Review Article: Transportation Control Measures for Air Pollution Reduction in Greater Cairo

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Abstract

Economic growth and urban development is normally associated with pressing need for transport. When public transport cannot support such development an increased demand on private cars is usually the result.

The fossil fuels related pollution has been recently aggravated by the rapid development and urbanization. Tailpipe emissions usually include hydrocarbons (HC) (totally/partly burned fuel), NOx (reaction of air nitrogen with oxygen in the high pressure conditions of the engines to give Nitrogen Oxides), carbon monoxide (CO) and carbon dioxide (CO_2). Traffic–related primary PM emissions may also include elemental carbon (EC), organic compounds (OC), and re-suspended dust and heavy metals from braking and general vehicles wearing processes

The stages through which automobile emissions can be controlled may be : pre-combustion stage in which fuel quality can be optimized, combustion stage where engines could be modified, and post-combustion stage where exhaust could be catalytically converted to more benign constituents. Policies and regulations can thus be directed toward any of these stages and can aim at either producers or dealers. Non-technical ways such as behavioral adaptations in the mode of transport and frequency of cars maintenance can also be applied. Moreover, governments can enforce vehicle emission control policies such as: 1- Phasing out leaded gasoline which was proven effective in reducing lead emissions, 2- Adoption of hydrogen fuel cell vehicles as an alternative to gasoline fueled ones was also suggested to reduce major pollutants and greenhouse gases emissions ,3- Compressed natural gas (CNG) engines emit significantly lower levels of CO, TSP, NOx and SO_2,4- Liquefied petroleum gas (LPG) usage in taxis and buses instead of diesel was also found to substantially reduce the emissions of NOx and respirable suspended particulates (RSPs) .So, there is a pressing need to promote CNG, LNG, and other clean alternative fuels used in public transport, and to promote the use of clean energy vehicles like the hybrid cars through preferential policies.

Keywords

Transportation, Control Measures, Air Pollution Reduction, Greater Cairo

Introduction

The continuous elevation in the concentrations of air pollutants in the last 100 years has become one of the major environmental challenges facing mankind. The rapid increase in the population growth, traffic density, urbanization and industrialization processes, have led to an uncontrolled growth and increased emissions of various air pollutants. This has, in turn, and in addition to the vicinity of residential areas to motorways and industrial premises, enhanced the possible adverse health consequences due the exposure to several possible pollutants and significantly increased the events of hospitalization due to asthma and lung functions deterioration (Holguin et al., 2007; Wilhelm et al., 2008; Chang et al., 2009; Rosenlund et al., 2009).

The increased global motorization and urbanization has led to a sharp rise in traffic density and fossil fuels demand. Driven by their concerns about the impact on the environment by fuels combustion, researchers have engaged in assessing the resulting implications on public health (Rodrigues et al., 2012). Traffic-related emissions affect not only air quality but also soil and vegetation in the vicinity of motorways. Ganatsas et al. (2011) found that seeds sampled around a city ring-road, up to 30 m away, were unable to germinate. Vehicular emissions contribute largely to the hazardous air pollutants (HAPs) such as mono- and polycyclic aromatic hydrocarbons (PAHs) and toxic metals (Nesamania et al., 2007; Chen et al., 2013; Batterman et al., 2015; Liu et al., 2015).

A serious implementation of measures that can reduce pollution levels, with long term plans, is thus indispensable. Developed and developing countries likewise have been hardly working to improve air quality through e.g. continuous air quality monitoring, usage of clean fuels and applying cleaner technologies in industry and transport. However, the negative impact of air pollutants is usually more severe in the developing countries for they have no choice but to prioritize economic and industrial development over environmental welfare. Nonetheless, responsible governmental administrations, within allowed resources, continuously develop management strategies to reduce traffic pollution by either reducing the number of running automobiles or mitigating the emissions through environment-friendly fuels or technologies (Colvile et al., 2001; Querol et al., 2001; Ghose et al., 2004; Feng and Liao, 2016).

The present review describes the transportation control measures aiming for reducing air pollution in Greater Cairo.

Transportation pollution control and policy strategies

Economic growth and urban development is normally associated with pressing need for transport. When public transport cannot support such development an increased demand on private cars is usually the result. It is thus essential to develop pollution control technologies (Wu et al., 2011; Feng and Liao, 2016). Economic regulations and reducing fossil fuel consumption through taxing and pricing is also required.

Kathuria (2002) discussed stages through which automobile emissions can be controlled. These are, pre-combustion stage in which fuel quality can be optimized, combustion stage where engines could be modified, and post-combustion stage where exhaust could be catalytically converted to more benign constituents. Policies and regulations can thus be directed toward any of these stages and can aim at either producers or dealers. Non-technical ways such as behavioral adaptations in the mode of transport and frequency of cars maintenance can also be applied.

Moreover, governments can enforce vehicle emission control policies such as phasing out leaded gasoline which was proven effective in reducing lead emissions (Rizkand Khoder, 2001; Hassan,2012; Zhang et al., 2012). Traffic signal coordination can also reduce vehicle pollution because busy traffic increases emissions for it reduces speed in comparison to free flow (Andre and Hammarstrom, 2000). However, it should be noted that applying signal coordination does reduce HC and CO emissions, while increases NOx (Rakha et al., 2000).

Adoption of hydrogen fuel cell vehicles as an alternative to gasoline fueled ones was also suggested to reduce major pollutants and greenhouse gases emissions (Stephens-Romero et al., 2009). Compressed natural gas (CNG) engines emit significantly lower levels of CO, TSP, NOx and SO_2 (Goyal and Sidhartha, 2003; Engerer and Horn, 2010; Suthawaree et al, 2012). Liquefied petroleum gas (LPG) usage in taxis and buses instead of diesel was also found to substantially reduce the emissions of NOx and respirable suspended particulates (RSPs) (Ning et al, 2012).

Catalytic converters may also improve the quality of both ambient and roadside air. Catalytic converters chemically transform exhaust gases into CO_2 and H_2O (Oidong et al., 2005). There are two types of catalytic converters:

a- Two-way converters which burn HC and CO molecules with the assistance of a metal catalyst to carnon dioxide anad water molecules.

b- Three-way converters which use two catalytic steps; reduction and oxidation. They are normally fitted with oxygen storage control system to use for the afromentioned conversion (Oidong et al., 2005).

Drivers' attitude, gender, experience, age and physical condition also affect emissions. For example, aggressive driving usually increases emissions (Vlieger et al., 2000) and it was found that most drivers spend 2% of their driving time in aggressive mode which alone accounts for about 40% of total emissions (Samuel et al., 2002).

Fuel quality is also a major factor in vehicle emissions levels (Hao et al., 2006; ICCT, 2006). Thus it is necessary to set fuel quality standards in bar with the emission standards for new vehicles.

To summarize, there is a pressing need to promote CNG, LNG, and other clean alternative fuels used in public transport, and to promote the use of clean energy vehicles like the hybrid cars through preferential policies.

Air pollution level in Greater Cairo

Egypt faces huge challenges in regard to its environmental and economic development. It is still lagging behind on environmental protection. However, the Egyptian Environmental Affairs Agency (EEAA) has made good achievements in terms of combating air pollution. Energy consumption, especially fossil fuel consumption, is the main source of anthropogenic air pollution emissions in Egyptian cities. Sources of air pollution in Egypt are several including: industrial pollution: cement, bricks, iron and steel, rice cultivation, oil refineries, power stations, sand-laden weather, chronic black cloud phenomenon and motor vehicles. Transport is widely recognised to be a signicant and increasing source of air pollution in Greater Cairo.

Environmental action in Egypt encounters numerous challenges that made it imperative to apply traditional and non-traditional techniques to bridge the gap between the quality of life Egyptians aspire to and that which they really get as a result of ongoing pressures affecting their environment. Greater Cairo region (Cairo, Giza &Shoubra El-Khiema cities) hosts the largest share of population, economy, industry, and human resources in Egypt. With a population of about 20.496222 million in 2012(CAPMAS,2012), and a fast urbanization rate. About 52% of the industries and about 40% of electrical power stations in Egypt are found in Greater Cairo, besides more than 2.992289 million vehicles are running in the streets of the Greater city (CAPMAS,2012). Consequently, it is considered one of the most polluted megacities in the world. Some vehicles are using compressed natural gas (CNG), gasoline and diesel. Greater Cairo is one of the largest megacities in the world (Abou-Ali and Thomas, 2011). With such a large population, the need to have an efficient and reliable public transport system is unequivocal. The reality is that traffic volumes and its problems are increasing and will continue to increase as population and economy grows. In Greater Cairo, about two-thirds of all motorized trips are made by public transport (mostly taxicabs and minibuses) (Abou-Ali and Thomas, 2011). Although the current urban transport system is highly diversified in Greater Cairo in terms of supply and related infrastructure and facilities, it still requires significant improvements to reduce the existing level of aggravated traffic congestion and carbon emissions. Traffic congestion is a severe problem in Greater Cairo with substantial adverse effects on personal travel time, vehicle operating costs, air quality, public health, and business environment operations. The causes of traffic congestion are complex.

Urban air quality of Greater Cairo has been seriously polluted with high concentrations of aerosols and gases. Air pollution in Greater Cairo is influenced by both local emissions and long-range transport from outside. In megacities such as Cairo, vehicle emissions have been one of the major sources of air pollution. The number of motor vehicles in Egypt was 3.8 million in 2006 and reached 6.7 million in

2012 (Figures 1 and 2), of which nearly one half is in Greater Cairo. In 2009, there were about 115,300 registered taxis in Greater Cairo, with 24% and 58% aged respectively 32 and 22 years or more (The World Bank, 2010). The Ministry of State for Environmental Affairs (2009) has estimated that vehicleemissions represent about 26 % of total pollution load for PM_{10} in Greater Cairo, 90 % forCO and 50% for NOx. About 40 %of national transport emissions (13 million ton CO_2-equivalent) are attributed to the Greater Cairo region alone (The World Bank, 2010), which represents about 50 % of all motorized vehicles in Egypt.

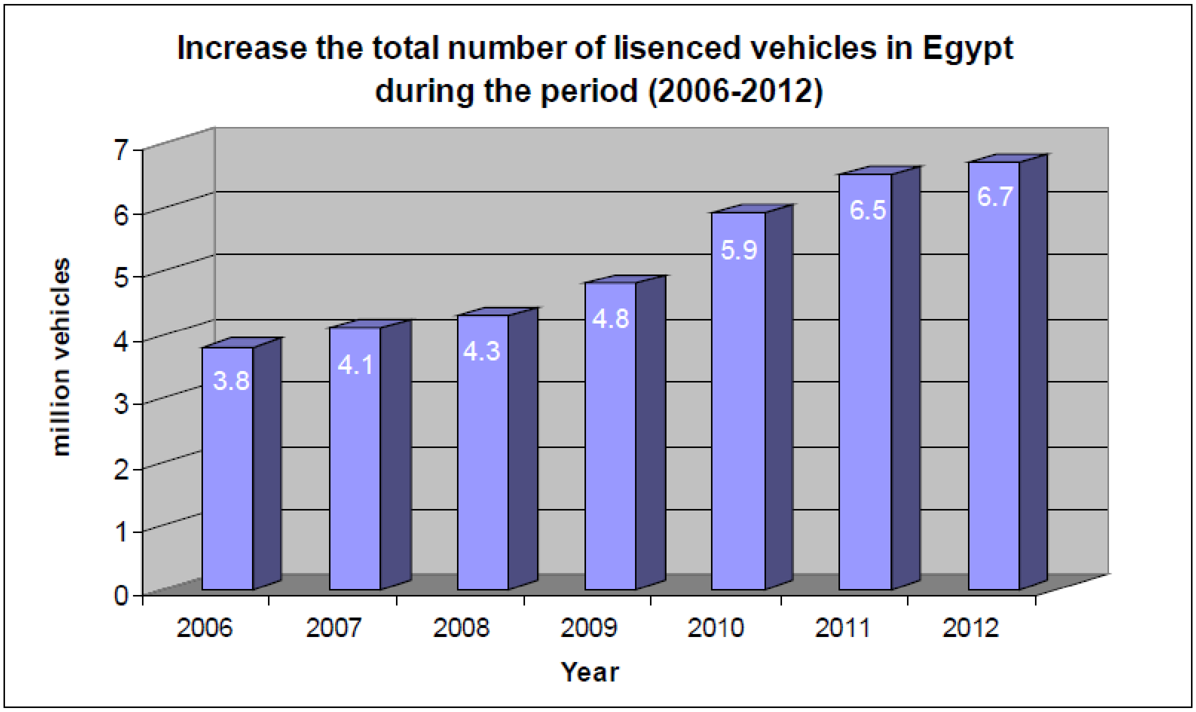

Figure 1: Total increase in licensed vehicles at the national level in Egypt (Source: General Directorate of Traffic, EEAA, 2012).

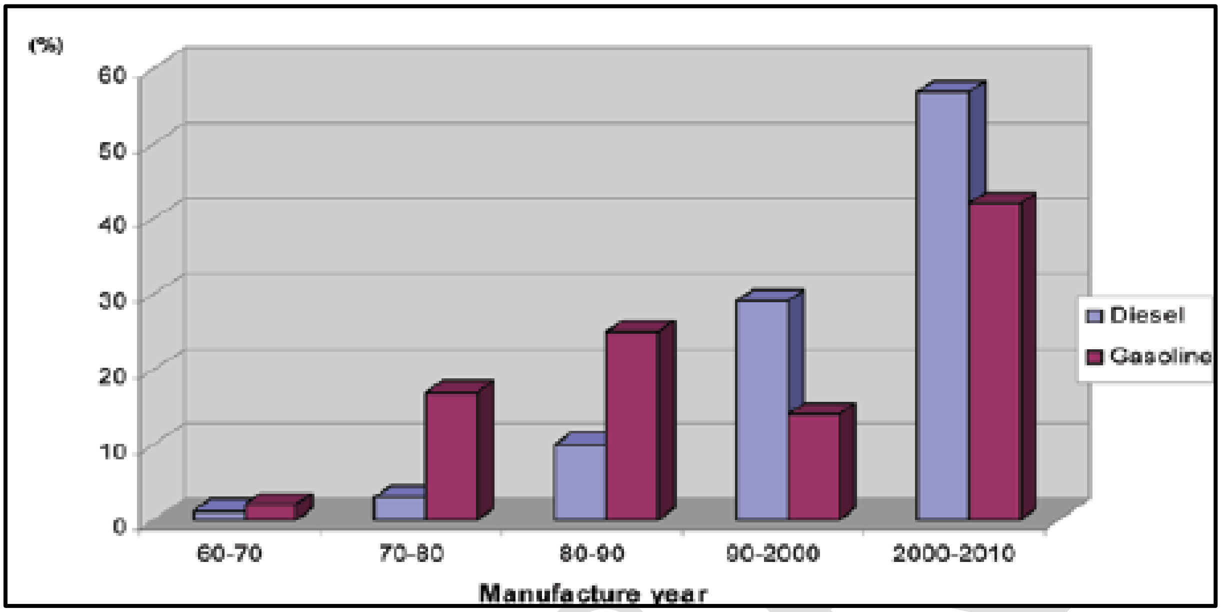

Figure 2: Relative distribution of vehicles on roads in Egypt (Source: General Directorate of Traffic, EEAA, 2010).

Mobile sources are considered one of the most important contributors to Greater Cairo air pollution. Egypt has an average concentration of $SO_2$of around 69 µg/m^3 in compared to the WHO standard of 50 µg/m^3 (Robert, 2001; El Raey, 2006). The annual average concentrations of particulate matter less than 10 micron (PM_{10}), O_3, NO_2, SO_2 and lead (Pb) in the atmosphere of Greater Cairo are summarized in Figures (3-7). Pb, nickel (Ni) and cadmium (Cd) concentrations in total suspended particulate at Cairo city centre were higher than the Egyptian and WHO air quality standard during 2001- 2002 (Shakour et al., 2006). In 15 May City, a distric of Cairo, the Ni and Cd levels in suspended particulate are higher than the proposed WHO, USEPA and the European Community standards (Hassan, et al., 2013). Greater Cairo has high levels of VOCs compared with many polluted cities in the world (Khoder, 2007). In a study carried out in Haram, Giza (Egypt), Khoder (2009) found that about 41.14% of the daytime hours concentrations in summer exceeded the Egyptian standard (100 ppb) for maximum hourly O_3 concentration, and photochemical smog was formed during the periods represented by the same percentages. Khoder and Hassan (2008) concluded that the TSP mean concentrations on weekdays and weekends exceeded the annual average of the Egyptian Ambient Air Quality Standard (90 µg/m3) (EEAA, 1994). Moreover, the daily concentrations of the total suspended particulate (TSP) on weekdays and on weekends exceeded the Egyptian Ambient Air Quality Standard (230 µg/m3) for 24-h during 100% of the investigated days during the period of study. Dokki area has high level concentrations of PAH compounds compared with many polluted cities in the world (Hassan and Khoder, 2012).

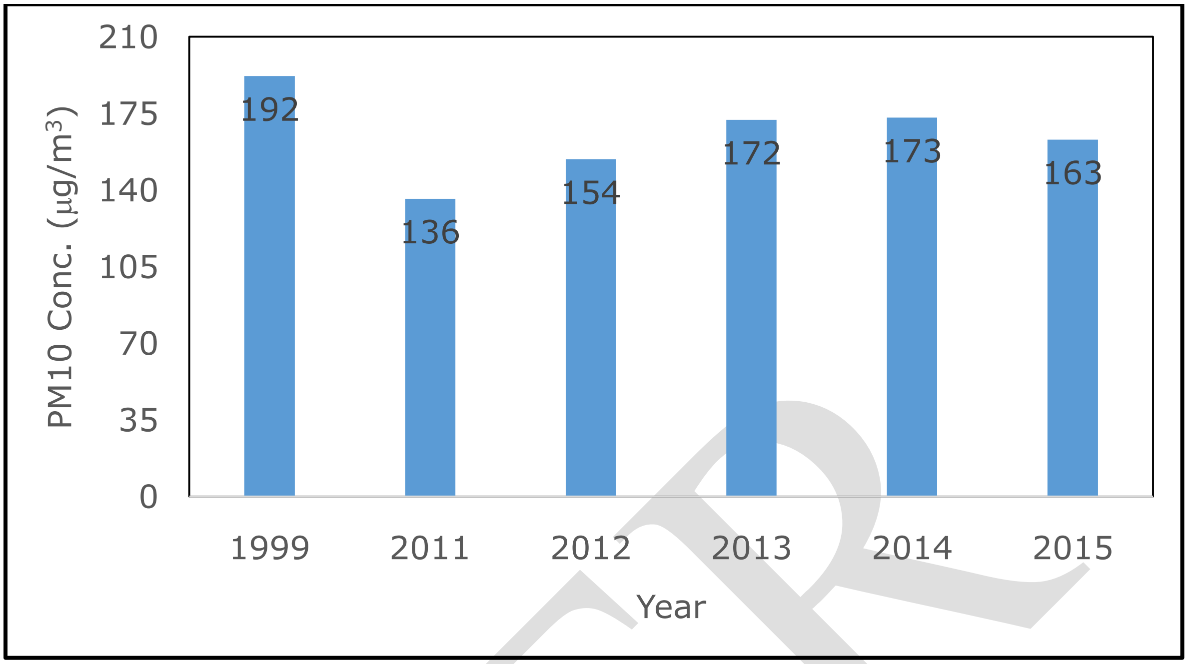

Figure 3: Annual average concentrations of PM_{10} in Egypt during 2011-2015 (Source: EEAA, 2016).

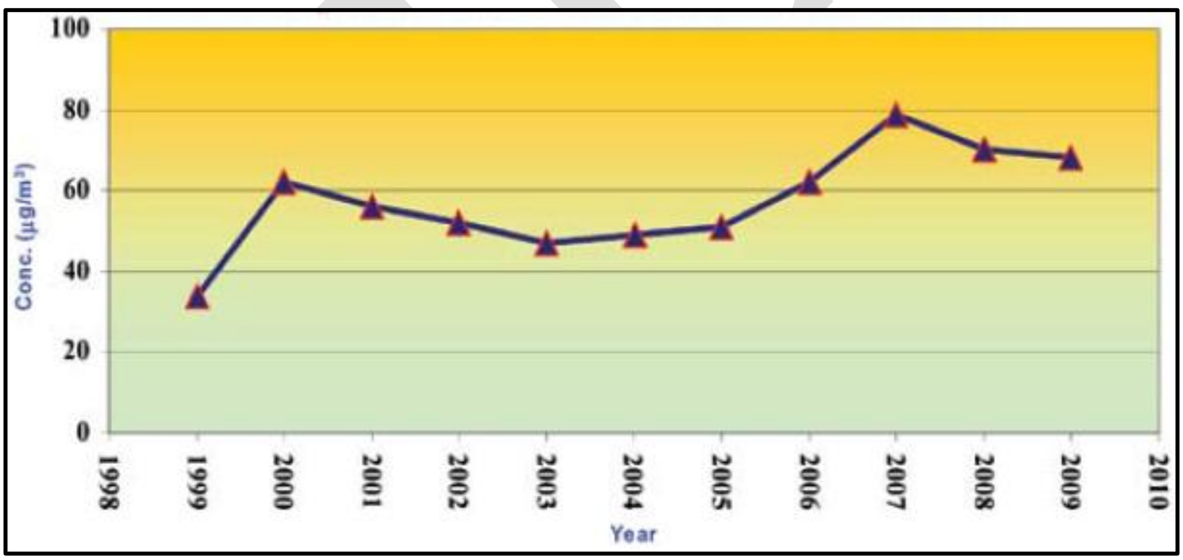

Figure 4: Annual average concentration of O_3 at different areas in Greater Cairo (Source: EEAA, 2010).

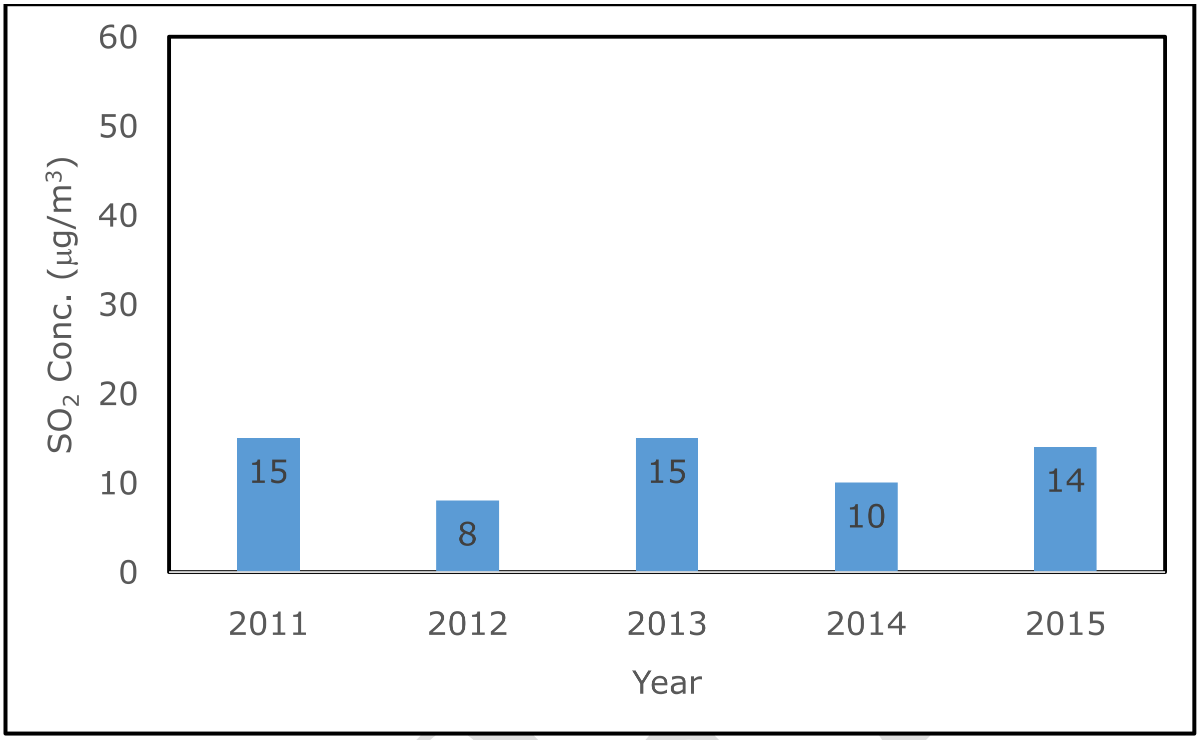

Figure 5: Annual average concentration of SO_2 at different monitored urban areas in Egypt (Source: EEAA, 2016).

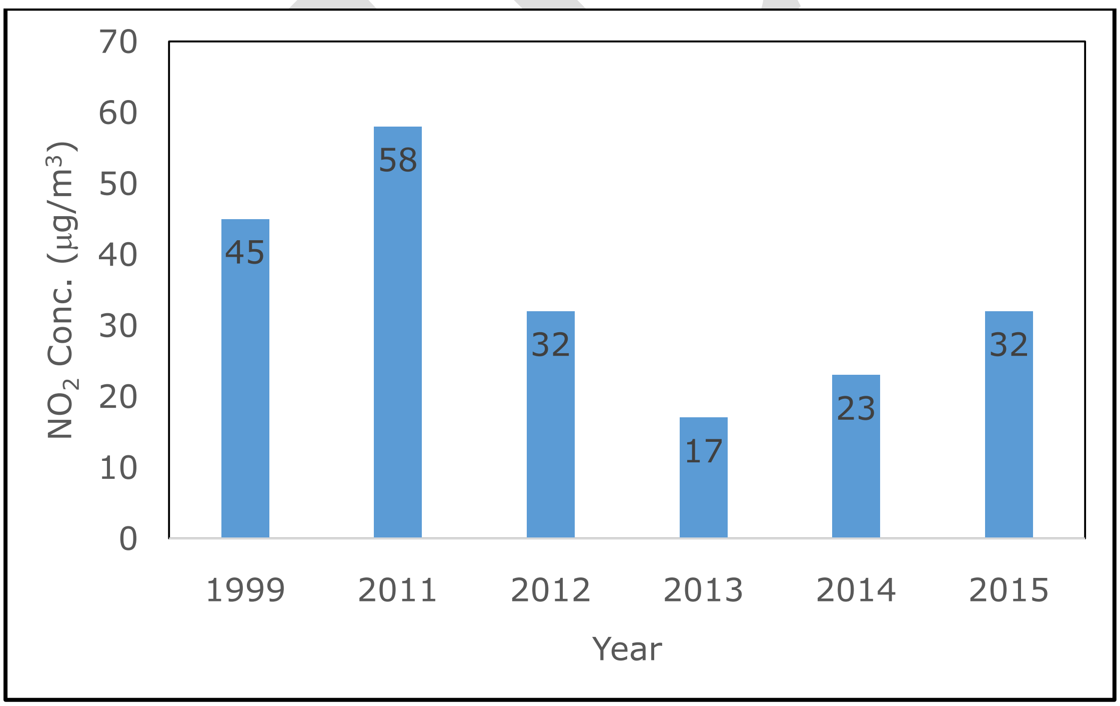

Figure 6: Annual average concentration of NO_2 at different monitored urban areas in Egypt (Source: EEAA, 2016).

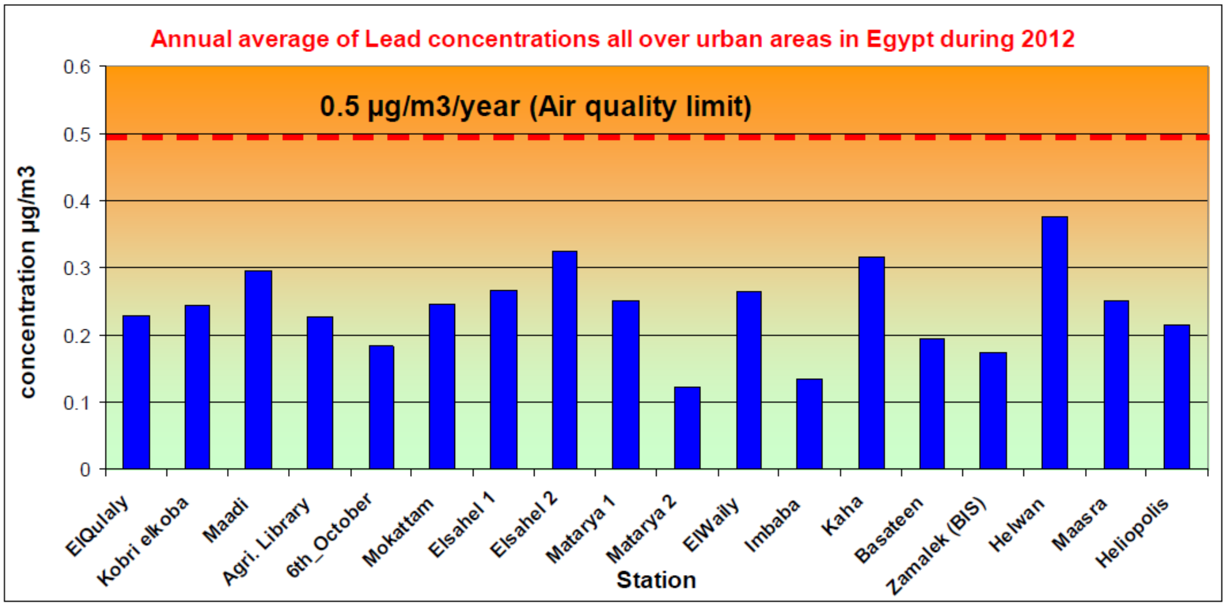

Figure 7: Annual average concentrations of Pb in Greater Cairo from 2000-2009 (Source: EEAA, 2012).

Transportation control measures for air pollution reduction in Greater Cairo

Emission controls in a single city are hardly effective to solve the problem. Joint prevention and control of outskirts air pollution must be taken into consideration. A comprehensive control policy focused on multiple source categories at both the local and outskirts levels is necessary to mitigate the air pollution issue in Greater Cairo. Efforts made by the EEAA to improve air quality concern mainly the cement industry which is an important economic sector of the Egyptian economy, but also agricultural waste management by controlling the bulk burning of rice straw (Abou-Ali and Thomas, 2011).

Regarding vehicle exhaust fumes, the EEAA has embarked on a number of projects to control air pollution resulting from vehicle exhausts such as: banning leaded gasoline, projects to replace old taxis, testing programs for vehicles on road and in license and registration units, promoting natural gas as an alternative to petrol, garage relocation projects as well as protection programs from motorbike exhausts (Abou-Ali and Thomas, 2011).

Existing policies in Egypt

Several programs have been recently applied to deal specifically with motor vehicles pollution through mass public improvement (Abou-Ali and Thomas, 2011).

Converting public sector vehicles to natural gas

In 2004, the EEAA made a survey to determine the public sector that can possibly be converted to natural gas. About 2300 gasoline vehicles were already converted to natural gas. The remaining ones were technically inspected to determine the possibility of conversion.

Replacing old taxis

A pilot project was conducted in 2007 to check the compliance of 35 year old taxis in Greater Cairo and were replaced by natural-gas taxis. This was extended through 2008. Expected emission reduction from this program is about 2.3 million ton of CO_2.

Inspecting vehicle emissions as part of vehicle licensing

Vehicle licensing together with inspection for emission measurement is now applied. By law, all public transport vehicles more than 20 years old are not eligible for licensing unless they pass the emission standard testing.

Inspecting motor vehicles on the road

About 50000 vehicles were inspected for exhaust emissions on the road in 2008, 70% passed. Inspection program of gasoline and diesel vehicles exhaust on the roads during 2005-2009 are summarized in Figures 9-12 according to the manufacturing year.

Inspecting Cairo transport authority buses

Around 4500 buses were tested in 2008, with a pass rate of about 43%. A further inspection of 4000 and 3.700 buses was carried out in 2009 and 2010. As a result, 20% of the buses are yearly retired from service.

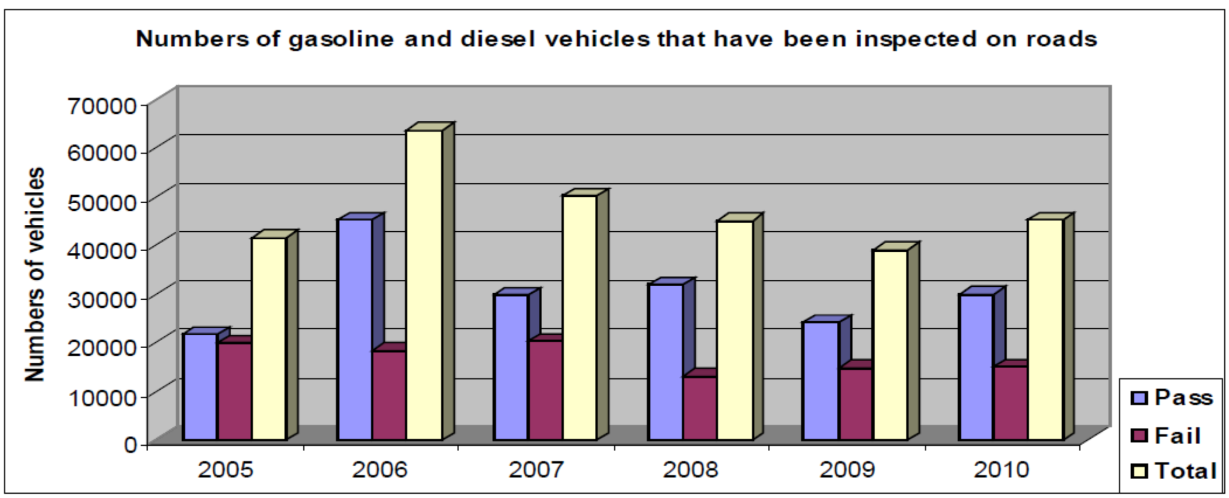

Figure 9: Results of inspection program of gasoline vehicles exhausts on roads (Source: EEAA, 2010).

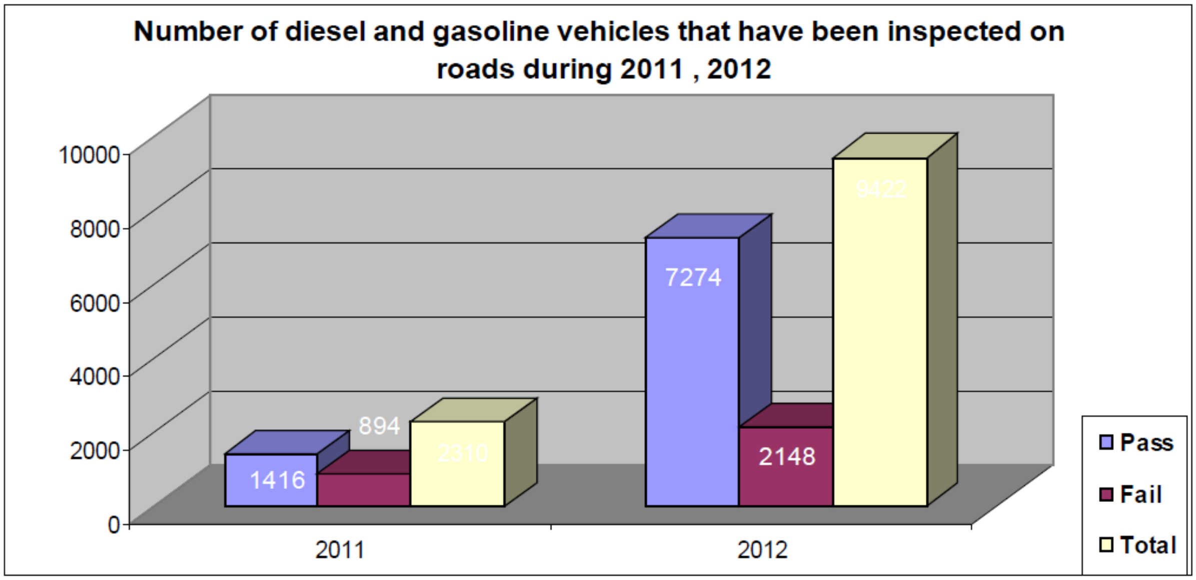

Figure 10: Results of inspection program of diesel vehicles exhausts on roads (Source: EEAA, 2012).

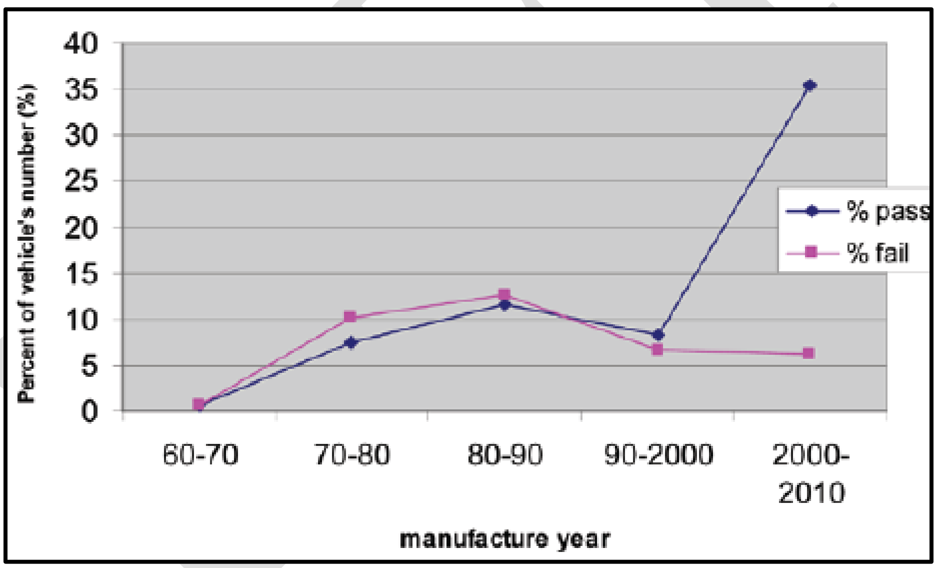

Figure 11: Gasoline vehicles tested on roads (Source: EEAA, 2010).

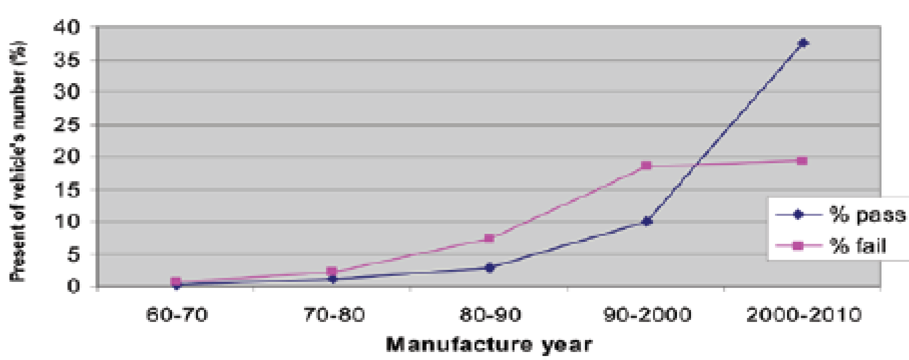

Figure 12: Diesel vehicles tested on roads (Source: EEAA, 2010).

Reducing motorcycle emissions

A program to control the elevated emission rate of hydrocarbons from two-stroke engines was put into action in 2008. With 200.000 motorcycles in Greater Cairo, that emit about 110.000 tons of pollutants annually, it was essential to take action. Moreover, production and import of two-stroke motorcycles was banned in Egypt since 2007.

Extending the existing public transportation system

The Greater Cairo Urban Transport Master Plan (JICA, 2003) represents the government vision to transform public transport. The master plan studies provided a new framework to insure:

- safe and environment-friendly transport system with low carbon footprint.
- economically effective transport
- fair mobility for pedsratins.

The Greater Cairo Urban Transport Master Plan has also promoted an integrated transport network including rapid transits e.g. suburban, underground and express-railways. The government has already completed 3 subway metro lines and the 4^{th} is planned to be inaugurated in 2017. These combined efforts are expected to reduce emissions by 17.7 and 19.5 million ton CO_2-equivalent by 2019.

Tariff of vehicle licensing

In May 2008, the licensing tariff scheme was revised and was considerably increased. The new tariffs became two to ten times higher the old tariffs depending on the vehicle registry, type and capacity.

Conclusion

Although the Egyptian government sequential put some measures to reduce and control the emission of air pollutants from transport such as continuous air quality monitoring, air quality standard, emission standards, use of unleaded petrol, periodic inspection of vehicle emissions during the license as well as on roads, replace old taxis and use of clean fuel such as natural gas, the improvement of air pollution in Greater Cairo is still a complex problem but not difficult to be solved. Therefore, more transportation control measures and economic instruments for air pollution reduction like those applied in many megacities must be enforced for solution or mitigation of the air pollution problem in Greater Cairo.These may include:

- Long-term emission prevention plans.
- Legalising more strict standards.
- Independent fuel testing labs for fuel quality check is a must.

- Encouraging clean vehicle technologies
- Automatic inspection and certification for commercial vehicles.
- Banning the use of poor condition vehicles.
- More frequent on the road inspection to control primary emissions.
- Completing the replacement of old taxis with mdern vehicles using cleaner fuel.
- Expansion of CNG stations.
- Eight years old buses should not be allowed unless they use CNG or other clean fuels.
- Desulphurisation of petrol to minimize sulfur emmisions.
- Allowing only 1% benzene petrol.
- Improving traffic flow by restricting trucks to off-peak periods.
- Promoting non-fuel vehicles for individuals use.
- Encouraging voluntary retirement of old vehicles.
- Introducing emission tax for all types of vehicles.
- Increasing vehicle registration and parking fees.
- Alternative modes such as rail and short-sea shipping should be developed.
- Improving motorways.
- Diverting traffic from cities to suburbns by regional ring roads.
- Reducing or lift ticket pricies for down town destinations.
- Promoting fuel efficiency tactices for tansport and industries.
- Reduce sulfur content of diesel gasoline to <500 ppm
- Operational catalytic converters shoud be attched to all new gasoline powered vehicles.

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