东北师范大学

硕士学位论文

马里巴马科市大气污染状况分析和危害及对未来演化趋势分析研究

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摘　要

马里是一个在非洲西部的发展中国家。当前，由于高速发展的城市工业化和城市中迅速增长的交通运输民个人汽车，释放了大量大气污染物，造成了这个国家和周边地区的空气质量的恶化。在这篇论文中，我们针对在巴马科市区及其附近的有害气体、微尘、微生物、金属氧化物和合成的有机化学物对大气将影响和有对人类健康和城市生态系的危害进行了研究。

我们首先对马里首都巴马科市的一些主要污染源进行了检测，包括城区的不同热能产品供应，制造水蒸气和其他工业废气的主要工业源，以及煤炭、重燃料等化石燃料的使用。工业污染物被认为是最主要的污染源。一个主要的原因是供热的需求量大和缺乏有效法律手段的控制和热废物的清除技术欠缺；交通运输产生的污染长时期以来被认为是一个亟需解决的问题，这主要是由于巴马科市区内快速增长的公共汽车和私家车造成的。汽车污染物被认为主要来源于大量的旧车的不完善的燃料系统，这造成了氮、碳、硫等各种氧化物、氧化铅和各种各样的碳氢化合物大量释放在以前洁净的大气中。农业活动的污染物虽然不是大气污染物的主要部分，但不定期的庄稼的化学药剂的喷洒，其它的污染物比如氨、甲烷、氮气低浓度氧化物和一氧化碳主要来自于有机物的分解和肥料的使用，还有植物的大量花粉也啬加了大气中悬浮颗粒物增加。

研究表明，在马里目前拥有大约 500,000 人的渔业行业人员，大量水产品造成了马里每年多达 100,000 吨的废物，这也是一个主要的空气污染源。黄金金属的制造业迅速增长，从 1995 年的 6,291 千克到 2004 年的 44,584,517 千克，同时也造成了工业空气污染物的增长。旅游季节的游客由 2006 年 37,000 人增长到 2007 年 150,000 人，越来越多的人对马里感兴趣也暗示了马里的快速发展。在运输部门中，有 80%以上的公共汽车已使用超过 11 年，其中 70%已超过 16 年并且其燃料不完善的燃烧。在 2004 到 2006 年之间，石油燃料造成的含硫氧化物增长了 12.77%。自从 2005 年来，含氮氧化物气体也显示了巨大的增长量。碳氧化物的水平从 2005 年 667 $\mu g/m^3$ 到 2006 年到 1107 $\mu g/m^3$，惊人地增长了 60.25%。巴马科市中有来自机械或沙尘暴的重金属颗粒物，这些重金属包括镍和钒，它们在空气中的浓度大约在 8－28 $\mu g/m^3$ 左右。与巴黎市冬天的 4.6 ng/m^3 相比，巴马科市的苯基(A)芘的平均浓度 4.59 ng/m^3 不是很显著。研究显示，大多数巴马科市的树和植被并没有严重受到空气污染的影响。因为土壤营养的不足和虫、疾病、真菌，以及干旱似乎对植物的影响比大气污染更大。由于空气污染物的煤灰和沙粒对巴马科市的建筑，穿衣和必要的清洁卫生等造成的损害只需要很少的清洁费用。只有很少数的建筑的外部油漆受到影响或有屋顶材料的恶化。直接由空气污染造成的人类死亡的数据很难得到，但是从相关的疾病中外推所得的数据显示有很高程度的死亡是由空气污染造成的。在本篇论文后部分中，我们也分析了马里政府对巴马科市的空气质量的评估和管理情况，其中包括了对污染情况的监控的有效措施。

总而言之，目前巴马科市的空气污染还不是很严重，但是如果现在不把空气质量的控制有效实施起来，我们认为象我们这样的发展中国家也会对象温室效应造成的全球气候变化带来一定影响的全球问题。本文中所涉及的所有的污染物也都与人类健康和发展中国家的政府长期关注的直接的联系。因此我们的国家和有关国际社会都应该行动起来，为我们未来的生存问题进行更彻底的周密考虑与谋划。

关键词：大气污染；污染物, 全球性变暖.

Abstract

Mali is a developing country in West Africa. Currently there are various pollutants which are being released into the country's atmosphere due to a high rate of industrialization and an increasing quantity of inefficient vehicles in the country urban centers. This has contributed to the deterioration of the normal composition of the quality of the air this country and its surrounding. In this Thesis we tested the hypothesis that air masses around Bamako are carrying harmful gases, dust particles, living microorganisms, metals oxides and synthetic organic chemicals which are adversely affecting or shall affect human health and the City ecosystems in the near future.

We examined some of the principal sources of pollution in the country capital Bamako. Namely: Thermal energy production at the individual level which include heating of the residences; at the industrial level which mainly causes an increase in production of water vapor and industrial exhaust gases also the use of fossil fuels (coal, heavy fuel, etc.). The industrial pollutants are being identified as the greatest contributors of pollutant emissions. One of the major reason why the industries are increasingly emitting pollutants is because of there requirements for thermal energy and lack of legal framework to regulate and treatment waste products. Pollution from the transport sector has been regarded for a long time as a problem of proximity, which is mainly perceived in Bamako city due to an increase in public vehicles and personal cars. Pollution from vehicles was identified as being caused by a large influx of old vehicles with incomplete engine combustion systems. This mainly caused the emissions of nitrogen, carbon, Sulphur, lead oxides and various hydrocarbons in the former clean air of the city. Pollution from agricultural activities has not been very significant in air pollution except in the unregulated use of chemicals in spraying crops. Other emissions are primarily ammonia, methane, the protoxide of nitrogen and the carbon monoxide which are mainly from the decomposition of the organic matter and the use of manure. Moreover, there is the pulverization of plant health products on a large scale which involves the setting of suspended particles in the air.

This study found out that the fishing makes Mali one of the large fresh water fish producers in the area with annual production of up to 100,000 tons. This is one of the sources of air pollution due to the large waste output of the 500,000 workers in this industry. The production of gold metal made a remarkable increase in production by moving from 6,291 kg in 1995 to 44,584,517 kg into 2004. This went along with air industrial waste production. The tourist season of 2006-2007 recorded an increase of visitors of 37,000 to 150,000 giving a hint to the rapid development and interest into this country. In the transport sector, more than

80% of the public vehicles are more than 11 years old while out of these 70% are above 16 years old with faulty combustion engines. Sulphur dioxide which is a product of the oxidation of sulphur in petroleum oil, had increased due by 12.77% between 2004 and 2006. Nitrogenous gases also showed tremendous increase since 2005. The level of carbon oxides was incredibly increasing at alarming rate from 667 $\mu g/m^3$ in 2005 to 1107 $\mu g/m^3$ in 2006 this was an increase of 60.25%. There are heavy metal gases from machines or carried by sand storms dusts into Bamako city. These heavy metals include nickel and vanadium which are in the atmosphere at concentration of about 8 to 28 $\mu g/m^3$. The average concentration of benzo (A) pyrene in Bamako was about 4.59 ng/m^3 compared to Paris which had 4.6 ng/m^3 in winter was found to be not significant. Most trees and vegetation examined in Bamako did not show any significant air pollution effects. This was because it appeared soil nutrient depletion and pests, diseases, fungi, and drought seems to affect the plants more than air pollution. The damage due to air pollutants on various materials in Bamako city was found to be moderate fallout of soot and grit on buildings, cars, and clothing and necessitated little cost in cleaning. Only a few buildings had exterior paint affects and deteriorated roofing materials. It was not easy to get information of deaths directly caused by air pollution, but we could extrapolate from data in related diseases that there is a significant death level among city dwellers due to air pollution. In this thesis we also analyzed the Mali government's evaluation and the management of the quality of the ambient air in Bamako. This included the steps which have been put into place to monitor the effects of pollution the environment.

In conclusion we propose that although the air pollution in Bamako is not significantly alarming at present but if plans to regulate and monitor pollution are not put in place now, we extrapolate that developing countries might also contribute to the emission of greenhouse gases which are causing climatic changes in the whole planet. Such effects have been identified to cause upheavals like rising of the sea level and oceans, potential increase in the cyclones and storms and global warming. All the pollutants in this study have been identified to have their toll in causing a direct impact on human health and have wide reaching implications in the national budgets of the developing countries in the long run. Hence national and international protocols are supposed to be implemented with all sincerity so that international policies can guarantee our future earthly survival.

Key Words: Atmospheric Pollution, Oxides Pollutants, global warming.

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Chapter One Introduction

1.0 Forms of Air pollution sources

Air pollution can be defined as one or more chemicals which are in high enough concentrations in the air and can cause harm humans, other animals, vegetation, or materials or even alter climate. Excess heat and noise are also considered forms of air pollution. Such chemicals or physical conditions are called air pollutants. Some of these chemicals can be added directly to the air by natural events or human activities and can accumulate into harmful concentrations. These are referred to as primary pollutants. But sometimes these primary pollutants react with other pollutants in air and cause a secondary form of pollution. This can be harmful to the ecosystem and gradually undermines the health and to the quality of human life both in the present and in the future. For example in 2005 Malaysia, the government declared a state of emergency because of a thick acrid haze which blanketed much of the capital Kuala Lumpur, causing a sharp increase in the number of people reporting to hospitals with respiratory, throat and eye complaints. This is now interesting that problems which were like preserved for developed countries have now become a major issue in developing countries. Mali is one of the fastest developing countries in West Africa. Its capital city Bamako has had an increase in Air pollution for the last ten years which has not been extensively been studied with global air pollution outlook.

This Thesis was instituted to identify the main causes; components; impact and future implications of air pollution in Bamako. The main causes of air pollution were identified as the high rate of industrialization; thermal energy from house holds; an increase in the number of fuel usage inefficient vehicles in the capital city. Some of the components of air pollution were identified as nitrogenous oxides, sulphur oxides, carbon oxides and metal oxides especially from fuel hydrocarbons. This has contributed to the deterioration of the normal composition of the quality of the air in this country and its surrounding. In this thesis we tested the hypothesis that air masses around Bamako are carrying harmful gases, dust particles, living microorganisms, metals oxides and synthetic organic chemicals which are adversely affecting or shall affect human health and the city ecosystems in the near future.

The industrial pollutants were being identified as being the greatest contributors of pollutant emissions. It was found out that one of the main reasons why the industries are increasingly emitting pollutants is because of their requirements for energy and lack of legal framework to regulate and treatment waste products. The transport sector in the city pollution

was identified to be caused by a large influx of old vehicles which have incomplete engine combustion systems. Pollution from agricultural activities has not been very significant in air pollution except in the unregulated use of chemicals in spraying crops. Other emissions are primarily ammonia, methane, the protoxide of nitrogen and the carbon monoxide which are mainly from the decomposition of the organic matter and the use of manure. Moreover, there is the pulverization of plant health products on a large scale which involves the setting of suspended particles in the air. In this thesis we analyzed the Mali government's evaluation and the management of the quality of the ambient air in Bamako. This included the steps which have been put into place to monitor the effects of pollution the environment.

In conclusion we proposed that although the air pollution in Bamako is not significantly alarming at present but if plans to regulate and monitor pollution are not put in place now, we extrapolate that developing countries might also contribute to the emission of greenhouse gases which are causing climatic changes in the whole planet. Most countries are signatories of the environmental protocol and hence they have the obligation to abide by international standards. The effects of air pollution are great contributors of climate change causing effects like upheavals of sea level rising and oceans, potential increase in the cyclones and storms and global warming. All the pollutants in this study have been identified to have their toll in causing a direct impact on human health and have wide reaching implications in medical expenses, construction industry, and agriculture and in the general the national budgets the Mali and other developing countries in the long run. Moreover, its long term effects can cause direct and indirect costs on the national economies. For example there shall be loss of productivity amongst the labors because workers health will be affected by industrial pollutants. Many factories in developed countries are actually investing more on medical care for there workers. Logically this cost is pegged on the prices of goods hence in the long run influence the economic status of the consumers and the whole country at large. Other sectors of the economy shall also be affected by air pollution for example tourism and further industrial investment. This is because now the world is like a global village and information spreads so fast. Many visitors and investors shall not risk to go in to areas which endanger there lives.

1.1 Air pollution in Mali as an example of an African developing country

Most disheartening is the rate in which majority of the developing countries are addressing the issue of air pollution. Most are inviting any kind of activity into their lands without regard of the after effects. For example some people shall not even worry of a smoking vehicle on road or leaded petrol on a gas pump. They regard the costs incurred for the replacement and the improvement of the vehicles and the installation of antipollution

devices in the industrial facilities and the power stations as less significant investment compared to the national healthy economic production. All government should actively arouse necessity for improvement of the air quality of among its citizens especially in urban centers in Africa. This can be effectively being done through the introduction of by laws comparable with those in the developed nations and in United Nations agreements. The challenge is to now lay down strategic plans to regulate the balance between industrial development and environmental degradation. The problem of our study area in Bamako city in Mali is compounded by the fact that the city is on a basin and the industries are located on the windward direction. This topographic setting is particularly good for dangerous air pollution to accumulate in residential areas in the city. Not much substantial action is has been introduced to improve the situation in the city. This is mainly due to lack of active determination by the authorities to supervise production and waste product disposal in industries. One of the weaknesses is the attitude of encouraging which ever investor. This project recommends that the United Nations organization and worlds back should assist in providing safe investors by recommending only those who are air and environment conscious to start industries in developing countries.

1.2 Objectives:

1.2.1 General objective:

To investigate the problem of gas emission in the city of Bamako in Mali as an example of an African developing country with an aim of identifying the causes and effects of air pollution together with an attempt to make an extrapolation of its contribution to global effect in the next ten years.

1.2.2 Specific objectives:

1. To analyze the current air pollution in Bamako city in Mali by evaluating its, causes, and its effects to the environment, human health and general global impact.

2. To identify the specific components and there possible flows in the atmosphere and eventual effects on the environment and health of the people of Bamako city.

3. To suggest effective remedies and legal frame work for the control of air pollution in Bamako City which can also be applied else where in the developing countries.

Chapter Two Study Area

2.0The West African country of Mali

Mali, is one of the largest countries in the heart of West Africa, is located between the 10° and 25° of Northern latitude and between the 4° of longitude East and 12° of Western longitude. It covers a surface of 1.241.238 Km^2 with a population of 13,000,000 inhabitants which is approximately $1/24^{th}$ of the total surface area of Africa. It shares 7 000 km of borders with 7 countries (**Figure 1**) namely; Senegal, Mauritania, Algeria, Niger, Burkina Faso, Ivory cost and Guinea. It is a country which lacks an outlet to the sea hence it has as to cross other countries in order to access the various ports for example it is 980 km to Conakry, 1.225 km to Abidjan, 1.228 km to Dakar, 1.967 km to Lome, 1.973 km to Téman, 2.096 km to reach Cotonou and 1.430 km to Nouakchott (CPS/Transport source). This study was done at the Bamako city and its environs. It included the collection of data at specific parts of the city.

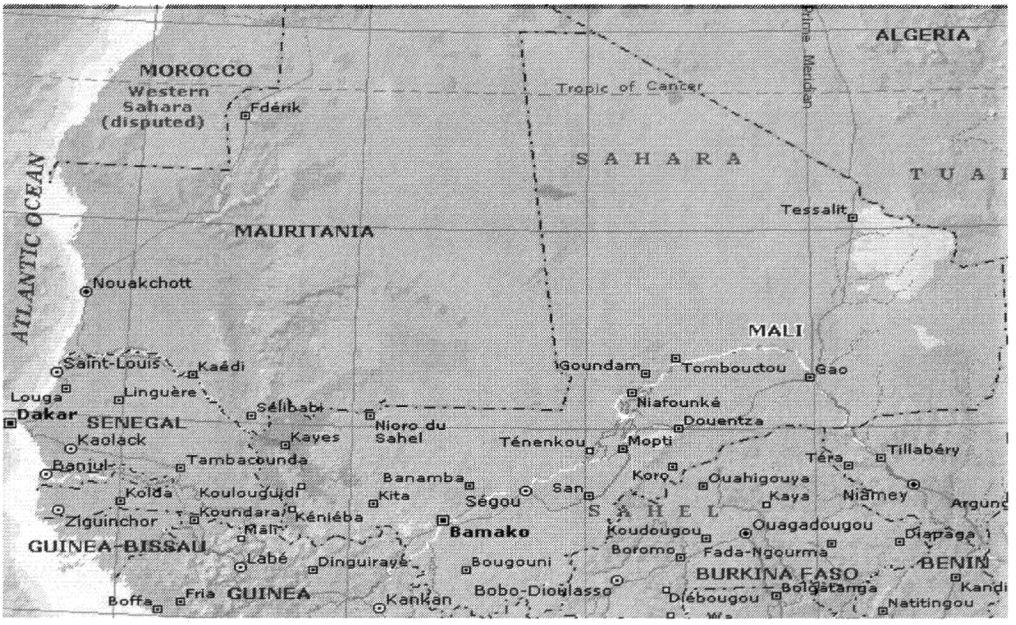


Figure 1: A map of Mali showing the major towns and the capital on the Southwestern part of the country

2.1 The City of Bamako in Mali

The city of Bamako has a population of over 1,500,000 inhabitants in area of 24,000 hectares in the Southwestern part of Mali. The Niger river pass across the city dividing it into two halves i.e. the right bank and the left bank; the right bank made up of the common V

and common VI blocks which are rapidly developing after the construction of a bridge called Fahd. The central part of the town is made up of mainly administrations and trade activities. The bridges and improved infrastructure have increased mobility amongst city dwellers and traders this zone and the peripheral districts. In addition to the railway line which connects the West of the city to the East, Bamako has in the last ten years undergone a tremendous construction and rehabilitation schedule as well an adjustment of certain infrastructures in roads, commercial spaces and parking areas.

The relief of Bamako is characterized by having sandy plates of the Mandingue Plate, which extends from the north of the Niger River at the border of Senegal. It extends 800 meters meeting the Plate of Koutiala which extends from the south of the course higher of the Niger River than the border of Burkina Faso. The highest point is about 791 meters in a cliff called Bandiagara. There is also on the East a chain of residual hillocks in a zone called Hombori where the highest point is at 1.155 meters.

To the north of the Mandingue Plate, is a unit which is made up of partially silt plains, called Hodh. It has an altitude which ranges between 260 and 320 meters. The lowest topographic zone in Bamako is the basaltic Plate of Kaarta which dominates the plains in the valley of Senegal. In the central part of the country there is a vast alluvial plain in the interior side of the delta of the Niger River. There is a zone called Goundam which has sand dunes and small rocky hills which limit the plains of the delta forming small lakes. The other plain extends to the east from the delta between the loop from Niger in North and the dogon Plate towards the South This unit is known as the Gourma. From the point one can observe fixed cords of dunes and small icebergs emerging from the stony or silt up plains. In the North-East, we find the Adrar of Ifoghas which extends a distance of about 890 m constituting a crystalline solid mass in the central Sahara. It is skirted to the west by the fossil valley of Tilemsi (**Figure 2**). In the south-east of the solid mass, one can observe the plates and plains of Tamesna like in the North-East of the valley of Azaouak. All this topography makes Bamako City to be like a city in a basin where air can not freely circulate except for heavy air currents. The original idea of having a city here was because it had water in the basin which was used by distance travelers as they crossed to the upper dry places. But modern development now necessitates another planning if air pollution especially from dense gases is to be avoided.

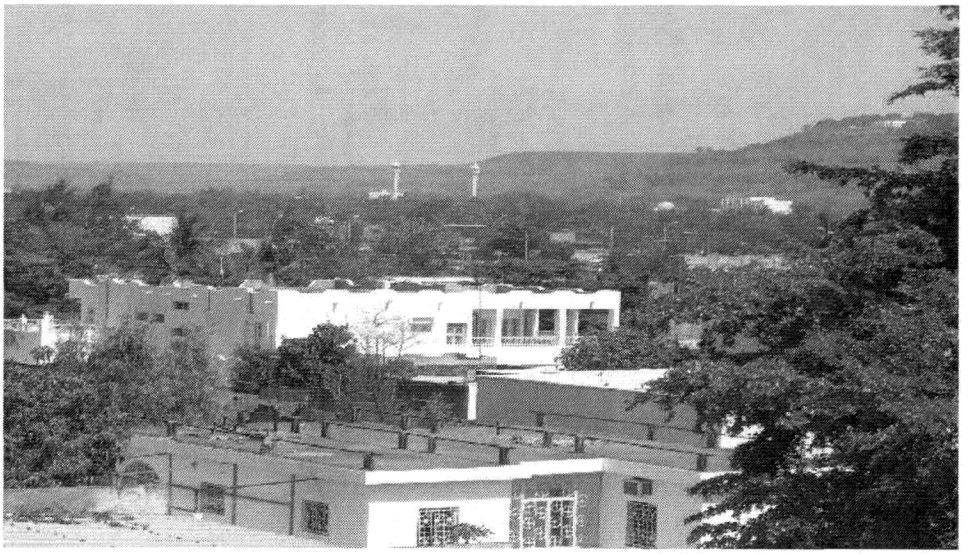


Figure 2: Profile of Bamako showing the Basin of Bamako

2.2 Economy of Mali

The economy of Mali rely primarily agriculture, livestock breeding, and fishing. These sectors employ about 80% of the working population.

2.2.1 Agriculture

Most of the country produces cereals such as millet, sorghum, rice, corn, folio, corn which are used to make most stable foods in Mali. In 2004, the land surface devoted to the growing of cereals was 3.473.782 ha including 120.000 ha which was under irrigation. The area which is irrigable is estimated to be close to 2 million hectares (DNGR, 2004). Because of the improvement of the infrastructures and measurements of liberalization of the market, rice grown in Mali has become more competitive than imported rice. More than half of the produced paddy comes from the zone framed by the Office of Niger, "the attic of West Africa ". The Mali national requirement of cereals is approximately 2 million tons per annum The has been a cereal surplus for the last five years which has made it possible for Mali to export cereals to Mauritania, Senegal Niger and Burkina Faso. Other cereals were also exported to these countries. Industrial crops are of special importance in the agricultural policy of the country. With a production of 592.000 tons cotton in 2004, Mali was the largest producer of cotton south of the Sahara in Africa. The zones reserved for the culture of cotton cover a surface of 151.000 km ^{2} and approximately 2 million peasants work in nearly 200.000 plantations.

As a first industrial crop and first product of export, cotton represents 10 % of the PIB of the primary sector and nearly 58 % of the export earnings. A good part of this cotton is sold to the U.S.A, Canada, on the markets of the European Union, China, Japan and South Africa.

2.2.2 Livestock Breeding

Animal breeding represents approximately 10 % of the national PIB and contributes for 18% to the income of the rural populations and for 80% of the income of the populations of the exclusively pastoral's zones. The livestock activity is been practiced on over 44 million hectares which make up about 70% of the country's territory. The Malian livestock, has 20.402.621 of heads from small ruminants and 7.531.737 of heads of bovines, this is most significant in West Africa. The breeding has been the traditional occupation of many communities in Mali. The population growth of livestock is variable according to a particular species; this trend is difficult to estimate with precision taking into account the lack of regular and reliable census. It thus would lie between 3% for the bovines and 10 to 12% for the poultries. The distribution of the herds is very unequal through the country. The cattle products make up the third main category of product export in Mali after gold and cotton. The growth of this industry was slowed down by the political turmoil in Ivory Coast. Moreover, the sharp competition from other countries of under. like Burkina-Faso and Niger increased the competition because they were more organized and hence contributed to the decline of livestock exports from Mali. The principal destinations for the bovines, sheep and the caprine ones are still Ivory Coast, Senegal, Mauritania, Guinea, Ghana, Burkina Faso and Niger. Camelines are exported to areas in the north such as Tombouctou, Gao and Kidal and also towards Algeria and Mauritania.

Table 1: The increase in the rate of exportations of livestock in Mali

Year	*Cattle*	*Sheep*	*Equines*	*Donkey*	Capelins
2004	279.356	439.507	160	77	4.271
2005	226.819	425.846	282.826	282.896	2.704
2006	106.792	252.395	187.639	187.639	2.433
2007	93.011	165.279	111.747	111.746	3.533

Source: DGRC, OMBEVI, DNAMR annual report 2007

2.2.3 Forestry industry

The Forest sector holds a place of choice in the national economy and contributes to the PIB making about 4.9 %. This makes up to 25% of the national exports. According to statistics of the DNEF (National Direction of Water and Forest), if one takes account of the products of gathering, the wild fruits and the gasoline's for the pharmacopoeia, the estimated value of the products of the forest sector independent of raised fodder would be about 70 billion francs per annum.

In the last five years the controlled national production was estimated at 373.633 m^3 of wood of heating and 23.880, 50 tons of coal (MEATEU, 2006). The trade of woody fuels represents a sales turnover of 21 billion CFA/year francs. According to official statistics', the controlled production of wood opens during five last years amounts to 204.418 m^3 (DNAER: National direction of Installation and the Rural Equipment, DNCN: National direction of the Nature conservation). The imports for the same period are evaluated to 75.091 m^3 (DNSI: National direction of the Statistics and Data processing).

The production controls wood of five last years service is estimated at more than 16.261 m^3 (DNAER: National direction of Installation and the Rural Equipment, DNCN: National direction of the Nature conservation). The gross amount generated per annum is estimated at 100 million francs. The Arabic gum represents 2 % of exports of the rural sector for an amount of 100 million francs together with almonds and the butter. The gum Arabic represents 2 % of exports of the rural sector for an amount of 100 million francs and the Shea almonds and butter pay to export nearly 1.1 billion francs/year is 3,6 % of the total of national exports.

Wild fauna plays the significant role one in the economic life of the country. It is under carrying sector in several fields (pharmacopoeia - food safety - trade - craft industry). It pays nearly 400 francs/year million to the budget of the State by the sale of the licenses and the taxation of the trophies. According to a report/ratio of the GTZ, the activity of hunting contributes to the family economy to a total value of 7 to 8% in medium rural.

2.2.4 Fishing industry

Fishing remains one of the pillars of the national economy, thanks to the rivers Senegal, Niger and their affluent. It makes Mali one of the large fresh water fish producer in an area in spite of the capricious dryness's and pluviometric's. It places Mali among the first fresh water fish producing African countries which produces mainly carps and captains types of fishes among others. The annual production of fish can reach 100.000 tons in a year. This sector contributes a total value of 4.2% of the total PIB of the country, employs nearly 500,000 people (7.2% of the working population) besides feeding the budget of the State and the local communities. This amounts to approximately 90 billion francs per annum.

The national fish production meets the domestic demand which is estimated at 10.5kg/an/hab compared to 7.8kg/an/hab demand for the meat. Mali exports about 5 600 tons per annum smoked and dried fish traditionally to Burkina Faso, Niger, Nigeria, the Ivory Coast, Ghana and Guinea although it also imports a marginal 300 tons per annum frozen and dried products from Ivory Coast and Senegal.

2.2.5 Extraction Industry

The mining sector remains a key national asset for the country's development. Mali has many mineral resources like Ferrous and nonferrous metals and other valuable products. The production of gold metal made a remarkable jump, passing 6.291 kg in 1995 to 44.584.517 kg into 2004. This production is equivalent to a sales turnover of 30 billion francs. Thus, gold is the main export product followed by cotton which hitherto provided half of the currencies of the country. Mali is the third producer of gold in Africa after South Africa and Ghana. The reserves are estimated at 145 tons in the two principal mines ie Sadiola in the extreme West of the country and Siama to 400 km in the South. There are prospects of other gold bearing areas which might start mining for example at Loulo, Tabokoto, Kodiéran and Kalana.

2.2.6 Tourism and Craft industry

The tourist season 2006-2007 is recorded as the in Mali. The number of tourists increased from 37,000 to 150,000. This is like four times when compared to the duration between 1998 and 2007. One of the factors for this tourism boom is the simplification of the procedures of entry in Mali and the reorganization of the sector. Several significant investments have been made in the manner of reception and lodging at the tune of more than 11 billion francs in the last few years.

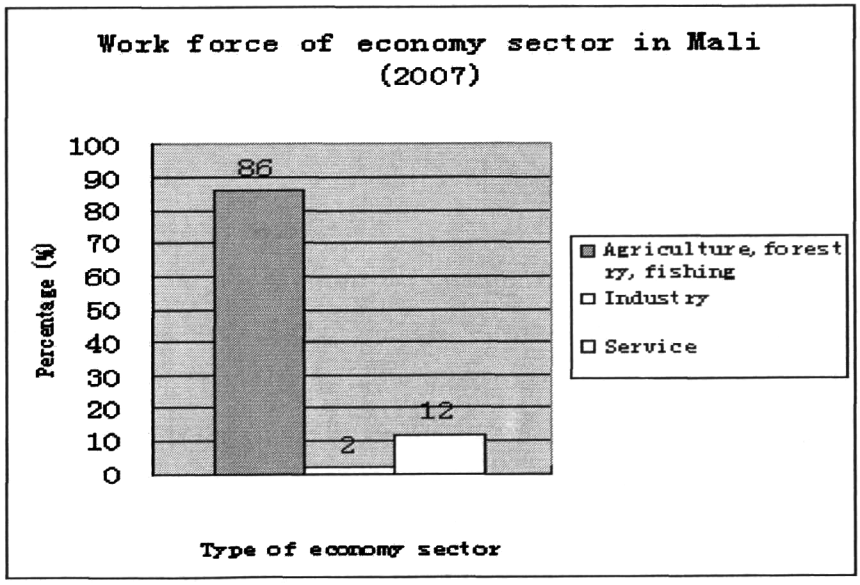


Figure 3: The percentage of the main Work force of Economy Sector in Mali (2007)

Chapter Three Literature review

3.0 Air pollution

There are several gases which make up the earth's atmosphere of which nitrogen (78.08%) and oxygen (20.9%) are the major components, together with a range of other gases such as argon (0.93%), carbon dioxide, neon and helium (Preston-Whyte and Tyson 1993). The country of Mali and its capital city Bamako obviously share its atmosphere with the rest of North Africa and the rest of the world hence the city's air quality is also largely governed by regional and global atmospheric conditions. The reason is that high or low air mobility causes impacts on the air quality at places far removed from the source. This depends on the dilution and mixing effects of the prevailing winds, climate, temperature and precipitation. There is also a vertical mixing of air within the troposphere (lowest atmospheric layer up to 10-15 km from the Earth's surface), which is dependent on temperature and seasonality. Studies show that environmental interactions between the three phases of the atmosphere (solid, liquid and gaseous) results in air quality affecting the quality of water, the terrestrial environment and ultimately human health. For example, acid rain is caused by high sulphur dioxide (SO_2) and nitric oxide levels in the atmosphere, which combine with water droplets in clouds and ultimately precipitate into the terrestrial environment. Therefore, SO_2 and nitric oxide can cause changes in acidity in the terrestrial environment leading to corrosive effects on buildings, acidification of soils and water, thereby impacting on ecosystems (DEAT 1999). There is an increasingly polluted atmosphere in the cities in sub-Saharan Africa which is emerging as a key threat to the health, environment, economy and quality of life of millions of people. Because of this the UN Environmental Program (UNEP) in Nairobi, 27 July 2006 called for new partnerships among countries to clear the air. The main contributor of this was identified as lack of planning in Africa's urbanization zeal alongside a rise in the number of faulty vehicles this is leading to a decline in air quality with all the health problems in most cities said Achim Steiner the executive director of UNEP. Mali, like other countries of sub Saharan region is subject of various economic problems which weaken its process of development. Amongst them is the ambient air pollution which today is not the subject of supported attention as it is the case for the other resources of the environment such as water, soil, the flora, and fauna. Africa is learning from developed countries and several bodies are concerned with the rate of air pollution in the continent, for example Air pollution information network of Africa (APINA) is a network of scientists, policy makers and private

sector and non-governmental organizations from which aims at transferring relevant air pollution information to policy makers for informed decision making. It is co-coordinated by the School of Mines, University of Zambia, through the Institute for Environmental Studies (IES), Zimbabwe. The present APINA project is a part of the 2001-2004 phase of the Sida-funded Program on Regional Air Pollution in Developing Countries (RAPIDC) which is coordinated by the Stockholm Environment Institute (SEI). Several governments are also educating the city dwellers about the importance of avoiding air pollution for example free vehicle diesel emission testing stations were planned to be set up around Cape Town in South Africa for three days, aimed at raising awareness around the importance of controlling air pollution in the city. Motorists who drove heavy vehicles suspected to emit heavy pollutants in the city were allowed to test their vehicle's diesel emissions free of charge, without the fear of being charged. (BuaNews Tshwane, 10 April 2008) The data collected was to be used to intensify the city's air quality management campaign. Which in 2006 and 2007, had exceeded World Health Organization air quality guidelines. This is the sad story in many cities in Africa hence there is a need for all cities to become more environmental conscious. There are many gases which pollute the air of which many have not been studied for example Africa contributes about 18% to the global isoprene emission and 15% to the global terpenes emission (Roeckner et. al, 2003). One of the reasons why air pollution should be controlled in Africa is that over tropical Africa emissions of volatile gases is taking place throughout the year because Africa exhibits less seasonal variability in comparison with other regions of the world. (Aghedo et al, 2008).

3.1 What Africa should do about its current city pollutions statuses

There are many facets which need to be brought into focus when dealing with air pollution on the African continent like the existence of respiratory hazards due to air pollution as a result of industrialization, tobacco smoking in which case we refer as personal pollution, domestic pollution and vehicular fuel combustion. The rate of air pollution is so high that we need to stimulate health workers, and various governments in Africa, to devote more attention to the subject of air pollution by engaging in and encouraging multidisciplinary research so that appropriate and effective control measures can be put in place (Tanimowo, 2000). Recent studies have shown that Africa contributes about 43% to global biomass burning activities and accounts for global tropospheric ozone enhancement of up to 9 Tg. A model of calculation by Adetutu at al., 2008, of Rast. Max-Planck Institute for Meteorology, Hamburg, Germany in 2008 suggested that about 75% of the African biomass-burning-related tropospheric ozone is transported out of the continent. Further sensitivity studies indicate about 26% contribution to global biogenic VOC (e.g. Isoprene) emissions by African

vegetation. Together with soil NO_x emissions, these contribute about 17 Tg to the global tropospheric ozone burden. They estimated that the sensitivity of these results to climate change by performing a set of simulations for climate conditions of the year 2030. Hence Africa can not be neglected in the global air pollution campaigns (Aghedo et al, 2008). Mali produces a lot of Oil products which can be a major source of pollutants. This is because oil is a mixture of hydrocarbons and can produce gases derived from C_2H_6 .Other oil products like paraffin and of cycloparaffin or cyclic aromatic hydrocarbons contain small quantities of benzene hydrocarbons, sulphur. A partial combustion of oil gives place to the polycyclic aromatic hydrocarbon formation (HAP), which are carcinogenic (Hoffman and Wydner, 2005). The relatively high concentration of the HAP in the air in Bamako could have harmful effects on health due to the the presence of compose carcinogenic like Benzo (**A**) pyrene. In fact the convincing evidence exists as for the bond between Benzo (**A**) pyrene and the cancer of the skin, the lungs and the bladder to man (International Agency for Research on Cancer, 2006).

It is difficult to estimate by risk analysis how many people die prematurely from respiratory or cardiac problems caused or aggravated by air pollution because people are exposed to so many different pollutants over their lifetimes. In the United States, the EPA estimates that annual deaths related to outdoor air pollution range from 65.000 to 200.000 (most from exposure to fine particles; Spotlight). If we include indoor air pollution, estimated annual deaths from air pollution in the United States range from 150.000 to 350.000 people-equivalents to 1-2 fully loaded 400-passenger jumbo jets crashing accidentally each day with no survivors. Millions more become ill and lose work time. A 2006 study by state and local air pollution officials estimated that each year more than 125.000 Americans (120.000 of them in urban areas) get cancer from breathing diesel fumes from buses, trucks, and other diesel engines. According to the EPA and the American Lung Association, air pollution in the United States costs at least $150 billion annually in health care and lost work productivity, with $100 billion of that caused by indoor air pollution. Air pollutants cause billions of dollars in damage to various materials we use. The fallout of soot and grit on buildings, cars, and clothing necessitates costly cleaning. Air pollutants break down exterior paint on cars and houses, and they deteriorate roofing materials. Irreplaceable marble statues, historic buildings, and stained glass windows around the world have been pitted, gouged, and discolored. The EPA estimates damage to buildings in the United States from acid deposition alone at $5 billion per year.

Complex mixture of air pollutants produced in the lower atmosphere by the reaction of hydrocarbons and nitrogen oxides under the influences of sunlight. Especially harmful

components include ozone, peroxyacyl nitrates (PANs), and various aldehydes. Any chemical reaction activated by light is called a photochemical reaction. Air pollution known as Photochemical Smog is a mixture of primary and secondary pollutants formed under the influence of sunlight. The resulting mixture of more than 100 chemicals is dominated by photochemical ozone, a highly reactive gas that harms most living organisms.

Chapter Four Contributors of air pollution in Mali

4.0 Air pollution in Bamako city in Mali

4.1 The main contributors of air pollution in Mali

Air pollution in Mali is mainly caused by the many sectors of transport sector, industrial, domestic and even agriculture. The four sectors contribute different pollutants to the atmosphere.

4.2 The transport sector

Mali is dominated by second hand vehicles which basically are not road worthy but in particular we can say they are not environment friendly. More than 80% of the public vehicles are more than 11 years old while out of these 70% are above 16 years old (**Figure 4**). We can measure the power consumption of these vehicles by considering the petroleum products used in Mali. Mali imports on average more than 6,059,904 tonnes metric of hydrocarbons per year (including more than fuel oil 45%) by one year since 5 years. In 2004, the transportation occupied a significant share in the consumption of conventional energy with more than 60%. The combustion of fossil fuels by the cars and other driving machines emits pollutants in the atmosphere like CO_2, NO_2, SO_2 and lead dioxide which are very toxic.

Table 2: The number of vehicles which where in Bamako city 2007

Bus	*Van*	*Lorry*	*Big Way*	*Trailer*	*Articulated Lorries*	*Taxi*	*Public Transport*	*Tractor*	Private Vehicles
65	12326	20521	10	97	7272	181	17126	7697	91921
0.04	7.8	13.0	0.01	0.06	4.62	0.12	10.89	4.90	58.47

Total: 157 216

Source: National Office of Transportation (ONT, 2007)

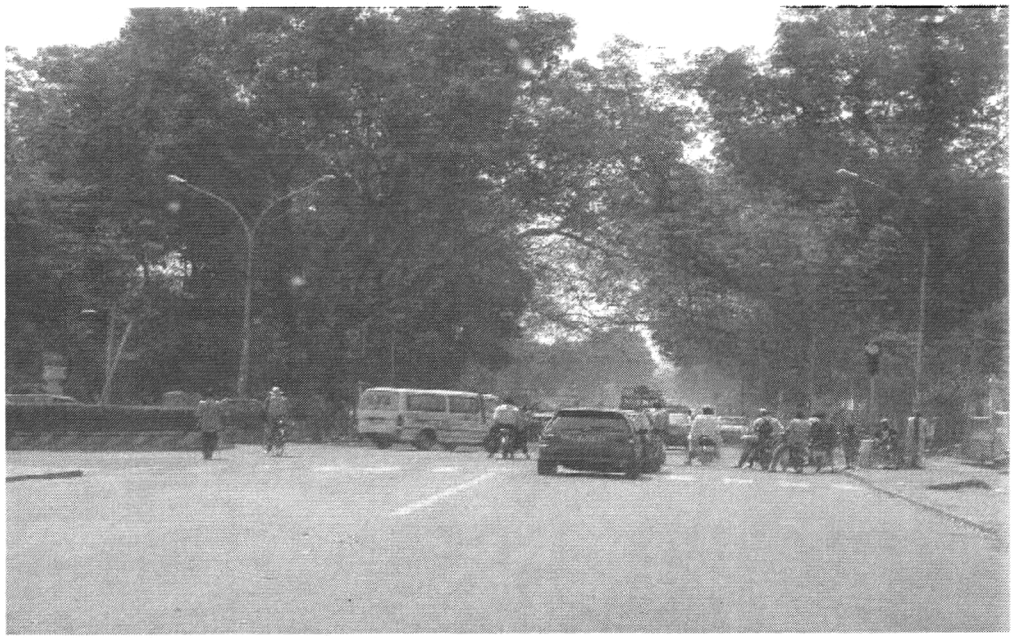


Figure 4: Smoke from Transport Sector in the town of Bamako City in Mali

4.3 The industrial sector

The industries are amongst main causes of the air pollution. Indeed, due to increase in industrialization, the consumption of fossil fuels and the release of the pollutants in the air have tremendously increased. The Bamako City has a large number of industries per example textile industry, metallurgical industry, fertilizer industry, rubber industry, paper manufacturer industry, sweet and biscuit production industry oil production industry, detergent production industry, medicine production industry, and ice production industry which make up to 51% of the town. They are located in an industrial park, established in the East of the city on the trajectory of the dominant winds (East-West). The industrial park releases each day a smoking gas to the city, which is in a basin. These gases are not easily diffused into the atmosphere and as a result the city is daily subjected to the toxic substances, with all the risks that accompany it. Another source of industrial air pollution is from some 108 power stations with a production more than 42162.66 tonnes of coal per year in Mali with burn every day to meet the requirements in electricity. Unfortunately currently none of them practically has an adapted system of treatment of the gas emissions. The magnitude of such can be overwhelming if projected to twenty years from today. The domestic energy need for the local people is mainly met by use of wood and charcoal which release mainly carbon dioxide into the atmosphere. The local and the municipal council frequently use anarchistic incineration of solid waste which produces a lot of smoke. This causes the atmosphere to look as if it has and suspended particles in the air especially in the early morning. The above activities have been are identified as also the principal causes of the air pollution in the

majority of the cities of the developing countries according to UNEP (United Nations for Environmental Protection) into 2006.

Table 3: Quantity of CO_2 emitted into the Atmosphere in 2006

Fuels	*Used quantity/year*	Liter of CO_2 emit/year
Super/Ordinary	94 822	$346{,}2.10^9$
Gas oil	226 066	$347{,}81.10^9$
DDO	110 879	$156{,}96.10^9$

Table 4: Greenhouse emission by different industrial units/Gig

Year		*2004*	*2005*	2006
Industries				
ITEMA	CH_4	$6{,}6.10^{-5}$	$3{,}4.10^{-5}$	$2{,}63.10^{-5}$
	NO_X	$3{,}6.10^{-3}$	$1{,}9.10^{-3}$	$1{,}46.10^{-3}$
	N_2O	$1{,}3.10^{-6}$	7.10^{-7}	$5{,}43.10^{-7}$
	CO	$3{,}4.10^{-4}$	$1{,}77.10^{-4}$	$1{,}4.10^{-4}$
UMPP	CH_4	$4{,}5.10^{-5}$	$4{,}3.10^{-5}$	$2{,}9.10^{-5}$
	NO_X	$2.5.10^{-3}$	$2{,}4.10^{-3}$	$1{,}62.10^{-3}$
	N_2O	$9{,}3.10^{-7}$	$8{,}83.10^{-7}$	$6{,}02.10^{-7}$
	CO	$2{,}32.10^{-4}$	$2{,}2.10^{-4}$	$1{,}51.10^{-4}$

Source: Thesis of Master, Physics of Atmosphere and Environment, April 2006.

4.4 Formation of pollutants in Bamako city

4.4.1 Possibility of photochemical and Industrial Smog

Here is a simplified version of the complex chemistry of photochemical smog formation. It begins when nitrogen and oxygen in air react at the high temperatures found inside automobile engines and the boilers in coal-burning power and industrial plants to produce colorless nitric oxide ($N_2 + O_2 \rightarrow 2NO$).Once in the troposphere, the nitric oxide slowly reacts with oxygen to form nitrogen dioxide, a yellowish-brown gas with a choking odor ($2NO + O_2 \rightarrow 2NO_2$). The NO_2 is responsible for the brownish haze that hangs over many cities during the afternoons of sunny days, explaining why photochemical smog sometimes is called brown-air smog. Some of the NO_2 reacts with water vapor in the atmosphere to form nitric acid vapor and nitric oxide ($3NO_2 + H_2O \rightarrow 2HNO_3 + NO$). When the remaining NO_2 is exposed to ultraviolet radiation from the sun, some of it is converted to nitric oxide and oxygen atoms (NO_2 + UV radiation $\rightarrow NO + O$). The highly reactive oxygen atoms then react with O_2 to produce ozone ($O_2 + O \rightarrow O_3$). Both the oxygen atoms and ozone then react with volatile organic compounds (mostly hydrocarbons released by vegetation, vehicles, gas

stations, oil refineries, and dry cleaners) to produce aldehydes. In addition, hydrocarbons, oxygen, and nitrogen dioxide react to produce peroxyacyl nitrates or PANs (hydrocarbons + O_2 + NO → PANs) (**figure 5**).

Collectively, NO_2, O_3, and PANs are called photochemical oxidants because they can react with and oxidize certain compounds in the atmosphere (or inside your lungs) that normally are not oxidized. Mere traces of these photochemical oxidants (especially ozone) and aldehydes in photochemical smog can irritate the respiratory tract and damage crops and trees.

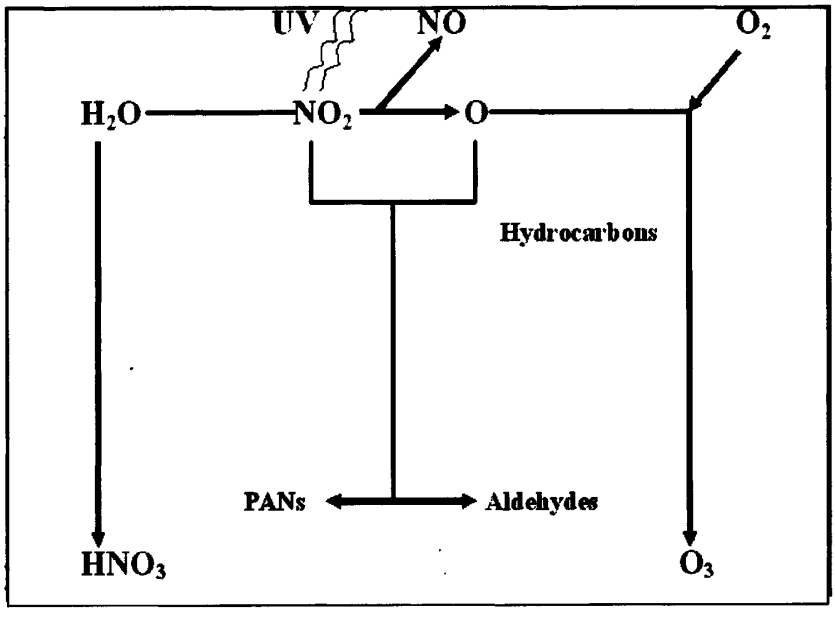


Figure 5: Simplified scheme of the formation of photochemical smog.

Hotter days lead to higher levels of ozone and other components of photochemical smog. As traffic increases in the morning, levels of NO_X and unburned hydrocarbons rise and begin reacting in the presence of sunlight to produce photochemical smog. On a sunny day the photochemical smog (dominated by O_3) builds up to peak levels by early afternoon, irritating people's eyes and respiratory tracts.

According to atmospheric chemist Sherwood Rowland, since 1900 the concentration of photochemical ozone near the earth's surface has increased by a factor 5-8 during summer in the northern hemisphere, 2-4 during the winter in the northern hemisphere, and 2-5 during winter and summer in the southern hemisphere. All modern cities have photochemical smog, but it is much more common in cities with sunny, warm, dry climates and lots of motor vehicles, this might be the next level of pollution in developed countries if air pollution control measures are not affected now.

4.4.2 Definition of Industrial Smog

The chemistry of industrial smog is fairly simple. When burned, the carbon in coal and oil is converted to carbon dioxide ($C + O_2 \rightarrow CO_2$) and carbon monoxide ($2C + O_2 \rightarrow 2CO$). Some of the unburned carbon also ends up in the atmosphere as suspended particulate matter (soot). The sulfur compounds in coal and oil also react with oxygen to produce sulfur dioxide, a colorless, suffocating gas ($S + O_2 \rightarrow SO_2$). Sulfur dioxide also is emitted into the troposphere when metal sulfide ores (such as lead sulfide, PbS) are roasted or smelted to convert the metal ore to the free metal.

In the troposphere, some of the sulfur dioxide reacts with oxygen to form sulfur trioxide ($2SO_2 + O_2 \rightarrow 2SO_3$), which then reacts with water vapor in the air to produce tiny suspended droplets of sulfuric acid ($SO_3 + H_2O \rightarrow H_2SO_4$). Some of these droplets react with ammonia in the atmosphere to form solid particles of ammonium sulfate ($2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$). The tiny suspended particles of such salts and carbon (soot) give the resulting industrial smog a gray color, explaining why it is sometimes called gray-air smog. This is still in insignificant levels in Bamako city but the rate of industrializations can reach at an influential level in the next decade. This because the factors which influence the formation of smog like the local climate and topography, population density, the amount of industry, and the fuels used in industry, heating and transportation are all present but only in small scales. Air pollution can be reduced by rain which helps cleanse the air of pollutants. This explains why cities with dry climates are more prone to photochemical smog than ones with wet climates. Winds also sweep pollutants away, dilute pollutants by mixing them with cleaner air, and bring in fresh air. However, these pollutants are blown and accumulated in Bamako due to its location in a basin like topography. Somewhere else or are deposited from the sky onto surface waters, soil, and buildings.

4.4.3 Legislative and regulation of air pollution

In Mali, the body which deals with the air quality control is the Management of the Cleansing and the control of pollution and harmful effects is the National Direction of the Control of Pollution and the Harmful Effects (DNACPN). Its task the elaboration of national policy regarded of cleansing and control of pollution, harmful effects and to ensure its elimination.

Chapter Five Data analysis

5.0 Results analysis

5.1 Atmospheric Gaseous Pollutants in Mali

Several gases were investigated in Bamako city, this included sulphur dioxide, Nitrogen dioxide and carbon dioxide. Sulphur dioxide which is a product of the oxidation of sulphur in petroleum oil, had increased due by 12.77% between by 2006 was high because of the significant high number of diesel vehicles in Mali. Nitrogenous gases also showed tremendous increase since 2005, but the level of carbon oxides was incredibly increasing at alarming rate from 667 μ g/m^3 in 2005 to 1107 μ g/m^3 in 2006 this was an increase of 60.25%. The hydrocarbons and the sulphurous acid measurements of the gaseous pollutants carried out were not too high to be alarming according to WHO standards (**Table 5**).

Table 5: Average and maximum total concentrations of the major air pollutants in Bamako station in Mali between April 2005 and July 2006 (Conc. μ g/m^3)

Pollutant Gas	**Bamako city air concentration**			
	2005		**2006**	
	Aver.	**Max.**	**Aver.**	**Max.**
Sulfur Dioxide	4.73	99.98	6.04	136.54
Nitrogen Dioxide	47.48	894.63	49.05	1512.,6
Carbon Dioxide	667	27947	1107	50485

The sulphur dioxide is probably the most dangerous of the pollutants which came from the combustion of the vehicles, machines and power stations in Mali.

The nitric oxide is produced from nitrogen by heat and then undergoes a second oxidation to form nitrogen dioxide. Near the source, the pollutant is especially in the form of nitric oxide. The nitrogen dioxide is more dangerous for health than nitric oxide. The average quantity of carbon dioxide was much higher in 2006 than it was it during the previous year), because of the significant increase in the vehicle traffic in 2005. Based on the values of

the standards established on the air quality by MEPA (Administration of the Meteorology and the Environmental protection) and on the basis of index of pollution air established by the U.S EPA (Agency of the United States for the Environmental protection), the concentrations of two polluting gases major (dioxide of sulphur and nitrogen dioxide), measured between April and July from Bamako city did not reach harmful levels (**Table 6**).

Table 6: A comparison data of EPA and MEPA level of Bamako city (Conc. μ g/m^3)

Pollutant Gas	***Average Level***	***Max Level***	***MEPA Standard of Air Quality***	**EPA US Alarm Level**
Sulfur Dioxide	7.88	136.54	730	790
Nitrogen Dioxide	49.05	1512.63	660	1175
Carbon Dioxide	730	50485	40000	40000

Pollution in a developing country is also changing hence several dynamic laws should be enacted to control air pollution for example in the U.S congress passed clean air acts in 2000, 2003, and 2006.With these laws the federal government establishes air pollution regulations that are enforced by each state and by major cities. Congress directed the EPA to establish national ambient air quality standards (NAAQS) for six outdoor criteria pollutants. The EPA regulates these chemicals by using criteria developed from risk assessment methods to set maximum permissible levels in outdoor air. One limit, called a primary standard, is set to protect human health, and another, called a secondary standard, is intended to prevent environmental and property damage. Each standard specifies the maximum allowable level, averaged over a specific period, for a certain pollutant in outdoor (ambient) air. The EPA has also established national emission standards for more than 100 different toxic air pollutants known to or suspected of causing cancer or other adverse health effects. Well established laws can have long time benefits in a country even a developed country like according to the EPA, between 2000 and 2006, national total emissions of the six criteria pollutants declined 29% while U.S. population increased 32%, gross domestic product increased 158%, and vehicle miles traveled rose 143%. Between 2000 and 2006, mean concentrations of five of six criteria air pollutants in the troposphere deceased by 98% for lead, 93% for volatile organic compounds (VOCs), 88% for suspended particulate matter (10 micrometers or less in diameter), 44% for sulfur dioxide, and 26% for carbon monoxide. The mean estimated human health and environmental benefits from air pollution regulations between 1995 and 2005 amounted to $6.8 trillion, compared to $436 million (in 1990 dollars) spent to implement all federal, state, and local air pollution regulations. Thus the net economic benefit of the clean

air act between 1995 and 2005 was $6.4 trillion. During this 20-year period, the act prevented an estimated 1.6 million premature deaths and 300 million cases of respiratory disease. Between 1990 and 2010, the 2003 amendments to the Clean Air Act should provide four times more health and environmental benefits than the estimated compliance costs to industries and consumers. By 2010, the 2003 amendments should prevent 23.000 Americans from dying prematurely avert 1.7 million asthma attacks per year. But there are some bad news like between 1990 and 2001; emissions of nitrogen oxides (NO_X) increased 20%. Between 1995 and 2003, ground-level concentrations of ozone increased, especially in the southern and northeastern regions of United States. Despite continued improvements in air quality, in 2004 areas in which approximately 142 million people lived did not meet the primary standards for one or more of the six criteria pollutants during part of the year. Hence developing countries like Mali can learn a lot from such advances.

A comparison of the maximum concentrations of the dioxide of sulphur and nitrogen dioxide measured between April and May 2006 in a residential zone of Bamako in Mali by a team showed that they are also lower than the environmental standards of reference, established in Japan, for these polluting gases (**Table 7**).

Table 7: Maximum concentrations of Sulphur dioxide and Nitrogen dioxide measured in the residential zone of Bamako in Mali. (Concentrations in $\mu g/m^3$)

Pollutant gas	**Maximal Value**	**Standard of air Quality in Japan (Average/day)**
Sulfur dioxide	73.52	105
Nitrogen dioxide	64.74	80 to 120

5.2 Pollutants in the form of particles

Bamako city was observed to have a load of solid particles, due to the dust and sandstorms. The dry climate, the hot summer, the great extents of dust and the hot and dry winds are factors which contribute to this load. The anthropogenic factors such as the vehicles of building sites and the sand and stone quarries disturb the surface of the ground, making it more fragile and easily removable by the wind. We could only speculate in connection with the impact of these particles in the ground. Information on the rate of suspended particles (TPS) was not also available, but we observed that that industrial parks, centre City, the commercial and residential zones showed a relatively high rate of particles of about $600\,\mu g/m^3$. Normally a monthly variation was noted with a higher rate in June April of about $1.050\,\mu g/m^3$ and a minimum rate in December of about $298\,\mu g/m^3$. The climatic conditions influence in a significant way the rate of particles. The average in the presence of the storms of dust of $1.650\,\mu g/m^3$ exceeds the values found during risings of sand which is $850\,\mu g/m^3$, or in the presence of dust in suspension roughly ($622\,\mu g/m^3$), or during the fogs

of dust roughly at about 360 μ g/m^3 The matter in the shape of particles measuring less than 10 micrometers (MP_{10}, matters in air inhaled particles, has the most significant impact on the respiratory system). The department of the environmental protection in Mali, the World Health Organization and a team of researchers have samples the MP_{10} for one given period the distribution of the particles which can be breathed in the zone located in the East and in the North of Mali. The average concentrations of the MP_{10} win Bamako was found to be 438, 3 μ g/m^3 the global average is 321, 5 μ g/m^3. The study of the distribution of the sizes of the MP_{10} has shown that approximately one third of the particles (38%) approximately measured 6 micrometers or more, while two thirds (60%) approximately had a lower size to 6 micrometers (the Council of the Environmental protection). The Agency of U.S Environmental protection A examines samples coming from two urban sites and A finds values of MP_{10} between 10 and 55 μ g/m^3 a share and of 320 μ g/m^3. A certain number of samples taken still further have watch of values MP_{10} between 120 and 950 μ g/m^3. The standard level of the MP_{10} bench in the east United States of 150 μ g/m^3 and the level of alarm is of 350 μ g/m^3. The standard level of the MP_{10} bench in Japan east 100 μ g/m^3.For various reasons, in particular the frequent storms of fogs and dust, Mali has an approximate annual average level exceeding the 800 μ g/m^3 which could be to regard as being highest of the world. Thus we must expect to that the effects on health causes by the particles and their chemical composition, are different in Mali compared to those observed in Japan, China, and United States or in other industrialize countries.

5.3 Climate inversions in Bamako

To date in Mali, no analysis of the phases of climatic inversion has been made by the weather stations in the Bamako city. However, not withstanding the climatic inversions, it is undeniable that the quality of the air in urban environment has a direct relationship with the entropic missions which carry reached has human health and contribute has the degradation of the framework of life. District records in the last ten years show an increase in the Low Acute Respiratory Infections and generally little change with regard to the High Acute Respiratory Infections, while on the level of the countries there is no increase significant. Being understood that pollution anthropogenic is expressed especially in will go low (because of fine dust which penetrates in the lungs), the observations described below could extremely well constitute an evidence of an increase in the air pollution has Bamako. In addition taking into account standards WHO (0, 21 ppm for the NO_2 and 31, 5 ppm for CO_2 per hour of exposure), the results obtained (0,543 ppm has the ITEMA and 0,602 ppm has the UMPP) should not be neglect and would be all the more closely connected since one would devote to it more means. The acid rains are not unknown phenomena in Mali even if it do not reach

the proportions known under others ways; However, certain relative data has the quality of surface water (PH~6, 3 e.g. for Bamako) must encourage has to take safeguard measures.

5.4 The presence of heavy metals in Bamako City atmospheric air

There are heavy metal gases from machines or carried by sand storms dusts into Bamako city. These heavy metals include nickel and vanadium which are in the atmosphere at concentration of about 8 to 28. Although these measurements were made over short periods, we can logically conclude, that these measurements, that the concentrations of nickel and vanadium Bamako city were higher than those found in its other clean areas. Nevertheless, the evaluation of these values must take into account the fact that the concentrations of nickel in the urban zones of Europe vary between 60 and 300 ng/m^3 and those of vanadium between 7 and 200 ng/m^3. Thus the concentrations of nickel and vanadium found in the matter in the shape of particles in Mali were not excessive. Studies showed that long-term exposure of these heavy metals in high concentrations nickel could produce a dermatitis and cancer of the nose and lungs and can have long time, serious effects on the well being of human (Last, 2006).

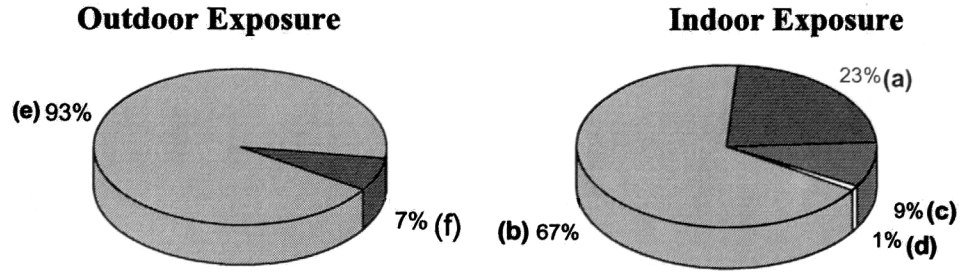
5.5 Polycyclic aromatic hydrocarbons (HAP)

Smoke resulting from the combustion of the machines in Mali contributed to the high rate of the HAP in the matter in the shape of particles inhales (MP_{10}). The total concentrations of compose HAP in the areas of Bamako were not particularly high, on the contrary they were even lower than those found in urban zones of certain parts of the world. The average concentration of benzo (**A**) pyrene in Mali was about 4.59 ng/m^3. By way of comparison, the average level of benzo (**A**) pyrene to Paris in winter is of 4.6 ng/m^3 and is not significant, but it is necessary to be wary of the possible effects of these long-term pollutants on health.

5.6 Deaths due to Air Pollution

It was not easy to get information of directly caused deaths due to air pollution, but we could extrapolate from data in related diseases that there is a significant death level among city dwellers due to air pollution. This can be compared to a study of 2005 which was done by Australia's Commonwealth Science Council, worldwide at least 3 million people (most of them in Asia) die prematurely each year from the effects of air pollution-an average of 8,200 deaths per day. About 2.8 million of these deaths are from indoor air pollution, and 200,000 are from outdoor pollution. This explains why the world Health Organization and the World

Bank consider indoor air pollution one of the world's most crucial environmental problems (**Figure 6**).



Total deaths 0. 2 million Total deaths 2. 8 million

Figure 6: Estimated premature deaths per year caused by indoor and outdoor air pollution in developing and developed countries, (Data from Australia's Commonwealth Science Council, 2005)

Outdoor Exposure:

(e) Developing countries (Urban)

(f) Developed countries (Urban)

Indoor Exposure:

(a) Developing countries (Urban)

(b) Developing countries (Rural)

(c) Developed countries (Urban)

(d) Developed countries (Rural)

Plant damage due to air pollutants

The effects of exposure of trees to a combination of air pollutants may not become visible for several decades, when large numbers of trees suddenly begin dying. Most trees and vegetation examined in Bamako did not show any significant air pollution effects. This was because it appeared soil nutrient depletion and pests, diseases, fungi, and drought seems to affect the plants more than air pollution. May be the effects shall be seen later if the pollution increase as it has been shown in other countries where air pollution, mostly by ozone, also was seen to threatens some crops especially corn, wheat, and soybeans and reduced U.S. food production by 5-10%. In the United States, estimates of agricultural losses as a result of air pollution (mostly by ozone) range from $2 to $6 billion per year, with an estimated $1 billion of damages in the highly polluted California alone. (**Figure 7**)

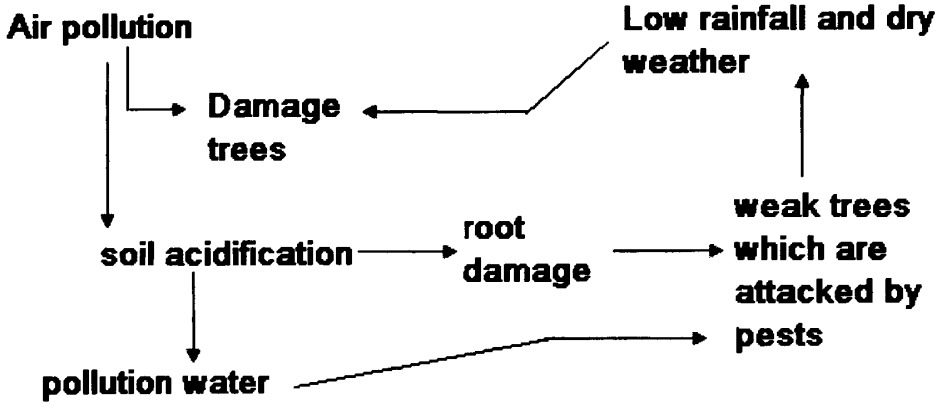


Figure 7: Air pollutants damaged, weaken, or kill trees in an ecosystem and reduce precipitation in an area.

The Effects of Air Pollutants on physical materials

The damage due to air pollutants on various materials in Bamako was assessed. We found out that fallout of soot and grit on buildings, cars, and clothing was minimal and necessitated little cost in cleaning. Only a few buildings had exterior paint affects and deteriorated roofing materials. No old marble statues, historic buildings, and stained glass windows around the city showed pitted, gouged, and discolored parts. This was because the acid rain deposition in the city was quite low and insignificant.

(Table 7)

Table 7: Harmful effects of Air Pollution on Materials in Bamako Mali

Material	*Effects observed*	**Expected principal air pollutants**
● Stone and concrete	No major surface erosion, discoloration was seen	Sulfur dioxide, sulfuric acid, nitric acid, particulate matter
● Metals	Only normal rust and corrosion was seen	Sulfur dioxide, sulfur acid, nitric acid, particulate matter, hydrogen sulfide
● Ceramics and glass	Surface erosion not seen	Hydrogen fluoride, particulate matter
● Paints	Old building had little discoloration	Sulfur dioxide, hydrogen sulfide, ozone, particulate matter
● Paper	Some were bleached	Sulfur dioxide
● Rubber	no discoloration seen	Ozone
● Leather	few Cracking, loss of strength	Sulfur dioxide
● Textiles	few surface deterioration, loss of strength and fading	Sulfur dioxide, nitrogen dioxide, ozone, particulate matter

Chapter Six Effects of air pollution

6.0 Consequences of Air Pollution in Mali

Although there is a great individual difference in susceptibility to the atmospheric pollutants, there is clearly a certain group of the population which is more sensitive than others in terms of effects on health. Allergic reactions due to pollution can easily be misdiagnosed as to lack of atmospheric composition analysis. The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, the individual's health status and genetics. People who exercise outdoors, for example, on hot, smoggy days increase their exposure to pollutants in the air. An experimental and epidemiologic study has made it possible for us to identify the following sensitive groups in the populations.

6.1 Sensitive groups in the population

6.1.1 Children

Children can easily be affected by air pollution because their respiratory tracts are still immature at the anatomical level. There bronchi as few muscles on their walls and are rich in bronchial glands which ramify out of bronchioles. If children are exposed to polluted atmosphere there respiratory tract secrete fluid in excesses can cause blockage. At has been documented that development of the bronchial tree continues up to and until the child is about 8 years of age. In addition, the immunity of the children is less developed although there thymus is a great buffer for excessive attacks on immunity. The children tend to be are more sensitive to the various aggressions against body systems especially atmospheric pollution leading to allergic coughing and colds.

6.1.2 Old people

The old people are very sensitive because of the reduction immunizing defenses mechanisms in there body. The asthmatic ones and the people affected by allergic rhinitides are more prone to pollution effects. Biologically speaking the epithelium inflammation which results from asthma or the allergic rhinitis can cause an increase in the epithelial permeability to substances hence, facilitating the passage of the pollutants into the body. This can lead to chronic irritants and entry points for bacterial and viral pathogens.

6.1.3 Patients

People who are weak and sick can be affected by air pollutants due to weakened bodies and medications. This kind of people becomes particularly sensitive to the oxidizing aggressions. Any inflammatory phenomenon on the level of the bronchi and bronchioles can compromise alveolar ventilation and ultimate level of gaseous exchange. These disturbances worsen the respiratory insufficiency in patients especially given the low standard of medical care in our towns. Patients with cardiovascular diseases have been identified to be more affected by certain atmospheric pollutants like the fine particles and carbon monoxide leading to the aggravation of their conditions.

6.1.4 Sport people

The people practicing sports in the open space are also highly exposed to air pollutants. Any outdoor sports activity needs an increase in lung ventilation. Although this can vary in proportions according to the quality and the intensity of the efforts involved, it definitely increases in a concomitant way the exposure and entry of atmospheric pollutants in to the body. For example in Mali its sometimes very on hot, and nowadays as is becoming smoggy can produce conditions which increase the effects of exposure to pollutants in the air especially to people who exercise outdoors. This can influence sport performance and overall life span.

6.2 Complications of heath due to air pollution

Although there are is a group of populations which can feel effects of even low concentrations of pollutants than the general population there is on the one hand group of people whose maladies can be triggered or complicated by air pollution. Given that the principal mode of exposure to the air pollution is inhalation, then majority of the effects on health would be expected to be related to the breathing apparatus. However, other mechanisms can be interfered or triggered by air quality for example asthma which is a regarded as a genetic disease is actually influenced by the environment. Because of the allergic ground and the genetic deformity the contact with the irritants can be very complicated. It is a chronic disease most frequent in childhood. The BPCO (obstructive chronic Broncho-pneumonopathy), in particular bronchitis and the emphysema, depend on genetic, behavioral and environmental factors. It is difficult to determine with precision the prevalence of the BPCO because the diagnosis of the disease is generally posed only among in-patients.

6.2.1 The complications of allergies due to air pollution

Allergies are body reactions due to foreign antigens. They are controlled by the immune system and influenced by a series of factors caused by genetic predisposition, the food particles, and way of life or exposure allergens into the environment. The signs of the respiratory allergy are: allergic rhinitis (hay cold), cough, asthma. It is considered that the atmospheric pollutants contribute to their increase, on the one hand, directly by increasing the reactivity of the respiratory tracts and, on the other hand, indirectly while returning the grains of pollen more allergens. The cardiovascular diseases WHO estimated that 1 to 2 % of mortality by cardiovascular disease (at the people already reached) can be allotted to the light increases in the air pollution by the fine particles.

6.2.2 Air pollution causes Asthma

It has been reported in Mali as other countries that asthma is becoming more common chronic disease among children and adults. Asthma attacks are triggered by exercise, body infection, allergies and even stress. One can diagnose it easily for it causes shortness of breath, coughing or wheezing or whistling in the chest. It can also be triggered by sensitivity to non-allergic types of pollutants present in the air.

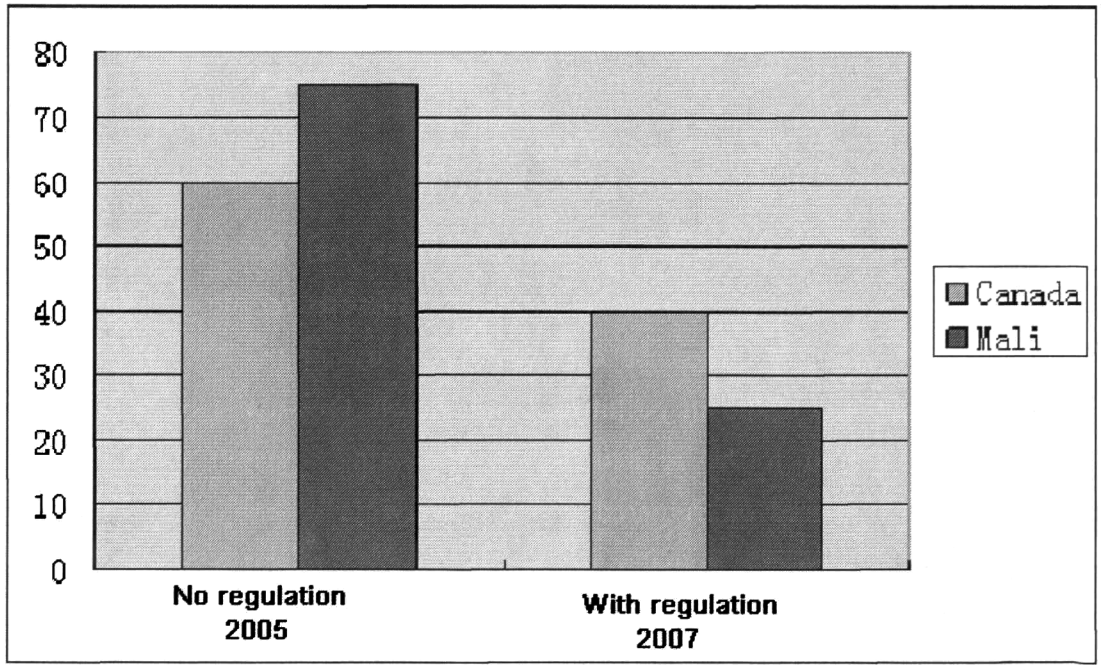


Figure 8: The percentage comparison of cost reduction before and after implementing air pollution regulations both in Canada and Mali in 2007.

A recent study examined the economic value of reducing the health effects of air pollution by introducing cleaner vehicles and fuels in Canada. This study found that the

economic value of avoiding these health effects was $24 billion over a period of 24 years, compared to a cost of $6 billion to implement the program, **Figure 8**. This is a reduction of 75%. Similar studies in Mali showed without regulation was 40% but with regulation it was to be reduced to 60% this is because currently there is little effort being made to reduce air pollution which is also not much.

6.2.3 The effects of carcinogenic particles

The presence of even in small quantities of carcinogenic substances in the environment can cause many concerns in a population. It is considered that the 3/4 of the cases of cancer is related to external causes and, in particularly due to the way of a person conducts his life. Tobacco is only being responsible for about third of mortality cases of cancer. There are now many governments which are concerned with the regulation of smoking cigarettes in public. These efforts shall reduce the cases of first and second hand smokers. Research indicates that invisible particles-especially fine particles with diameters less than 10 microns (PM_{10}) and ultra fine particles with diameters less than 2.5 microns ($PM_{2.5}$)-pose a significant health hazard. Such particles are emitted by incinerators, motor vehicles, radial tires, wind erosion, wood-burning fireplaces, and power and industrial plants.

Such tiny particles are not effectively captured by modern air pollution control equipment, are small enough to penetrate the respiratory system's natural defenses against air pollution and can bring with them droplets or other particles of toxic or cancer causing pollutants that become attached to their surfaces. Once they are lodged deep within the lungs, these fine particles can cause chronic irritation that can trigger asthma attacks, aggravate other lung diseases, cause lung cancer, and interfere with the blood's ability to take in oxygen and release CO_2, which strains the heart and increases the risk of death from heart disease. Several recent studies of air pollution in U.S. cities have indicated that fine and ultra fine particles prematurely kill 65.000-200.000 Americans each year, There is no known threshold level below which the harmful effects of fine particles disappear. Exposure to particulate air pollution is much worse in most developing countries, where urban air quality has generally deteriorated. The World Bank estimates that if particulate levels were reduced globally to WHO guidelines, 300.000-700.000 premature deaths per year could be prevented. In 2004, the EPA announced stricter emission standards for ultra fine particles with diameters less than 2.5 microns ($PM_{2.5}$). The EPA estimates the cost of implementing the standards at $7 billion per year, with the resulting health and other benefits estimated at $120 billion per year.

According to industry officials, the new standard is based on flimsy scientific evidence, and its implementation will cost $200 billion per year. EPA officials say that their review of the scientific evidence-one of the most exhaustive ones ever undertaken by the

agency-supports the need for the new standard for ultra fine particles. Furthermore, a 2006 study by the Health Effects Institute of 90 large American cities supported the link between fine and ultra fine particles and higher rates of death and disease.

6.2.4 Effects of Air Pollution on Living Organisms and Materials

The respiratory system has a number of mechanisms that help protect it from air pollution, This includes having a lot of hairs in the nose, which filter out large particles, having a sticky mucus in the lining in the upper respiratory track, which captures smaller (but not the smallest) particles and dissolves some gaseous pollutants, sneezing and coughing, which expel contaminated air and mucus when pollutants irritate the respiratory system and having hundreds of thousands of tiny mucus-coated hair like structures called cilia, which line your upper respiratory tract. They continually wave back forth and transport mucus and the pollutants they trap to your throat (where they are swallowed or expelled). Years of smoking and exposure to air pollutants can overload or break down these natural defenses, causing or contributing to respiratory diseases such as lung cancer, asthma (typically an allergic reaction causing sudden episodes of muscle spasms in the bronchial walls, resulting in acute shortness of breath), chronic bronchitis (persistent inflammation and damage to the cells lining the bronchi and bronchioles, causing mucus buildup, painful coughing, and shortness of breath), and emphysema (irreversible damage to air sacs or alveoli leading to abnormal dilation of air breath. Older adults, infants, pregnant women, and people with heart disease, asthma, or other respiratory diseases are especially vulnerable to air pollution.

6.3 Steps in reducing outdoor air pollution

Until recently, emphasis has been on dispersing and diluting, the pollutants by using tall smokestacks or adding equipment that removes some of the particulate pollutants after they are produced. However, under the sulfur reduction requirements of the 2005 amendments to the Clean Air Act, more utilities are switching to low-sulfur coal and oil to reduce SO_2 emissions. Environmentalists call for greater emphasis on such prevention methods. There has been much controversy over requiring better pollution control for 17.000 older coal-burning plants; most of the larger ones located in the eastern half of the United States. These plants and several thousand older manufacturing plants that burn coal make a major contribution to acid deposition, cause large numbers of premature deaths and health problems, and degrade many terrestrial and aquatic ecosystems in the eastern United states. Owners of most of these plants have used emissions trading to avoid having to reduce air pollution emissions. To help deal with this problem, the Clinton administration announced enforcement of a Clean Air Act rule requiring older plants to install modern air pollution control devices when they improve or expand their facilities significantly. In 2006, a study by Abt Associates (a primary technical consultant firm for the EPA) estimated that reducing emissions from older coal-fired plants

could prevent 18.700 premature deaths per year and 3 million lost work days annually from respiratory illness. The affected utility and manufacturing companies vigorously opposed enforcement of this rule, arguing that it would cost them too much money, raise electricity prices, and cause them to shut down some of their older plants. In 2006, the Bush administration said it would not enforce this rule. In protest of this decision, Eric Schaeffer resigned his job as chief of Civil Enforcement for the EPA. He said that the Abt Associates report "shows how the Bush administration's failure to enforce the Clean Air Act is a serious threat to public health".

Six eastern states and several large cities (including Chicago and New York), fed up with dirty power plants and the lack of desire of elected officials to do much about them, are taking matters into their own hands. They are studying ways to reduce pollution from such plants or have passed legislation or implemented policies to accomplish this. An important way to make significant reductions in air pollution is to get older, high-polluting vehicles off the road. According to EPA estimates, 10% of the vehicles on the road in the United States emit 50-70%of the pollutants. But people who cannot afford to buy a newer car often own old cars. One suggestion would be to pay people to take their old cars off the road, which would result in huge savings in health and air pollution control costs. Here is some good news. During the past 30 years, outdoor air quality in Tokyo, in Japan, and in most western European cities has improved. The bad news is that outdoor air quality has remained about the same or has gotten worse in most rapidly growing urban areas in developing countries. To reduce indoor air pollution, it is not necessary to impose indoor air quality standards and monitor the more than 100 million homes and buildings in the United States. Instead, air pollution experts suggest that indoor air pollution can be reduced by several means. Another possibility for cleaner indoor air in high-rise buildings is rooftop greenhouses through which building air can be circulated.

In developing countries, indoor air pollution from open fires and leaky and inefficient stoves that burn wood, charcoal, or coal (and the resulting high levels of respiratory illnesses) could be reduced if governments gave people simple stoves that burn biofuels more efficiently (which would also reduce deforestation) and that are vented outside or provided them with simple solar cookers.

6.4 The practical way forward on air pollution

It is very encouraging that since 1970 most of the world's developed countries have enacted laws and regulations that have significantly reduced outdoor air pollution. However, without strong political pressure by individuals and organized groups of individuals on elected officials in the 1970s and 1980s these laws and regulations would not have been enacted, funded, and implemented. In turn these laws and regulations spurred companies, scientists, and engineers to come up with better ways to control outdoor pollution. These laws and regulations are a useful output approach to controlling pollution. To environmentalists, however, the next step is to shift to preventing air pollution. With this approach, the question

is not "what can we do about the air pollutants we produce? "But "how can we not produce such pollutants in the first place? " Burning fossil fuels is the major cause of most outdoor air pollution. Thus preventing such pollution over the next 40-50 years involves the following steps; Integrating government policies for energy and air pollution, Improving energy efficiency to reduce the use and waste of fossil fuels, Relying more on lower-polluting and more climate-benign natural gas than on oil and coal, Increasing use of renewable energy, especially solar cells, wind, and solar-produced hydrogen., Regulating air quality for an entire region or air shed with primary emphasis on prevention., Transferring the latest energy-efficiency, renewable-energy, pollution prevention, and pollution control technologies to developing countries, In terms of human health, the most serious problem is indoor air pollution. This is caused primarily by burning of wood, charcoal, dung, and crop wastes in open fires or inefficient stoves in developing countries, poverty, which is the primary reason people in developing countries, cannot afford less polluting ways to cook and heat their dwellings and water and indoor smoking in developed and developing countries. Thus, the most important ways to reduce and prevent indoor air pollution are the following: Greatly reducing poverty Distributing cheap and efficient cook stoves and solar cook stoves in developing countries, greatly reducing or banning indoor smoking. Like the shift to controlling air pollution between 1994 and 2006, this new shift to preventing air pollution will not take place without political pressure on elected officials by individual citizens and groups of such citizens. See the website material for this chapter for ways you can reduce your exposure to indoor and outdoor pollutants.

Laying Down Strategic Governmental Policies

Mali has signed and ratified a great number of conventions, agreements and treaties regarding to the environmental protection in particular the convention of Vienna and its protocol of Montreal on the substances impoverishing the layer of Ozone and the convention regarding to the safeguarding of fauna and flora in their natural habitat. Since then the country has been actively working on their implementation. In addition to these provisions, to improve quality of the air in urban environment, it is necessary now became more imperative to set up monitoring systems in Bamako and other cities. There should be a proven system of collecting and disposing litter for example domestic and public mechanical litter collectors, hydraulic vacuum cleaning, dry vacuum cleaning etc. But important is the education of the masses concerning the value of a clean atmosphere use of unleaded gas efficient automobile combustion industrial emissions evaluated constantly epidemiologic and toxicological study depending to the air pollution. The implementation of some of this can be costly now but the eventually cost shall be less than if control and regulation measures are not taken now. More than 100 countries ratified the protocol of Kyoto aiming at reducing by 5.2 % the emissions of gases for purpose of greenhouse of 1990 to 2010. We investigated the problem of gas emission in the city of Bamako in Mali which is a developing country with an aim of

identifying the causes and effects of air pollution together with an attempt to make an extrapolation of its contribution to global effect in the next ten years. This was mainly because the problem of greenhouse effect can only be effectively tackled by a collective effort of developed and developed countries and the best approach should be according to a principle of sustainable emission proportionality. Like underlined it the Policy chief Wallstrôm, we have analysed the importance of collective responsibility to work in the reduction of emissions of gases coming from the small air-conditioners to large industries. This is because the fluorinated gases and the carbon dioxide used in air-conditioning are obviously covered by the protocol of Kyoto. Most industrial countries like all European Union countries including the current and future member states, the USA, Japan, China, India and Canada are all of the signatories of this agreement.

Mali was in this study identified as having a lot of faulty and old inefficient machines and cars which are the major contributors of air polluting gases. Other factors like improper implementation of a legal frame work of industrial emission and education of the population on global expectation together with health hazards due to air pollution have also been identified as key players in sustainable air pollution control in Mali. The Town of Bamako seems to have a topographical disadvantage because of the hills which surround it. The City is in a depression which seems to allow air to settle and accumulate in its atmosphere more than other places. Hence this project proposes a stricter control of industrial pollution and that any further expansion of the City should be done at an area which does not cause industrial emission to flow back to residential areas of the city.

Chapter Seven Conclusions and Recommendations

7.0 Conclusions

This thesis has identified that Bamako City in Mali in West Africa is producing various pollutants which are being released into the country's atmosphere due to a high rate of industrialization and an increasing quantity of inefficient vehicles in the country urban centers. The fishing industry makes Mali one of the large fresh water fish producers the area with annual production of up to 100,000 tons in a year was a source of air pollution due to the waste output of 500,000 people who work in this industry. This is about 7.2% of the working population. The production of gold metal made a remarkable increase in production by moving from 6,291 kg in 1995 to 44,584,517 kg into 2004. This went along with air industrial waste production. The tourist season of 2006-2007 is recorded an increase of visitors of 37,000 to 150,000 giving a hint to the rapid development and interest into this country. In the transport sector, more than 80% of the public vehicles are more than 11 years old while out of these 70% are above 16 years old with faulty combustion engines. Sulphur dioxide which is a product of the oxidation of sulphur in petroleum oil, had increased due by 12.77% between 2004 and 2006. This was expected to increase in the next decade at an exponential rate especially due to the large willing investors from the West and Europe. Nitrogenous gases also showed tremendous increase since 2005. The level of carbon oxides was incredibly increasing at alarming rate from $67\mu g/m^3$ in 2005 to $1107\mu g/m^3$ in 2006 this was an increase of 60.25%. There are heavy metal gases which were identified to have come from active machine industries or carried by sand storms dusts into Bamako city. These heavy metals included mainly nickel and vanadium which are in the atmosphere at concentration of about 8 to $28\mu g/m^3$. The average concentration of benzo (A) pyrene in Bamako was about 4.59 ng/m^3 compared to Paris which had 4.6 ng/m^3 in winter was found to be not significant. Most trees and vegetation examined in Bamako did not show any significant air pollution effects. This was because it appeared that soil nutrient depletion and pests, diseases, fungi, and drought seemed to affect the plants more than air pollution in the water starved lands of Mali. The damage due to air pollutants on various materials in Bamako city was found to be moderate fallout of soot and grit on buildings, cars, and clothing and necessitated little cost in cleaning. Only a few buildings had exterior paint affects and deteriorated roofing materials. It was not easy to get information of deaths directly caused by air pollution, but we could extrapolate from data in related diseases that there is a significant death level among city dwellers due to air pollution. The effect of this has been an increase in the deterioration of the normal composition of the quality of the air in the city and its surrounding. In this Thesis prove that air masses around Bamako are have limited amount harmful gases, dust particles, few species of living microorganisms, an insignificant amount of metals oxides. Almost no

synthetic organic chemicals can currently adversely affect human health and the City ecosystems are present in the Capital city's atmosphere.

The principal sources of pollution in the city of Bamako are from thermal energy production at the individual level which includes combustion gases from residential houses and at the industrial level we found that water vapor, industrial exhaust gases like fossil fuels (coal, heavy fuel, etc.) are the threat. The industrial pollutants are being identified as the greatest contributors of pollutant emissions. The major reason being an increase in the demand for thermal energy and lack an established legal framework to regulate and treatment waste products. Pollution from the transport sector was shown to be due to an increase in faulty public vehicles and personal cars with incomplete engine combustion systems. This mainly caused the emissions of nitrogen, carbon, Sulphur, lead oxides and various hydrocarbons in the former clean air of the city. Pollution from agricultural activities was seen as been very insignificant in air pollution except in cases of unregulated use of chemicals in spraying crops. Other future threats of air hygiene in the city include gases like Ammonia, methane, the protoxide of nitrogen and the carbon monoxide which are mainly from the decomposition of the organic matter and the use of manure. There are also little of plant health products on a large scale which involves the setting of suspended particles in the air.

The Mali government's has initiated measures to evaluate and manage the quality of the ambient air in Bamako city. In conclusion we state that although the air pollution in Bamako is not significantly alarming at present but if plans to regulate and monitor the current little pollution we extrapolate that this developing country might also contribute to the emission of greenhouse gases which are causing climatic changes in the whole planet. Such effects have been identified to cause upheavals like rising of the sea level and oceans, potential increase in the cyclones and storms and global warming. All the air pollutants in this study have been identified to have their toll in causing an indirect or direct impact on human health and have wide reaching implications in the national budgets of the developing countries in the long run. Hence national and international protocols are supposed to be implemented with all sincerity so that international policies can guarantee our future earthly survival. We also remark that regular studies should be conducted in other cites and also periodically in this major capital of Bamako.

7.1 Recommendations

In general, the industries in Mali have a general regulation order to control pollutions to significant levels. They are to control the emissions of atmospheric pollutants are committed to reduce and manage their emissions in the long-term. There are several ways in which industries are able to reduce their impact on air quality in the Bamako city and Mali in general.

This can include; Introduction of scrubbers; Shifting to renewable energy (or low Sulphur fuel); Introduction of cleaner technology; Implementation of process equipment changes and process changes; Improvement of operating practice; Ensuring regular maintenance; and Ensuring maximum energy conservation. Several air quality monitoring initiatives are currently underway in the North West Province: This study concludes that little quantitative data is available to illustrate the state of air quality in the Bamako city. There is much information on the human activities taking place in the city that may lead to poor air quality, in the city and surroundings. In addition, information that quantifies the impact of poor air quality in the city is equally limited.

Ambient air quality in the Bamako city is not considered to be a major problem on a provincial scale. However air quality in some areas shows signs of deterioration. Un-rehabilitated mines in the Mali continue to pose serious health threats to the surrounding communities. Further remedial actions to alleviate this situation are required. Little is known about the effects of vehicular emissions, and the quantities of ozone depleting substances and greenhouse gases emitted in Mali. Various air quality monitoring initiatives are currently undertaken in the city. Much of the monitoring is for Sulphur dioxide and particulate matter. Several industries in the city have shown their commitment to reducing emissions by seeking to employing 'environmentally clean' technology. Non-point sources of pollution (e.g. dust from farmlands) are difficult to quantify. Indoor air pollution still poses a health threat to those individuals using domestic fossil fuels. The city should establish a central point for data collection on environmental quality, particularly air quality. This central point should facilitate sharing of data between industry, tertiary education facilities and government, for the mutual benefit of all parties. Air quality monitoring network needs to be established. Existing monitoring sites could be linked to a new coordinated network to ensure air quality data is available for future State of Environment Reports for the city. A scheduled process database needs to be compiled, consolidated, updated and managed efficiently. All abandoned mines and mine dumps should be rehabilitated to minimize their potential for pollution: Every effort should be made to ensure that asbestos fibers in the surrounding environment are also cleaned up. Areas of special concern include villages, schools and other areas frequented by village inhabitants. Tailings dams from many different mining operations should be rehabilitated and vegetated to prevent wind-blown dust. Chrome, vanadium, gold and platinum smelters in the city should be certified that dust and metal vapour collection technology is effective and maintaining emissions within acceptable limits. Any gold processing operations should use the latest cyanide handling techniques recommended by the Chamber of Mines to eliminate unnecessary potential toxic emissions to the environment. The Bamako city should select air quality indicators once the National Environmental Indicators

Program (DEAT) has been completed. The electrification of homes should be an on-going activity to prevent carbon fuel pollution in the next decade. Dirt and gravel roads should be paved or tarred to reduce the amount of particulate matter in certain areas. A comprehensive quantitative assessment of the state of air quality in the Bamako city should be conducted regularly.

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DEDICATIONS

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