

Rapid Urban Air Quality Assessment (RUA): A Cost-effective Tool for Air Quality Management in Less Developed Countries

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Abstract

This paper presents an alternative approach to air quality management (AQM) at urban scale, which is cost-effective and easy to implement, thereby being recommendable in less developed countries. The alternative is named Rapid Urban Air Quality Assessment (RUA) and it was first proposed by a team of air pollution scientists at the Swedish Environmental Research Institute (IVL). Successful tests of RUA have been conducted in Europe and East Asia, but further tests are required to validate the method. Currently, RUA is being implemented in two neighbouring cities (Maputo and Matola) in Mozambique to test its applicability in Africa. Preliminary results from a 2-month long field campaign show hot spots of particulate matter (PM), nitrogen dioxide (NO₂), sulphur dioxide (SO₂) and non-methane volatile organic compounds (VOCs) emissions within the study area. Ambient concentrations of PM were found to be exceedingly high, with a median of 173.2 µg m⁻³ during the reported period. The other air pollutants (NO₂, SO₂ and VOCs) were recorded at much lower concentrations, with medians of 9.1 µg m⁻³ for NO₂, 1.2 µg m⁻³ for SO₂ and 2.6 µg m⁻³ for benzene (the most important species of VOCs from health perspective). The results seem to prove that RUA is indeed a valid, cost-effective methodology to assess risks of exposure to air pollution, and enable early planning and implementation of emissions control strategies, especially for rapidly growing cities in countries with low income.

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1 Introduction

After several decades of strives for political independence followed civil wars, many African countries are currently experiencing accelerated economic growth, which has been leading to increasing urbanization, automobile fleets, industrialization and waste generation. Currently, urban population growth rates in Africa are the highest in the world, averaging about 3.5% every year [1], and are more likely to increase even further in the future. These developments often take place in the absence of regulations for preventing and controlling emissions of air pollutants into the atmosphere, thereby resulting in air quality degradation, especially in urban areas [2]. This is in contrast to what is happening in developed countries, where the implementation of programmes for managing air quality is conducting to reduced emission of air pollutants from human activities into the atmosphere [3].

Systematic exposure to high concentrations of air pollutants represents an obstacle to sustainable development, since it increases disease burdens and causes environmental damage, thereby limiting life expectancies and causing huge economic losses [4]. Sustainable development can only be viable if pursued in a such a manner which ensures that human activities are less harmful to human health and the environment. Accordingly, sound and effective environmental management tools that are affordable to all countries including the less developed are needed.

In this paper, a cost-effect methodology for conducting quick air quality scoping studies is presented. The method, nicknamed RUA (Rapid Urban Air Quality Assessment), was first introduced by IVL in Europe and East Asia. Preliminary RUA results from Mozambique are used to validate the method in Africa.

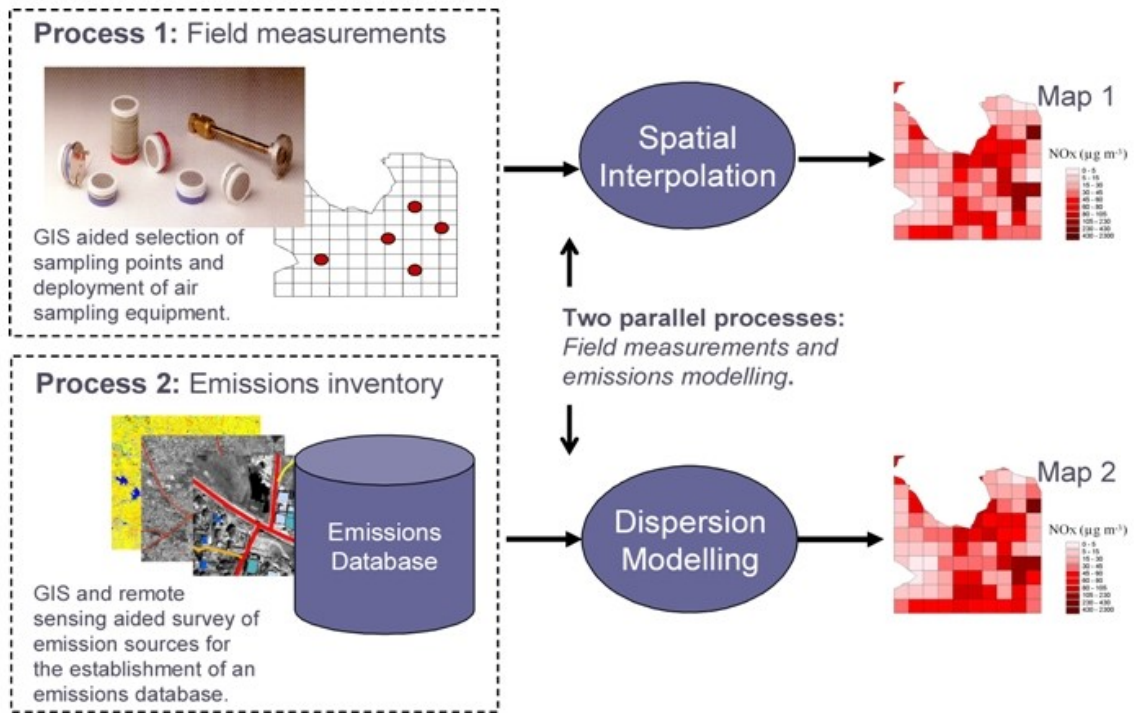
2 Rationale for conducting RUA in Mozambique

The success of efforts to managing environmental quality is strongly dependent on the level of public awareness and participation in air pollution prevention and control activities. To foster awareness raising and adequate appreciation of benefits that can be derived from sound environmental management, focusing especially on AQM in Africa, the Air Pollution Information Network for Africa (APINA) was created [5]. APINA has commissioned RUA in Mozambique as a task for the development and/or enhancement of technical capacity for air quality assessment in southern Africa.

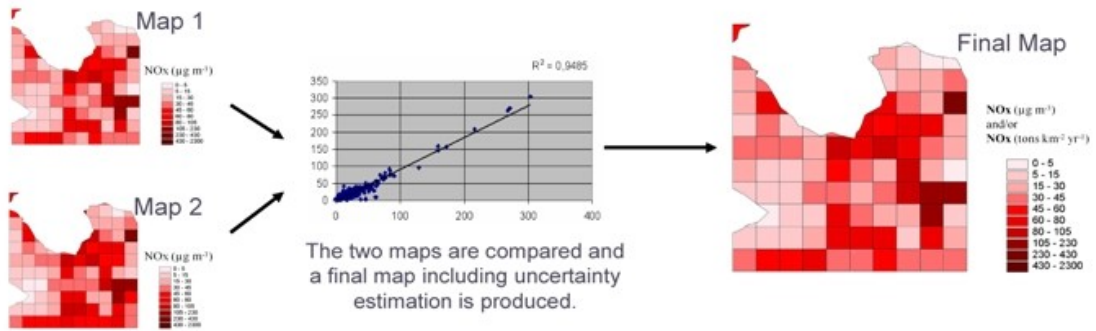
The rationale for choosing Mozambique to carry out RUA in southern Africa was twofold. Firstly, apart from the lack of financial resources and adequate technical infrastructure and skills for effective and sustainable AQM in the country, there is no specific legislation for the prevention and control of air pollution. Secondly, Mozambique is experiencing fast economic development, which results in increasing urban population, industrialization and energy demand [6]. Since these developments are taking place in absence of emissions control regulations, they are raising concerns on air pollution and related impacts, especially in fast-growing cities such as Maputo and Matola. Therefore, Mozambique (and especially the cities of Maputo and Matola, with over 1.5 million inhabitants in total) has been thought as a good test ground for RUA in southern Africa.

3 RUA process and methodology

The RUA process is a novel approach to AQM at urban scale [7]. Figure 1 shows the schematic of this process. As seen from the illustration, RUA is actually a two-way process that culminates with a calibrated map displaying ambient concentrations or deposition rates of air pollutants under investigation in a given region.



(a) Stage 1



(b) Stage 2

Figure 1: Schematic of the RUA process.

An emissions inventory (EI) of air pollutants is carried out and the results gridded (mapped) over the study area, using geographic information systems (GIS) and remote sensing data and tools. The EI is carried out to provide comprehensive information on emission sources and emission fluxes of air pollutants into the atmosphere over the study region. These data are required as input to air pollution dispersion models, which produce estimates of pollutant concentrations in the ambient air over the study region. Since direct measurements of emissions to the atmosphere are difficult and expensive to carry out, emissions of air pollutants are usually estimated using emission factors (EFs) applied to statistics on human activities within the region of interest. This approach to EI has been adopted for RUA, and both bottom-up and top-down methods are used complementarily to construct the emissions database [8]. The gridded emissions database obtained from this exercise can be used to attach an EF per unit area of the surface covered by the study. To this end, a land-use/land-cover classification must be carried out using GIS tools and remote sensing data [9, 10]. This integration of GIS tools and remote sensing data (i.e., integration of geomatics) into the EI process represents a novel aspect of the RUA process.

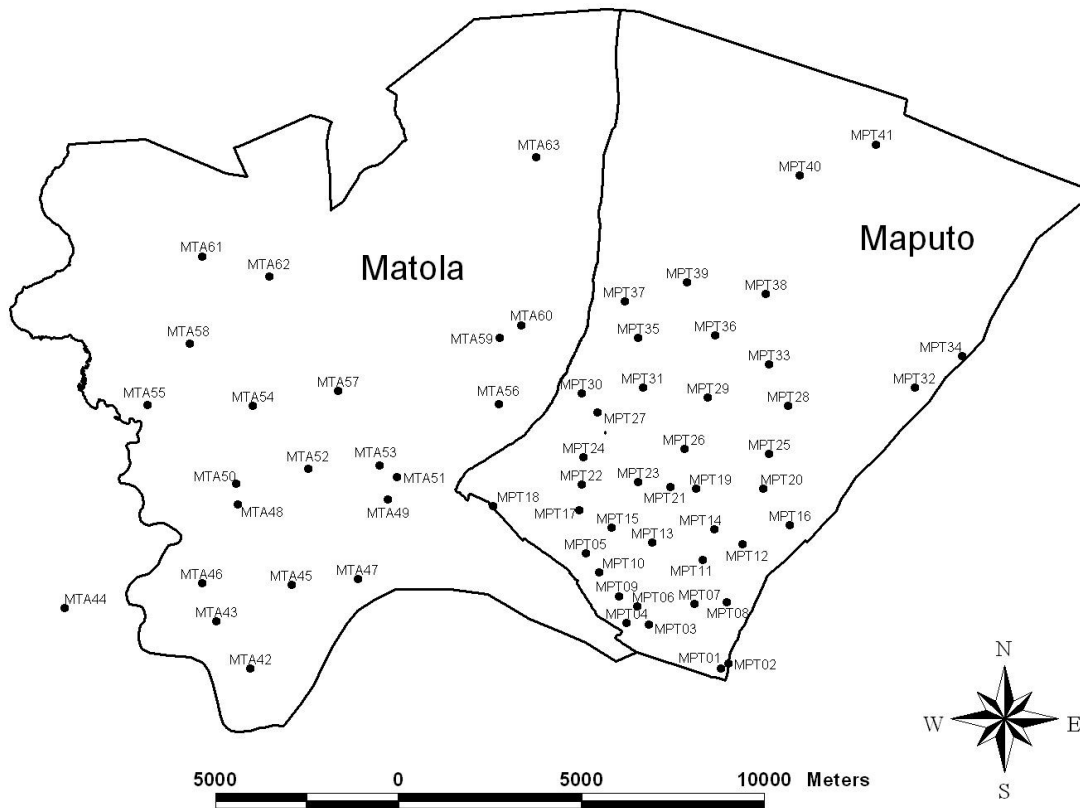


Figure 2: Locations of RUA sampling station in Maputo (MPT) and Matola (MTA), Mozambique.

Table 1: Characteristics of RUA sampling stations in Maputo and Matola, Mozambique.

Station Code	Station Name	Geographic coordinates		Measured air pollutants				Comments
		Latitude (S)	Longitude (E)	PM	NO ₂	SO ₂	VOCs	
MPT01	Polana Cimento	25°58'45.88"	32°35'36.04"	Y	Y	N	N	Less business and high income residential area.
MPT02	BP-Clube Naval	25°58'41.20"	32°35'43.59"	N	N	N	Y	Less used PB Garage.
MPT03	Praça de Independência	25°58'7.11"	32°34'25.18"	Y	Y	Y	N	Downtown Maputo – business and medium income residential area.
MPT04	Ferroviário da Baixa	25°58'5.40"	32°34'3.59"	Y	Y	N	N	Downtown Maputo – transition from shopping area to industrial area; terminal of public transport.
MPT05	Porto de Maputo	25°57'3.45"	32°33'23.47"	Y	Y	N	N	Maputo Harbor.
MPT06	Cnr Av. 24 de Julho & Av. Guerra Popular	25°57'50.83"	32°34'14.04"	N	N	N	Y	Heavy traffic intersection.
MPT07	Self-BP OK	25°57'48.58"	32°35'10.36"	Y	Y	N	N	Medium income residential area.
MPT08	Colégio Kitabo	25°57'47.27"	32°35'42.21"	Y	Y	Y	N	Paved raved roadside in high-income residential area, close to green recreational area. The place is busy during weekends. There is pizza bakery nearby the station.
MPT09	BP-Francisco Manyanga	25°57'41.84"	32°33'56.47"	N	N	N	Y	Paved roadside in medium-income residential area. This measurement site is located at the busiest PB feeling station in Maputo.
MPT10	Malanga-Casa Naran	25°57'20.11"	32°33'36.80"	Y	Y	N	N	Medium income residential area.
MPT11	Praça da OMM	25°57'9.61"	32°35'18.32"	Y	Y	N	N	Paved roadside in medium-income residential area, at a busy road intersection.
MPT12	Faculdade de Ciências-UEM	25°56'55.45"	32°35'57.57"	Y	Y	N	N	Paved car parking area in the UEM main campus, far from busy roads. Traffic volumes in the park are quite small. There is a construction site close to the station.
MPT13	Mafalala	25°56'53.78"	32°34'29.21"	Y	Y	N	N	Paved roadside in low-income residential area. The road is carries low traffic. Charcoal/wood is the main source of energy in most households in the area.

Table 1: (Continued)

Station Code	Station Name	Geographic coordinates		Measured air pollutants				Comments
		Latitude (S)	Longitude (E)	PM	NO ₂	SO ₂	VOCs	
MPT14	Instituto Industrial de Maputo	25°56'42.35"	32°35'29.67"	Y	Y	Y	N	Campus of a Polytechnic institute, 100s of meters away from a busy road, in low-income residential area. The area is barely paved.
MPT15	Xipamanine	25°56'40.60"	32°33'49.20"	Y	Y	Y	N	Paved roadside, in a very busy market place in low-income residential area. There is terminal of public transport nearby the station.
MPT16	Escola Portuguesa de Moçambique	25°56'39.03"	32°36'44.27"	Y	N	N	N	School campus. There is low-traffic road passing and a back-up electricity generator. Otherwise paved and green site, far from car park.
MPT17	Chamanculo-ADM	25°56'25.20"	32°33'17.90"	Y	N	Y	N	Densely populated and low income residential area.
MPT18	Luis Cabral-Esquadra da PRM	25°56'21.13"	32°31'52.99"	Y	Y	N	N	Densely populated and low income residential area – heavy traffic motorway.
MPT19	Campo do 1° de Maio	25°56'6.37"	32°35'12.10"	Y	N	Y	N	Unpaved roadside, in densely populated low-income residential area, where charcoal/wood is the main source of energy in most households.
MPT20	Polana Caniço-Hospital	25°56'6.36"	32°36'18.43"	Y	N	Y	N	Paved roadside, in low-income residential area, close to hospital parking area. Charcoal/wood used as main source of domestic energy supply in the area.
MPT21	Ministério da Agricultura (MINAG)	25°56'5.02"	32°34'46.77"	Y	Y	Y	N	Office park, close to a busy road circular intersection, in low-income residential area.
MPT22	Unidade 7	25°56'2.28"	32°33'19.68"	Y	Y	N	N	Densely populated low income area.
MPT23	Aeroporto-Mags	25°56'0.22"	32°34'15.63"	Y	Y	N	N	Unpaved roadside, in a medium-income residential area. The road carries very low traffic.
MPT24	Jardim Zoológico	25°55'38.26"	32°33'21.86"	Y	Y	N	N	Zoo – sampler locate at heavy traffic roadside.
MPT25	Praça dos Combatentes	25°55'35.34"	32°36'24.05"	Y	Y	Y	N	Market place – terminal of public transport.
MPT26	Mavalane-Escola da Solidariedade	25°55'30.60"	32°35'1.00"	Y	Y	Y	N	Low income residential area.

Table 1: (Continued)

Station Code	Station Name	Geographic coordinates		Measured air pollutants				Comments
		Latitude (S)	Longitude (E)	PM	NO ₂	SO ₂	VOCs	
MPT27	Inhagóia-Círculo	25°54'58.33"	32°33'35.59"	Y	Y	Y	N	Low income residential area.
MPT28	Ferr. Mahotas-Esc. Sec. Ed.Mondlane	25°54'52.87"	32°36'43.11"	Y	Y	N	N	Mixture of medium and low income households.
MPT29	Hulene-Farmácia (1)	25°54'45.60"	32°35'24.05"	Y	Y	Y	N	Mixture of medium and low income households.
MPT30	25 de Junho (1)-Casa Macamo	25°54'41.63"	32°33'19.99"	Y	N	Y	N	Medium income residential area.
MPT31	25 de Junho (2)-Lixeira Donwind 2	25°54'36.24"	32°34'20.25"	Y	Y	Y	N	Medium income residential area; downwind solid waste dump-and-burn site
MPT32	Costa do Sol-Fish Farm	25°54'36.73"	32°38'46.97"	Y	Y	Y	N	Open space - some water, some green (mangrove), some dry bare soil. There are two unpaved roads nearby carrying low traffic.
MPT33	SOS-Centro Emissor dos ADM	25°54'16.25"	32°36'24.27"	Y	Y	Y	N	Low income residential area – open space with mixture of green and bare soil.
MPT34	Costa do Sol-Esc. Prim. Costa do Sol	25°54'9.59"	32°39'33.53"	Y	Y	N	N	Unpaved roadside, in low-income residential area. The road carries low traffic.
MPT35	Bagamoyo-Esc.Sec. de Bagamoyo	25°53'52.03"	32°34'16.12"	Y	Y	Y	N	Low income residential area - agglomerate of public facilities (schools, hospital, church).
MPT36	Hulene (2)-Esc.10 de Out.	25°53'50.44"	32°35'31.71"	Y	Y	Y	N	Mixture of medium and low income households; downwind solid waste dump-and-burn site.
MPT37	Benfica-Esc. Prim.	25°53'19.49"	32°34'2.91"	Y	Y	Y	N	Low income residential area.
MPT38	Bairro 3 de Fevereiro-14ª Esq. PRM	25°53'13.85"	32°36'21.58"	Y	Y	N	N	Mixture of medium and low income households.
MPT39	Bairro de Malhazine-Esc. Sec.	25°53'2.97"	32°35'4.28"	Y	Y	N	N	Medium income residential area.
MPT40	Bairro de Magoanini-Esc. Sec.	25°51'28.24"	32°36'54.98"	Y	Y	Y	N	Medium income residential area.
MPT41	Bairro do Albazine-Casa Uthui	25°51'1.44"	32°38'10.09"	Y	N	Y	Y	Background urban site.
MTA42	Matola A-4 Cantinas-INAV	25°58'44.70"	32°27'54.14"	Y	Y	N	N	High income residential area.

Table 1: (Continued)

Station Code	Station Name	Geographic coordinates		Measured air pollutants				Comments
		Latitude (S)	Longitude (E)	PM	NO ₂	SO ₂	VOCs	
MTA43	Matola A-C.M. Matola	25°58'2.70"	32°27'20.89"	Y	Y	Y	N	High income residential area.
MTA44	Matola Rio-Tubiacanga	25°57'50.13"	32°24'51.63"	Y	N	N	N	Sparsely populated medium income area.
MTA45	Bairro Santos	25°57'30.09"	32°28'34.69"	Y	Y	Y	N	Low income residential area.
MTA46	Matola C-João Mateus-Casa do Simbine	25°57'28.42"	32°27'6.80"	Y	Y	N	N	High income residential area.
MTA47	PB-Língamo Depositos	25°57'25.59"	32°29'39.95"	N	N	N	Y	Hot spot (BP Tank Farm).
MTA48	Matola F-Assembleia Provincial de Maputo	25°56'18.90"	32°27'41.95"	Y	Y	N	N	Medium income residential area.
MTA49	Bairro Língamo	25°56'14.50"	32°30'9.20"	Y	Y	Y	N	Low income residential area.
MTA50	Matola G-OTM-Matola	25°56'0.43"	32°27'40.72"	Y	Y	Y	N	Medium income area – open space with mixture of green and bare soil.

On the other hand, the RUA process involves conducting an experiment to measure ambient concentrations of air pollutants within and at the boundaries of the study area. The measurements can be carried out using cost-effective, inexpensive devices, such as diffusive samplers (a.k.a. passive samplers) [11], over a long enough period (typically, a year) to gather good measurement statistics and capture seasonal trends on emissions and ambient concentrations of air pollutants in the region of study. The other novel aspect of RUA is that particulate matter (PM) can also be measured using diffusive samplers. The number of measurement points should be as high as possible, and should be inclusive of all representative land-use/land-cover classes identified within the study area. The rationale for using inexpensive sampling techniques becomes clear here; deploying conventional, sophisticated and expensive air sampling equipment to into a dense sampling grid, at urban scale, can be prohibitive even for the richest countries. The results from measurements are then gridded to produce a concentration map, which is then compared to the concentration map generated using air pollutant emission data and dispersion modelling.

The hypothesis is that if all emission sources are properly accounted for, the two maps obtained from the processes described above should match; that is, there should be a high linear correlation between measured and estimated ambient concentrations of air pollutants in the study area. The assumption here is that the measured concentrations are more accurate, hence they are used as reference data to fine-tune the emissions database and calibrate the dispersion model. An example of fine-tuning the emissions database is checking missing sources or adjusting the EFs used to compute emission estimates. Once conformance between measured and modelled concentrations is achieved, the RUA process is completed. A final air pollution exposure (ambient concentration) map is then produced for each air pollutant of concern, which can be used to devise and implement measures for emissions control.

4 RUA Field measurements in Mozambique

RUA field measurements are being conducted using IVL passive samplers [12, 13]. Figure 2 shows the locations of the sampling stations in the cities of Maputo and Matola, Mozambique. The sampling points were selected to be representative of a wide range of point, line and area sources, within identified land-cover/land-use classes including roadsides and residential, industrial, recreational, bare soils and green spaces. Accordingly, the selection of points for the location of samplers has been preceded by an analysis of spatial distribution of sources, performed for the study area using GIS and remote sensing data. This approach to measurements for RUA is crucial to attaching EFs for identified land-use/land-cover classes, especially during the validation of the missions database.

In total, there are 63 different locations (hence forth also called stations), spanning the entire study domain (Figure 2), where RUA measurements are being conducted in Maputo and Matola, Mozambique. At 15 out of the 63 stations, the measurements are carried out continuously for a period of one year (starting 9 March 2007); 10 of these 15 permanent stations measure PM, NO₂ and SO₂; the remaining 5 stations measure VOCs. At the other 48 stations, the measurements are made only twice during RUA lifetime: in winter and then in summer. The pollutants measured at these 48 stations are PM (49 stations, including one VOC station), NO₂ (39 stations) and SO₂ (19 stations). Sampling stations located at the northern and western borders of the study area are considered as background stations. Table 1 presents a summary of station characteristics.

Table 2: Summary of relevant statistics on RUA results from Mozambique.

Statistic	PM	NO ₂	SO ₂	VOCs				
				Benzene	Toluene	Octane	Ethylbenzene	Nonane
Median	173.22	9.13	1.25	2.61	7.01	2.41	3.56	1.73
Minimum	31.56	2.60	0.48	0.34	0.42	0.11	0.11	0.31
Maximum	1200.91	20.99	16.05	8.41	33.47	12.26	6.77	15.93
Count	59	49	29	5	5	5	5	5

The samplers for PM, NO₂ and SO₂ are exposed for a period of 2 months, after which they are returned to the laboratory for chemical (gravimetric for PM) analyses. The VOC samplers are exposed for 7 days. The shortest sampling time for VOCs is due to the fact that benzene, which is the critical VOC in this study (it is also the most important species from a health perspective), has the weakest bound to the sorbent [14]. Since the sorbent used for VOC sampling is not a perfect sink for benzene, longer sampling periods (or keeping exposed samplers for long time before the analyses are carried out) may result in the collected sample being partly desorbed when its ambient concentration decreases. The above argument means also that an empirical uptake rate has to be used in the laboratory for determining the ambient concentration of benzene from the collected sample. The empirical VOC uptake rates available in the laboratory at IVL were developed for 7-day exposure time, which is why VOCs are sampled only for 7 days.

These 2-month winter and summer field campaigns were designed to assess the variation of source strength in the study area for the two seasons. The hypothesis has been that the increase in energy demand in winter should result in increased emissions of PM, NO₂ and SO₂. It should be noted that most people (over 70% of the households) in municipal territories of Maputo and Matola rely on the burning of firewood and charcoal for domestic energy supply [15]. Consequently, by comparing the ambient concentrations of measured air pollutants in winter and in summer, it should be possible to have an estimate of the relative contribution of the domestic energy sector to the emissions burden in the study area. The difference in atmospheric ventilation potential in summer and in winter should be considered in deriving such an estimate.

5 Data processing and analysis

The laboratory analyses of NO₂, SO₂ and VOCs yielded ambient concentrations (in $\mu\text{g m}^{-3}$) for these air pollutants, integrated over the relevant sampling period. The PM analyses were performed to yield monthly deposition rates (in $\mu\text{g cm}^{-2} \text{ month}^{-1}$). The 2-month sampling time for PM allowed to compensate for the airflow rate (ca. 0.05 L min^{-1}), which is typical in PM diffusive sampling. Longer sampling times allow to gather enough PM mass for subsequent gravimetric analyses in the laboratory.

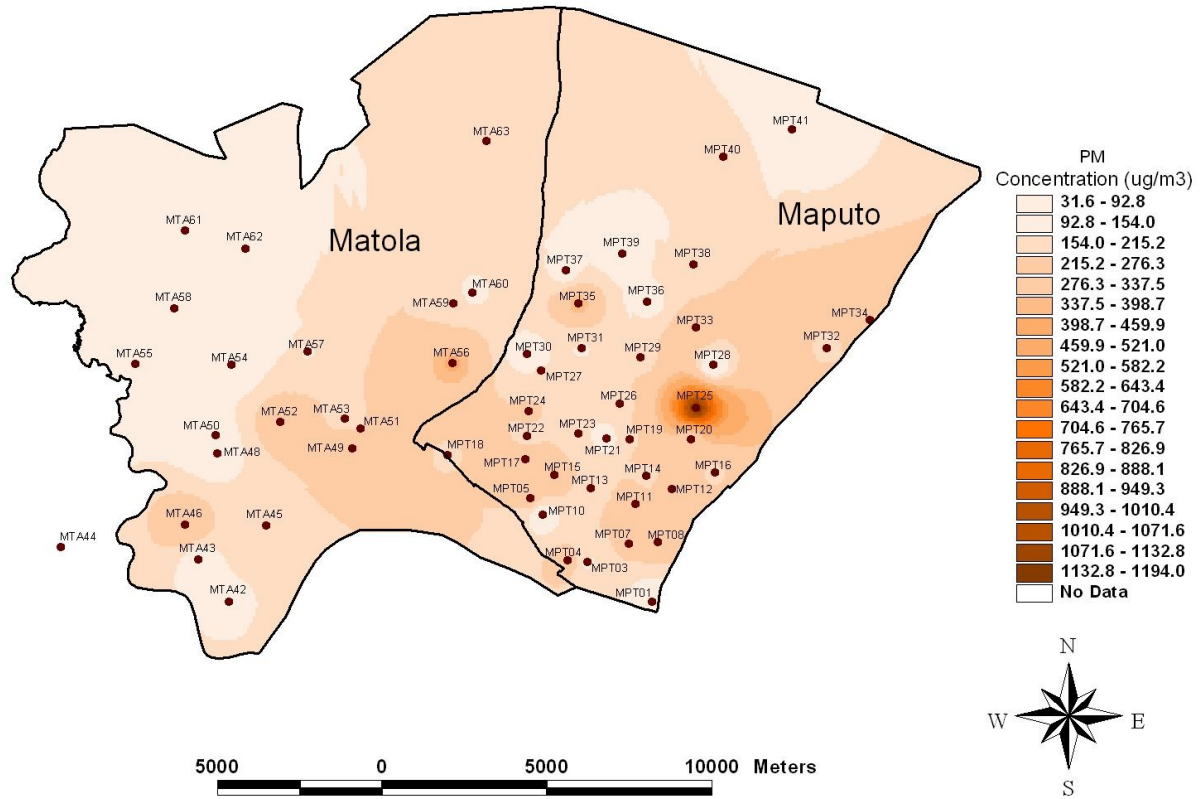


Figure 3: Map of ambient PM concentrations in Maputo and Matola, Mozambique.

Since the setting of air quality guidelines and standards for air pollution is done in terms of concentrations of pollutants in the ambient air, the observed PM deposition rates may be converted into PM concentrations monthly mean and then compared against the relevant World Health Organisation (WHO) air quality guideline value [16]. The PM concentrations can be obtained indirectly by dividing the deposition rates by an average deposition velocity, which has been assumed to be 3 mm s^{-1} for Maputo and Matola.

The data obtained through direct measurements of PM, NO_2 , SO_2 are mapped over the study area using spatial analysis tools integrated in the ArcGIS package [17]. These maps are then compared to corresponding maps of estimated PM, NO_2 and SO_2 ambient concentrations. The concentration estimates for these air pollutants are computed using the emissions database constructed for this study, coupled with “The Air Pollution Model (TAPM)”. The latter (i.e., TAPM) is a PC-based meteorological and air pollution dispersion modelling system [18]. The choice of TAPM for used in this study has been determined by the fact that the model incorporates global terrain and land-use data as well as global synoptic analyses, which enable predicting local meteorological parameters with adequate spatial and temporal resolution. Since there are no reliable local meteorological data with the appropriate spatial and temporal resolution for Maputo and Matola, TAPM is used also to generating these data.

6 Results and discussion

Although a thoroughly description of the RUA experimental procedure was presented in the previous sections, only the results from the first RUA 2-month field campaign (9 March through 9 May 2007) are presented here. The intent is to demonstrate that the RUA process does indeed enable to draw a quick picture of the air quality situation at urban scale, which can be used to inform decision makers to devise and implement measures to protect public health and the environment from air pollution, quite early. A summary of relevant statistics on the results is presented in Table 2.

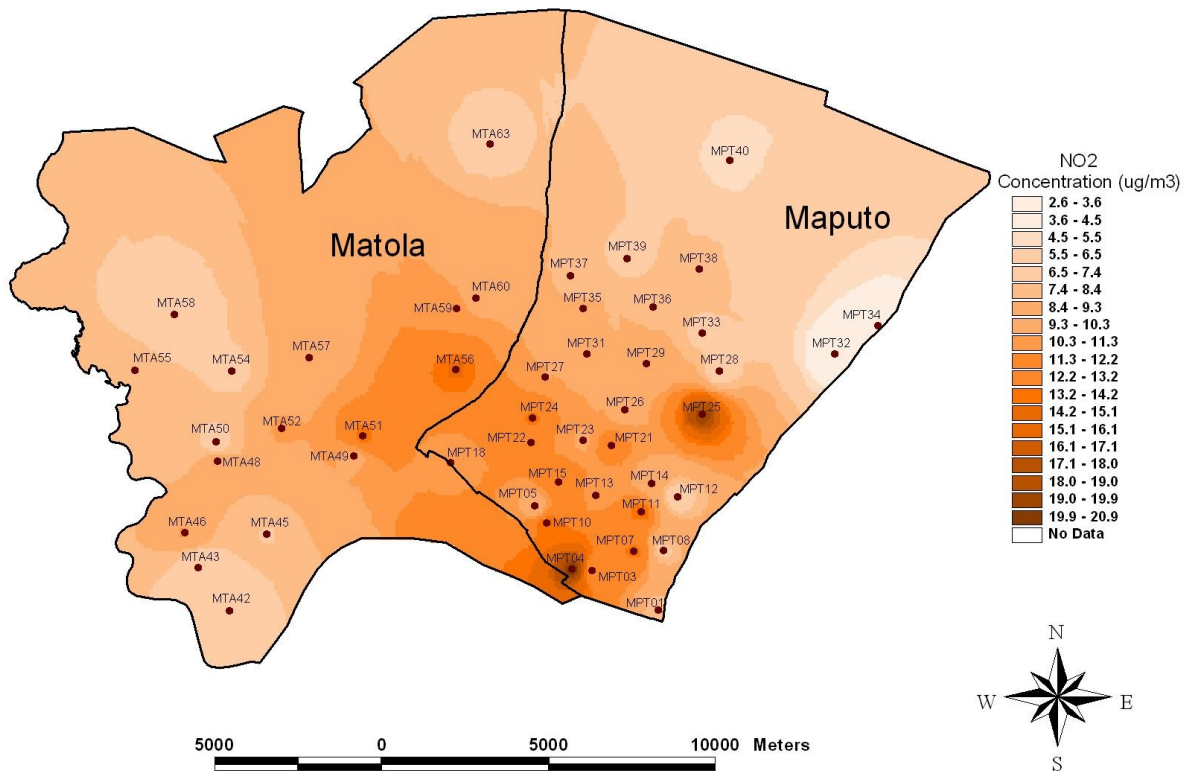


Figure 4: Map of ambient NO₂ concentrations in Maputo and Matola, Mozambique.

Figures 3 through 5 display the spatial distribution of PM, NO₂ and SO₂, obtained by spatially interpolating the concentration values recorded at all the stations where these air pollutants were measured during the field campaign under report. In Maputo, market places (stations MPT15 and MPT25) stand out as hot spots of PM, NO₂ and SO₂ emissions. In Matola, high concentrations of PM, NO₂ and SO₂ were recorded at stations MTA49 (Lingamo) and MTA59 (T3); station MTA49 is located in vicinity of a cement plant.

A further look at the results is provided in Figure 6. Here, the stations are ordered from the South to the North and plotted in the horizontal axis. In both Maputo and Matola, the Central Business District (CBD) is located in the South. Again, the hot spots of PM, NO₂ and SO₂ concentrations in both cities stand out clearly. As indicated by the trend lines, generally the concentrations of air pollutants decrease from the South to the North, consistent with the fact that most human activities causing air pollution in a city take

place in the CBD. However, in Matola NO_2 concentrations show an increase towards the North, away from the CBD. No obvious reason has been found thus far to explain this unexpected NO_2 concentration pattern in Matola; it could be that there is a strong source of NO_2 to the North of this city. Further investigation is required to explain this feature. Another feature apparent from Figure 6 is that PM is the most conspicuous air pollutant throughout the study area, followed by NO_2 ; ambient SO_2 concentrations are the lowest throughout.

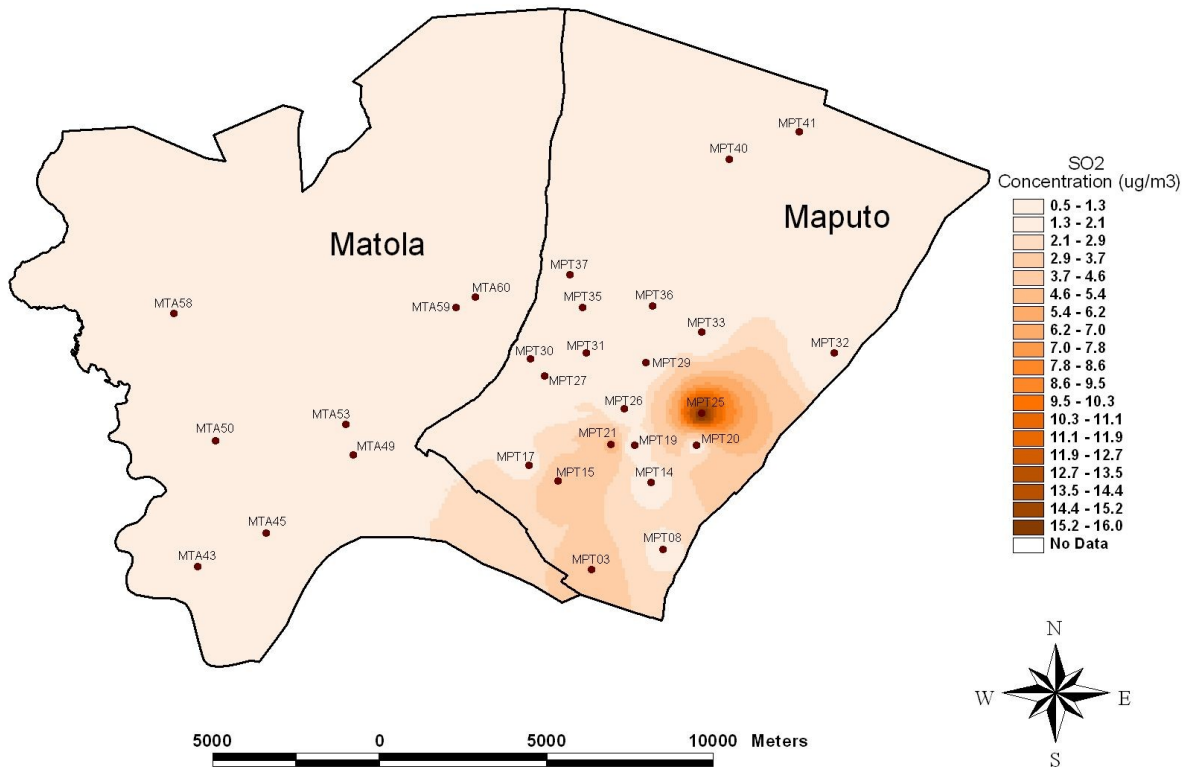


Figure 5: Map of ambient SO_2 concentration in Maputo and Matola.

A comparison of median PM, NO_2 and SO_2 ambient concentrations recorded per city is shown in Figure 7. The highest ambient concentrations of PM and NO_2 were recorded in Maputo, while SO_2 is slightly higher in Matola than in Maputo. This is consistent with the fact that most industrial facilities known to emit SO_2 are located in Matola. In both cities, the median PM concentration during the reported period is above $100 \mu\text{g m}^{-3}$; the NO_2 median is just below $10 \mu\text{g m}^{-3}$, while for SO_2 the median concentration is below $3 \mu\text{g m}^{-3}$, for the same period. It is not very clear yet which sources contribute largely to the high ambient concentrations of PM in the study area. However, since there are so many dust sources in both cities, re-suspension of dust by wind and traffic might be the dominant emission process. A source apportionment study is required to ascertain which sources contribute most the air pollution due PM in Maputo and Matola. Traffic seems to be the major source of the observed NO_2 and SO_2 emissions in both cities. However, the concentrations are fairly low, but very likely to be increasing steadily, since vehicle fleets continue to increase, as shown in Figure 8, in absence of emissions control regulations.

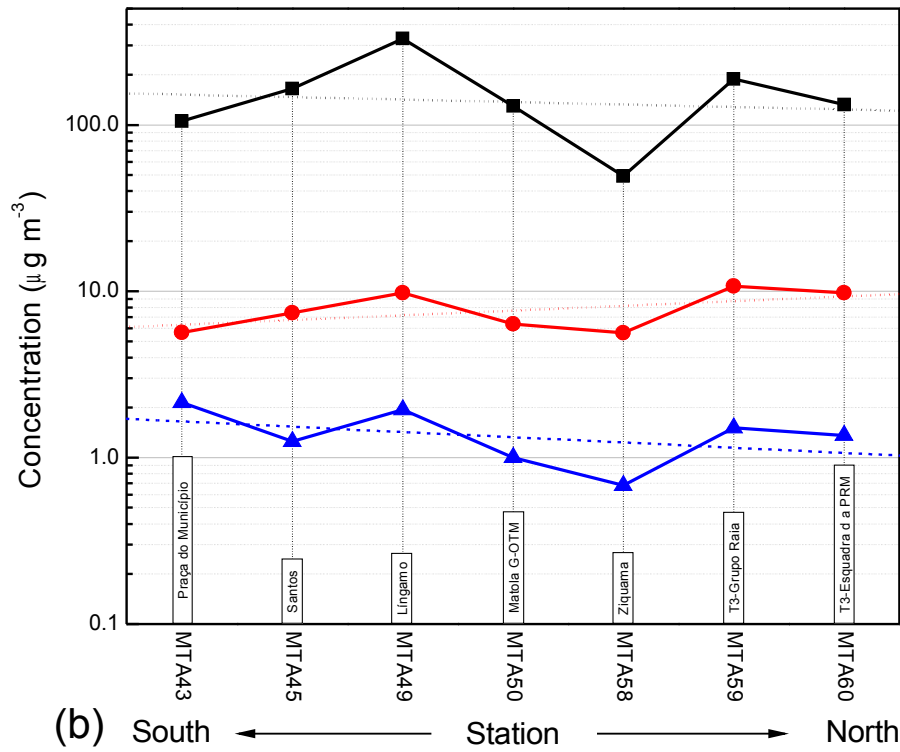
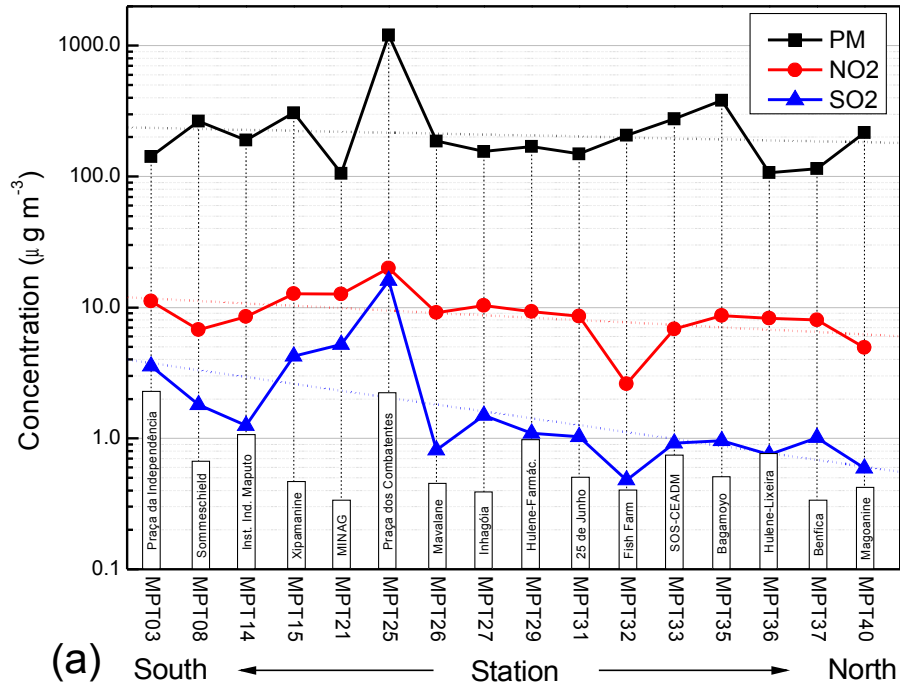


Figure 6: Results from simultaneous measurement of PM, NO₂ and SO₂ at selected stations in the study area.

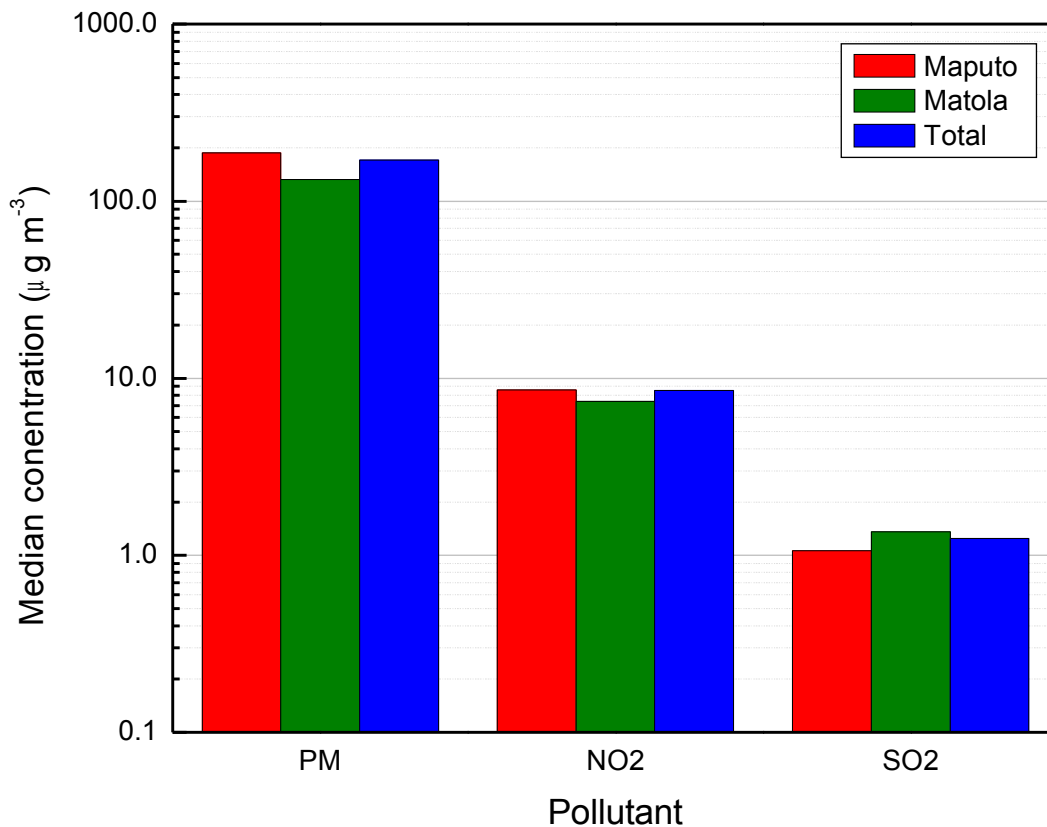


Figure 7: Comparing results from stations measuring PM, NO₂ ad SO₂ simultaneously in the study area.

Figure 9 presents the results obtained at the five stations where VOCs are measured, in Maputo and Matola. The samplers from these stations have been analysed for a suite of non-methane VOCs, including benzene and its derivatives (toluene, ethylbenzene, and o-, m-, p-xylene), octane and nonane. Station MPT41 was set to be a background station (inclusive of PM, NO₂ and SO₂). High ambient concentrations of VOCs have been recorded at busiest fuel filling stations (e.g., station MPT09), fuel tank farms (e.g., station MTA47) and intersections of roads carrying high traffic volumes. Toluene (a.k.a. methylbenzene) and m+p-xylene are the most abundant species at virtually all stations where VOCs are measured. Nonane is as abundant as m+p-xylene at the BP Tank Farm (station MTA47), followed by octane and then toluene. Benzene concentrations are highest at road intersections (e.g. station MPT06) and petrol filling station (e.g., station MPT09). At the background station, MPT41 (Albazine), ambient concentrations of all measured VOC species are less than 1.0 µg m⁻³.

To interpret the results displayed in Figure 9, it is important to recall that VOCs may be released from gasoline-powered motor vehicle exhaust pipes (exhaust VOC emissions) as well as from vents of storage and distribution facilities (evaporative VOC emissions). Accordingly, at station MPT09 (filling station), ambient VOC concentrations are contributed by both exhaust and evaporative emissions, which may explain the high values measured there. At station MPT06 (road intersection), exhaust emissions appear

to contribute exclusively to the observed VOC concentrations; while at station MTA47 (Tank Farm), evaporation of fuels is more likely the sole source of VOCs measured there. A closer examination of data from all VOC stations seems to suggest that the occurrence of nonane in the ambient air is a result of evaporative emissions of fuels and solvents derived from fossil fuels, while benzene comes mostly from exhaust emissions.

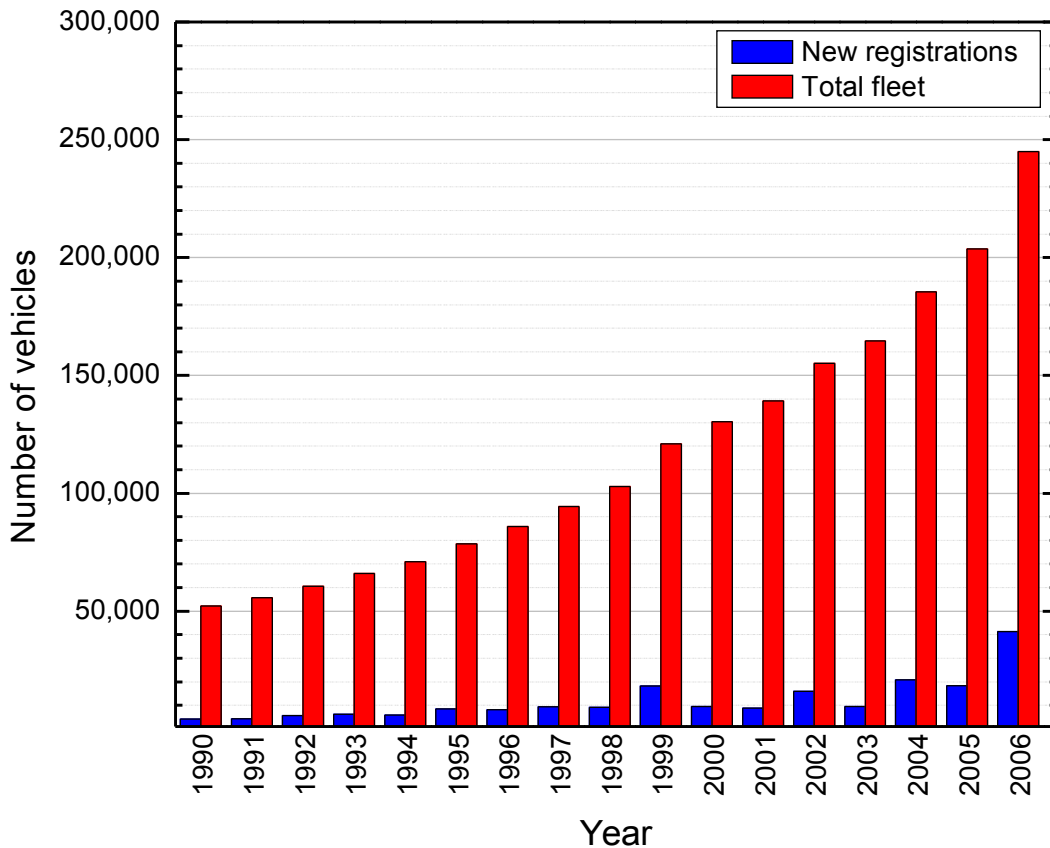


Figure 8: Evolution of traffic in Mozambique.

7 Summary and conclusion

A method for conducting quick air quality assessments at urban scale has been described. Preliminary results from a 2-month field campaign using the proposed method have been presented. These results provide a snapshot of the air quality situation in the study area. The results suggest that PM is the most conspicuous air pollutant in the study area. For the other pollutants, ambient concentrations are still quite low, but they likely to increase in response to increasing motor vehicle fleets in absence of emissions control regulations. Work continues to constructing the EI required to conduct air pollution dispersion modelling and derive concentration estimates for the pollutants under investigation.

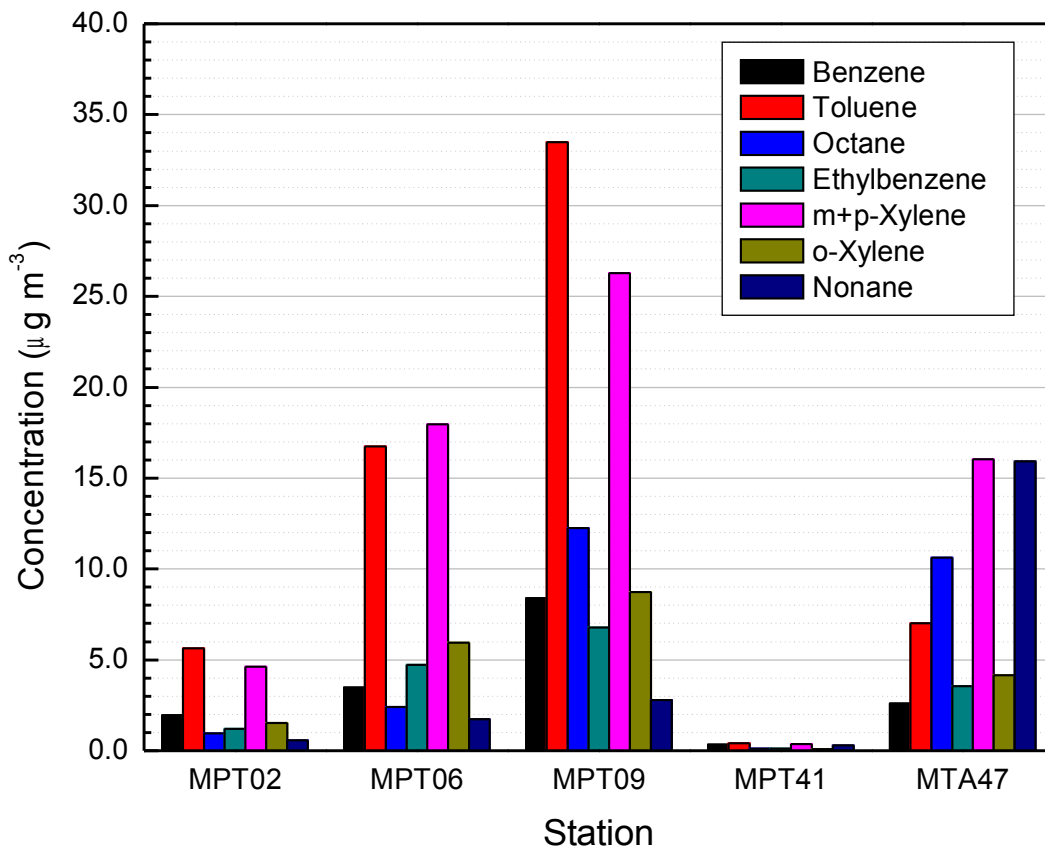


Figure 9: Ambient VOC concentrations in Maputo and Matola, Mozambique.

The RUA process as described above may not seem truly rapid, as suggested by its denomination. Indeed, the logistics involved in constructing the emissions inventory, conducting the field experiment and analysing is intimidating. However, the costs involved are rather low if compared to those of conventional approaches, based on deploying sophisticated and expensive equipment for air pollution monitoring. Further, the RUA process is actually rapid and versatile in that once the emissions database has been developed and validated, and EFs attached to all representative land-cover/land-use classes within the study area, it becomes easy, fast and cost-effective to update the emissions database periodically. This can be done by just observing and accounting for changes in land-cover/land-use data and activity statistics in the study area over a given time period.

These aspects (i.e., being inexpensive, rapid and versatile) make the RUA process well-suited to conduct baseline studies aimed at developing air quality management strategies at urban scale. However, this does not mean that RUA is a substitute of more matured, conventional air pollution monitoring methods. In fact, the RUA process suffers from being less accurate and for demanding intensive team work, involving expertise not only in air pollution science and air quality management, but also in geomatics (i.e., GIS and remote sensing). Forming such a multidisciplinary team to carry out RUA in a short time period can

prove very challenging and outweigh the advantages of the method. Therefore, RUA should be considered only in those cases when it is easy to build a committed team of experts drawn from relevant fields of expertise, to carry out the different tasks involved in the process.

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