Second report of Zimbabwe Air Pollutant Emissions Inventory preparation effort as part of the APINA Activity 2.2

Authors: [1]Godfrey Dombo, and [2]Caroline J. Maredza

[1]*Department of Metallurgical Engineering, University of Zimbabwe, Mount Pleasant Drive, P.O. Box MP 167, Mount Pleasant, Harare Zimbabwe,*
gtdombo@eng.uz.ac.zw

[2]*Scientific and Industrial Research and Development Centre (Sirdc), Alpes Road, P.O Box 6640, Harare Zimbabwe*
cmaredza@sirdc.ac.zw

1. Introduction

Air pollution has become a major health and environmental problem globally and the southern Africa region is no exception. Adverse impacts of air pollution on public health, crop yields, ecosystems, materials and climate change have been widely documented. It is a fact that air pollutants can be transported over long distances, sometimes transboundary and therefore any attempts to mitigate impacts on the environment call for regional intergovernmental co-operation. As a measure to reduce air pollutants, a regional network of scientists, policymakers and non-governmental organizations - the Air Pollution Information Network for Africa (APINA) is working towards developing regional models of transboundary air pollution in southern Africa. At a Regional Policy Dialogue held in Maputo, Mozambique in September 2003, APINA recommended, among other things, the setting up of an Emissions Inventory task team **(Simukanga *et al*, 2003)**. The team comprising members from southern African countries namely Botswana, Malawi, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe, has a mandate to carry out emissions inventories for the individual countries. Compilation of the inventory was identified as the first step towards formulating regional models to curb transboundary air pollution. Indeed it is important that the regional community quantify systematically all present day and past anthropogenic emissions, employing comparable methods, to assess the regional impacts of such emissions. This report outlines the salient aspects of an emissions inventory of Zimbabwe as one of the regional countries under consideration.

Unlike in other southern African countries such as Zambia and South Africa where air pollution inventories have been done, there are numerous gaps with regards to emissions inventory in Zimbabwe. The United Nations Framework Convention on Climate Change (UNFCCC) – sponsored First National Communication document of 1998 only focused on Greenhouse Gases (GHGs) inventory. On the other hand ambient air quality monitoring exercises that have been done mainly focused on SO_x and NO_x gases in the city large cities. Levels of air pollutants like CO, PM_{10} and $PM_{2.5}$ in the atmosphere are unknown (**Motooane *et al*, 2003**).

Despite the lack of comprehensive air quality monitoring and reporting measures, legislation governing control of air pollution has been in place for a fairly long time. The Atmospheric Pollution Prevention Act of 1971 was mainly focused on control of pollution sources that produce gases which have serious negative impacts on human health. The law had its shortcomings in that it failed to address and harmonize all legislation on environmental issues. More recently (2002), the Environmental Management Act was put in place to cater for all environmental issues including transboundary air pollution. The Act seeks to provide for sustainable management of natural resources and protection of the environment; the prevention of pollution and environmental degradation through the functions of various wings. However, despite the ratification of the regulation, a lot need to be done on the ground to reduce air pollution because the emission of air pollutants still continues unabated.

The emissions inventory under the current exercise is based on a common methodology developed by the Swedish Environmental Institute (SEI) for countries in southern Africa - itself derived from various inventory approaches used in other regions of the world. According to the SEI approach, sources of air emissions are categorized into six sectors namely;

a) energy,
b) industrial processes,
c) solvent and other product use,
d) agriculture,
e) vegetation fires and forestry, and
f) waste

For each sector the basic approach for calculating emissions of a particular pollutant is simple in concept:

$$\text{Emissions} = \text{Activity level} \times \text{Emission factor}$$

The pollutants under spotlight in this exercise are sulphur dioxide (SO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), ammonia (NH_3) and particulate matter (PM_{10} and $PM_{2.5}$). Large points sources (LPS), which were not covered in the first inventory report (July 2006) are included in this current work, albeit in a less extent.

2. Inventory Results

Data from the sectors that were covered in the inventory indicate that the total amount of anthropogenic emissions in Zimbabwe during year 2000 was 5446.9kt/year. Figure 2.1 shows the percentage distribution of the pollutants.

CO has the highest total emission load (3583.0 kt/yr or 66% of total) followed by PM_{10} (512.6 kt/yr or 9%). All the other pollutants contribute about 5% on average.

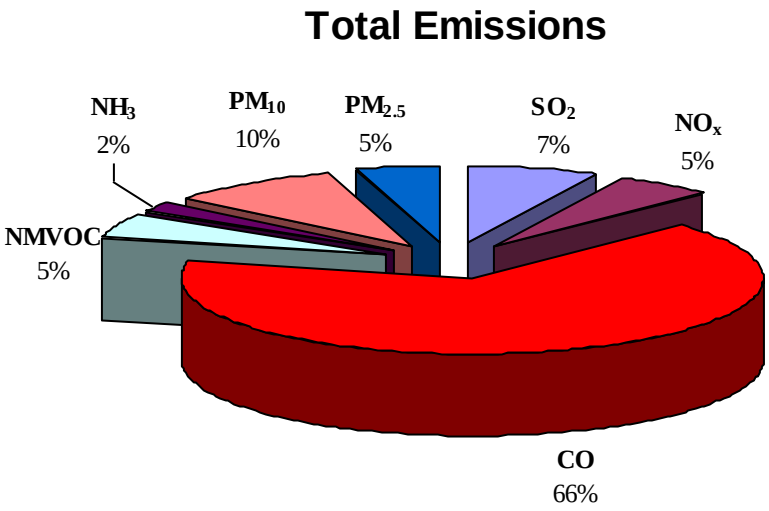

Figure 2.1 Percentage distribution of pollutants

The trends in percentage distribution of particular pollutants are explained by the nature of the dominant economic and social activities in the country and these will become apparent in the following section which focuses on individuals sectors.

3. Emission by pollutant type

3.1 Sulphur dioxide

Sulphur dioxide emissions from all the sectors considered amounted to 388.3kt/yr, with the bulk (66%) of it emanating from the energy industries. Zimbabwe has four thermal power stations that use coal to raise steam for power generation, contributing about 41% of the country's electricity needs. The manufacturing and construction industries also released significant percentage (13%) of the total SO_2. Figure 3.1 presents the proportion of SO_2 generation by sector for the various industries that were inventoried.

The industrial processes sector, in which metal production is the most dominant, also emitted a significant quantity of SO_2 (32.1kt/yr or 8%). Less significant SO_2 emission sources were the transport, agriculture and waste management sectors.

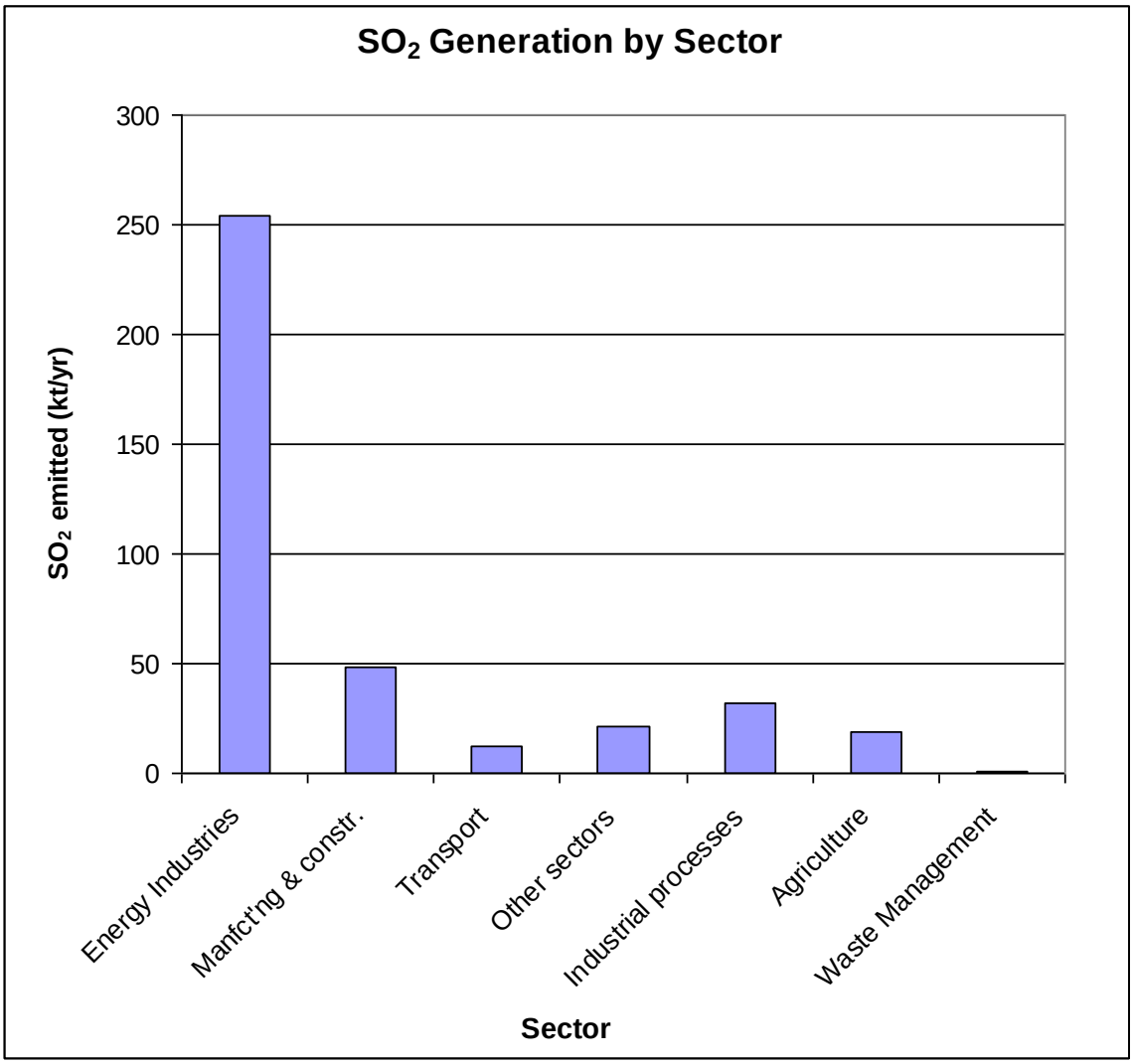

Fig. 3.1 Quantities of SO_2 emitted in various sectors

3.2 Oxides of Nitrogen

The agriculture sector was responsible for the bulk of NO_x emitted. Of the total 291.7 kt/yr of NO_x recorded, the agriculture sector accounted for about 76%, while the transport sector and electricity generation also emitted significantly at 8% and 7% respectively. Fig. 3.2 presents the data collected on NO_x emissions.

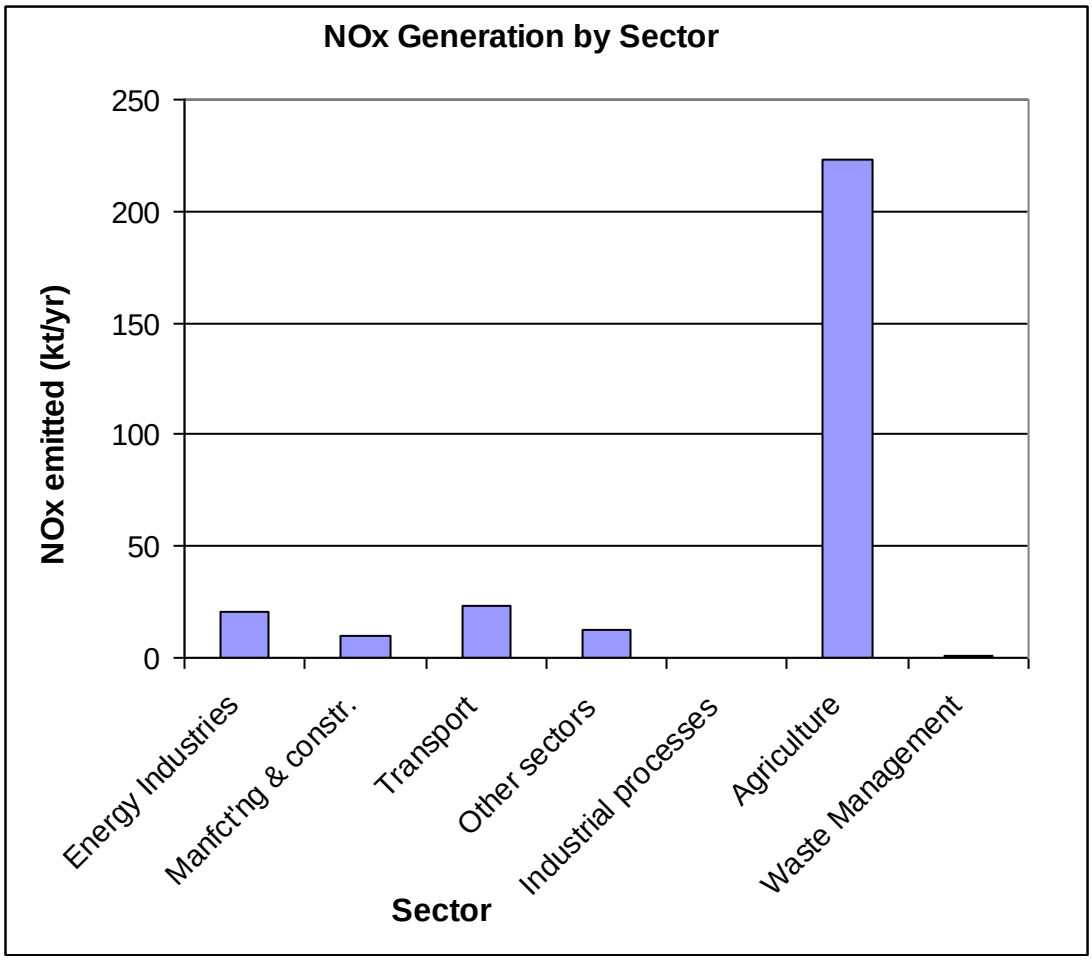

Fig. 3.2 Quantities of NO_x emitted in various sectors

Although agriculture was the economic backbone and a major contributor to the country 's gross domestic product during the period under review, NO_x emissions were not related to productive agriculture but rather to savanna burning. Indeed veld fires were a major source of NO_x, as more than 10 000kha of land were damaged **(Environmental Management Agency (EMA), 2005)**.

3.3 Carbon Monoxide

Savanna burning, which falls under agriculture, was again the main source of CO emissions. About 2940 kt/yr of CO (or 82% of total) were released from that sub-sector. Combustion of wood in residential areas also accounted for a considerable portion of total CO emitted. The sub-sector emitted 359.9 kt/yr (or 9% of total) and is included under 'other sectors' in figure 3.3. Road transport under the transport sector was another culprit as it contributed 6% to the total CO emissions.

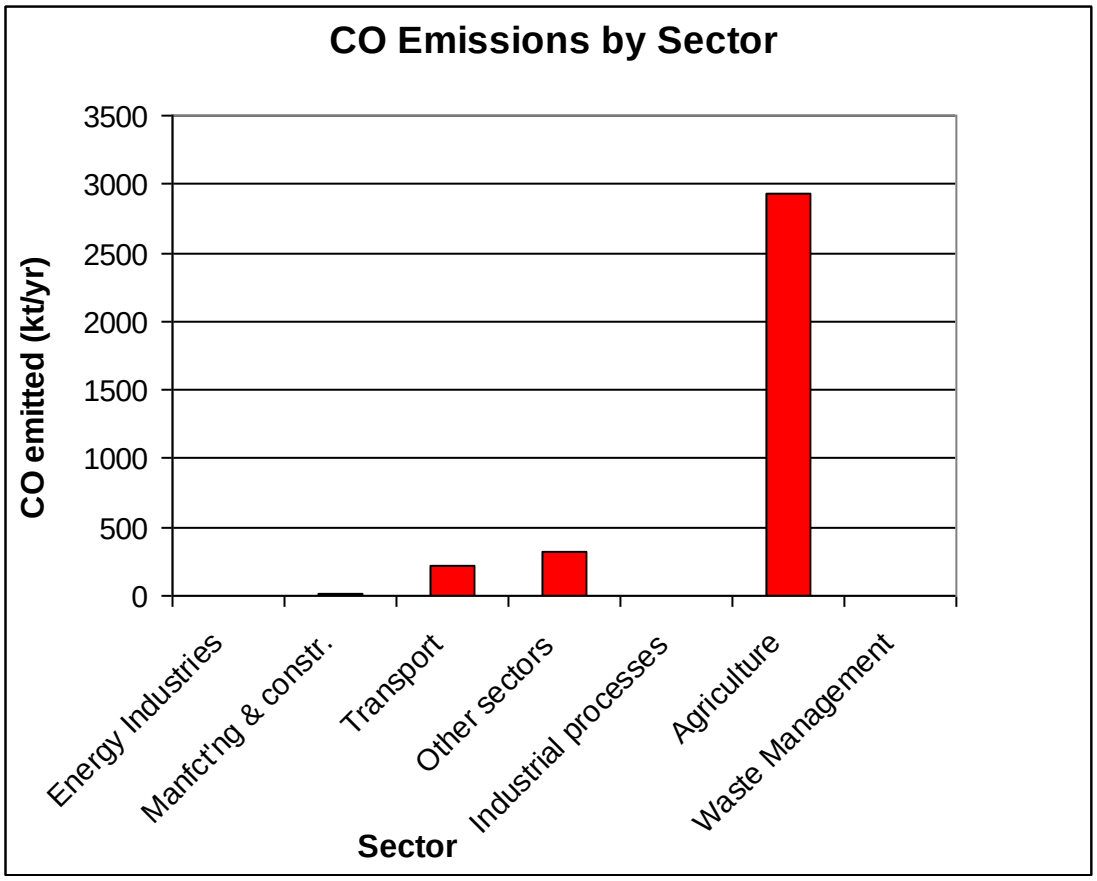

Fig. 3.3 Quantities of CO emitted in different sectors.

3.4 Non-Methane Volatile Organic Compounds

More than 50% of the total (295.6kt/yr) NMVOC emissions emanated from the agricultural sector. Domestic burning of firewood which is classified under 'Other Sectors' was another significant contributor to NMVOC emissions at 34%, transport 11%, industrial processes 2% and the rest less than 1% as depicted in figure 3.4.

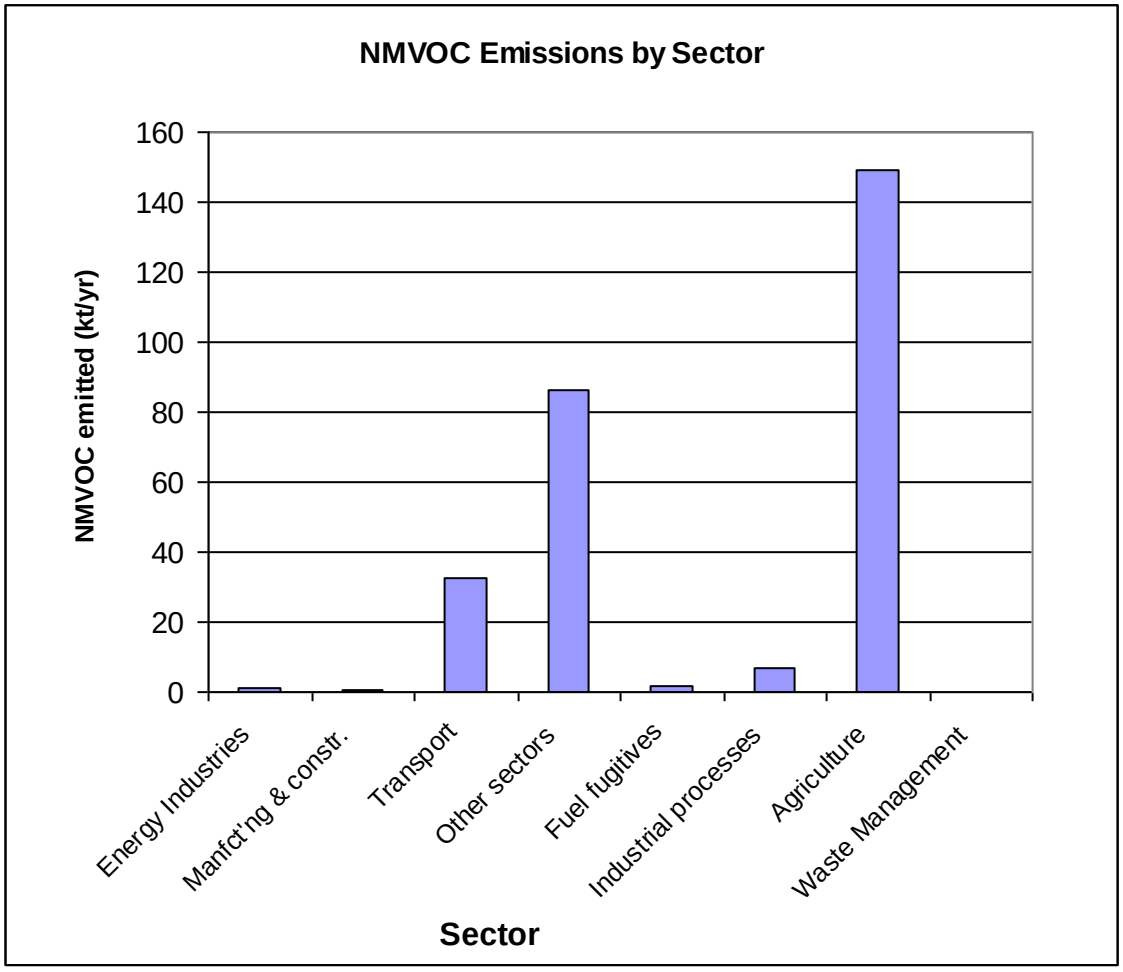

Fig. 3.4 NMVOC emissions from different sectors

It is important to note that NMVOC emissions from the use of solvents and paints was not included due lack of activity data. Emissions of this nature are therefore expected to increase once figures from that sector get integrated into the inventory.

3.5 Ammonia

Agriculture accounted for 79% of the total (122.3kt/yr) NH_3 emitted, while industrial processes and waste management accounted for approximately 8% each. About 4% came from the use of firewood for domestic purposes. The emissions loads are revealed in Fig. 3.5.

The major NH_3 emitting sub-sector in agriculture turned to be manure management (71.9kt) followed by the use of nitrogen-based fertilizers at 12.6kt/yr.

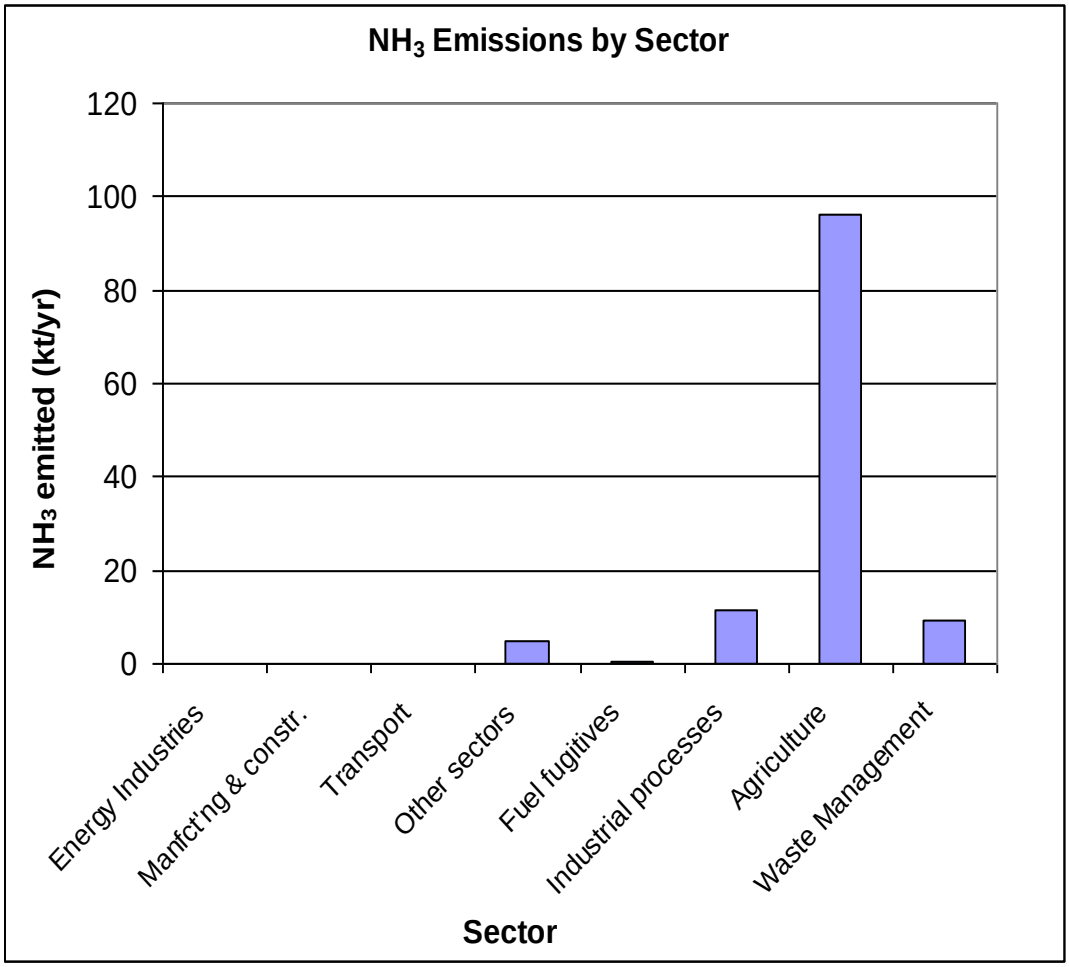

Fig. 3.5 Amount of NH_3 emitted form different sectors

3.6 Particulate matter less than 10µm

All sectors, save for transport, were accountable for PM_{10} emissions, releasing a total of 512.6kt during the year under review. The agriculture sector was the chief source at 84% of the total. Industrial processes also emitted significantly (12%) while the remaining sectors accounted for the balance. Figure 3.6 reveals the emission loads.

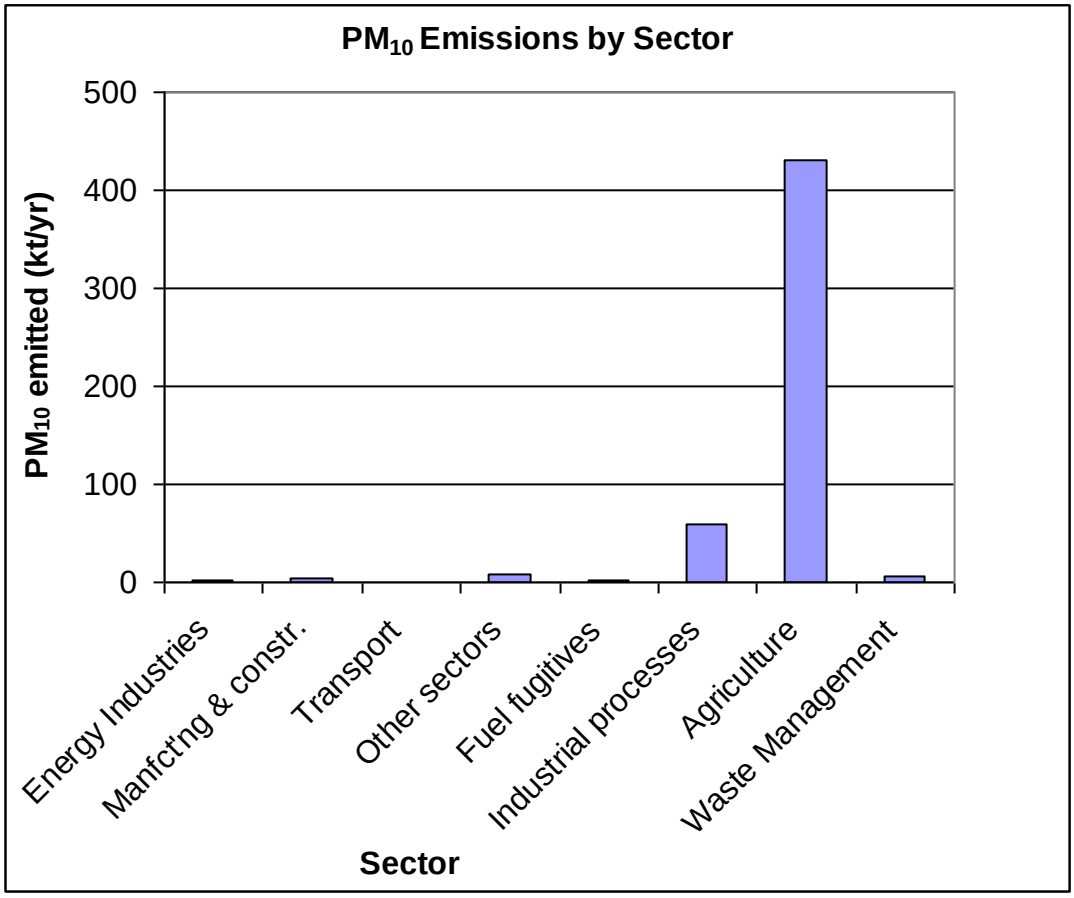

Fig. 3.6 PM_{10} Emissions from Various sectors

Emissions related to activity data in the construction industry were not included in the inventory as no data was available.

3.7 Particulate matter less than 2.5µm

The generation of $PM_{2.5}$ was also common in all the sectors except for transport sector and waste, as shown in Fig. 3.7. The bulk of this pollutant was produced from the agriculture sector and in particular savanna burning which accounted for about 92% of the total. The industrial processes sector and 'other sector' contributed 3% and 2% of the total 253.4kt respectively.

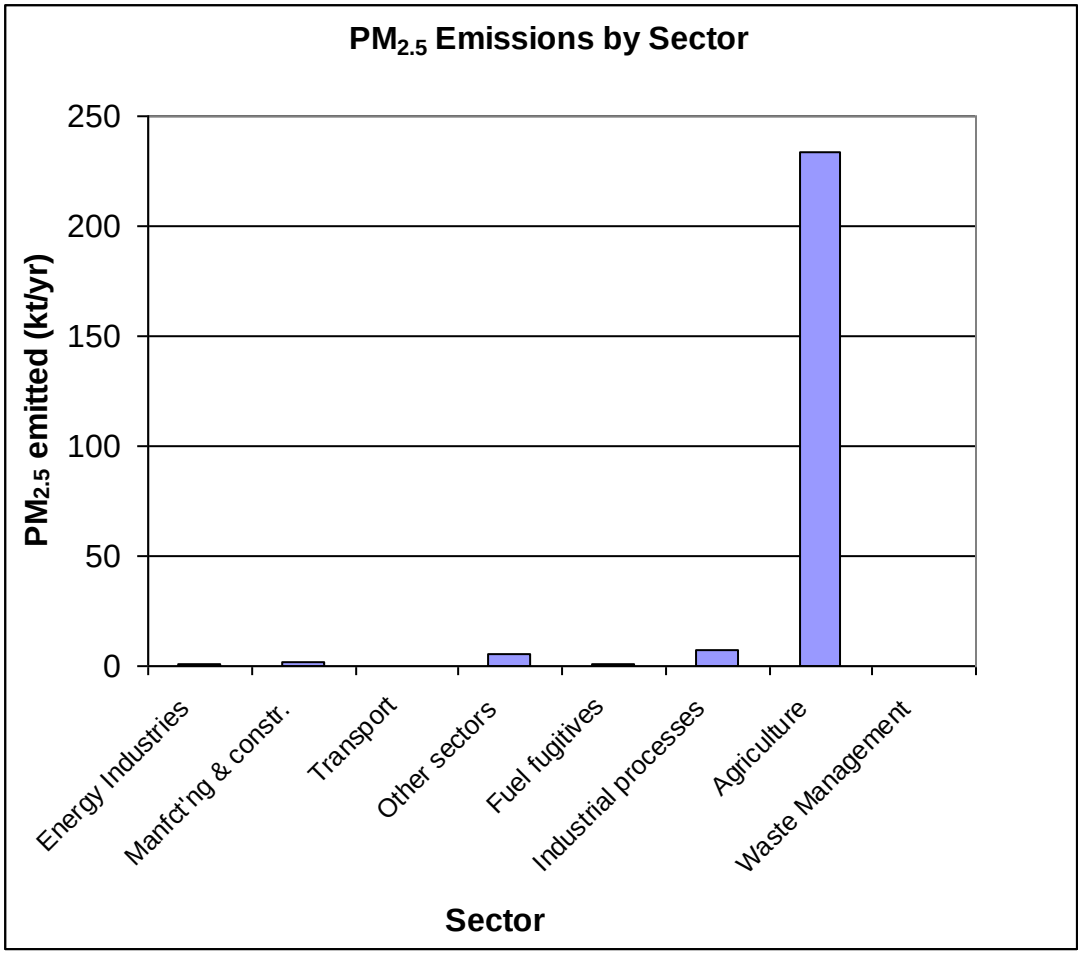

Fig. 3.7 $PM_{2.5}$ Emissions from Various sectors

4. Emissions by Sector

In order to fully assess the impacts of different economic and social activities on air pollution, it is vital consider each and every sector individually in terms of the quantity and quality of emissions generated. This section of the report is devoted to the individual sector emissions, which define the baseline of inventories in some regions of the world, derived from the IPCC method.

4.1 Combustion in energy industries

The major pollutant discharged from the combustion of fossil fuels in energy industries was SO_2, as Fig. 4.1 shows.

A total of 254.4 kt of SO_2 was emitted during the year, representing 90% of the total pollutants from the energy industries. The sector also emitted significant quantities of NO_x and CO, amounting to 20.17kt/yr and 4.33kt/yr respectively. Nonetheless, the sector was a minor contributor to NMVOC, PM_{10} and $PM_{2.5}$ emissions, while almost no NH_3 was released.

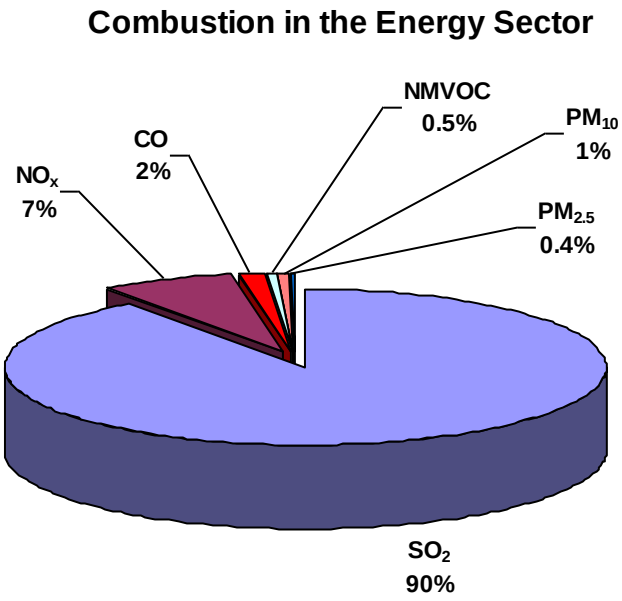

Fig. 4.1 Percentage of pollutants in the Energy Industries emissions

The energy sector in Zimbabwe is characterized by use of coal for power generation at four power stations. About 40% of the country's electrical energy was generated using coal in the year 2000 **(Zimbabwe Electricity Supply Authority (Zesa), 2001)**. The balance came from a hydro power plant and imports from the region. Table 4.1 shows the statistics of coal-based electricity generation during the year under review.

Table 4.1: Coal used in Electricity Generation

Power Station	Energy (GWh)	Coal consumption (kt)
Hwange	4809	2 577
Bulawayo	48	27
Munyati	44	30
Harare	27	17

Source: Zesa, 2001.

It is important to note that coal plays a major role in the country's energy sector and will continue to do so in the foreseeable future. Therefore any measures taken to reduce air pollutants from the process should be centred on improving the quality of the fuel and process efficiency, rather than wholesale technological substitution.

4.2 Combustion in the Manufacturing Industry and Construction

Manufacturing is an important economic activity in Zimbabwe that contributes significantly to gross national output and employment. It is diversified and well integrated with other key sectors like agriculture, mining and construction. Coal remains the major energy source in manufacturing processes that require fossil fuel combustion and is responsible for most of the emissions that were inventoried in the sector.

SO_2 emerged the bulk pollutant discharged from the combustion of fossil fuels in the manufacturing and construction industries. Fig. 4.2 shows that of the total 106.33 kt/yr, released, 55.7% was SO_2.

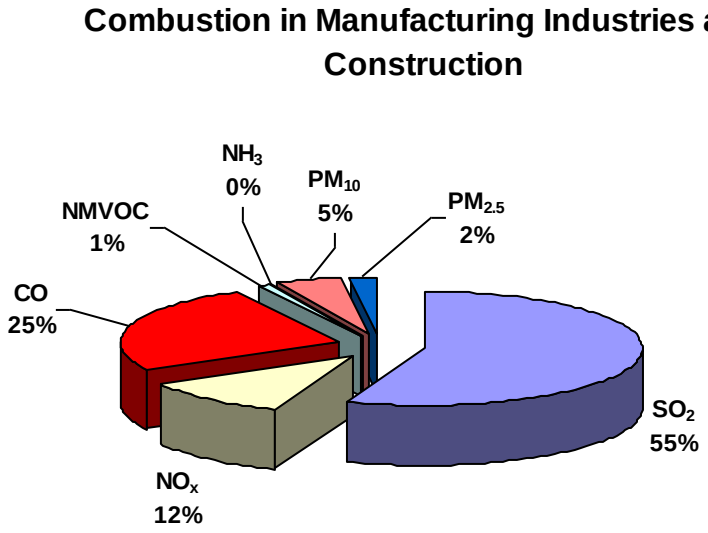

Fig. 4.2 Percentage of pollutants in the Manufacturing and Construction Industries emissions

Also in significant quantities were emissions of CO, NO_x, and PM_{10}, at 25%, 12% and 5% respectively. The $PM_{2.5}$ pollutant, at 2% level was in less significant quantities, while NMVOC and NH_3 were almost non-existent.

4.3 Combustion in the Transport Sector

Zimbabwe's road transport sector grew by about 45% from 1995 to year 2000 **(Gono, 2005)**. This was marked by a concomitant increase in the amount of liquid fuels consumed in the sector.

Results of the current inventory reveal that a total of 294.3kt of emission were released from the entire transport sector in year 2000. CO constituted the bulk (77%) of the total emissions while NMVOC, NO_x and SO_2 emissions represented 11%, 8% and 4% respectively. Low levels of NH_3 were discharged and completely no particulate matter was recorded in the sector. Fig. 4.3 shows the percent distribution of the major pollutants in emissions from the transport sector.

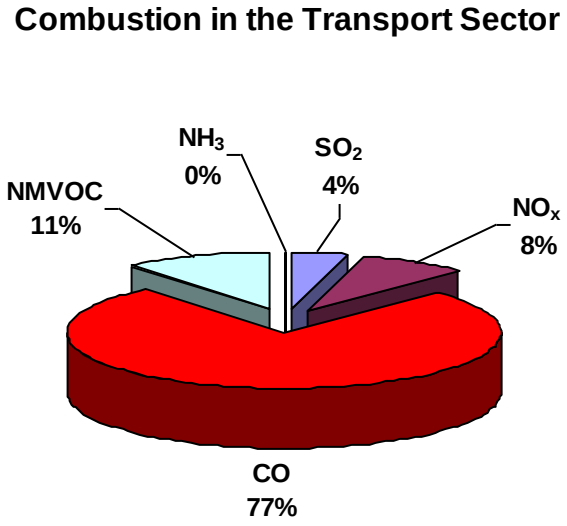

Fig. 4.3 Percentage of pollutants in emissions from the Transport Sector

Emissions inventory in this sector was based on the 'simple method' because the information available was not sufficient to carryout the 'detailed method'. However, it is hoped that in future more records on the sector will be available so that the detailed method can be adopted in future inventories.

4.4 Combustion in Other Sectors

The sub-sectors that were covered in this category include the commercial, residential, agriculture/forestry and other non-specified sub-sectors. Emissions from combustion in the whole category were characterized by high levels of CO. The pollutant contributed about 70% to the total 542kt/yr that emanated from the sector. NMVOC constituted about 19%, which was quite substantial and SO_2 comprised about 5% of the emissions. The remaining pollutants; NO_x, NH_3, PM_{10} and $PM_{2.5}$ were all in relatively small quantities as depicted in Fig. 4.4.

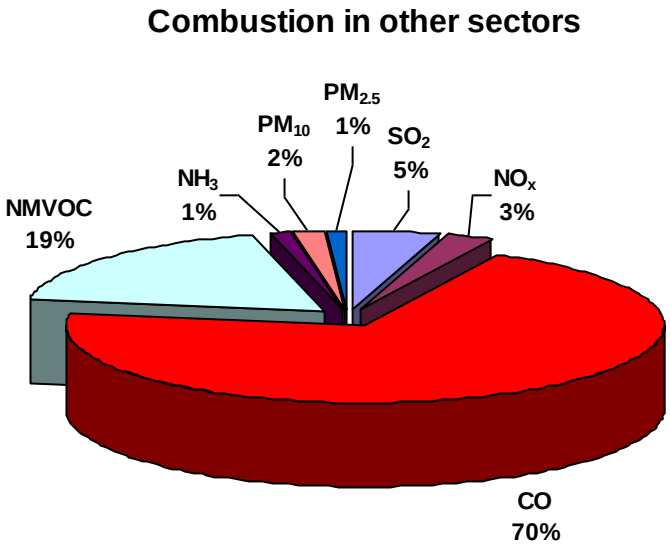

Fig. 4.4 Percentage of pollutants from Combustion of fuels in Other Sectors

Combustion of firewood in residential areas was the major source of all pollutants in this category. Wood is the single largest source of energy in Zimbabwe. Previous estimations on wood fuel consumption put the figure at between 6 and 9 million tonnes per annum **(Zhakata, 2004; Ministry of Environment and Tourism, 1998)**. However, under the current assessment the consumption was estimated to be about 3.7 million tonnes per year. The approximation, based on Central Statistics Office (CSO) 2002 data, assumes that about 1.7 million households (64% of country's households, mainly in rural areas) use about 6kg each of dry wood for cooking, heating and lighting daily.

4.5 Fugitives from Fuels

Fugitive emissions from fuels comprised mainly of NMVOC as reflected in Fig. 4.5. Also present in the emissions from this sector were PM_{10}, $PM_{2.5}$ and NH_3 to give a total emission load of 4.3kt/yr. NMVOC constituted 42.1% of the total while PM_{10}, $PM_{2.5}$ and NH3 contributed 31.5%, 16.3% and 10% respectively. In Zimbabwe there is no production and processing of crude oil, which in other countries is a major source of NMVOC emissions. The country imports all her petroleum products and gasoline handling is the only major contributor to NMVOC emissions.

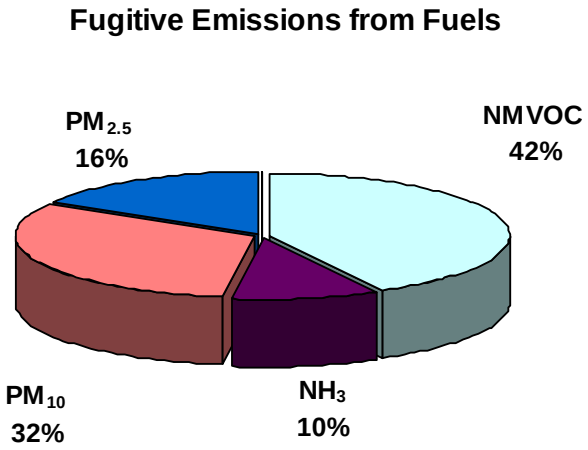

Fig. 4.5 Percentage of pollutants in Fugitive Emissions from Fuels

4.6. Emissions from Industrial Processes

The sector was characterized by a large proportion of PM_{10} pollutant in the emissions as figure 4.6 shows. At 56% of the total load (119.5kt/yr) PM_{10} formed the bulk of emissions, followed by SO_2 at 30%. The $PM_{2.5}$ and NMVOC pollutants were also released in significant proportions; 7% and 6% respectively.

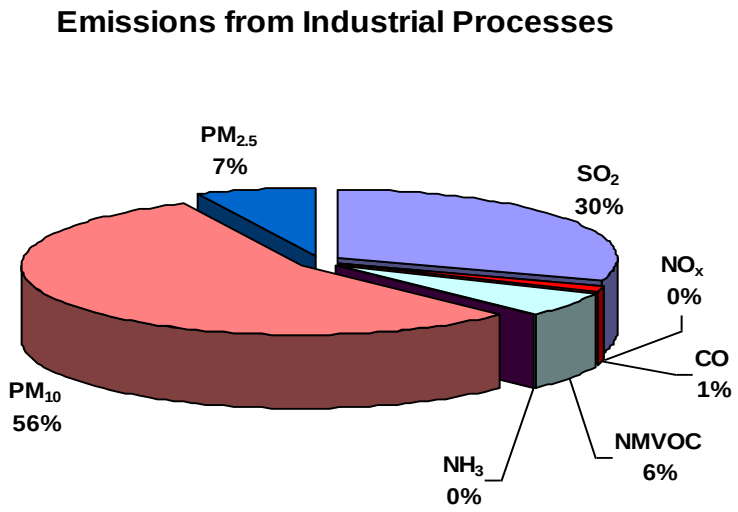

Figure 4.6 Percentage of pollutants from Industrial Processes

Zimbabwe has a fairly diverse processing industry which was covered in the inventory under the following sub-sectors;

- Minerals production (mainly cement and lime)
- Chemical and fertilizer production
- Metals production
- Pulp and paper production
- Food and beverages

Statistics on emissions from most of the industries were captured in the inventory. The fertilizer manufacturing sub-sector in particular is a major source of pollutants. With a total annual production of about 750kt **(Kachere, 2006)**, the sub-sector is a significant source of SO_2, NH_3 and particulate matter. A typical fertilizer manufacturing plant in Zimbabwe is shown in figure 4.7.

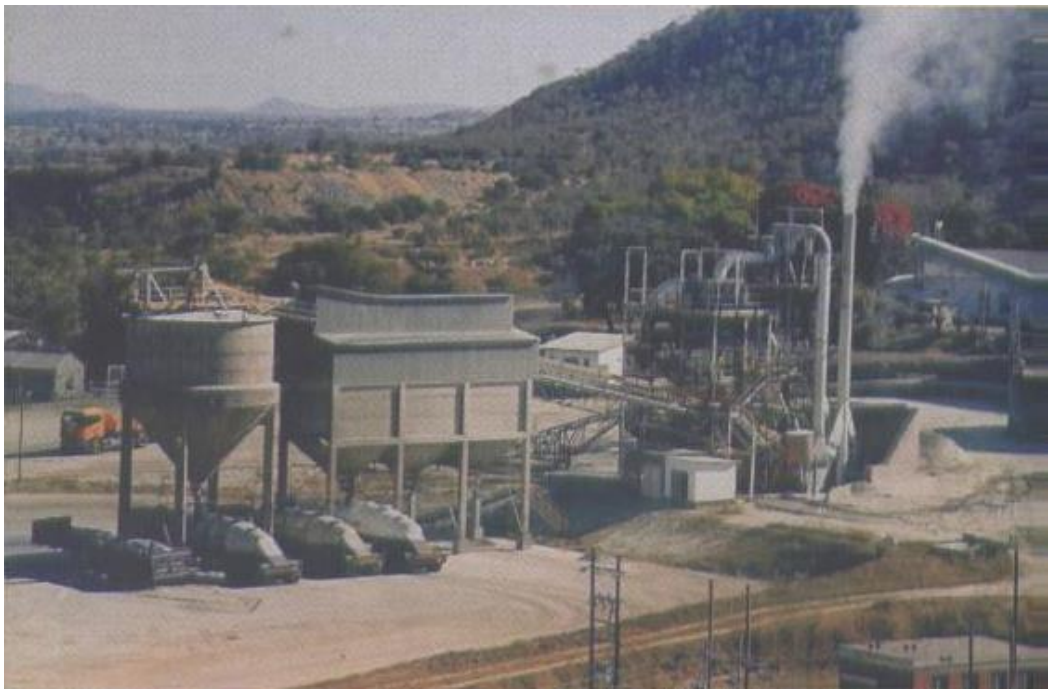

Figure 4.7 Emissions from a fertilizer manufacturing plant in Zimbabwe

Sub-sectors like ferrochrome and nickel production, for which activity data is available, were however not included in the exercise due to the unavailability of emission factors. Efforts to source them from IPCC emissions factors database (EFDB) proved futile as it contains factors related to GHGs only.

Fig. 4.8 A cement manufacturing plant

The construction industry is quite active in Zimbabwe, but information on the total number of hectares put under construction during the period under review was not available. Instead, only information related to the number of buildings was made available.

4.7 Emissions from Agricultural Activities

Agriculture is one of the most important sectors of the Zimbabwean economy. The country produces a wide range of crops and livestock. Crops range from cereals such as maize, wheat, sorghum, barley, hops and millet to tobacco, cotton and sugarcane. Livestock includes cattle, sheep, goats, pigs, poultry, donkeys and a few horses. Emissions inventoried emanated from several sources, which include manure management, use of nitrogen-based fertilizers, savanna burning and the burning of agricultural crop residue.

Out of a total 4092.9kt/yr of emissions that came from agricultural activities, CO accounted for a massive 72%, which almost entirely came from savanna burning. As mentioned before savanna burning has become a cause for concern in Zimbabwe. Statistics show that cases of wanton destruction of forests using fire increased enormously since from the inception of the land reform programme in the country in year 2000 **(Nhema, 2006)**. It is from such cases that incomplete combustion of pastures results in emission of large volumes of CO. Another significant pollutant from the sector was PM_{10} at 11% while $PM_{2.5}$ and NO_x each contributed about 6%. NMVOC and NH_3 emissions were also quite considerable at 4% and 2% respectively, while the balance (0.5%) was SO_2. Figure 4.9 illustrates the different proportions of the pollutants.

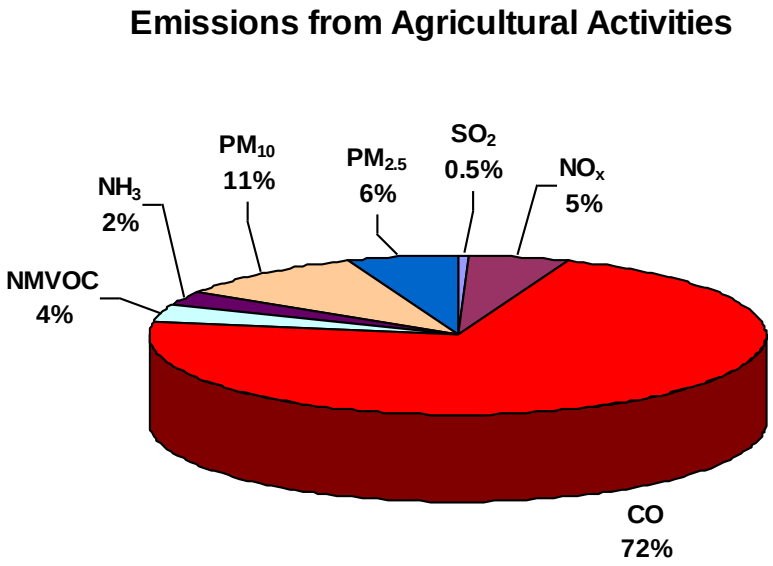

Fig. 4.9 Percentage of pollutants in Agricultural activities emissions

Sugarcane production for the year was quite high at 4830kt. However emissions from the burning of the crop residue were not very high compared to other crops. That was obviously due to the emission factor used by the inventory method. It was felt that some of the emission factors for sugarcane, for instance 0.25 for the “fraction of dry matter burned in fields”, were on the lower side given that the process burns almost everything leaving the cane stalk only. Further research on sugarcane residue burning may produce more accurate information for use in future inventories.

4.8 Emissions from Waste Management

Urban waste in Zimbabwe is in general disposed of by landfilling, recycling, planned incineration and unsanctioned burning in open dumping sites. Statistics show that on average the waste comprises 43% combustible materials (paper, plastic, and textiles) and the balance is incombustible materials such glass, gravel and foodstuffs **(City of Harare, 2001)**. Data for waste (mainly surgical) incineration at designated sites was available for most urban centres, giving a country total of 205.8kt/yr. However there were also cases of unauthorized burning of refuse in open dumping sites which was estimated to be 30% of the total refuse generated **(Muza, 2007)**.

It was not difficult to acquire information on the use of latrines. Data relating to the number of people using different toilet facilities is well documented by the government's Central Statistics Office (CSO). About 34% of the country's population use pit latrines (or blair toilets) while a further 25% have no toilet facilities at all **(CSO, 2002)**.

Results of the inventory are summarized in figure 4.10. A total of 24.1kt/yr of emission was generated from the sector. NH_3 emissions were the highest at 39%, emanating entirely from human waste. Also in quite significant proportions were CO, PM_{10} and $PM_{2.5}$ pollutants at 24%, 21% and 10% respectively. Waste incineration/burning also released some SO_2, NO_x and NMVOC, though in relatively small quantities of an average 2% each.

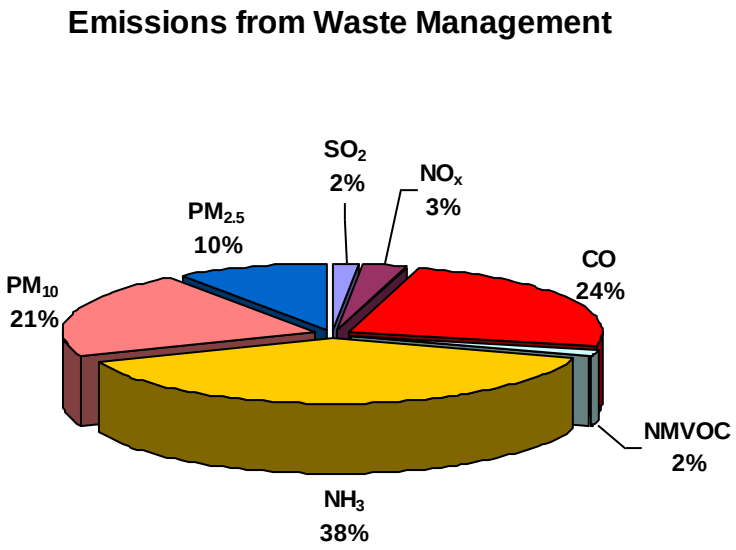

Fig. 4.10 Percentage of pollutants in Waste Management emissions

5. Large Point Sources (LPS)

In the context of this inventory, the definition of LPS is based on the Corinair90 methodology in which LPS include the following;

- Power plants with input capacity ≥ 300MW
- Refineries
- Sulphuric acid plants
- Integrated iron and steel works with production capacity > 3 Megatonnes/year
- Pulp and paper plants with production capacity > 100kt/yr.

In the case of thermal power generation only Hwange thermal power station would qualify to be a LPS. However, an exception that was made specifically for this inventory to include all power plants with an output of 25MW automatically paves way for smaller thermal power plants to be considered in the inventory. Harare, Bulawayo and Munyati thermal power plants generated 55MW, 85MW and 75MW respectively during the period under review **(Zesa, 2001)**.

Zimphos plant, a Sulphuric acid plant situated in Harare was included in the LPS category whilst a similar nitric acid plant situated just outside Kwekwe was not incorporated due to lack of sufficient information. Figure 5.1 shows a view of the Sulphuric acid plant.

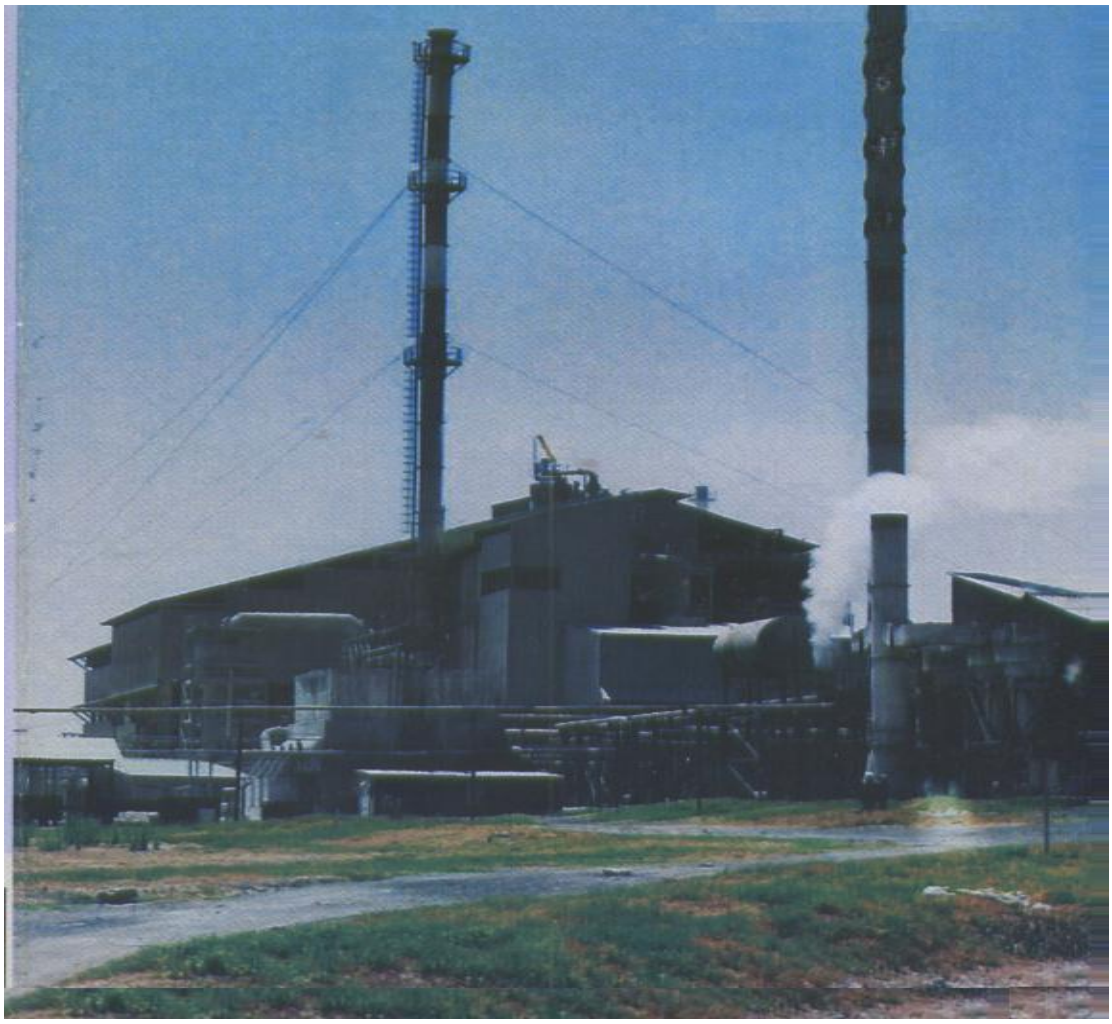

Fig. 5.1 Part of a Sulphuric acid plant in Zimbabwe

Although the annual production of pig iron at Ziscosteel (277kt) was well below the stipulated 3Mt for the plant to qualify under LPS, the plant was considered in this case to be a LPS. That decision was made because the plant is "large" in terms of production level as compared to some small foundries dotted around the country. Secondly, apart from pig iron production, there is also steel production by conversion of iron in the LD converter. However, emissions from the steel production plant were not included in the inventory due to the unavailability of emission factors.

Metal refineries in the country were also not considered in the inventory due to lack of sufficient data especially the emission factors as mentioned before. Studies that were conducted at Bindura Nickel Corporation (BNC) to try and establish the emission factors of the smelting operations were not conclusive. Preliminary investigations by the Task Team gave an emission factor of 2487kg of SO_2 per tonne of nickel produced, but the figure was not used in the current inventory pending confirmatory analyses. It is hoped the next version of this report shall incorporate emissions from all those sources.

Overall, the LPS regarded in this inventory were;

- The thermal power stations – Hwange, Bulawayo, Munyati and Harare,
- Zimphos Sulphuric acid plant in Masasa, Harare
- Ziscosteel Iron plant in Redcliff, near Kwekwe.

The total pollutant load from LPS was 148,8kt/yr, representing only about 3% of the total emission inventoried. SO_2 was the major pollutant from LPS contributing 85% to the total followed by NOx at 13%. The rest, including CO, NH_3, NMVOC and particulate matter contributed about 2% as shown in Fig. 5.2.

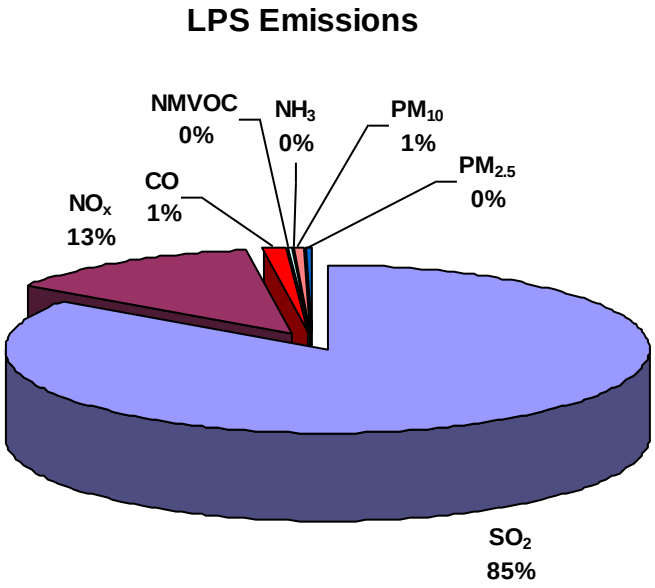

Fig. 5.2 Emissions from Large Point Sources

6. Limitations and Challenges

Although remarkable improvement has been realized in this second draft compared to the initial one, some gaps still remain in the inventory, due to a host of challenges. The problems varied widely in nature.

Activity data in some sectors and sub-sectors proved difficult to acquire. Reasons for that ranged from lack of cooperation from the responsible organizations to complete unavailability of records. The "solvent and other product use" sector is one example in which there were no activity data records at all. Although Zimbabwe has a number of paints and adhesives manufacturing companies, no statistics were made available to the TTM. Some companies concealed vital information fearing exposure to competitors and environmentalists among other reasons. Efforts made to get the data through the Central Statistics Office (CSO) proved futile as there were no such records. In a few cases the CSO could not divulge production data for a product coming from less than three companies under the Statistics Act. On the other hand, one of the major chambers of industries organizations, the Confederation of Zimbabwe Industries (CZI) managed to provide data based on monetary value only, with no link at all to the production figures.

Similar challenges were met in trying to get information relating to fugitive emissions of particulate matter from major building construction activities. The facts made available only related to the number of residential, industrial and commercial stands approved for construction. Information on the area under construction and the duration of the project remained unknown.

Some major breakthroughs were made in as far as accessing figures in the Waste Management sector was concerned. Nevertheless some information gaps still exist and in some cases the TTM resorted to estimates. Figures on unauthorized burning of residential refuse, for instance, was not available in the local authorities' records. City of Harare Authorities however estimated that about 30% of the total generated waste remained uncollected and the combustible fraction of that (43%) would be burned. The ratio was therefore applied to all the urban centres.

Bureaucratic procedures that are required in some quasi-government organizations remained a major obstacle in assessing information. In some cases letters sent to the relative authorities soliciting for information related to the inventory were never responded to. It is hoped that the forthcoming National Stakeholders Workshop on air pollution will help to convince the relevant authorities that they have a role to play in coming up with a national emissions inventory.

In some cases where activity data was available, the TTM were limited in accessing reliable emission factors. The IPCC EFDB was consulted but found not to be useful in all the cases. Particular sub-sectors that could have been inventoried but were eventually left out due to that limitation include;

- Conversion of pig iron to steel in the LD converter
- Smelting of sulphide nickel concentrates in a sirosmelt furnace
- Smelting of platinum group of metals (pgms) concentrates
- Roasting of sulphide gold ores in a roasting plant.

It is hoped that future inventories shall incorporate emissions from these sources.

7. Conclusions and future plans

7.1 Conclusions

In general the data compilation process for the national emissions inventory has been successful. Some information that could not be accessed in the first draft of the inventory has been filled in. Based on the plans that were made following assessment of the first draft inventory, the achievements made are summarized in Table 7.1.

Table 7.1 Major Achievements of the Second Draft Inventory

Target (from 1st Draft)	Status (achieved/not achieved)	Remarks
Engaging (CSO) to get information on industrial production, mining etc	Achieved	Data obtained useful
Liaising with local urban authorities to get statistics on waste incineration	Achieved	Data obtained useful
Visiting LPS to collect activity data and emission rates	Achieved	Data obtained useful but inadequate
Updating the inventory workbook in line with Cape Town changes	Achieved	

Although all the targets set in the previous report were achieved, some information gaps still exist. The worst sector in that regard is the use of paints and solvents. LPS data compilation is still in progress. It is hoped that all the problems will be dealt with and a complete emission inventory for Zimbabwe will be ready in the not too distant future.

7.2 Future Plans

The TTM envisage complete compilation of the year 2000 emissions inventory of Zimbabwe by end of January 2008. To achieve that, the following guiding steps shall be pursued.

1. Capitalizing on the forthcoming (22/08/2007) *National Stakeholders Workshop on Issues Related to Air Pollution* to market the objectives of Apina in the hope that the all the organizations concerned will provide data required by TTM to complete the inventory.
2. Addition of LPS to the current 6 inventoried. Information such as emission rates, stack dimension, gas exit temperature and velocity also need to be gathered for use by the modeling team.
3. The emission factors of some metal smelters and roasters need to be ascertained so that all emissions from that sub-sector can be integrated in the inventory.

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APPENDIX 1 - Total Annual Emissions of each Pollutant by Source Sector

Sector	Sub-sector	Total emissions (kilotonnes pollutant per year (kt/yr))						
		SO_2	NO_x	CO	NMVOC	NH_3	PM_{10}	$PM_{2.5}$
1. Combustion in the Energy Industries	Public Electricity and Heat	127.18	19.97	1.33	0.33	0.00	0.85	0.37
	Petroleum Refining	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacture of Solid Fuels and Other Energy	127.19	0.21	3.00	1.02	0.01	0.63	0.63
2. Combustion in Manufacturing Industries and construction	Iron and Steel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-ferrous metals	4.73	1.17	0.59	0.08	0.00	0.19	0.08
	Non-metallic minerals	6.67	1.04	0.52	0.07	0.00	0.59	0.25
	Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and print	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mining and Quarrying	4.47	0.85	0.34	0.05	0.00	0.37	0.16
	Construction	2.66	0.42	0.21	0.03	0.00	0.24	0.10
	Sugar Production	2.23	0.35	0.17	0.02	0.00	0.20	0.08
	Autoproduction of electricity/heat	13.82	2.16	1.08	0.14	0.00	1.23	0.52
	Remainder (Non-specified)	13.82	4.09	18.77	0.41	0.00	1.34	0.57
3. Transport	Civil Aviation (Simple--not used if Detailed used)	0.16	0.85	54.43	0.04	0.00	0.00	0.00
	Civil Aviation (Detailed)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Road transport (Simple--not used if Detailed used)	4.08	19.80	170.30	32.07	0.00	0.00	0.00
	Road transport (Detailed)		0.00	0.00	0.00	0.00	0.00	0.00
	Railways	8.03	3.08	1.19	0.30	0.00	0.00	0.00
	Navigation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pipeline transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-specified transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Combustion in Other Sectors	Commercial/Institutional	2.56	0.81	0.61	0.08	0.00	0.06	0.03
	Residential	3.05	11.87	359.88	100.05	4.83	7.20	5.71
	Agriculture/Forestry/Fishing	16.44	1.40	22.66	2.58	0.00	1.67	0.71
	Non-specified "Other sectors"	0.00	0.00	0.00	0.00	0.00	0.00	0.00

5. Fugitive emissions from fuels	Production of coke				0.18	0.43	1.36	0.70
	Oil exploration and crude oil production and transport				0.00			
	Oil refining	0.00	0.00	0.00	0.00			
	Distribution and handling of gasoline				1.63			
	Production and distribution of natural gas.				0.00			
	Flaring during oil and gas extraction		0.00	0.00	0.00			
6. Industrial processes	Mineral products	0.30		0.00	0.00		55.52	4.64
	Chemicals	0.05	0.17	0.56	0.33	11.43	1.88	0.00
	Metals	31.58	0.02	0.37	0.03		3.37	2.80
	Pulp and paper	0.22	0.01	0.00	0.00		0.00	0.00
	Food and drink				6.23		0.00	0.00
	Major construction site activities (Fugitive PM only)						0.00	0.00
7. Solvent and other product use					0.00			
8. Agriculture	Manure management					71.88		
	Application of N-containing fertilizers		2.88			12.57		
	Savanna burning	18.42	218.42	2912.26	145.61	11.14	428.27	231.27
	Burning of agricultural crop residues	0.22	1.58	29.01	3.84	0.66	2.46	2.46
9. Vegetation fires and Forestry	On-site burning of forests and grasslands	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10. Waste	Waste incineration	0.42	0.65	5.76	0.45	0.00	5.14	2.33
	Latrines					9.34		
Total anthropogenic		388.30	291.79	3583.04	295.58	122.29	512.57	253.41

APPENDIX 2 - Large Point Sources Emissions

Sector	Sub-sector	LPS emissions (kilotonnes pollutant per year (kt/yr))						
		SO_2	NO_x	CO	NMVOC	NH_3	PM_{10}	$PM_{2.5}$
1. Combustion in the Energy Industries	Public Electricity and Heat	125.15	19.56	1.30	0.33	0.00	0.85	0.36
	Petroleum Refining	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacture of Solid Fuels and Other Energy	127.19	0.00	0.00	0.00	0.00	0.00	0.00
2. Combustion in Manufacturing Industries and construction	Iron and Steel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-ferrous metals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-metallic minerals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and print	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mining and Quarrying	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sugar Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Autoproduction of electricity/heat	13.82						
	Remainder (Non-specified)							
3. Transport	Civil Aviation (Simple--not used if Detailed used)	0.16						
	Civil Aviation (Detailed)							
	Road transport (Simple--not used if Detailed used)	4.08						
	Road transport (Detailed)							
	Railways							
	Navigation							
	Pipeline transport							
	Non-specified transport							
4. Combustion in Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/Fishing							
	Non-specified "Other sectors"	0.00						

5. Fugitive emissions from fuels	Production of coke				0.00	0.00	0.00	0.00
	Oil exploration and crude oil production and transport							
	Oil refining	0.00	0.00	0.00	0.00			
	Distribution and handling of gasoline							
	Production and distribution of natural gas.							
	Flaring during oil and gas extraction							
6. Industrial processes	Mineral products	0.00		0.00	0.00		0.00	0.00
	Chemicals	0.03	0.00	0.00	0.00	0.00	0.00	0.00
	Metals	0.83	0.02	0.37	0.03		0.01	0.00
	Pulp and paper	0.00	0.00	0.00	0.00		0.00	0.00
	Food and drink				0.00		0.00	0.00
	Major construction site activities (Fugitive PM only)							
7. Solvent and other product use								
8. Agriculture	Manure management							
	Application of N-containing fertilizers							
	Savanna burning							
	Burning of agricultural crop residues	0.22						
9. Vegetation fires and Forestry	On-site burning of forests and grasslands	0.00						
10. Waste	Waste incineration							
	Latrines							
Total anthropogenic		126.01	19.58	1.68	0.36	0.00	0.86	0.36

APPENDIX 3 – Area Source Emissions

Sector	Sub-sector	[1]Area source (total minus LPS) emissions (kilotonnes pollutant per year (kt/yr))						
		SO_2	NO_x	CO	NMVOC	NH_3	PM_{10}	$PM_{2.5}$
1. Combustion in the Energy Industries	Public Electricity and Heat	2.03	0.41	0.02	0.00	0.00	0.00	0.00
	Petroleum Refining	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacture of Solid Fuels and Other Energy	127.19	127.19	0.21	3.00	1.02	0.01	0.63
2. Combustion in Manufacturing Industries and construction	Iron and Steel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-ferrous metals	4.73	1.17	0.59	0.08	0.00	0.19	0.08
	Non-metallic minerals	6.67	1.04	0.52	0.07	0.00	0.59	0.25
	Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pulp, Paper and print	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mining and Quarrying	4.47	0.85	0.34	0.05	0.00	0.37	0.16
	Construction	2.66	0.42	0.21	0.03	0.00	0.24	0.10
	Sugar Production	2.23	0.35	0.17	0.02	0.00	0.20	0.08
	Autoproduction of electricity/heat	13.82	13.82	2.16	1.08	0.14	0.00	1.23
	Remainder (Non-specified)	13.82	4.09	18.77	0.41	0.00	1.34	0.57
3. Transport	Civil Aviation (Simple--not used if Detailed used)	0.16	0.16	0.85	54.43	0.04	0.00	0.00
	Civil Aviation (Detailed)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Road transport (Simple--not used if Detailed used)	4.08	4.08	19.80	170.30	32.07	0.00	0.00
	Road transport (Detailed)		0.00	0.00	0.00	0.00	0.00	0.00
	Railways	8.03	3.08	1.19	0.30	0.00	0.00	0.00
	Navigation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pipeline transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-specified transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Combustion in Other Sectors	Commercial/Institutional	2.56	0.81	0.61	0.08	0.00	0.06	0.03
	Residential	3.05	11.87	359.88	100.05	4.83	7.20	5.71
	Agriculture/Forestry/Fishing	16.44	1.40	22.66	2.58	0.00	1.67	0.71
	Non-specified "Other sectors"	0.00	0.00	0.00	0.00	0.00	0.00	0.00

5. Fugitive emissions from fuels	Production of coke				0.18		1.36	0.70
	Oil exploration and crude oil production and transport				0.00			
	Oil refining	0.00	0.00	0.00	0.00			
	Distribution and handling of gasoline					1.63		
	Production and distribution of natural gas.					0.00		
	Flaring during oil and gas extraction			0.00	0.00	0.00		
6. Industrial processes	Mineral products	0.30		0.00	0.00		55.52	4.64
	Chemicals	0.02	0.17	0.56	0.33	11.43	1.88	0.00
	Metals	30.74	0.00	0.00	0.00		3.35	2.80
	Pulp and paper	0.22	0.01	0.00	0.00		0.00	0.00
	Food and drink				6.23		0.00	0.00
	Major construction site activities (Fugitive PM only)							0.00
7. Solvent and other product use					0.00			
8. Agriculture	Manure management					71.88		
	Application of N-containing fertilizers			2.88			12.57	
	Savanna burning	18.42	218.42	2912.26	145.61	11.14	428.27	231.27
	Burning of agricultural crop residues	0.22	0.22	1.58	29.01	3.84	0.66	2.46
9. Vegetation fires and Forestry	On-site burning of forests and grasslands	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10. Waste	Waste incineration	0.42	0.65	5.76	0.45	0.00	5.14	2.33
	Latrines					9.34		
Total anthropogenic		262.29	272.21	3581.37	295.22	121.86	511.71	253.05