Levels of Aerosol in Dar es Salaam, Tanzania, Compared to Some Cities

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Abstract

The aerosol concentrations in the city of Dar es Salaam were found with aim of investigating pollution levels. The aerosol samples were collected on the sites of Tanzania Oxygen Limited (TOL) which is purely an industrial area, Ocean Road Cancer Research Institute (ORCRI) located along the sea shore at the port exit, and Dar es Salaam International Airport (DIA) far from the city center. The PM10 dichotomous impactor was used for sample collection. The analysis of the samples was conducted with x-ray fluorescence spectrometer. The values obtained for Dar es Salaam aerosol samples are compared to similar samples of aerosol data available for the cities of Kinshasa and Butare in the republic of Congo and Rwanda respectively. The elements found in the aerosol samples include Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Br, Rb, Sr, Zr, Pb and Se. The variations of the minimum and maximum values of the elemental concentration in the sample for these elements are given for the months between September 1996 and May 1997. The elemental variation was affected by seasonal weather parameters like rain, wind speed and their directions. Temperatures varied between 29 and 32°C; rainfall between 5 and 70 mm while wind speed varied between 5 and 20 m/s.

Key words: Aerosol concentrations, urban pollution level element, season, Dar es Salaam, Butare, Kinshasa, Tanzania

Résumé

Les concentrations d'aérosols dans la ville de Dar es Salaam ont été échantillonnées avec le but d'évaluer le degré de pollution. Les échantillons d'aérosols ont été collectés de l'usine Tanzania Oxygen Limited (TOL) situé dans la zone industrielle, et de Ocean Road Cancer Research Institute (ORCRI) localisé le long de la côte maritime entre l'embouchure du port et l'Aéroport International de Dar es Salaam loin du centre urbain. L'analyse des échantillons a été effectuée au moyen d'un spectromètre fluorescent à Rayons X. Les valeurs obtenues des échantillons des aérosols de Dar es Salaam ont été comparés à celles de Kinshasa en République Démocratique du Congo et à celles de Butare au Rwanda. Les éléments trouvés dans les échantillons d'aérosols incluent Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Br, Rb, Sr, Zr, Pb et Se. Les variations des valeurs minimales et maximales de concentration de ces éléments dans les échantillons sont données pour les mois entre septembre 1996 et mai 1997. La variation des éléments et leur concentration sont subordonnées aux facteurs régissant les saisons comme la pluie, la vitesse du vent et leurs directions. Les températures variaient entre 29 et 32 oC et la pluviométrie entre 5 et 70 mm tandis que la vitesse du vent oscillait entre 5 et 20 m/s.

Mots clés: concentrations d'aérosols, pollution urbaine, éléments, saison, Dar es Salaam, Butare, Kinshasa, Tanzanie

Introduction

Aerosol sources and their contribution to environmental pollution are well documented elsewhere (Oblad, 1986; Koleleni, 1989; Van Grieken and Labreque, 1985; Dzubay, *et al,.* 1977). The significance of studying aerosol in relation to health hazards makes the subject of pollution attractive to several researchers (Malmqvist, 1981; Oikawa, 1997; Bghard, 1983; Boeker and Van Grondelle, 1995; Markowicz and Abdunabi, 1991). The fine particles when inhaled have a health effects on the respiratory tract and the chemical parts may be absorbed into the blood system and cause several types of diseases. Apart from inhalation of aerosol, particles may be deposited on the skin surface, food, and crops, soils and water that may find ways into human body and may have health effects. Some levels of aerosol are considered tolerable while others excessive and completely toxic especially the heavy elements. The particles may have health effects due to their chemical effects or radioactive properties. The aerosol particles differ in composition from one place to another depending on the source of pollutants. This makes the need of studying these particles, their composition and their effects on health. The understanding of the levels of aerosol is facilitated by both the availability of the sampling equipment (Lodge, 1988) together with accurate, fast, non-destructive, multi-element analyzing spectrometer (Giauque and Jacklevic, 1972; Markowicz and van Grieken, 1993; Jacklevic *et al.*, 1990; Aiginger and Wabrauschek, 1974, Nonomiya *et al.*, 1989; Aiginger and Wabrauschek, 1985). It is certainly important that knowledge on the linkage

between the sampling places, sources and the sample results in relation to the meteorological parameters provides the insight on the interpretation of the data (Van Grieken and Adams, 1976; Oblad and Selin 1986). In many tropical countries, aerosol contributions mainly originate from burning biomass, soil dust, combustion of fuel, industrial and marine activities. In this work aerosol research was performed with the objective of identifying the sources of aerosol pollution and looking at variation of the elemental composition in consideration with the different seasons of the year. Samples were collected between September 1996 and May 1997 in Dar es Salaam at three centers. These are, the Tanzania Oxygen Limited (TOL) purely located at the industrial area, Ocean Road Cancer Research Institute (ORCRI) located at the seashore and port exit, and Dar es Salaam International Airport (DIA) located at the outskirts of the city. The sampling cites reflects the working, residential and the port areas. The average results of the data obtained are given in Table 1 and the comparison has been done with that of Kinshasa and Butare in the Democratic Republic of Congo and Rwanda, respectively. These are neighboring countries with completely different environmental conditions although the results may generate interest in the levels for which the present work was only limited to Dar es Salaam. Some aerosol work going on in other African cities have so far not been available for inclusion in this work.

Methodology

Sample collection

Aerosol sampling was conducted using Sierra Andersen™ PM10 dichotomous impactor with ability to separate two particle sizes of less than 2.5mm as fine particles and greater than 2.5mm as coarse particles which are collected on two different filters. The detailed description of the sampler is given elsewhere (Wesolowski *et al.*, 1985; Lawson, 1980; Gladney, 1974; Paciga and Jervis, 1976; Koleleni, 1990; Loo *et al.*, 1995; Hinds, 1982; IAEA, 1992; IAEA, 1997; Oblad *et al.* 1982; Oblad and Selin, 1985). The vacuum pump sucks in air at the rate of 1 m^3/h and the particles are collected on Millipore TM filters whose pore size is 0.9 μm diameter for 24 hours. The flow rates together with the geometry of the impactor nozzle allow the separation of the two particle sizes according to their aerodynamic diameters. For a flow rate of 1 m^3/h, there are two paths referred as minor and major flow, which share 10% and 90% of the total flow. This means that 0.1 m^3/h deposits the coarse particles while 0.9 m^3/h deposits the fine particles on their respective filters. The sampling stations were Tanzania Oxygen Limited (TOL), Ocean Road Cancer Research Institute (ORCRI), and Dar es Salaam International Airport (DIA). The data available for samples of Kinshasa and Butare were actually not part of this work but were conducted by other authors (Akilimali and Maenhautt, 1990).

Sample Analysis

The aerosol samples collected on filters were placed on a holder system for excitation with x-rays. The x-rays from the Siemens FK60 series tube strike the secondary target to produce monochromatic x-rays, which are, then incident on the sample. The fluorescent x-rays from the sample are detected by the Si (Li) model SL 30180 semiconductor liquid nitrogen cooled detector whose signal is processed via the Canberra ™ model 2008 pre-amplifier, Canberra™ model 2026 amplifier, Canberra™ model 8701 ADC, Canberra™ S-100 multi-channel analyzer. The quantitative analysis was possible after the system calibration (IAEA, 1993; Van Espen *et al.* 1986; Wobrauschek, 1989; Koleleni and Van Grieken, 1991). In EDXRF spectrometer, once the high voltage is applied to the x-ray tube, electron beams are produced and accelerated from the cathode to the anode. The x-ray bremsstrahlung are then produced at the anode. This broad band of energy spectrum is arranged to strike a Mo secondary target so as to get a mono-energetic x-ray photon of Mo, which is in turn used to excite the characteristic radiation from the sample atoms. The characteristic radiation is detected by the Si(Li) semiconductor detector. All the elements in the sample heavier than phosphorous were accurately detected. The concentrations from the sample were evaluated using the relation:

$$I_i = K_i C_i A_i$$

Where I_i is the intensity of the element i, K_i is the sensitivity of the element i, C_i is the concentration of the element i, and A_i is the absorption correction of the element i

The sensitivity of the low Z elements are affected by absorption in the air compared to high Z elements. It is also noted that the sensitivity of elements close to Molybdenum, which was an exciting energy, are slightly diminishing. This is due to these elements being affected by the tailing effect of the Compton scattered peaks. Most of the elements were finally detected when the counting times were prolonged. The errors were mainly due counting statistics. Obviously a lot of work has previously been done on the set-up to lower down the detection limits of many elements and to correct for the absorption.

Results and Discussion

The results presented in this section are those, which were analysed for the Dar es Salaam sampling sites. However, the results quoted in this section for samples obtained from Kinshasa and Butare were from the literature (Maenhaut and Akilimali, 1985) just for comparison purposes in terms of the levels though the sampling times, places and conditions were completely different from Dar es Salaam. All the results presented in Table 1 for three stations of Dar es Salaam namely TOL, ORCRI, DIA are range of values (minimum to maximum) and those of the cities of Kinshasa (Democratic Republic of Congo) and Butare (Rwanda) are average elemental concentrations in ng/m^3. In our discussions it may be found to be incorrect to compare soil elements for Kinshasa, Butare and that of Dar es salaam since the land formations and industries of these three places are completely different. It can further be pointed out that the wind directions which may very much determine where the aerosol were picked were only available for Dar es Salaam and not the rest in the other cities mentioned. However, the inclusion of the data from the other cities is important for readers to grasp the idea of what levels they should expect from other cities in addition to Dar es Salaam.

Table 1: The average atmospheric concentration in Dar es Salaam (TOL, ORCRI, DIA) compared to the average values of Kinshasa and Butare in (ng/m^3)

	Democratic Republic of Congo and Rwanda		Dar es Salaam		
Element	Kinshasa	Butare	TOL	ORCRI	DIA
Si	2800	141	-	-	-
P	34	4.4	-	-	-
S	370	36	73	105	354
Cl	49	-	58	30	232
K	410	87	132	91	166
Ca	410	30	182	312	304
Ti	110	7.7	29	14	8
V	2.6	-	-	-	-
Cr	2.3	-	9	7	1.5
Mn	15.0	1.80	115	102	100
Fe	770	70	248	178	136
Ni	0.69	-	-	-	-
Cu	1.48	0.19	122	72	52
Zn	7.1	1.06	116	37	21
Ga	0.56	-	-	-	-
Br	4.1	8.2	33	24	11
Rb	1.54	0.56	-	-	-
Sr	3.3	0.29	11	15	5
Zr	3.1	0.42	10	6	4
Pb	13.8	14.7	170	60	370
Se	-	-	6	9	5

The S values in aerosol are higher in Kinshasa than in Butare (Table 1) in the republic of Congo as outlined by Maenhaut and Akilimali (1987) and Maenhautt and Akilimali (1985). When these values are compared to those obtained in this work, they stand between the TOL and DIA values in content. The average values for DIA and ORCRI are much higher for the reasons of its location between the ocean coast exposed directly to sea marine activities and sea vessels, the places where S originates. The same applies to Cl values(58-232 ng/m^3 for which Dar es Salaam International Airport (DIA) has higher values. The Soil elements of K, Ca, and Ti in Dar es Salaam have higher values of Ca because some industries use raw materials rich in Ca. The comparison of elemental concentration between Dar es Salaam and Kinshasa provides an insight of environmental aerosol levels in these two cities in countries, which are neighbors despite the incorrectness of the comparison due different factors, which are not co-existing in the two cities.

The elements such as Fe, Cu, Zn and Mn in Dar es Salaam are contributions from industrial and soil activities. The levels of these elements depend on how much soil was covered by vegetation as well as the wind direction for which the values depend very much on the month of collection, which have weather variations. The combustion elements of Pb and Br for the Dar es Salaam stations depend very much on the sampling sites and time. For example, the high levels of Pb originating from combustion are mainly during the daytime when you have high traffic intensity.

In all, it must be appreciated that Kinshasa, Butare and Dar es Salaam are cities with several sources of pollution which are not comparable. The cities have different types of industries, and land formation, different seasons and other different environmental factors. Nevertheless, the table of the three cities provides an insight on the apparent levels observed at different places.

Monthly variations of elemental concentrations in the aerosol samples

The high concentrations of Ca, Fe, and Cu in Dar es Salaam are due to local air pollution from soil and industrial effluents passing over the sampling sites, whereas some levels appear to be added apparently due to transport over long distances. Here we refer to short transport as that from localized source and a long-range transport as from a long distance air mass movement regional (East Africa), and occasionally intercontinental (outside East Africa) . The continuous changing of wind directions result into mixing of aerosol from different parts and therefore continuously affecting their concentrations. Hids (1982) report on the chemical composition of the coarse particle mostly

Al, Si, Ca and Fe originating from soil and the finer particles containing mostly, sulfur and lead from combustion source, similar to those suggested by Lawson (1980), Gladney *et al.* (1974), Paciga and Jervis (1976), Koleleni (1990) and Loo *et al.* (1995). Figures 1 to 9 show monthly fluctuations for the minimum and maximum elemental composition for all aerosol collection months from August 1996 to May 1997.The fluctuations are due to a number of reasons. These are partly due meteorological monthly changes such as wind movements at different speeds and in different directions. It could also be due to the differences in sampling locations for which the levels are changing with the surrounding environment. It is also due to influences of variations of distances from the polluting sources. The wind also pass over the polluting sources and picks the particles and deposit them in other places and thus contributing to the increase in levels.

Figure 1: The minimum and maximum elemental concentrations in August 1996

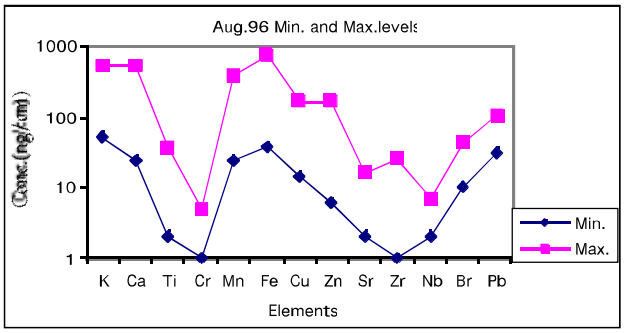
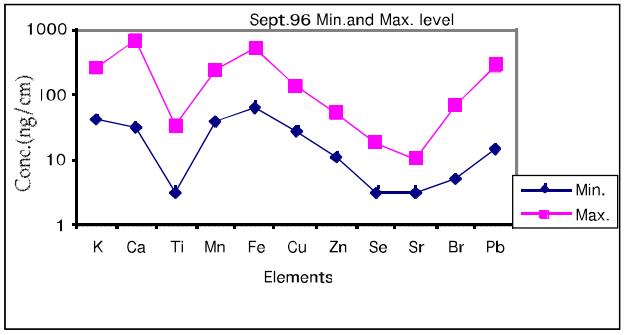


Figure 2: The minimum and maximum elemental concentrations in September 1996



The high maximum values are observed for elements like K, Ca, Mn, Fe, Cu, Zn and Pb and low minimum values of Ti, Cr, Sr and Zr in August 1996 and September 1996. The values of the same elements are much lower in October 1996 and December 1996. The reason was due to variations in wind speeds fluctuating between 10 and 20 m/s and directions changing from North Easterlies to South Easterlies. The months of March 1997 and April 1997 have undetected Ti, Cr and Mn levels in the air. Sr, Br and Pb for these two months are also low. This was due to rainy season whereby some aerosol particles coagulate with raindrops and fall down because of gravity. In April 1997, rainfall was between 5 mm and 22 mm, May 1997 rainfall amounted to 5 mm on 3rd day, 5 mm on 4th day and 2 mm on 13th day, 32 mm on 17th day, 30 mm on 18th day and between 5 and 15 mm on 23-30th day.

Figure 3: The minimum and maximum elemental concentrations in October 1996

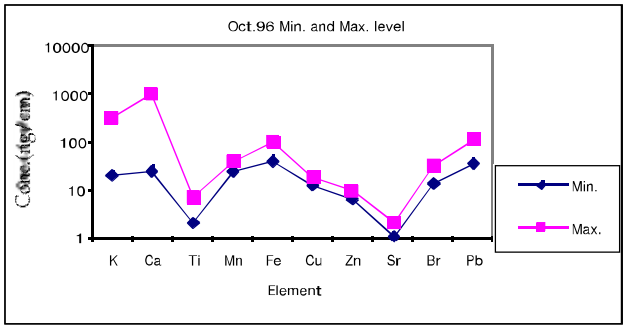


Figure 4: The minimum and maximum elemental concentrations in December 1996

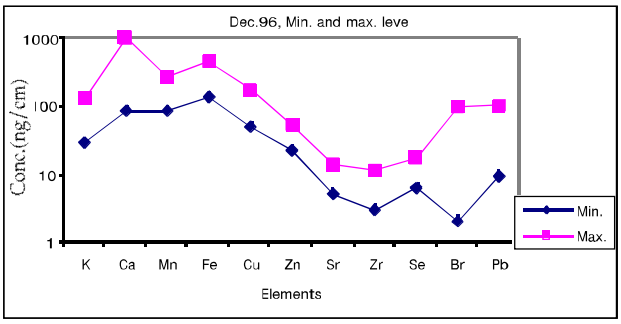


Figure 5: The minimum and maximum elemental concentrations in January 1997

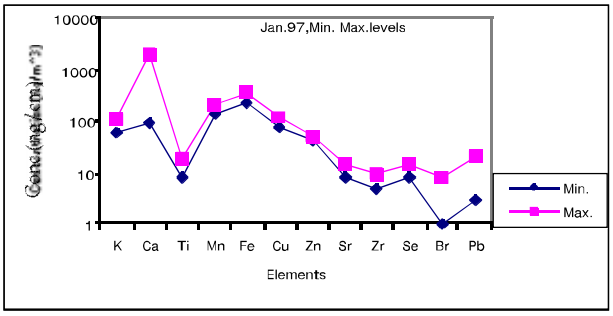


Figure 6: The minimum and maximum elemental concentrations in February 1997

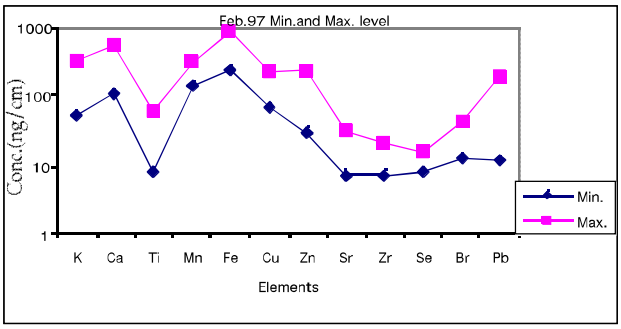


Figure 7: The minimum and maximum elemental concentrations in March 1997

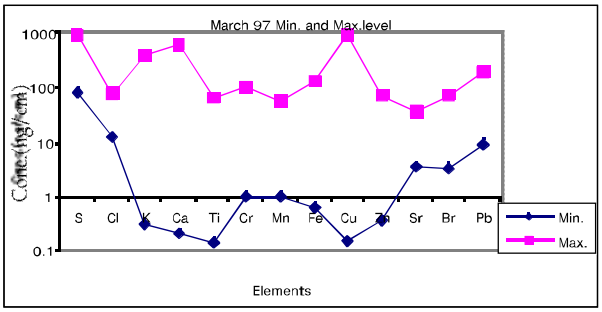


Figure 8: The minimum and maximum elemental concentrations in April 1997

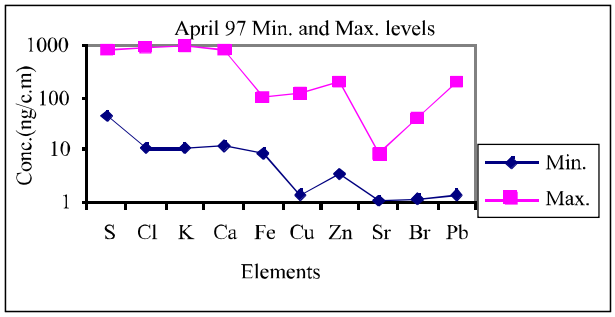


Figure 9: The minimum and maximum elemental concentrations in May 1997

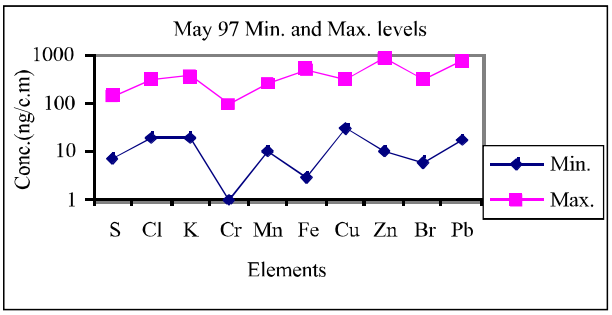
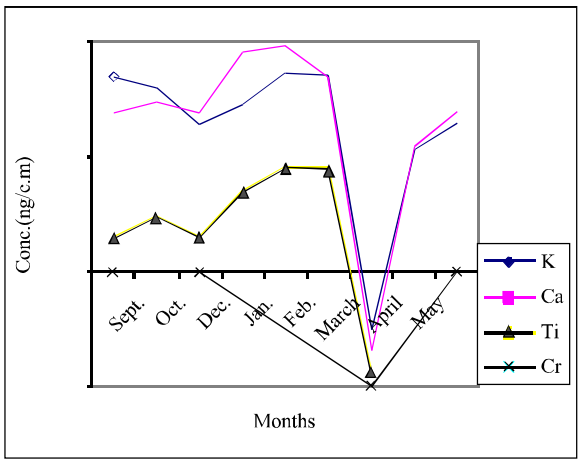


Figure 10: The monthly minimum elemental concentrations of K, Ca, Ti and Cr



The concentrations of elements like K, Ca, Ti and Cr have their monthly minimum shown in Figure 10 and maximum shown in Figure 11. The minimum concentrations of K, Ca and Ti are varying in the same way (Figure 10), which indicate variation of polluting sources purely affected by the sampling areas.

The elemental monthly maximum concentrations for Ca, K, Ti and Cr are shown in Figure 11. Except for K and Ca, elements like Ti, Cr and Mn were absent in April 1997. These elements could have been cleared from the atmosphere by rainwater. Some elements like Ca peaks up at the months of August 1996, February 1997 and May 1997 simply because of the influence of the sampling position of TOL. Ca is abundant as industrial raw material used in the factory.

The minimum levels of Mn, Fe, Cu, Zn, Sr and Zr are shown in Figure 12. These elements vary in the same way between August 1996 and February 1997. In March 1997, there was a sudden drop of minimum levels of these elements because of influence of rain and vegetation. The monthly maximum levels for these elements are shown in Figure 13.

Figure 11: The monthly fluctuation of K, Ca. Ti, Cr and Mn maximum levels

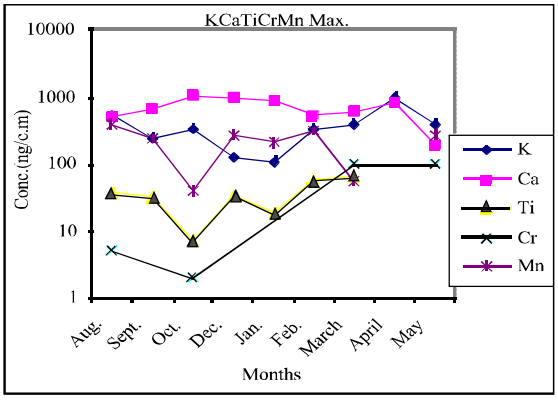


Figure 12: The monthly fluctuation of Mn, Fe, Cu, Zn, Sr and Zr minimum levels

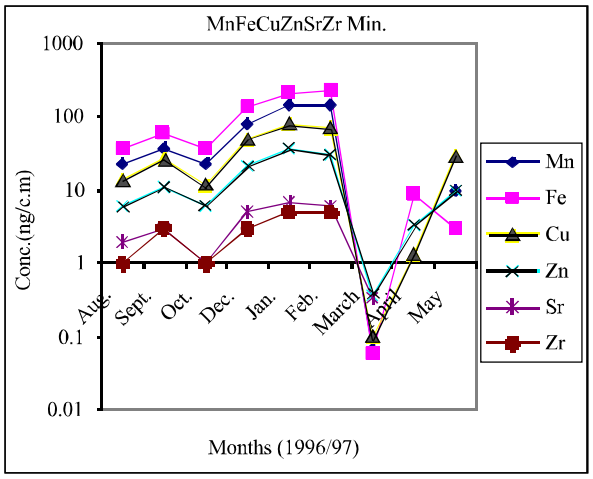
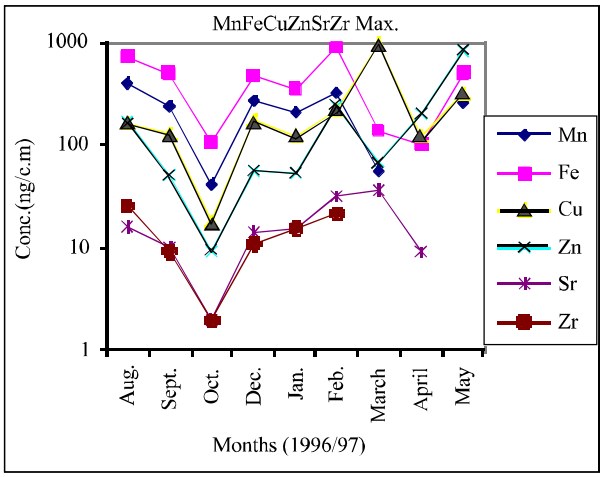


Figure 13: The monthly fluctuation of Mn, Fe, Cu, Zn, Sr and Zr maximum levels



These elements are sometimes originating from more than one source of pollution such as industries, eroded soil and marine activities. Air movements may transfer some pollutants from one area to another (Oblad, 1986; Koleleni, 1977; Oblad and Selin, 1985; Larsson and Oblad, 1984). The low concentration values are observed for elements such as Mn, Fe, Cu, Zn, Sr and Zr in the month of October 1996 and April 1997 (Figure 13) at ORCRI, which is slightly far from the industrial areas but close to the port entry. The drop in concentration may be a result of differences in the sampling times where each sample was collected for a period of 24 hours, monthly changes of sampling stations rotated from TOL, DIA and ORCRI as well as variation in meteorological conditions. A high maximum concentration levels of Mn, Fe and Cu (Figure 13) are observed in TOL, the sampling station close to industrial area where sampling took place in August 1996, February 1997 and May 1997.

Figure 1 and Figure 2 show that K and Ca in August 1996 and September 1996 have similar trends. The concentration of Ti was lower in August 1996 compared to September 1996 while the concentration of Mn, Fe, Cu, Br, Pb and Sr show similar trends for the two months. However, small amounts of Cr appear in August 1996 and May 1997 and not in any other month. The months of October and December 1996 show similar trends as those of August and September 1996 with only the difference that in the latter, the values go down by 10%. January 1997 had a similar pattern as February 1997 with former months values down by 10% that of latter. March and April 1997 look similar in pattern. However, elements like S, Cl, K, Ca, have higher values of order of 10% that of April 1997 while minimum levels of Br and Pb are lower by the factor of 10% that of April 1997. Values of March and May 1997 for Sr, Br and Pb are very close. The variation is due to differences in collection seasons and sampling sites.

The presence of sulphur, bromine and lead are result of fuel combustion and are examined by their correlation. Apart from Br and Pb, fuels often contain vanadium and nickel (Hansson, 1983). The concentrations of V and Ni vary somewhat depending on the origin of the oil. The sulphur emissions are mainly in the form of sulphur dioxide gas which is gradually converted to sulphates at a rate dependent on the pollution level, and typically in the range of 0.1 to 10% per hour (Bouland *et al.*, 1978; Calvert *et al.*, 1978; Harrison *et al.*, 1983 and Lannerfors *et al.*, 1983).

El-Shabokshy *et al.* (1990) provides values of elemental concentrations for S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Br and Pb for the City of Riyadh. Oblad and Selin (1986) presents concentrations of the same elements for two cities of Sweden and Maenhaut *et al.* (1981) for the Atlantic Ocean. The general trend appears to show that Riyadh has higher values of concentration than the rest of the cities for all the elements. This may be due to high elemental contents of rocks and sands in the desert with strong wind influences. In the Oblad and Selin (1986) presentation, the two cities within same countries one has relatively higher values compared to the other but both very low compared to Riyadh. Scheff and Valiozis (1990) measured the same elemental values for Athens, Greece and provided values, which are by factor of 10 less than that of Riyadh, Saudi Arabia. In general, the values obtained by other authors compared to this work in Dar es Salaam for TOL, DIA and ORCRI show that pollution levels in Dar es Salaam is between that of Saudi Arabia and that of the City of Athens. The Athens values are relatively higher than what is recorded by Maenhaut *et al.* (1981) for Atlantic

Ocean. However, the comparisons are very superficial since the meteorological and environmental conditions of these countries are completely different.

Samples collected from DIA, TOL and ORCRI show significant amounts of S, Cl, K and Ca higher in ORCRI than other places due to sea spray (Morales *et al.* 1990; Weisel *et al.* 1984). Coarse particles can easily settle on the ground due to their mass while fine particles may be blown up to very far distance for the same reason. The concentrations of coarse particles may be higher than that of fine particles for the localised particles. The concentrations of fine particles may for that matter be higher as it may be a combination of localised and distant sources.

The first and last five days of December 1996, rain amounted to between 1 and 5 mm. The aerosol samples were collected from Dar es Salaam International Airport (DIA) and the temperature registered ranged between 25°C early in the morning and about 32°C in the afternoon.

There was rain in January 1997 on the ninth day amounting to 1.7 mm while the temperature averaged to 26°C in the morning and 32°C in the afternoon. Sampling during the month of January was at Ocean Road Cancer Research Institute (ORCRI).

There was no rainfall in February 1997 except on the eighth day which amounting to 0.3 mm^3 and the temperature averaged to 24°C in the morning and 32°C in the afternoon. At the Tanzania Oxygen Limited (TOL) sampling center Ca is among the raw material used in the factory and therefore influences the aerosol content of this element. For the same station, Fe and Mn which are associated as natural composition of soil and are introduced to the atmosphere by soil erosion and human activities (Parekh and Husain, 1981). The aerosol amounts in DIA could mainly originate from vegetation, aeroplanes and vehicles. The elements of Cu, Zn, Pb and Br are mainly related to fine particles emitted by anthropogenic activities. These originated from industrial activities and transport (Pb and Br are common in all and are result of fuel effluents) and their contributions to the atmosphere seem to be higher than that produced by natural sources (Nriagu, 1979; Pacyna, 1986). Although many times the amount of the fine particles depends very much on the wind direction, the traffic intensity and how close the sampling site is from the bare soil.

The measured concentrations of heavy metals were implicated to road, air and sea traffic. The leaded gasoline is the main cause of Pb and Br (Nriagu, 1990, Metternich *et al.*1981; TIPPER, 1999). On the question of levels of other elements (Li and Winchester, 1990; Thurston and Spengler, 1985; Infante *et al.* 1990; Parekh, 1990; Maenhaut *et al.* 1981; El-Shobokshy *et al.* 1990; Abu-Hilal and Badran 1990; Lee, 1990; Leland *et al.* 1987) did aerosol research and their conclusions were based on the temporal evolution of the anthropogenic components in the atmosphere and found abundance in elements such as Si, S, Cl, K, and Ca. Measures for planting trees and grasses to cover the soil as well as using irrigation to water the soil may change the aerosol contents especially that result from natural emissions such as erosions and drying vegetation. This is so because the analysis showed a good linear correlation between Mn and Fe, indicating that anthropogenic Mn and Fe were coming from the soil rich in the two elements. Sweeping the tarmac roads may reduce elements such as Ca, K, Fe and Mn, which show high levels of inhalable fine particles that could easily be picked by moving wind and introduced to the atmosphere.

In future when a number of impactors together with their meteorological facilities are simultaneously placed in different stations, air mass trajectories would be used to interpret the observed aerosol concentration in terms of atmospheric transport regionally or internationally. A striking resemblance is seen in many of the features of the time variability patterns at different sampling stations in all periods between August 1996 and September 1996 and December 1997 to May 1997. The different sites show concentrations, which are initially low and later peak up to higher values. This is due to air mass trajectories originating from certain parts with high concentration sources. The Br and Pb elements resulting from burning fuel are shown in Figure 14 and Figure 15 for minimum and maximum levels. The Br and Pb form a similar pattern with values of Pb being higher than that of Br and therefore making the ratio of the two constant.

Figure 14: Variation of the minimum Br and Pb levels between August 1996 and May 1997

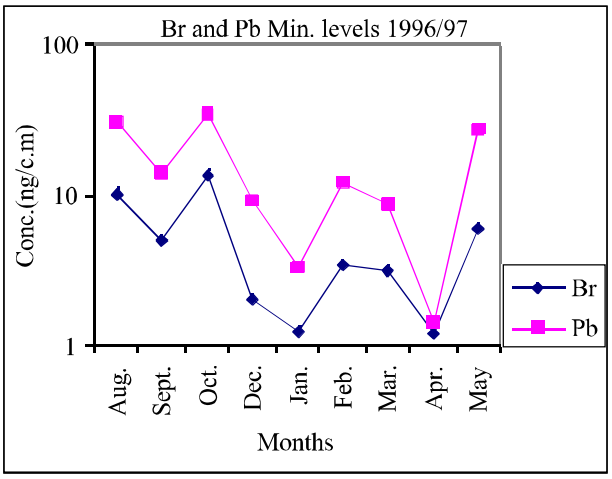
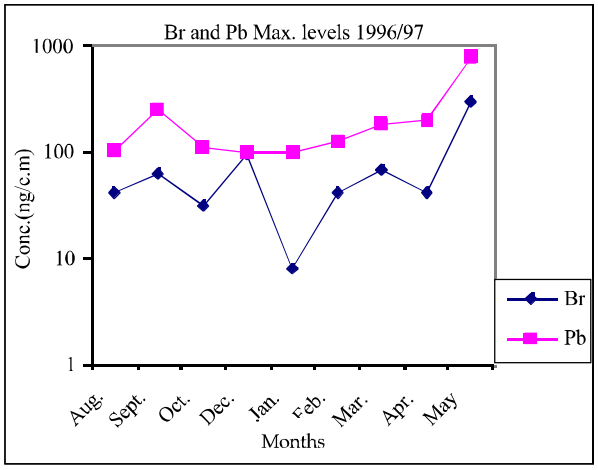


Figure 15: Variation of the Maximum Br and Pb levels between August 1996 and May 1997



The Br and Pb composition normally originate from the addition of the lead bromide compound to the automotive fuel to facilitate the ignition of the engine. This constitutes to what is known as the ethyl ratio of Br: Pb concentration. The ratio which has a fixed value of 0.386 from the added compound (Oblad, 1986; Oblad and Selin, 1985; Harrison and Sturges 1983; El_Shobokshy *et al.*, 1990; Parekh and Hussein, 1981) and therefore confirmation of the source when the ratio is checked. When individual values for different stations are compared, roughness and the meteorological conditions sometimes affect this ratio. In our case, the ratio varied between 0.200 and 0.400. According to earlier established results (Oblad 1986; El-Shobokshy *et al.*,1990; Koleleni, 1998; Alves *et al.*, 1998) for the road cases lead airborne emissions agglomerate rapidly into heavier particles and most tend to settle near their point of emissions, usually along highways and streets. It is also noted that except for TOL and DIA stations, ORCRI has values of Br slightly higher than the rest of stations at lower levels. The ORCRI is right at the beach of Indian Ocean and therefore influence of the sea bromide salts could be another contributing factor.

Conclusion

The combination of the dichotomous impactor for sample collection and the EDXRF technique for sample analysis has made the aerosol studies possible for determination of daily values of K, Ca, Ti, Mn, Fe, Cu, Zn, Se, Sr, Br and Pb. The data obtained have been compared to the minimum and maximum values of these elements for months of August, September, October and December 1996, January, February, March and May 1997. The values obtained in Dar es Salaam were campared with literature values for Kinshasa and Butare. It's absolutely incomparable because of the different conditions of the environments of the three cities but still it gives a picture of the levels one can expect from the different cities. The variation in composition is affected by seasons as well as change of polluting sources like human activities on dry soil and vegetation, which constitute to high aerosol contents. In the month of December 1996 there were light rain showers, which contributed to both settling down of the aerosol from the atmosphere to the ground. The rain also facilitated the growth of vegetation, which in a way reduces aerosol from the topsoil.

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