytech International, 2011). Measurements at the scrubber outlet have found SO_2 concentrations between 11 and 35 ppm, an emission rate of 4 to 35 kg/h (Ecoserv, 2006). No results are available for power station emissions. It should be noted that no sulfur dioxide is stored at CBG facilities.

Experimental studies have shown health effects, primarily diminished pulmonary function, in asthmatics exposed to concentrations of 0.4 to 0.5 ppm (during physical exertion). No effect was observable in healthy adults at this same concentration (NAC, 2008). In the revised guidelines released by the National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances on SO_2 exposure, a concentration of 0.2 ppm was identified as the no-observed-effect level (NOEL) during experiments.

A number of years ago the US EPA (1982) presented evidence of respiratory symptoms in asthmatics exposed to peak concentrations of SO_2 over periods of 5 to 10 minutes. A more recent study (US EPA, 2009) was carried out with the objective, among others, of developing a national ambient air quality standard (NAAQS) for the general population and for subgroups with higher potential risks of effects from ambient air pollution. The research group concluded that, in urban environments, SO_2 remained one of the most useful indicators for the purposes of air quality, exposure and risk assessment. Based on the health effects of SO_2, the exposure duration parameter used was one hour (short-term exposure). Since the US EPA concludes that sufficient evidence exists of a causal relationship between short-term SO_2 exposure and respiratory difficulties, anything above 0.05 ppm should be considered a maximum exposure. In light of uncertainties noted during the study review process, the US EPA finally set its NAAQS levels for sulfur dioxide at 0.075 ppm (1 hour) and 0.5 ppm (3 hours) not to be exceeded more than once per year.

The World Health Organization (WHO) guideline values are 0.05 ppm (24-hour mean / Interim Target 1) and 0.2 ppm (10-minute mean). Given that health effects arise from short-term exposures at higher concentrations, SO_2 standards are set primarily for short-term periods rather than longer ones.

For workers, the American Conference of Governmental Industrial Hygienists (ACGIH) recommends a short-term exposure limit of 0.25 ppm (TLV-STEL).

4.1.2 Nitrogen dioxide (NO_2)

In addition to SO_2, CBG's fuel-burning activities also generate nitrogen oxides (NO_x). These include nitrogen dioxide (NO_2), which is used as an indicator by the WHO and other organizations. NO_2 is a colorless, non-inflammable gas that irritates respiratory passages if inhaled in excessive concentrations. Its olfactory threshold varies from 0.1 to 5 ppm (CSST, 2014). It is classed as non-carcinogenic for humans and is not considered a skin sensitizer.

Experimental studies have found health effects, primarily diminished pulmonary function, in asthmatics exposed to concentrations from 0.3 to 0.5 ppm, while other studies have demonstrated no symptoms at concentrations from 0.5 to 4 ppm (NAC, 2008). The National Advisory Committee for the Development of Acute Exposure Guideline Levels for Hazardous Substances uses 0.5 ppm as the level causing no adverse health effects during experiments (NAEL).

For workers, the ACGIH recommends a time-weighted average threshold limit value (TLV-TWA) of 0.2 ppm. In 2010, the ACGIH lowered this value from 3 ppm to 0.2 ppm (380 $\mu g/m^3$) and eliminated its 5 ppm short-term exposure limit (TLV-STEL). This modification was intended to protect asthmatic workers from lower-respiratory tract irritation.

In addition to the ACGIH review of the health impacts of NO_2, a US EPA (2008) review considers the impacts of NO_2 on asthmatics. The US EPA exposure and risk assessment demonstrated that most asthmatics could experience a respiratory hypersensitivity response following short-term exposure to concentrations of NO_2 starting at 0.1 ppm. The US EPA set a lowest-observed-effect level (LOEL) of 0.1 ppm. Because people with more severe asthma can react at lower concentrations, a maximum level of 0.05 ppm (daily 1-hour period) was recommended as a possible alternative. Currently, the US EPA standard (NAAQS) is 0.1 ppm (1 hour) and 0.053 ppm (annual mean).

The WHO guideline limits are 0.02 ppm (annual mean) and 0.1 ppm (1-hour mean).

As mentioned above, NO_2 is mainly produced by the combustion of fossil fuels. As is the case for SO_2, the main sources of NO_2 emissions at CBG are the power station, the dryers and the heavy machinery and vehicles. Measurements at the outlet of the dryer scrubbers have found concentrations between 8 and 12 ppm, an emission rate of 3 to 6 kg/h (Ecoserv, 2006). No results are available for the power station. It should be noted that no nitrogen dioxide is stored at CBG facilities.

4.1.3 Particulate matter (PM)

At CBG, although a portion of PM emissions come from fossil fuel combustion, the majority are generated by the transportation (i.e., dust stirred up on mine roads) and processing of bauxite. Very few studies have been carried out on human exposure to bauxite and no occupational diseases are directly linked to it. No limits exist for exposure to bauxite dust, which is recognized as having no specific effects. Bauxite dust is considered inert from a regulatory standpoint. A study on respiratory symptoms and lung function in bauxite miners (Beach et al., 2001) showed no evidence that bauxite exposure at the levels observed (average of 5.9 mg/m^3) was associated with respiratory deficiency. Subjects with higher cumulative exposures did not report symptoms at a higher frequency than a group with lesser exposure.

Even if considered non-toxic, particulate matter has been shown to have a wide range of adverse respiratory and cardiovascular effects, particularly in vulnerable individuals such as children, the elderly and people with existing health conditions.

From the environmental health perspective, particulate matter is generally divided into two categories: PM_{10} (diameter of 10 microns or less) and $PM_{2.5}$ (diameter of 2.5 microns or less). Among other sources, $PM_{2.5}$ is emitted by all types of combustion. The particle composition and potential health effects vary depending on the source. Commonly referred to as fine particles, $PM_{2.5}$ can penetrate deep into the lungs, causing irritation of the respiratory tract. For example, fuel combustion releases elemental carbon which, as $PM_{2.5}$, can cause respiratory irritation in vulnerable populations. Moreover, fine particles emitted in diesel exhaust can increase the risk of developing lung cancer.

In recent years, some studies have suggested that exposure to dust particles less than 10 µm in diameter can be a risk factor for cardiovascular disease. Studies have also demonstrated PM effects on heart rate variability, although not necessarily for any specific fraction. Such effects have been observed with both short-term and long-term exposure.

One recent study (Brook et al., 2014) showed a possible relationship between exposure to $PM_{10-2.5}$ (coarse particles) at an average concentration of 0.076 mg/m^3 and increased heart rate and elevated blood pressure. They concluded that exposure to higher concentrations could contribute to cardiovascular disease. This category of dust is not currently regulated as an atmospheric pollutant, although it may be associated with short-term health effects. Thus, exposure to high concentrations of particulate matter seems to be an important risk factor to consider, particularly for vulnerable populations. Additional research would be necessary to validate this.

Exposure to high concentrations of particulate matter can contribute to the development of health problems such as ischemia and arrhythmia, and can even alter vasodilation performance. In terms of increased risk of mortality, the results are difficult to interpret because the data come from different cities, all with different particulate matter compositions. Very recently, a study looking at outside air pollution and out-of-hospital cardiac arrest concluded that short-term exposure to particulate matter in the prior 48 to 72 hours was associated with an increased risk of cardiac arrest (Yorifuji et al., 2014). Other epidemiological studies of this type are in progress. Finally, although the effect of particulate matter on the central nervous system is an emerging field of study, few studies are available at this time.

For workers, ACGIH recommends a time-weighted average threshold limit value (TLV-TWA) of 10 mg/m^3 (inhalable fraction) for particles not otherwise classified, and 3 mg/m^3 for the respirable fraction. Additional exposure criteria can be used to monitor dust compounds such as iron, aluminum or silica.

The US EPA has established national standards (NAAQS) for $PM_{2.5}$ and PM_{10}, as shown in Table 3 below.

Table 2: Time-weighted average threshold limit values for the different pollutants

Pollutant	TLV-TWA
Dusts not otherwise classified	3 mg/m$^{3 (R)}$ / 10 mg/m$^{3 (I)}$
Silica (SiO_2) – Crystalline	0.025 mg/m$^{3 (R)}$
Silica (SiO_2) – Amorphous	3 mg/m$^{3 (R)}$ / 10 mg/m$^{3 (I)}$
Titanium dioxide (TiO_2)	10 mg/m^3
Iron oxide (Fe_2O_3)	5 mg/m$^{3 (R)}$
Aluminum oxide (Al_2O_3)	1 mg/m$^{3 (R)}$

$^{(R)}$ Respirable fraction, $^{(I)}$ Inhalable fraction

Source: ACGIH, 2014 TLVs and BEIs.

Table 3: US EPA National ambient air quality standards (NAAQS) for particulate matter

Pollutant	Primary/secondary	Averaging time	Level
$PM_{2.5}$	Primary	Annual	0.012 mg/m^3
	Secondary	Annual	0.015 mg/m^3
	Primary and secondary	24-hour	0.035 mg/m^3
PM_{10}	Primary and secondary	24-hour	0.15 mg/m^3

Source: National Ambient Air Quality Standards (NAAQS) | Air and Radiation | US EPA

The WHO guidelines for PM_{10} are 0.02 mg/m^3 (annual mean) and 0.05 mg/m^3 (1-hour mean), with interim target values for annual and 1-hour exposure also recommended. For $PM_{2.5}$ the WHO guidelines are 0.01 mg/m^3 (annual mean) and 0.025 mg/m^3 (1-hour mean), with interim target values for annual and 1-hour exposure also recommended.

Based on data from the World Bank (David R. Wheeler et al., 2006), average PM_{10} concentrations in residential areas of Guinean cities with over 100,000 inhabitants were estimated at 0.07 mg/m^3 (Conakry). The average for all cities with 100,000 or more inhabitants in West Africa is 0.09 mg/m^3. All of these values exceed the annual mean limit of 0.02 mg/m^3 recommended by the WHO.

Table 4: WHO ambient air quality guidelines

Pollutant	Averaging period	Target	Value mg/m^3	Value ppm
$PM_{2.5}$	1-year	Interim target-1	0.035	N/A
		Interim target-2	0.025	N/A
		Interim target-3	0.015	N/A
		Guideline	0.01	N/A
	24-hour	Interim target-1	0.075	N/A
		Interim target-2	0.05	N/A
		Interim target-3	0.0375	N/A
		Guideline	0.025	N/A
PM_{10}	1-year	Interim target-1	0.07	N/A
		Interim target-2	0.05	N/A
		Interim target-3	0.03	N/A
		Guideline	0.02	N/A
	24-hour	Interim target-1	0.15	N/A
		Interim target-2	0.1	N/A
		Interim target-3	0.075	N/A
		Guideline	0.05	N/A
SO_2	24-hour	Interim target-1	0.125	0.05
		Interim target-2	0.05	0.02
		Guideline	0.02	0.01
	10-minute	Guideline	0.5	0.2
NO_2	1-year	Guideline	0.04	0.02
	1-hour	Guideline	0.2	0.1

Source: IFC, Environmental, Health, and Safety (EHS) Guidelines, p.6.

4.2 Environmental noise

The human ear constantly receives input from the environment. Such sound does not necessary constitute an annoyance or create health risks. The effects of low-level noise on humans are often difficult to interpret because they are often more qualitative than quantitative.

Excessive noise levels can cause hearing loss. The US EPA and several other organizations use 70 dBA measured over a 24-hour period as a reference value for prevention (LAeq, 24h). Levels from 78 to 80 dBA have been found to cause hearing loss (Stephenson et al.). It has been demonstrated that with exposure levels under this threshold, measurable hearing loss over a lifetime is prevented. However, there does seem to be a higher risk for certain groups, such as children. The risk of hearing loss can also be greater if subjects are exposed at the same time to vibration, a chemical agent or an ototoxic drug, or if they are exposed to noise levels higher than 70 dBA (LAeq, 24h). Data on the relationship between exposure level and hearing loss in the general population are relatively rare. However, based on the limited number of studies available, we can conclude that the risk of hearing loss is very low if the 70 dBA (LAeq, 24h) limit is not exceeded. To eliminate the risk of damage, the peak impact noise level should not exceed 140 dBA for an adult or 120 dBA for a child.

Environmental noise is controlled mainly to prevent interference with talking and sleep, as well as to prevent annoyance. According to the literature, starting at 50 dBA conversation between people a few meters apart can become more difficult. Up to 45 dBA normal speech can be heard with ease, but voices must be raised once 65 dBA is reached. Other factors such as age come into play, as hearing can begin to deteriorate after 40.

Studies have shown that both continuous and intermittent noise can cause sleep disturbance, and the level of disturbance increases with the sound level. Such effects are observable starting at 30 dBA (LAeq). One of the effects measured is the alteration of the sleep phases, particularly the paradoxical (REM) phase. Other, subjective effects have also been noted, such as difficulty falling asleep, changed perception of sleep quality, as well as secondary effects such as headaches or fatigue. The groups most sensitive to these effects are the elderly, shift workers and people with mental or physical disabilities. In the case of continuous noise, an average level of 30 dBA (indoors) is the recommended limit to prevent sleep disturbance. For intermittent noise, levels exceeding 45 dBA (indoors) should be avoided. Note that a given sound level becomes more disturbing as the level of background noise falls.

According to epidemiological studies, cardiovascular effects can be felt with exposure to levels above 65 dBA (LAeq, 24h). This association is weak, however, and more data is needed to confirm it. Other impacts have been observed, such as effects on mental health, performance and social habits, although noise level guidelines have not been suggestion by these researchers.

To limit the impacts of noise on sleep quality and to prevent interference with human activity, the US EPA suggests that noise levels in residential areas be kept under 55 dBA on average to protect public health and welfare with an adequate safety margin. In certain documents, the US EPA recommends an average exposure level of 45 dBA for indoors and 55 dBA for outdoors. These guideline values do not take technical feasibility into account and are not intended to be regulatory. Another reference is provided by the US Department of Housing and Urban Development (HUD), which only agrees to finance real estate projects in areas where noise levels are under 65 dBA, which it considers the generally acceptable level. Moreover, the US Department of Defense and Federal Aviation Administration use this same criterion in regard to disturbance caused by air traffic. Finally, the US Federal Highway Administration adopts 67 dBA (LAeq, 1h) as a reference value to determine the need for mitigation measures.

In developed countries, local governments often determine guidelines for their own municipalities. In addition, the WHO has established guidelines of 45 dBA (outdoors, from 22:00 to 7:00) and 55 dBA (from 7:00 to 22:00). There are also guidelines involving the difference between sound level and background noise. The IFC recommends that noise level increases above background or initial conditions should be less than 3 dBA, although inclusion criteria are not clearly identified. We can assume that the IFC's objective is to minimize the perception of change. The literature mentions that increases of less than 3 dBA are barely perceptible and have marginal or no impacts. Increases of over 3 dBA are more readily perceptible, but the impact is considered low up to 5 dBA. At more than 5 dBA above background the impact is considered moderate, and at more than 10 dBA above background the impact is high (Bies, 1997) and the perceived noise level doubles. A study by the US EPA (EPA, 1974) suggests that complaints and legal proceedings are foreseeable when the average baseline noise is increased by 5 dB or more by another community source and vigorous action is taken when the difference exceeds 20 dB.

For workers, depending on the country, guidelines vary from 85 dBA to 90 dBA (LAeq, 8h). The formerly used level of 90 dBA does not appear to be low enough, as many studies have since demonstrated a risk of occupational hearing loss at lower exposure levels. In 1997, the report entitled Technical Assessment of Upper Limits on Noise in the Workplace, approved and published by the International Institute of Noise Control Engineering, recommended among other things:

- a limit of 85 dBA for an 8-hour shift;
- a maximum of 140 dB-C for impulsive sounds;
- an exchange rate of 3 dB for determining doubled sound levels;
- adoption of a noise control program when exposure levels exceed 85 dBA (LAeq, 8h);
- the use of hearing protection, to be encouraged in workers exposed to levels above 85 dBA (LAeq, 8h) and required for levels above 90 dBA (LAeq, 8h); and
- audiometric testing by employers for workers exposed to levels above 85 dBA (LAeq, 8h) at least every three years.

Countries such as Australia, France, Germany and Great Britain have already adopted these recommendations as minimum requirements.

4.3 Water quality

Access to drinking water is essential for local communities and is a fundamental aspect of human rights. Drinking water quality can have a direct impact on public health. Various factors can influence its quality, including microbiological characteristics, disinfection, chemical and radiological compounds, taste, odor and appearance.

It is important to clearly define the roles and responsibilities for the management of drinking water supply points. A wide range of participants may be involved in control and monitoring activities, from public health services to local authorities (e.g., technical services), community organizations and, ultimately, consumers.

Performance criteria must be established. The evaluation of physical parameters carried out by SENES Consultants for the purposes of the ESIA took into account the Drinking Water Directive of the European Union (Council Directive 98/83/EC), which stipulates:

> "In the event of non-compliance with the parametric values or with the specifications set out in Annex I, Part C, Member States shall consider whether that non-compliance poses any risk to human health. They shall take remedial action to restore the quality of the water where that is necessary to protect human health."

Whereas the values presented in Annex I of the EU directive are to be used as guidelines, the values presented in Annex I, Part C are for monitoring purposes only. The present report primarily references the Guidelines for Drinking-water Quality prepared by the WHO, which are based on direct human health effects. For example, the WHO does not recommend a guideline for iron because it is an essential element of the human organism. It mentions that levels lower than 2,000 µg/l would have no health effects, but that odor and appearance would be affected at much lower levels. The EU directive, however, recommends 200 µg/l as a monitoring parameter. Similarly, for manganese the WHO mentions a concentration of 400 µg/l while the EU recommends 50 µg/l as a monitoring parameter.

4.4 Transmissible disease

According to investigations carried out by Insuco for the socioeconomic study of the Expansion Project ESIA, the main pathologies observed at the hospital are:

- malaria;
- pulmonary diseases (including acute respiratory infections and tuberculosis);
- HIV/AIDS (associated with other pathologies);
- digestive diseases and diarrhea.

The socioeconomic study report (Insuco, 2014) mentions that, apart from HIV/AIDS, which is generally related to concentrations of workers and foreigners, the pathologies observed are not directly related to mine operations. This risk assessment therefore covers HIV/AIDS along with malaria, which is the first cause of death on a national scale.

4.4.1 HIV/AIDS

Nationally, HIV/AIDS is the 8th cause of illness and the 11th cause of death for children under 5 years of age (WHO, 2012), with a general mortality rate of 48/100,000 people (WHO, 2007). In the ESIA socioeconomic study for the Expansion Project, Insuco clearly described the situation regarding the presence of HIV/AIDS in the region. They mention that the epidemiological situation in the project area has been studied by Partners Against AIDS, an NGO created by the Agence Française pour le

Développement (AFD), SIDA-Entreprises and the Global Business Coalition on HIV/AIDS, Tuberculosis & Malaria. Seven mine sites in the Republic of Guinea's three main mining areas were the subject of a feasibility study to integrate HIV/AIDS medical and psychosocial care services. Published in 2009, this study was based on the Guinea HIV/AIDS behavioral and biological surveillance survey carried out in 2007 by the NGO Stat View International (ESCOMB, 2007). The survey included 600 industrial miners and 600 artisanal operators from different mining areas in Guinea.

Although UNAIDS estimates the prevalence of HIV/AIDS in Guinea at 1.7%[2], the ESCOMB survey determined its prevalence (HIV-positive and infected people) to be 5.2% among men working in the mining sector and up to 7.5% for workers in Lower Guinea. The same survey maintained that the rate could be as high as 14.2% among single miners. As for fishermen, 5.6% carry the virus. In Boké prefecture, mining areas are magnets for those seeking work, but also for sex workers, among whom prevalence rises to 34.4%[3]. Throughout Africa, the prevalence for adults from 15 to 49 years of age is estimated at 4.9% (WHO, 2010).

4.4.2 Malaria

Guinea is a malaria-endemic region, with a high rate of transmission throughout the country. In 2006, malaria-related mortality was 164 per 100,000, while the average for Africa was 104. In Guinea malaria is the first cause of illness, and the first cause of death for children under five years old (WHO, 2012). According to the World Malaria Report of 2013, the primary strain found is *P. falciparum* (WHO, 2013).

In 2009, the Republic of Guinea carried out a program to distribute insecticide-treated mosquito nets free-of-charge to people of all ages. This intervention was shown to reduce clinical episodes by 50% and reduce mortality in children under 5 years of age by 18%. In 2012, Guinea also adopted a measure making malaria diagnosis and artimisinin-combination therapy (ACT), now the only type considered truly effective, free-of-charge for anyone in the public sector. Over the past 10 years the fight against malaria in Guinea has been funded primarily by The Global Fund, the World Bank, WHO/UNICEF and USAID/PMI.

5 SAMPLING STRATEGY AND RESULTS

5.1 Combustion gases

The gas sampling was done with passive samplers, which can take gas or vapour samples from ambient air at a rate based on a physical process, like diffusion across a membrane. This process does not require active air movement through the sampler. The PASS sampler used for this study was

[2] http://www.unaids.org/fr/regionscountries/countries/guinea/

[3] http://www.sidaentreprises.org/fr/UserFiles/file/Guinee%20faisabilite%20PEC%20secteur%20mines.pdf

developed by the Maxxam laboratory with support from Alberta Environment and Parks (AEP) and the National Research Council of Canada (NRC), among others.

Two series of samples were taken at the boundary of the Kamsar industrial area and the first dwellings, each over a one-month period during the dry season. The first series was taken from February 28 to April 2, 2014, and the second from May 14 to June 14, 2014. Given the location of the plant in relationship to the town and the direction of the prevailing winds, a single sampling point was adequate for the purposes of this assessment (See Chapter 2 of the ESIA).

In the mining area, two sampling points were selected, upwind and downwind of the mining operations. The sampling was carried out in March and April (dry season). Given the size of the area and the presence of villages and hamlets all around it, more than one sampling point was required (see Chapter 2 of the ESIA).

For each series, two (2) passive samplers per gas type were installed (NO_x, NO_2, SO_2). Parallel sampling was used to validate the accuracy and precision of the results. A control sample was also added for each sampling day. A detailed description of the sampling procedure is given in Annex II.

Source: S. Dallaire – CBG 2014.

Figure 2: Placement of gas samplers in Kamsar

The average concentration of SO_2 obtained in the town of Kamsar was 0.0019 ppm (4 results) throughout the sampling period, with a standard deviation of 0.00059 and a maximum of 0.0027 ppm.

The average concentrations of NO_x and NO_2 were 0.0073 ppm and 0.0027 ppm respectively throughout the same period, with standard deviations of 0.00069 and 0.00021 respectively.

Table 5: Gas sampling results

Location	Number	Average concentration (ppm)			Maximum concentration (ppm)		
		NO_2	NOx	SO_2	NO_2	NOx	SO_2
AQ-1-Alcoa	4	0.0027	0.0073	0.0019	0.0029	0.0081	0.0027
AQ-10-Parawi	2	0.0005	0.00085	0.0002	0.0005	0.002	0.0002
AQ-12-Petoun BW	2	0.0013	0.0023	0.0001	0.0014	0.0028	0.0001

In the area near the mining operations (AQ-12), the average concentrations were 0.0013 ppm (NO_2), 0.0023 ppm (NOx) and 0.0001 ppm (SO_2). Measurements were also taken during the same period in an area of the mining concession not in operation to serve as a baseline (AQ-10). Over a period of 31 days, the concentrations obtained were 0.0005 ppm (NO_2), 0.00085 ppm (NOx) and 0.0002 ppm (SO_2).

5.2 Particulate matter

Particulate matter sampling was carried out using a MiniVol, a portable air sampler manufactured by Airmetrics. Developed in collaboration with the US EPA, it is used to sample total suspended particles, particles under 10 µm (PM_{10}) and particles under 2.5 µm ($PM_{2.5}$). It consists of a pump that forces air through a particle size separator (cyclone) and then a filter at a constant flow rate of 5 liters/minute. The particle separation is achieved by impaction.

The sampling and calibration instruments were all previously inspected and calibrated by the manufacturer using a primary standard. Before and after each sample the instruments underwent secondary calibration directly at the sampling site using a digital pressure gauge that had been calibrated with traceability by the U.S. National Institute of Standards and Technology (NIST). The MiniVol is designed to function at flows from 4.5 to 5.5 L/min. The temperature and atmospheric pressure at the time of calibration were obtained from a meteorological station in the immediate vicinity. The flow was calculated using the formula below, obtained when the pressure gauge was calibrated (certificate):

$$Flow(l/min) = \frac{5{,}6465\sqrt{P1*T}}{P2} + 0.0719$$

P1 = Pression from the gauge (in H_2O)
P2 = Atmospheric pressure (mm Hg)
T = Temperature (K)

In Kamsar, sampling was divided into two (2) series of six (6) sampling days (24 hours). Sampling was carried out in parallel at two (2) different points at the boundary of the industrial zone and the first dwellings. At each point, three (3) samplers were installed to ensure simultaneous sampling of total suspended particles, PM_{10} and $PM_{2.5}$. A control sample was added for each sampling day. In addition to gravimetric analysis, a metals analysis was also requested every two (2) sampling days. The sampling procedure is detailed in Annex III.

The results show an average PM_{10} concentration ranging from 0.113 to 0.123 mg/m^3 and an average $PM_{2.5}$ concentration of 0.07 µg/m^3. Composition analysis of the total dust collected revealed the presence of aluminum at about 2% on average (maximum 3%). Other potentially toxic elements such as antimony, arsenic, cadmium, chromium, copper and nickel were not detected in any of the samples analyzed.

Source: S. Dallaire – CBG 2014.

Figure 3: PM sampling station in Kamsar

Table 6: Results of particulate matter sampling

Location	Number	Average concentration (mg/m^3)			Maximum concentration (mg/m^3)		
		PM10	**PM2.5**	**Al**	**PM10**	**PM2.5**	**Al**
AQ-1-Alcoa	12	0.113	0.071	0.003	244.4	0.118	0.007
AQ-2-Ecole	12	0.123	0.070	0.003	245.3	0.124	0.008
AQ-10-Kourawel	5	0.125	0.076	0.001	195.0	0.153	0.002
AQ-13-Parawi	5	0.081	0.036	0.001	89.7	0.054	0.002
AQ-11-Hamdal.	6	0.096	0.062	0.002	115.2	0.085	0.002
AQ-12-Petoun	6	0.111	0.073	0.0009	133.0	0.085	0.001

Results from the samples taken in the vicinity of the mining operations (Sangarédi) show average PM_{10} concentrations ranging from 0.096 to 0.111 mg/m^3 and an average $PM_{2.5}$ concentration of 0.068 mg/m^3. Composition analysis of the total dust collected showed it contained aluminum at an average of about 1.4%. Other potentially toxic elements such as antimony, arsenic, cadmium, chromium, copper and nickel were not detected.

Measurements were carried out in parallel in an area of the mining concession not in operation (AQ-10, AQ-13) to provide baseline data. Over the course of ten 24-hour sampling periods, average concentrations were 0.103 mg/m^3 (PM_{10}), 0.057 mg/m^3 ($PM_{2.5}$) and about 1% aluminum.

In addition to the sampling campaign carried out by CBG, SENES Consultants carried out an air quality impact assessment for the CBG Expansion Project. The results of that assessment, including modeling data, are available in Section 2.1 of the ESIA.

5.3 Noise

During the update of physical parameters by CBG, an intensive sound level measurement campaign was carried out. Measurements were taken continuously over a 48-hour period as suggested by the IFC in five locations in the Kamsar region and 15 in the Sangarédi (mine) region. The results were sent to SENES Consultants for analysis and interpretation, and the results were used in the development and validation of their diffusion models.

Table 7: Results of environmental noise measurements in the Kamsar region (dBA)

Location	Day		Night (22:00-7:00)		Total	
	L_{eq}	L_{90}	L_{eq}	L_{90}	L_{eq}	L_{90}
NR-1	50.9	45.9	51.7	47.1	51.0	46.1
NR-2	52.8	45.6	47.5	43.7	52.3	45.4
NR-3	60.0	48.3	52.5	47.2	59.3	48.1
NR-4	59.2	55.3	53.4	46.3	58.6	54.6

Table 8: Results of environmental noise measurements in the Sangarédi region (dBA)

Village	Day L_{eq}	Night (22:00-7:00) L_{eq}	Total
Tiewere	38.2	30.9	35.7
Fassali	36.5	36.5	36.5
Parawol Sitako	40.1	39.6	39.9
Pavari	39.4	38.8	39.1
Hamdallay	53.1	55.1	54.1
Dounsi	36.2	37.1	36.5
Kogon Lingue	48.6	45.0	47.8
Kagnaka	50.4	52.3	50.9
Paragogo	NI	NI	NI
Bandodji	38.6	32.1	36.4
Kourawel	38.0	34.0	36.5
Petoun B. Wande	43.9	43.9	43.9
Samayabhe	41.4	39.5	40.9
Hore Lafou	45.5	51.8	47.6
Parawol	NI	NI	NI

NI – Result not included due to non-representative meteorological conditions

The sampling and calibration instruments were all previously inspected and calibrated by the manufacturer using a primary standard. Before and after each sample, the instruments underwent secondary calibration directly at the sampling site using a sound source that had been calibrated with traceability by the U.S. National Institute of Standards and Technology (NIST).

5.4 Water quality

During the update of physical parameters by CBG, a surface and groundwater sampling campaign was carried out. Samples were taken from wells (Sangarédi), the Rio Nuñez, the Dougoufissa River and from various watercourses in the Sangarédi mining area. The samples were sent to SENES Consultants for analysis and interpretation, and were used in the development and validation of their diffusion models. These results are available in Section 2.3 of the ESIA report.

6 DISCUSSION

The results from this assessment were primarily compared to WHO guidelines and the Environmental Health and Safety (EHS) Guidelines – General EHS Guidelines of the International Finance Corporation (IFC). These two organizations are used as reference standards by banking institutions financing international projects. Criteria and studies from other organizations (e.g., the US EPA) were also consulted in order to more accurately interpret and assess health risks.

6.1 Combustion gases (SO_2, NO_2)

The results show that the average values obtained during the sampling period for SO_2 and NO_2 are below the most stringent WHO guidelines (15 - 30%) and far below the ACGIH guidelines (1 - 2%). Ambient SO_2 concentrations also appear to be relatively stable, as the results of the two sampling series are similar. The results of the sampling in parallel, which again are quite similar, also support the accuracy of the values.

We estimate the contribution of CBG sources to the concentration measured in Kamsar to be 80-90%, given the concentrations of NO_2 (0.005 ppm) and SO_2 (0.0002 ppm) obtained in the area of the mining concession not currently in operation (AQ-13 Parawi). CBG's contribution to SO_2 emissions would be greater, mainly due to the use of residual fuel oil (Bunker C) to run the power station and the dryers. This type of fuel oil has a higher sulfur content than, for example, diesel fuel, which is generally used for heavy vehicles and machinery.

The sampling method used cannot reveal variations in concentrations over a precise period of time. However, based on the modeling carried out by SENES Consultants, it is unlikely that WHO guidelines would be exceeded by current operations, even with unfavorable meteorological conditions or for short periods (e.g., 24 hours, 1 hour, 10 min.).

Expanded production could lead to a significant increase in gas concentrations. Based on the modeling done by SENES Consultants, short-term exposures could occasionally exceed current guidelines, primarily in the 27.5 MTPA production phase. Over a short-term period, the population of the industrial area in Kamsar could be exposed at times to SO_2 concentrations of about 0.25 to 34 ppm (10 min) and NO_2 concentrations of 0.14 to 0.20 ppm (1 hour) during unfavorable meteorological conditions. These projected values would be up to double the WHO guideline values. SENES Consultants points out that these values estimated over a short period (10 min, 1 hour, 24 hours) represent the maximum single concentration that may be measured during an event that could occur at any time over a five-year evaluation period. However, the assessment by SENES Consultants suggests that the maximum 24-hour and annual exposure values would meet current guidelines.

In the mining area, the analyses and assessments carried out by SENES Consultants demonstrated that average long-term (annual) concentrations were negligible. However, for NO_2 arising from mine blasting, exceedances may be possible with existing operations and with the future expansion. In order to meet guidelines, a setback distance of 525 to 595 meters should be maintained between mining operations and communities.

According to the US EPA health risk and exposure assessments, the risk that the ambient-air concentrations we measured could be associated with respiratory diseases seems to be low, given that the maximum estimated one-hour exposure level of SO_2 was close to the national ambient air quality standard (*NAAQS*) of 0.075 ppm for the closest dwellings, and diminished with distance. The production expansion could aggravate this risk, especially the 27.5 MTPA phase, when the maximum estimated one-hour exposure level could be between 0.047 ppm (maximum 24-hour concentration) and 0.34 ppm (maximum 10-min. concentration).

The concentrations of NO_2 measured under existing operating conditions meet the WHO and US EPA guidelines, but could increase when the 18.5 MTPA production phase is reached. This would be in addition to the sulfur dioxide impacts.

At the mine, given the required setback distance of 500 meters for blasting, the population would not be exposed to levels in excess of the lowest-observed-effect level (LOEL) of 0.1 ppm. However, vulnerable individuals such as asthmatics could be affected starting at 0.05 ppm.

For CBG workers, concentrations of NO_2 meet the ACGIH guidelines for occupational exposure in all production phases. With regard to SO_2, the models suggest that concentrations could be higher. These results must be interpreted with caution, however, because these are primarily stack emissions, which are problematic as a basis for estimating worker exposure inside the industrial area.

A more detailed sampling program should be considered to properly document more long-term emissions and variability over time, particularly under unfavorable meteorological conditions. Continuous monitoring would allow CBG to more accurately quantify the increased risks associated with its Expansion Project. It is therefore advisable to establish a continuous measuring station for combustion gases (NO_2, SO_2) and a meteorological station at sampling point AQ-2 to closely monitor variations in gas concentrations over time. Selecting this location, which is in a low-traffic area, will reduce the influence of roadway dust, as opposed to point AQ-1 located near two busy roads. A community communication plan must also be developed.

With data from continuous monitoring, CBG would be able to develop contingency plans in case established standards were exceeded, such as switching to residual fuel oil with a lower sulfur content, a public advisory plan to be implemented in case of unfavorable conditions (i.e., development of an air quality index to be broadcast over the radio) or the use of emission reduction technologies.

In the mining area, a periodic passive sampling program based on the different production phases is suggested to validate the models and allow for transparent communication with the nearby communities. The recommended indicator for this is nitrogen dioxide (NO_2). It is also important to give villagers advance notice of mine blasting so that vulnerable individuals living within a 1-km radius (e.g., infants, the elderly and asthmatics) can distance themselves or stay indoors for a short time after the blast. Blasting at regularly scheduled times would make this easier.

Finally, a targeted assessment of worker exposure is recommended to more fully document the situation for this group.

6.2 Particulate matter

The results obtained in Kamsar were compared to those obtained in the part of the mining area with no production nearby (i.e., Kourawel, Parawi). The results of the sample analysis demonstrate that the average values obtained exceed the WHO guidelines. Surprisingly, however, the concentrations obtained in the mining area are similar to the dust concentrations measured in Kamsar. It is difficult to conclude that CBG operations in Kamsar could significantly influence total concentrations of suspended particulate matter. Clearly, additional emission sources were present during sampling.

It is interesting to note that the percentage of aluminum in the total dust collected in Kamsar was approximately 2%. Although in the mining area we do find aluminum in the dust collected in areas not in operation (average of 0.95% for the outlying sampling points), assuming that in Kamsar one should not find aluminum in suspended particles (without the presence of CBG) and given that the aluminum percentage is at least 48% in the bauxite processed in the plant and shipped, we can estimate that a small percentage of the dust collected during the Kamsar sampling came from CBG operations (contribution estimated at about 4%).

This contribution would be raised slightly by the emission of elemental carbon mainly from fuel combustion to run the dryers, the power station and the fleet of heavy machinery and vehicles.

A study carried out by an environmental management institute in Brussels (Institut de gestion environnementale de Bruxelles) demonstrated a strong correlation between concentrations of NO_2 and the presence of elemental carbon in urban air. Results from the air quality report of New York City show that elemental carbon represents approximately 4.6% of the concentration of NO_2. Given that CBG contributed 80% of the NO_2 measured, we can attempt to estimate the elemental carbon concentration at about 0.0001 mg/m^3 for 0.0022 ppm of NO_2. Based on the moderate correlation between PM_{10} and elemental carbon (Y = 0.0776 * X) and the fact that $PM_{2.5}$ represents about 60% by weight of the PM_{10}, the contribution of $PM_{2.5}$ generated by fuel combustion would seem to be negligible (0.0008 mg/m^3). CBG's total contribution to measured $PM_{2.5}$ would therefore be about 0.0036 mg/m^3 and to PM_{10} about 0.0055 mg/m^3, or 36% and 28% respectively of the WHO guidelines for annual exposure.

Table 9: Estimated contribution of CBG to emissions measured at the Kamsar sampling stations

Type of emission	Estimated concentration (mg/m^3)
PM (bauxite)	0.0066
PM_{10} (bauxite)	0.0047
$PM_{2.5}$ (bauxite)	0.0028
Aluminum (bauxite)	0.0031
Quartz (bauxite)	< 0.00007 – 0.0002
$PM_{2.5}$ – fossil fuel	0.0008
Elemental carbon	0.0001
NO_2	0.0022 (ppm)
SO_2	0.0017 (ppm)

The rest of the particulate matter measured during sampling would be from cooking fires, trash burning, and dust stirred up on cleared land or unpaved roads by the wind or vehicles. Note also that the sampling period overlapped the West African Harmattan, a continental trade wind blowing south from the Sahara to the Gulf of Guinea in winter, from the end of November to mid-March. This very hot, dry wind carries a substantial amount of dust and sand (fines particles of 0.05 to 1 µm).

The modeling studies by SENES Consultants corroborate the above analysis, with projected average annual concentrations at the nearest dwellings estimated to be from 0.018 to 0.023 mg/m^3 for $PM_{2.5}$ and from 0.034 to 0.044 mg/m^3 for PM_{10}. Note that the modeling by SENES Consultants only includes emissions generated by CBG. Over the shorter-term periods, the maximum 24-hour concentration estimated by the model varies from 0.120 to 0.122 mg/m^3 for $PM_{2.5}$ and from 0.243 to 0.246 mg/m^3 for PM_{10}. As for combustion gases, SENES Consultants indicated that these short-term values (10 min, 1h and 24h) represent the maximum single concentration that may be measured in an event that occurs at any time over a five-year assessment period.

Unlike for combustion gases, the CBG Expansion Project should not increase airborne particle concentrations. The plant has been operating since 1973 with outdated equipment and technologies. The new car dumping station will be underground rather than above ground and less handling will be required, thereby minimizing the release of dust into the air. The station will also be equipped with a dust suppression system using the latest technology. Unlike the current, open conveyors, the new conveyors will be closed and at each chute and transfer point a dust suppression or collection mechanism will be installed. Finally, the new dryers will be linked to a system of scrubbers.

Although the modeling by SENES Consultants allows for possible exceedances of the guidelines for existing operations and for short-term events, in light of the results from the baseline study and the modeling studies, it is estimated that the guidelines will be met once the 18.5 MTPA production phase is reached and during all subsequent phases.

Mining operations also generate particulate matter emissions which must be taken into account. Under existing operations, the concentrations projected by SENES Consultants meet current guidelines for the closest villages, i.e., Hamdallaye (AQ-10), Petoun Boundou Wande (AQ-12) and Pora (SR-58). The model estimates for the different production phases are based on the areas currently affected by mining operations. There seem to be two (2) sensitive areas that will be affected by the planned production increase. The population of Hamdallaye, a village near the planned stockpiling facility, could be exposed to an average annual PM_{10} concentration that exceeds guidelines (0.084 mg/m^3) once the 18.5-MTPA production phase is reached. A second sensitive area is Carrefour Parawol (SR59), where the average annual concentration could reach 0,081 mg/m^3 during the 18.5-MTPA production phase.

SENES Consultants based its assessment of air-quality effects for short-term events on generic cases, given that the actual sources are intermittent (blasting) or moving (machinery and vehicles). Starting with these generic cases, they estimated a maximum concentration and then calculated the minimum setback distance required for the concentration to meet the guideline. While no exceedance is predicted for $PM_{2.5}$, when it comes to heavy machinery and vehicles on roadways, PM_{10} guidelines are met only at a distance of at least 130 to 220 meters from the road, depending on the scenario.

This interpretation is based on results obtained under conditions associated with the sampling period (dry season). Additional sampling campaigns would be necessary to document particulate matter concentrations during other periods of the year, such as the rainy season. A sampling campaign right at the end of the rainy season (November) would give us a better understanding of the influence of the Harmattan and brush fires on total suspended particle concentrations, thereby providing a more representative picture of how urban pollution combines with industrial emissions.

6.3 Environmental noise

Looking at the results from the Kamsar region, we see that the sound levels at the boundaries of the industrial area are all under the 80 dBA (LAeq, 24 h) limit established to prevent any hearing loss. The results projected by SENES Consultants indicate a baseline level with existing operations from 46 to 55 dBA (LAeq, 24 hours). This is below the US EPA recommendations but slightly above the WHO guidelines for nighttime, because the results were projected under outdoor conditions. We estimate that indoor sound levels are below 45 dBA. The buildings in the vicinity of the industrial area and within the 45 dBA isopleth are made of concrete and have sealed windows and doors. Based on the available research, these levels should be acceptable and would not be considered a nuisance for human activities such as talking, resting, sleeping, etc.

In cases where background noise is above guidelines, the IFC recommends a maximum increase limit of 3 dBA, considered barely perceptible to the human ear. Based on the models produced by SENES Consultants, the increased CBG production in Kamsar would lead to a maximum increase of 1 dBA during the 18.5-MTPA phase, 2 dBA during the 22.5-MTPA phase, and 3 dBA for the 27.5-MTPA phase. Thus, the projected rise in sound levels is considered marginal in terms of perception.

The situation is more complex in the mining area, because in several locations background levels are very low. We measured average nighttime sound levels as low as 31 dBA in more distant locations (Tiewere). On the contrary, sound levels near larger villages were in some cases over 45 dBA (Hamdallaye, Kagnaka, Hore Lafou), but always well below the thresholds of 80 dBA (LAeq, 24h), above which hearing loss can be observed, and 65 dBA, often used as a guideline by US organizations.

No sound levels above 55 dBA were registered or estimated (outdoors, at night). In the mining area, however, not all the houses are constructed or protected in the same way as in the industrial area of Kamsar. Therefore sounds are less attenuated and the occupants are more exposed to outdoor conditions. The populations of the villages of Hamdallaye, Kagnaka, and Hore Lafou are more likely to experience secondary effects from higher sound levels, particularly at night. Unlike for the industrial area of Kamsar, any impacts caused by potential noise increases will be temporary, lasting only for a period determined by the CBG mining plan. Once the plateau has been mined, the site will be rehabilitated and left vacant.

Based on the above analysis, the possible noise increase has important implications for CBG mining operations. The modeling by SENES Consultants shows that several areas are at risk and mitigation measures will be necessary to minimize the nuisance for the nearby communities during operations. CBG's environmental management plan should adopt a limit of 3 dBA as the maximum increase above background to be used in establishing setback distances and mitigation measures. Meeting this guideline would ensure that perceived noise from mine operations was marginal in the nearby communities, would minimize increases in sound levels, which are already high in certain areas, and would minimize the number of noise complaints.

6.4 Water quality

Results from the samples taken for the baseline parameter update do not seem to indicate any health risk for the populations in the nearby communities.

The main parameters to be validated are the concentrations of metals in the water. The various concentrations in the samples are below WHO guidelines for drinking water. Although seawater is not considered drinking water due to its characteristics, we observe a high concentration of aluminum both in the Dougoufissa river (K-05), where CBG has no impact, and offshore of the loading quay (K-01). These two (2) samples contained concentrations from 1,200 to 1,700 µg/l compared to the WHO guideline of 900 µg/l. These concentrations are above what we should normally find in surface water.

The concentration of zinc is elevated in two (2) of the samples, but not above the WHO guideline of 3 000 µg/l. The other elements were found in normal concentrations for sea water.

All of the samples taken from surface water in the Sangarédi watercourses met WHO guidelines for all of the elements (metals).

The pH observed in fresh water varied from 6.2 to 6.7, which is lower than that suggested for drinking water, while the ground water pH was neutral and the sea water pH varied from 7.8 to 7.9. Although the pH level itself is not considered a human health risk, a pH between 6 and 8 minimizes the risk of finding dissolved organic or inorganic aluminum compounds (Gardner *et al.,* 2002). At a pH above 6, aluminum is primarily in the form of particles, which are much less toxic than dissolved aluminum.

Regarding the two (2) well water samples, the analysis again shows that WHO guidelines are met. The well water analysis should nevertheless be expanded to include a larger number of samples in order to confirm that there is no risk to the nearby communities.

These results, some of which exceed monitoring parameters set by the European Union, demonstrate that CBG's ESMP should include a water management plan along with continued assessment and monitoring of surface and ground water quality (sampling program). However, we conclude that no health risk is present given that, in the water destined for human consumption, the elements that pose human health risks were found in concentrations below WHO guidelines. The monitoring program will clarify any medium-term impacts caused by the CBG Expansion Project.

6.5 Transmissible diseases

At present, in Sangarédi and Kamsar, CBG personnel and their dependents are eligible for healthcare services if they are HIV-positive. The CBG health center is equipped to offer both screening and treatment (i.e., screening kits, antiretroviral drugs).

With the implementation of the Expansion Project, Kamsar and Sangarédi will draw even more people in search of work, thereby increasing the risks of HIV/AIDS transmission. CBG will have to make a commitment as part of its expanded operations to develop an HIV/AIDS prevention strategy focused on increasing community awareness of the issue.

Because CBG operations have no impact on the numbers of malaria cases, increasing production will have no negative effect on the transmission of this disease.

7 CONCLUSION

This health risks assessment enabled us to identify the various CBG emissions, put them into context and evaluate their impacts on environmental health. We were able to establish baseline data, clarify the actual contribution of CBG to the results obtained and evaluate the health risks for the nearby communities. In particular, the study demonstrated that concerns about an association between pollution generated by CBG and serious health effects are unfounded.

Air quality in the Kamsar region has diminished mainly due to increased airborne particulate matter, with the addition of combustion gases contributing little to this deterioration. Increased sound levels in the Sangarédi region may increase the number of nuisance and annoyance complaints. As for water quality, although it meets WHO guidelines it should be monitored over time to check the effects of increased production in the various areas impacted by CBG. Finally, the influx of new Guinean and foreign workers should be managed with caution due to an increased risk of HIV/AIDS transmission in an already vulnerable population.

CBG must leverage its commitment to the communities and take a leadership role. This study will allow its teams to communicate transparently with the nearby communities and implement measures to mitigate and monitor the situation for its present operations and future expansion.

ANNEX I

SAFETY DATA SHEET – SHIPPED BAUXITE

ANNEX II

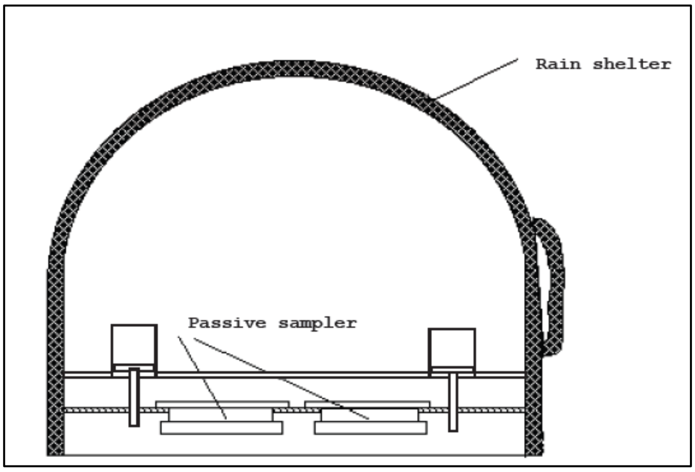
GAS SAMPLING PROCEDURE

Operating principle:

A passive sampler is able to take a gas or vapour sample from ambient air at a flow rate based on a physical process such as diffusion across a membrane. This process does not require active air movement through the sampler. The PASS sampler was developed by Maxxam with the support of Alberta Environment and Parks (AEP), the Alberta Research Council (ARC), the Clean Air Strategic Alliance (CASA) and the National Research Council of Canada (NRC).

Equipment necessary for each sampling point:

- 2 rain shelters
- 2 passive samplers – SO_2
- 2 passive samplers – NO_2
- 2 passive samplers – NOx
- 2 straps
- Lab gloves (nitrile or latex)



Source: Maxxam

Figure 1: Sectional view of the rain shelter assembly

Installation:

Each rain shelter should contain: one (1) NOx sampler, one (1) SO2 sampler and one (1) NO2 sampler. For each sampling point, two (2) assemblies should be installed in parallel, as follows:

1. Find a placement allowing for proper and safe installation of the shelters:
   1.1. The bottom of the shelter should be facing downward. The base should be positioned 1 to 3 meters above the ground.

1.2. The sampling point should be at least 10 meters from any type of roadway or traffic.
1.3. The sampling point should be well clear of any buildings or other obstacles. Select a point at least 20 meters from the closest trees.

Source: Maxxam

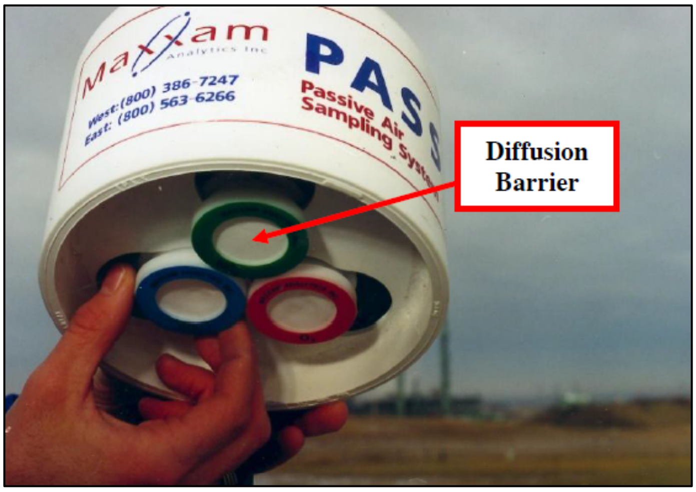
Figure 2: Installation of the rain shelter

2. Using protective gloves, remove one sampler from its container and from the reusable plastic bag. Store the plastic bag in the container to use later. When handling the samplers:
   2.1. Do not touch the diffusion barrier (the white part in the center) and do not set it down on any surface.

Source: Maxxam

Figure 3: Installation of the passive samplers

3. Remove the cover from the sampler and also place it in the original container for later use.
4. Hold the sampler with the colored side facing down, push one of the three white buttons on the underside of the shelter and slide the sampler up into it. Ensure that the button is back down once the sampler is in position (protection mechanism).



Source: Maxxam

Figure 4: Installation of passive samplers

5. Log the date and time of installation.
6. Repeat the above steps to install the other samplers.

Removing the samplers:

1. Log the end date and time of the sampling period. The duration should be at least 30 days (720 hours).
2. Using protective gloves, grasp the sampler on its sides and slide it out.
3. From the original container, take the plastic cover and place it on the sampler, put the sampler into the plastic bag and place in the container. Close the container.
4. Fill out the analysis request forms and ship the samples to the lab as quickly as possible.

End of procedure

ANNEX III

PROCEDURE FOR THE SAMPLING AND ANALYSIS OF PARTICULATE MATTER

List of material per station:

- 1 metal tripod
- 3 horizontal support arms (aluminum)
- 3 metal attachments (aluminum)
- 1 calibration gauge
- 1 blue tube
- 1 calibration adapter + calibration filter
- 3 MiniVols
- 3 sampling assemblies (TSP, PM_{10}, $PM_{2.5}$)
- 3 lithium batteries
- 3 pre-weighed filters with holders (prepared by the laboratory)
- Powderless nitrite or latex gloves

1. **At the sampling site, place the 3 MiniVols on a flat surface (in the shade).**

2. **Prepare the calibration gauge (Figure 1):**
    a. Press ON|OFF to turn it on.
    b. Before removing the rubber caps, press ZERO for 2 seconds and then let go to reset the instrument to zero.
    c. Remove the two rubber caps.
    d. Connect the blue tube to the "Negative" jack and leave the other one unconnected.

3. **Prepare the calibration adapter**
    a. Remove the cap of the sampling assembly to be calibrated and replace it with the blue calibration adapter (cap on).
    b. Place the calibration filter into the sampling assembly.
    c. Connect the blue tube to the inlet of the calibration adapter.

Source: S. Dallaire – CBG 2014.

Figure 1 – Connecting the calibration kit to the PM_{10} or TSP sampling assembly

4. Initial calibration

a. Remove the black rubber plug from the MiniVol tube.
b. Loosen the tightening ring at the bottom of the tube.
c. Pull the tube upwards until it stops.
d. Retighten the ring.
e. Connect the calibration kit to the MiniVol with the assembly corresponding to the sample to be taken (TSP, PM_{10}, or $PM_{2.5}$) using a calibration filter.
f. Install a fully-charged battery and make sure the counter is lit.
g. Start the MiniVol by pressing twice on ON/AUTO/OFF to put it in manual mode.
h. Adjust the flow to about 1.92 INWC (about 5 LPM).
i. Let the instrument run for 3-5 minutes, until the pressure gauge reading has stabilized.
j. Log the pressure gauge reading and the time of calibration.
k. Press ON/AUTO/OFF twice to turn the MiniVol off.
l. Remove the calibration adapter.
m. Repeat the steps above for the other 2 MiniVols.

5. Preparing the MiniVol for sampling

a. Put on lab gloves.
b. Put together the sampling assembly (TSP, PM_{10}, or $PM_{2.5}$):
    i. TSP: single sampling unit without impactor
    ii. PM_{10}: single sampling unit with a gold impactor;
    iii. $PM_{2.5}$: sampling unit with a silver impactor (top) along with an adaptor (extension) containing the gold impactor (bottom).
c. Screw off the base of the sampling assembly.
d. Install a filter holder containing a filter, facing up.

i. Note the filter number for the instrument (series no.) and the type of assembly (TSP, PM_{10}, or $PM_{2.5}$) in the proper columns of the notebook.

e. Screw on the base of the sampling assembly.
f. Write the counter reading in the proper column.
g. Loosen the safety screw.
h. Close the cover of the MiniVol.
i. Take the MiniVol and place it on the tripod at the sampling site.
j. Reopen the cover and tighten the safety screw to firmly attach the MiniVol to the tripod.
k. Repeat the steps above for the other 2 MiniVols.

Source: S. Dallaire – CBG 2014.

Figure 2: Installation of MiniVols on the tripod

6. Programming the sampler

a. Adjust the timer:
   i. Press CLOCK and then MIN to set the minutes.
   ii. Press CLOCK and then HOUR to set the hour.
   iii. Press CLOCK and then WEEK to set the day.

b. Program the auto-start:
   i. Press PROG once until 1^{ON} appears.
   ii. Set the start time and day by pressing HOUR, MIN and WEEK. This determines when the instrument will start. ***N.B.: Make sure to properly select AM or PM (AM: 0:00 – 11:59 / P: 12:00 – 23:59).***

c. Program the auto-stop:
    i. Press PROG once until 1^{OFF} appears.
    ii. Set the stop time and day by pressing on HOUR, MIN and WEEK. This determines when the instrument will stop.
    iii. For a 24-hour sampling period, the stop time must be identical to the start time, with the day set one day later.
d. When finished programming, press CLOCK to come back to the main screen (current time). You can check the programming by pressing repeatedly on PROG.
e. Note the start time programmed and the counter reading in the proper columns.
f. Press ON/AUTO/OFF so that the line appears above AUTO.
g. Close the case.
h. After the 24-hour period, open the case and note the counter reading to ensure that the instrument has been functioning properly for the required time (24 hours).
i. Remove the instruments from the tripod and take them to a work surface (in the shade).
j. Unscrew the base of the assembly.
k. Remove the filter holder and put it back in the proper container (filter no.):
    i. Place the container by itself in a labeled airtight bag.
l. Reassemble the sampling unit and remove it.
m. Repeat the steps above for the other 2 MiniVols.

7. Final calibration:
a. Connect the calibration kit to the instrument (steps 2 and 3).
b. Start the MiniVol by pressing ON/AUTO/OFF to put it in manual mode.
c. Let the instrument run for 3 to 5 minutes, until the pressure gauge reading is stabilized.
d. Log the reading and time of calibration.
e. Press ON/AUTO/OFF to turn off the MiniVol.
f. Remove the calibration adapter.
g. Remove the battery.
h. Store the instrument in the carrying case.

8. Analysis:
a. Filters should be sent to an accredited lab for gravimetric analysis and metals analysis (if needed).
b. Include a control filter for each sampling day.
c. Methods:
    i. TSP, PM_{10}, $PM_{2.5}$: US EPA IO-3.1 (gravimetric) ;
    ii. Metals: US EPA IO-3.5 (ICP/MS).

End of procedure

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