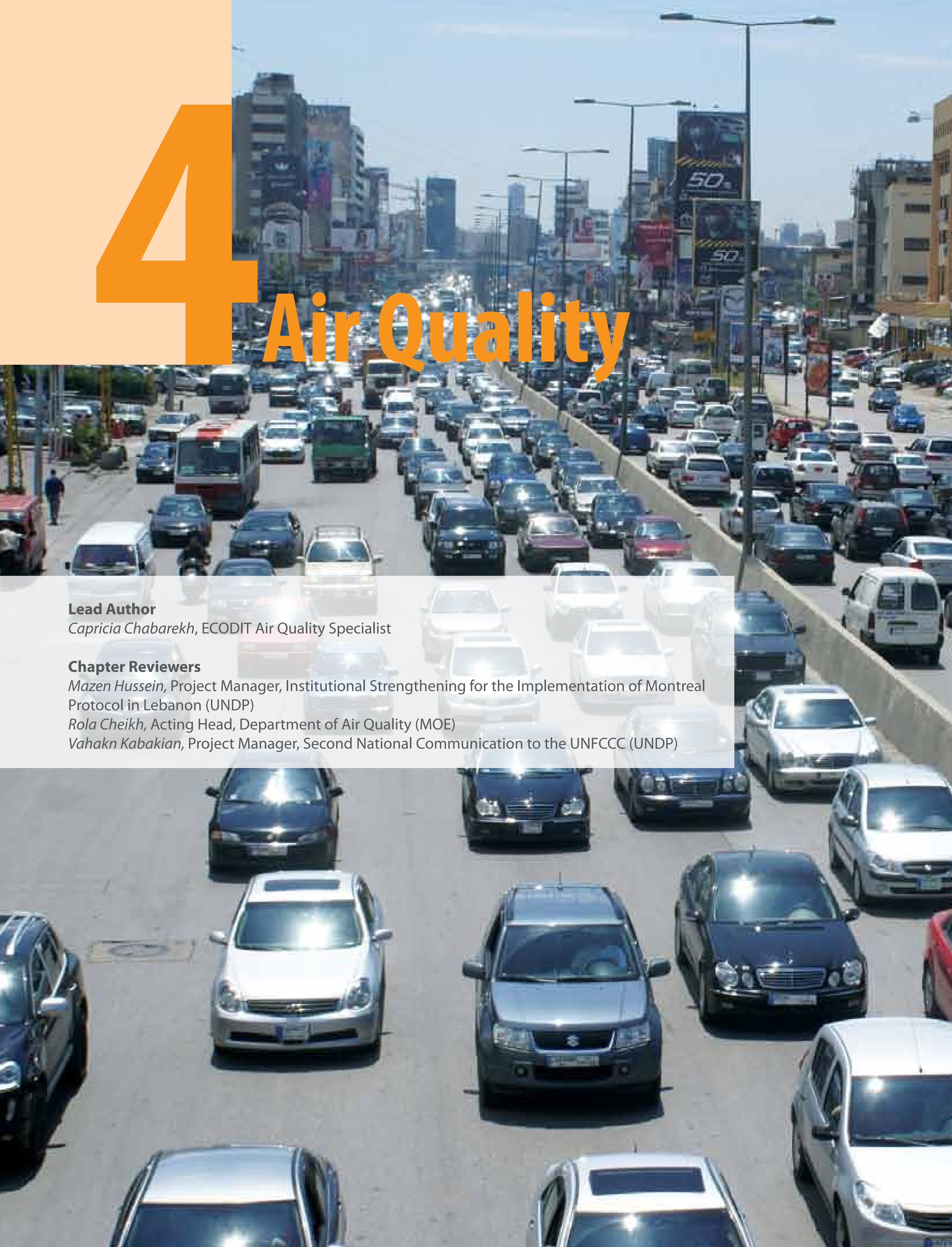

4 Air Quality

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ABBREVIATIONS & ACRONYMS

AQRU	Air Quality Research Unit
AUB	American University of Beirut
CAS	Central Administration of Statistics
CDM	Clean Development Mechanism
CNRS	National Council for Scientific Research
EIA	Environmental Impact Assessment
EPA	Environment Protection Agency
GBA	Greater Beirut Area
GHGs	Greenhouse Gases
GOL	Government of Lebanon
HEFF	High Emission Factor Fuel
HFO	Heavy Fuel Oil
LCPC	Lebanese Cleaner Production Center
MOE	Ministry of Environment
MOEW	Ministry of Energy and Water
MOF	Ministry of Finance
MOI	Ministry of Industry
MOIM	Ministry of Interior and Municipalities
MOPH	Ministry of Public Health
MOPWT	Ministry of Public Works and Transport
NA	Not Available
NAAQS	National Ambient Air Quality Standards
NEAP	National Environmental Action Plan
NOU	National Ozone Unit
ODS	Ozone Depleting Substances
PCBs	Polychlorinated Biphenyls
PFCs	Per-fluorocarbons
POPs	Persistent Organic Pollutants
RE	Renewable Energy
SEEL	Supporting the Judiciary System in the Enforcement of Environmental Legislation
SELDAS	Strengthening/State of the Environmental Legislation Development and Application System in Lebanon
TEDO	Tripoli Environment and Development Observatory
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USJ	Université Saint Joseph
WHO	World Health Organization

SYMBOLS

NH_3	Ammonia
$(NH_4)_2SO_4$; $(NH_4)HSO_4$,	Ammonium sulfates; Sulfate particulates
$(NH_4)NO_3$	Ammonium Nitrate; Nitrate particulates
µg/m^3	Microgram per cubic meter (Concentration Unit)
$Al_2Si_2O_5(OH)_4$	Kaolinite
As	Arsenic
C_6H_6	Benzene
Ca	Calcium
$CaCO_3$	Calcium carbonate
Cd	Cadmium
CFCs	Chlorofluorocarbons
$CH_3C(O)OONO_2$	Peroxyacetyl Nitrate (PAN)
CH_4	Methane
Cl	Chlorine
Cl^-	Chloride
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_3^{2-}	Carbonate ions
CO_x (CO & CO_2)	Carbon Oxides
Cr	Chromium
Cu	Copper
Fe	Iron
H_2S	Hydrogen Sulfide
H_2SO_4	Sulfuric acid
HBr	Hydrobromic Acid
HC	Hydrocarbons
HCFCs	Hydrochlorofluorocarbons
HCl	Hydrochloric Acid
HCN	Hydrogen Cyanide
HNO_3	Nitric acid
HO_x (HO & HO_2)	Hydrogen Oxides
K	Potassium
K_2S	Potassium Sulfide
Mn	Manganese
N_2	Nitrogen
Na	Sodium
NH_4^+	Ammonium
Ni	Nickel
NMVOC	Non Methane Volatile Organic Compounds
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NO_3^-	Nitrate
NO_x(NO & NO_2)	Nitrogen Oxides
O_3	Ozone
PAHs	Polynuclear Aromatic Hydrocarbons
Pb	Lead
$PM_{0.1}$	Particulate Matter with an aerodynamic diameter (ad) of 0.1 µm or less
PM_1	Particulate Matter with an aerodynamic diameter (ad) of 1 µm or less
PM_{10}	Particulate Matter with an aerodynamic diameter (ad) of 10 µm or less
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter (ad) of 2.5 µm or less
ppb	part per billion = 10^{-9} mol
ppm	part per million = 10^{-6} mol
RO_x (RO & RO_2)	Organic Radicals
Si	Silica
SiO_2	Quartz
SO	Sulfur Monoxide
SO_2	Sulfur Dioxide
SO_4^{2-}	Sulfate
SO_x (SO & SO_2)	Sulfur Oxides
TEQ	Toxic Equivalent
Ti	Titanium
TSP	Total Suspended Particles
V	Vanadium
VOC	Volatile Organic Compounds
Zn	Zinc

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The degradation of air quality in Lebanon, estimated at $170 million per year (WB, 2004), is a growing environmental concern (see Table 4.1). While urban air quality in some industrialized countries has improved in recent decades, in Lebanon the problem persists and has become a major source of concern to public health. Air pollution (see Box 4.1) in Lebanon is affecting millions of people living in mostly urban and peri-urban areas where smog, small particles, and toxic pollutants pose serious health concerns. In addition to respiratory problems, long-term exposure to air pollution and to certain pollutants can cause cancer and damage to the immune, neurological and reproductive systems. Many recent epidemiological studies have consistently shown positive associations between levels of exposure to air pollution and health outcomes.

Box 4.1 What is "Air Pollution"?

Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere (WHO, 2011). It occurs when various gases, droplets, and particles are found in the atmosphere beyond their normal concentrations and/or introduced to the atmosphere by anthropogenic sources or natural phenomena.

Table 4.1 Annual costs of air quality degradation

Ambient/ Indoor air pollution	$M per year	% of GDP	Damages
Urban Air pollution-Lead	28-40	0.20	Impaired neurological development in children
Urban Air Pollution-PM_{10}	26	0.56	Respiratory illnesses including chronic bronchitis, emergency room visits, respiratory hospital visits, restricted activities, etc.
Indoor Air Pollution	10-46	0.18	Respiratory illnesses
Total Costs from Outdoor/ Indoor Air Pollution & Loss of Quality of Life	112-225	0.02	Respiratory illnesses, hospital visits, general discomfort, etc.
Average Cost of Air Pollution	**170**	**1.02**	

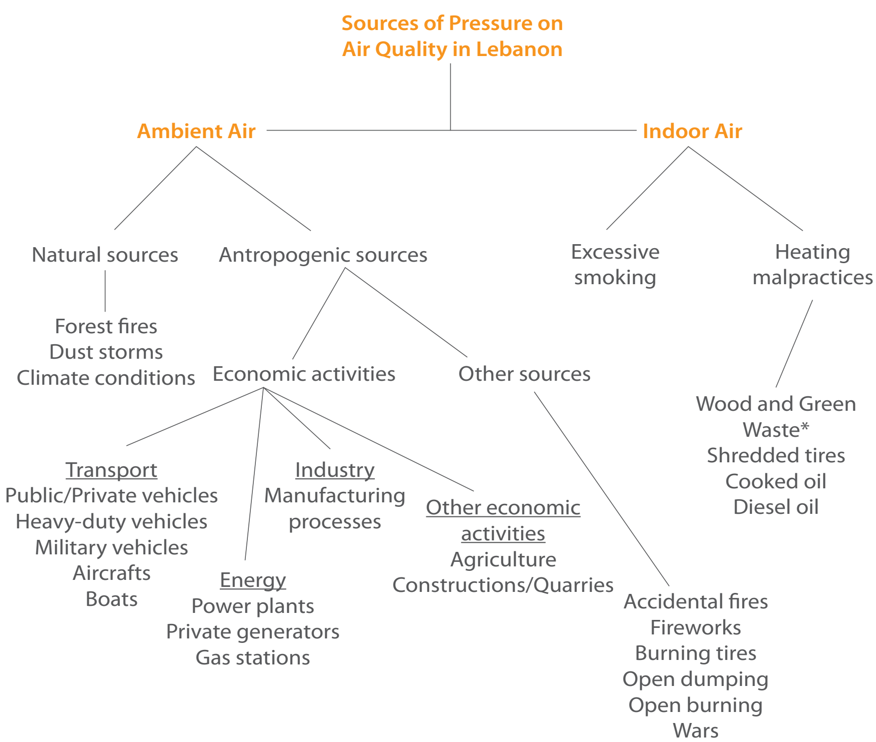
Source: WB, 2004

This chapter describes the drivers of change affecting ambient and indoor air quality (transport, energy, industry, smoking, etc.) in the country, the current situation of air pollution, major national responses to air pollution issues and air quality improvement opportunities in the future.

4.1 DRIVING FORCES

Many forces, acting together or in isolation, are impacting air quality in Lebanon. These forces may affect ambient and/or indoor air, and may stem from natural phenomena or anthropogenic activities. *See summary of driving forces in Figure 4.1.*

Figure 4.1 Driving forces affecting air quality in Lebanon



*Green wastes include grass cuttings, leaves, shrubs and tree trimmings

4.1.1 Ambient Air

Ambient air is affected by anthropogenic activities such as driving cars, burning oil and fossil fuels, industrial and manufacturing processes as well as agriculture, quarries, construction activities, open burning and many other operations. Ambient air is also affected by natural phenomena including forest fires, dust storms and climatic conditions. Everyday activities such as cleaning, painting, degreasing also release pollutants into the air we breathe- *see air pollutants classification in Box 4.2.*

Box 4.2 An overview of air pollutants

Air pollutants are divided into two categories (gas and particles) and two sub-categories (primary and secondary). Primary pollutants are those emitted directly from the source; secondary pollutants are primary pollutants that undergo chemical and photochemical reactions in the atmosphere. The main air pollutants are listed below:

Primary	*Secondary*	*Can be Primary & Secondary*
	Gaseous pollutants	
Nitrogen Oxides NOx (NO & NO_2), Sulfur Oxides SOx (SO & SO_2), Carbon Oxides COx (CO & CO_2) Hydrocarbons (HC) Volatile Organic Compounds (VOC) Chlorofluorocarbons (CFCs) Hydro-chlorofluorocarbons (HCFCs) Persistent Organic Pollutants (POPs)	Nitrogen Dioxide (NO_2) Ground level Ozone (O_3) Peroxyacetyl Nitrate (PAN) ($CH_3C(O)OONO_2$)	Sulfuric acid (H_2SO_4) Nitric acid (HNO_3) Others
	Aerosol, Particles, Particulates or Particulate Matter (PM)	
PM_{10} (with an aerodynamic diameter ad of 10 µm or less; ad≤10 µm; measured by mass - µg/m³) are primary coarse particles usually formed by erosion of soils a/o adsorption of several small particles to form an aggregate.	$PM_{2.5}$ (ad≤2.5 µm; measured by mass -µg/m³), PM_1 (ad≤1 µm; measured by number –particle/m³) and $PM_{0.1}$ (ad≤0.1 µm; measured by number –particle/m³) are secondary pollutants resulting from a conversion of gas/particle	PM_{10}, $PM_{2.5}$

Source: Compiled by ECODIT for the 2010 SOER

The chemical composition of particles (aerosols) is complex. Atmospheric aerosols constitute a mix of chemical constituents combining mineral and organic elements, including acids (nitrates and sulfates), soil or dust elements, heavy metals and other organic components (HC).

4.1.1.1 Anthropogenic Sources

The most significant sources of pollution from economic activities are the transport, energy and industry sectors.

Transport Sector

Transport involves the combustion of fossil fuels to produce energy translated into motion. In Lebanon, the transport sector (including land, air and maritime) is the main source of air pollution in the country (MOE/EU/NEAP, 2005u). It is one of the largest contributor to urban air quality deterioration accounting for 59 percent of the national NO_x emissions in 2005 (MOE/GEF/UNDP, 2010 unpublished data)—*see Figure 4.4*. The combustion of fossil fuels by the transport sector release pollutants that cause damage to (1) human health by inhalation and congestion of pollutants, (2) agriculture and sensitive ecosystems by: dry deposition of Particulate Matter (PM) and heavy metals on leaves (see example of contamination of agricultural crops in Box 4.6), wet deposition of pollutants due to acid rain, appearance of necrotic and chlorotic spots on leaves caused by tropospheric O_3, acceleration of leaf senescence, depression of photosynthetic mechanism, etc. Pollution is primarily the result of the **incomplete** combustion (non-uniform oxygen supply within the combustion chamber and lower flame temperature leads to incomplete combustion) of fuel[1] resulting in emissions of unburned HC and other pollutants including various types of particulate matter (PM_{10}, $PM_{2.5}$, PM_1, $PM_{0.1}$), soot and a variety of gases including CO_x, SO_x and NO_x. These pollutants are dispersed into the atmosphere subject to prevailing meteorological conditions where they undergo multiple chemical and photochemical reactions to form secondary pollutants including tropospheric ozone O_3 and sulphate/nitrate particulates $(NH_4)_2SO_4$ / $(NH_4)NO_3$.

[1]Including Benzene, Diesel, Kerosene and other petroleum products

The Lebanese population is excessively dependent on private cars for daily commuting. Sources estimate that the total number of vehicles in Lebanon is about 1.2 million (MOE/EU/NEAP, 2005u), equivalent to one vehicle to every four people. In reality, the fleet size is probably significantly higher since the number of vehicles removed from circulation every year is not known and many vehicles operate illegally without a license. Records from the Central Administration of Statistics (CAS) show a dramatic increase in annual vehicle registration from 40,515 vehicles in 2001 (including 25,883 cars) to 106,959 vehicles in 2008 (including 79,899 cars) –equivalent to a 15 percent annual increase in registration. Almost 70 percent of vehicles are private cars -*see annual vehicle registration in Figure 4.2 and a summary of the transport fleet in Table 4.2.*

The precursors of most air pollutants emitted from the transport sector are fuels and lubricants used in vehicles. SO_2 and Lead emissions are directly correlated to the Sulfur and Lead content in fuels. Accordingly, lead emissions in the country have gradually decreased since the introduction of unleaded gasoline in 1993 and the ban on leaded gasoline in 2001 (Law 341/2001) (Hashisho *et al.* 2001). However, the 2001 ban on Diesel oil in vehicles (not to be confused with Diesel oil in Europe with physical and chemical properties described under EN 590) and the 1995 emission standards on trucks, buses and motor vehicles (Decree 6603/1995) did not lead to significant emission reductions as trucks and buses continue to run on Diesel oil without any inspections generating significantly more pollutants (PM, soot, NO_x and CO) than gasoline.

Table 4.2 Road and non-road transport in Lebanon (2007)

Road Transport	***Some Figures***
Public Collective Transport (Buses)	3.2 million passengers per year 61,360 bus trips per year
Private Collective Transport (Buses)- Lebanese Commuting Company	13 lines 52,385 bus trips per year
Number of Registered Motorcycles	12,154
Number of Licensed Taxis	33,500
Number of Licensed Vans	4,000
Number of Red Numbers - Buses (25-55 passengers)	2,236
Number of Red Numbers - Trucks	14,000
Non-Road Transport	***Some Figures***
Boats (Beirut, Tripoli, Tyr, Saida, Jieh & Zahrani)	3,289
Aircrafts - Landings and take-offs	39,060

Note: Licensed taxis and vans carry red number plates (the number of unlicensed vehicles is unknown)

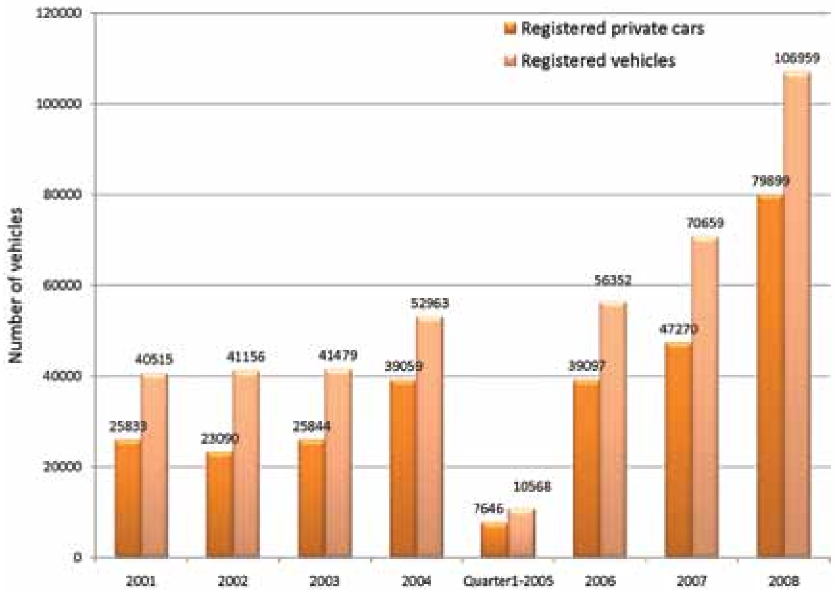
Source: CAS, 2008

Vehicle emissions are also influenced by a number of factors including age, maintenance, speed, traffic, and road conditions. Vehicle performance usually drops on bad roads. All these factors will reduce combustion efficiency resulting in higher emission of PM, HC, CO_x, SO_x and NO_x. Generally, combustion efficiency during start-up and acceleration is lowest and it is highest during moderate speeds (about 80 km/hr). Bumper traffic has an acute effect on air quality because of low combustion effect increasing levels of PM, CO and VOC emissions in tail pipes.

Energy Sector

Energy industries (thermal power plants) are one of the largest contributor to air pollution in Lebanon emitting black plumes of HC, CO, CO_2, SO_2, NO_x, soot, PM, and other pollutants (MOE/EU/NEAP, 2005u). They are the largest producer of CO_2 emissions, accounting for 39 percent of national CO_2 emissions in 2005 (Figure 4.4). Thermal power plants generate 85 percent of total electricity in the country of which five plants are located in the coastal zone, while hydropower plants generate an additional 4 percent. The remaining 11 percent come from imports - *see Chapter 9 for more information on Lebanon's energy sector.*

Figure 4.2 Vehicle registration in Lebanon (2001-2008)



Source: CAS 2006, 2007, 2008, 2009

Proximity of Zouk power plant stacks to residential units

Population growth and changing lifestyles increase demand for electricity and other sources of energy. Because Lebanon's formal energy production currently does not meet demand, private backup generators produce an estimated 500MW, equivalent to 20 percent of the total production (MOEW, 2010).[2] Private generators (un-surveyed but in the thousands) are found in industries and other establishments, and may be located on balconies, in basements, empty lots, and curbsides. They usually have short stacks, are not properly maintained, generate significant noise (especially if not

[2] According to the World Bank Electricity Sector Public Expenditure Review for Lebanon (2008), self-generation represents 33 percent of total electricity production in the country.

cased or equipped with noise mufflers) and release soot and PM inside cities and between buildings.

The impact of thermal power plants on air quality is further aggravated by the sulfur content of burning High Emission Factor Fuel (HEFF) such as Heavy Fuel Oil (HFO); containing typically around 2.5 percent Sulfur by weight (MOE/EU/NEAP, 2005u). Their stacks are not equipped with effective treatment units such as Dust Collection Units, and/or Flue Gas Desulfurization (FGD) to reduce SO_x. Therefore, $SO_{2(g)}$ is the major energy pollutant causing the formation of H_2SO_4(major constituent of acid rain) as well as Sulfate particulates $(NH_4)_2SO_4$ and $(NH_4)HSO_4$. Energy industries accounted for 68 percent of national SO_2 emissions in 2005 (MOE/GEF/UNDP, 2010 unpublished data). Non-Methane Volatile Organic Compounds (NMVOC) are also generated from thermal power plants during fuel storage, loading and unloading operations. They react with NO_2 to form ground level O_3, in the tropospheric layer, a major constituent of smog and in high concentrations may cause health problems including asthma, irritation and damages of the respiratory system as well as other respiratory infections.


Plumes of smoke at Jiyeh power plant

Gas stations also affect air quality. They are a major source of NMVOC emissions during fuel loading and unloading. Such emissions are currently not measured in the country and consequently there are no measures in place to reduce NMVOC emissions from fuel stations – *see Chapter 9 for more information on gas stations.*

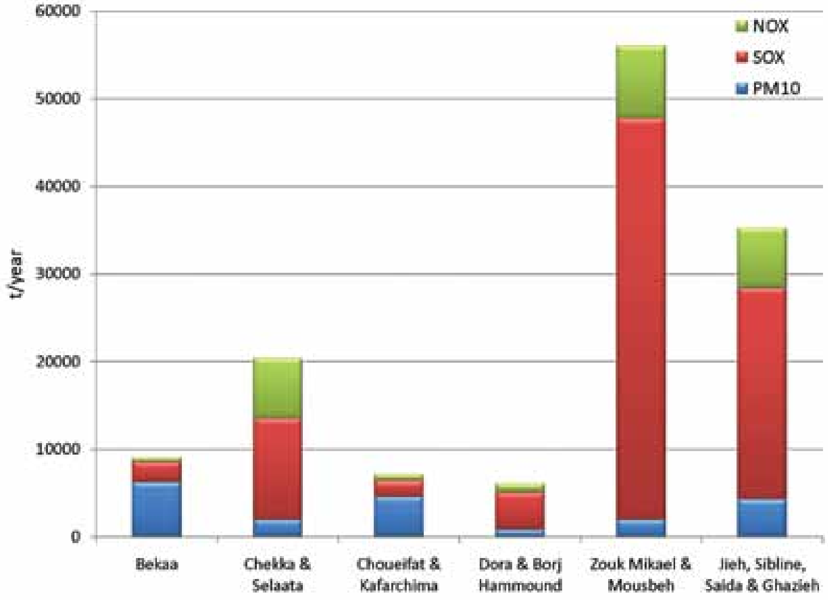
Industrial Sector

Industries in Lebanon are spread all over the country and the majority is small scale. The last comprehensive survey was conducted by the Ministry of Industry (MOI) in 2000 according to which there were 22,026 industrial establishments in the country. The majority is small-scale and employs less than five workers. According to a 2007 update conducted by the MOI, there are currently 4,033 industries that have a surface area greater than $100m^2$, employ more than five people, and consume more than 20KVA annually (data not published). These industries may have potential negative impacts on the environment but they also play an important role in the economic development of the country. Although there are 72 decreed industrial zones, the majority of industries are located outside industrial zones, in cities and villages. These industries are mostly located in urban areas where two thirds of Lebanon's population reside (CDR-NLUMP, 2004). Industries generate two types of emissions: (1) combustion emissions, and (2) process emissions. Combustion emissions are similar to those of the energy and transport sector and include HC, NMVOC, PM, Soot, CO_x, SO_x and NO_x, produced from burning oil and fuel to generate on-site electricity. However those of the manufacturing process are different depending on the process itself and the efficiency of industrial equipments, as well as the loading and unloading operations of raw materials before entering into the process .

In 1998 the METAP/World Bank estimated the air pollution loads (t/year) from industrial activities in Lebanon (based on an earlier survey conducted by MOI in 1994 according to which there were 22,205 industrial establishments). Figure 4.3 shows estimated NO_x, SO_x and PM_{10} loads in major industrial poles. The data show that Zouk Mikael and Zouk Mosbeh host the most polluting industries emitting 45,819 t of SO_x annually. This data should be treated with caution as they were generated many years ago.

Lebanon's First National Communication to the UNFCCC documented the contribution of different industries to air pollution in Lebanon. For example, NMVOC emissions are mainly produced during road asphalting; the production of sulfuric acid is the biggest source of SO_2; iron; steel mills are the major source of CO emissions; and the cement industry is the greatest producer of CO_2 (MOE/GEF/UNDP, 2002) –*see summary of air pollutants from cement industries in Box 4.3.*

Figure 4.3 Estimated air pollutant loads from industrial activities in Lebanon



Source: Adapted from WB 2010

Box 4.3 An overview of Lebanon's cement industry

In Lebanon, the cement industry represents the largest source of CO_2 emissions in the sector. Lebanon has five plants (Holcim Lebanon, Cimenterie Nationale SAL, Ciment de Sibline, Cimenterie du Moyen Orient, Societe Libanaise des Ciments Blancs) of which four are located in North Lebanon. Raw materials include silica, aluminum, iron and lime which is obtained from calcium carbonate. Other raw materials are introduced as sand, clay, shale, iron ore and blast furnace slag. The cement industry includes many processes such as mining/quarrying, crushing, grinding, and calcining, all of which generate pollutants:

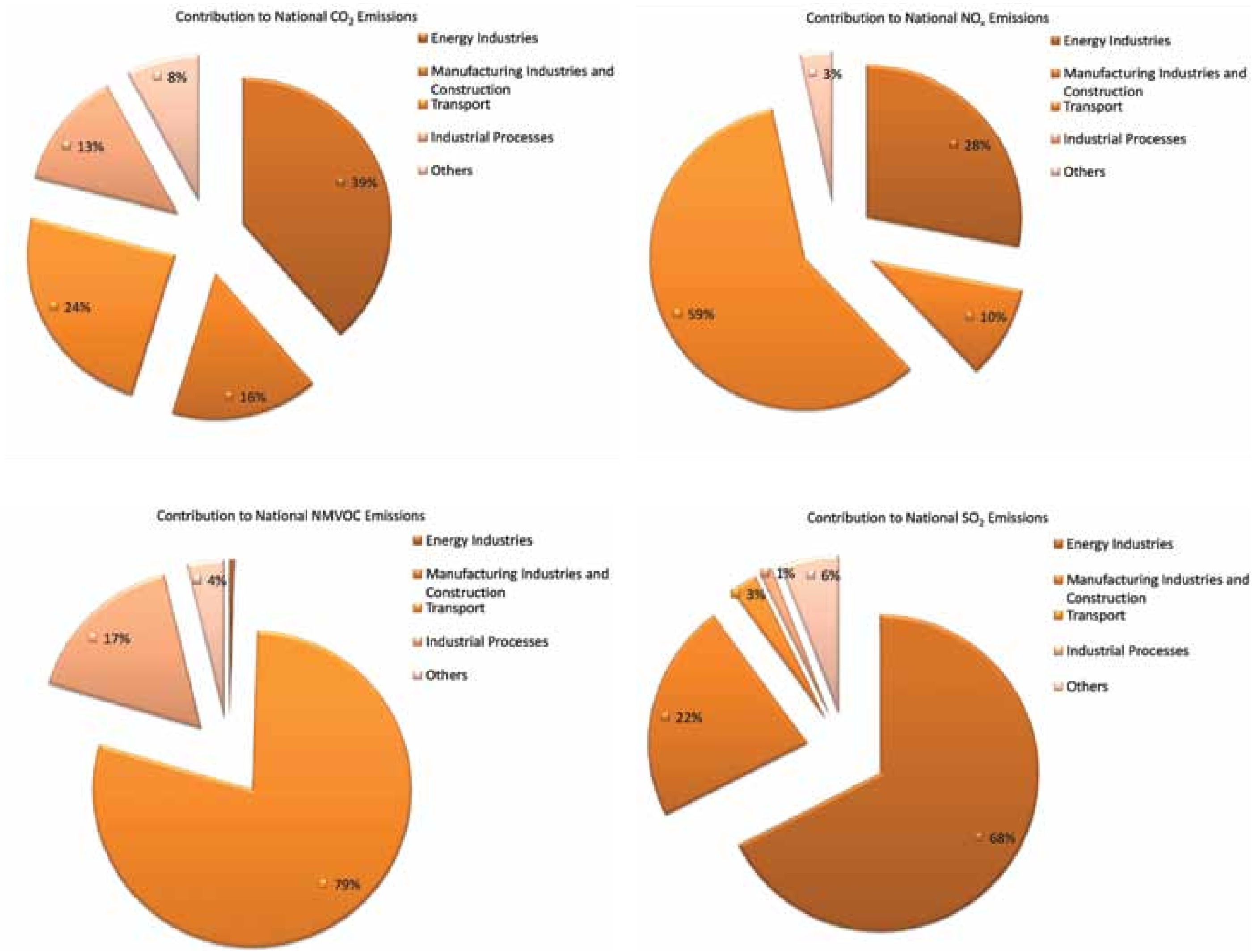
- Extraction, crushing and grinding of raw materials > particulates
- Kiln operation and cooling > particulates, CO, SO_2, NO_x, HC
- Grinding and bagging of cement > particulates

In 1997, the MOE prepared a guidance note (Decision 191/1) for the cement industry on how to protect the environment and workers from exposure to industrial pollutants. The note included conservation measures of air and water quality and kick-started a process of self-monitoring stack emissions that requires further improvements –see Section 4.4.3.

Cement factory in Sibline, one of five plants in the country

The recently published Second National Communication (SNC) to the UNFCCC provides a detailed analysis of national GHG emissions for the reference year 2000 (MOE/GEF/UNDP, 2011). As part of the preparations for the SNC, data on greenhouse gases were collected through 2006. As emissions in 2006 may have been impacted by the war that year, this SOER has retained emissions values for 2005. Figure 4.4 summarizes the contribution of energy industries, manufacturing industries and construction, transport, and industrial processes to national GHG and precursor emissions in 2005.

Figure 4.4 Contribution of economic activities to national air pollutant emissions (2005)



Source: MOE/GEF/UNDP, 2010 unpublished data

Other Sources

In addition to transport, energy and industry, the three major economic activities in Lebanon, other economic sectors also affect air quality including agriculture, construction and quarrying. Other sources of air pollution include open dumping and/or burning of municipal solid waste, burning of tires, fire and explosion accidents in poorly regulated warehouses (see Box 4.4), fireworks and wars. *See summary of pollutants by type of activity in Table 4.3.*

Box 4.4 Fire incident in Ain al-Remmaneh

On 9 November 2010, a severe fire broke out in an underground storage site in Ain al-Remmaneh (Beirut Suburb) that contained chemicals including resins (cellulose combined with halogens, used for water disinfection) and polymer packages. The fire released vast plumes of smoke over Beirut containing hazardous pollutants such as PM, HC, CO_x, Cl_2, HCl, dioxins, furans, etc. Investigation into the incident revealed that unexpected chemical reactions occurred between stocked materials that caught fire. Emissions from an open fire can represent acute (short-term) and chronic (long-term) health hazards to firefighters and nearby residents. Depending on the length and degree of exposure, these health effects could include irritation of the skin, eyes, and mucous membranes, respiratory effects, central nervous system depression, and cancer. The storage site was categorized by MOE as Class I Establishment according to Decree 4917/1994 and must be separated from residential areas according to Legislative Decree 21/l/1932. Moreover, these establishments require a permit from the Governor. The Ain Al-Remmaneh storage site was operating illegally, without a permit, similar to thousands of other warehouses in the country. The incident prompted MOE, in coordination with the Civil Defense, to review storage permits and inspect storage conditions more consistently. The GOL has yet to decide how to deal with the more persisting issue –the relocation of storage areas/warehouses containing potentially hazardous substances outside densely populated residential areas.

The July 2006 war with Israel resulted in extensive air pollution and adverse impacts on human health. Exploded ammunitions, ignited fuels, forest fires, damaged industrial facilities and buildings caused air quality deterioration in the southern suburb of Beirut, South Lebanon and the Bekaa region (UNDP-ELARD, 2007). Emissions were quantified whenever possible to provide an order of magnitude of pollutants emitted and guide decision-makers as to which impacts to mitigate. The burning of 60,000 m^3 of fuel oil at the Jiyeh Power Plant and 5,000 m^3 of kerosene at the Beirut Rafiq Hariri International Airport generated large plumes of SO_2, NO_2,

Table 4.3. Summary of pollutants from other anthropogenic activities

Activity	Generated air pollutants (incl. pathogens)
Farming-Agriculture	Sprayed pesticides, NH_3, Odors, GHGs (CH_4, CO_2)
Open dumping	GHGs (CH_4), Bacteria, Viruses
Open burning	Products from incomplete combustion: CO, NO_x, SO_x, HC, PM and other hazardous substances including dioxins and furans (POPs)
Burning tires	CO_x, SO_x, NO_x, NMVOCs, PAHs, dioxins, furans, HCl, benzene (C_6H_6), PCBs; Metals: As, Cd, Ni, Zn, Hg, Cr, and V
Quarrying, construction, open-air storage sites	Large dust plumes comprising PM_{10} and $PM_{2.5}$
Fireworks	CO_2, $K2_S$ and N_2 – For every 270 grams of black powder (gunpowder, propellant) used, 132 grams of CO_2 are created. Colors are generated by oxidized metals (e.g., the color red derives from strontium, blue from copper, gold from charcoal and iron).

Source: Compiled by ECODIT

Uncontrolled roadside burning of solid waste is widespread in rural Lebanon

CO, soot, PM, VOC, dioxins, furans, and other compounds from the incomplete combustion of oil and oil products. Accordingly, an air pollution model projected PM concentrations near pools of fire (oil and kerosene) at various distances (see Table 4.4). The model indicated that particle concentrations were at their highest levels near pools of fire.

Following site clearing and removal, disposal of demolition wastes and construction activities, Total Suspended Particles (TSP) were estimated to reach 860µg/m^3 under worst-case scenario and 190µg/m^3 under typical scenario in the ambient air of Beirut Southern Suburbs, exceeding the Lebanese (120 µg/m^3), EPA (75 µg/m^3) and WHO (150 µg/m^3) 24-hr exposure standards for TSP in ambient air. Impacts from Jiyeh and airport fires on the neighborhoods were considered to be short-term (< than 1-year); those of construction activities in Beirut suburb were considered to be medium-term (1-10 years). *See other impacts of the 2006 war in Chapters 6 and 9 of this report.*

Burning fuel storage tanks at Beirut Rafic Hariri International Airport (July 2006)

Table 4.4 PM concentrations near pools of fire

Particulate Concentrations	*Oil Fire (Jiyeh Power Plant)*	*Kerosene Fire (Beirut Rafiq Hariri International Airport)*
Near the Pool of Fire	34mg/m^3 (Vertical Elevation 0m)	31mg/m^3 (Vertical Elevation 0m)
At 1-4 km downwind	217-295µg/m^3 (Vertical Elevation 695m)	30.3µg/m^3 (Vertical Elevation 725m)
At 20 km downwind	21µg/m^3 (Vertical Elevation 780 m)	1µg/m^3 (Vertical Elevation 260m)
At 20 km downwind	29µg/m^3 (Vertical Elevation 350 m)	3.2µg/m^3 (Vertical Elevation 725m)

Source: UNDP-ELARD, 2007

4.1.1.2 Natural Sources

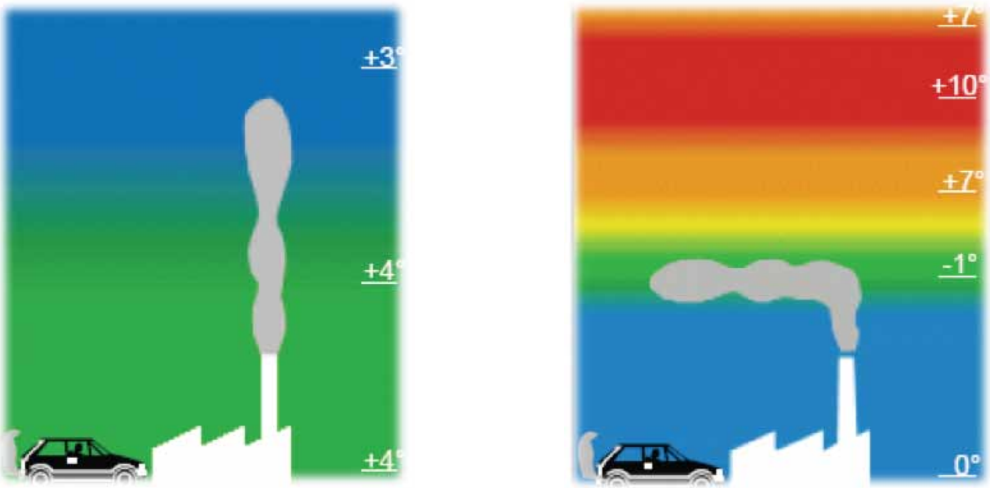
In Lebanon, the following natural phenomena impact air quality:

- Forest fires are caused by natural drought, accumulation of dead and highly flammable wood, or by arson. In Lebanon, sources of raging forest fires remain unclear. Between 2008 and 2009, there were 705 recorded fires in the country, devastating around 45 km^2 of forests which is equivalent to 1.8 percent of the forest cover (MOE, 2010). Generally, forest fires cause significant damages to the wildlife and the forest cover, produce large smoke plumes charged with fine particles rich in carbon and potassium that spread across large tracts of land and have considerable impacts on human health – *see more details on forest fires in chapter 5.*
- Dust storms (*reyah khamseenyah)* affect Lebanon every year. They originate in Africa (spring) and the Arab Peninsula (autumn) and sweep across vast land areas. These hot air masses are loaded with crustal elements increasing levels of PM_{10} in the atmosphere.
- Atmospheric and climatic conditions include temperature, humidity, atmospheric pressure, wind speed, wind direction and the height of the mixing layer (height: 1km). All these conditions have an effect on the concentration of air pollutants in the atmosphere. Under normal conditions, temperature decreases with height *–see Figure 4.5A*. In case of temperature inversion (an increase in temperature with height) with low wind speeds, pollutants are trapped in the mixing layer and move horizontally since their dispersion is blocked vertically *–see Figure 4.5B*.

Figure 4.5: Dispersion of air pollutants in the atmosphere

A-Vertical Dispersion –Normal Conditions-

B-Horizontal Dispersion –Temperature Inversion-



Internal Security Forces controlling a forest fire using beaters

4.1.2 Indoor Air

Indoor air quality is affected by combustion sources (oil, gas, coal, and wood), tobacco smoking, building materials and furnishings, asbestos-containing insulation, pressed wood products; household cleaning and maintenance products, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides, and outdoor air pollution. In Lebanon, the main sources of indoor air pollution are smoking and heating malpractices.

4.1.2.1 Excessive Smoking

In Lebanon, smoking cigarettes, cigars and the so called *narguileh* is excessive in both public and private areas. According to a 2005 Global Youth Tobacco Survey which investigated the self-reported attitudes and behaviours related to tobacco among 3,314 Lebanese schoolchildren aged 13–15, 80 percent of youth experience Second Hand Smoking (a.k.a. Passive Smoking) at home. This percentage does not include pre-school children exposed to *narguileh*. The mean age for starting smoking is 14, and smoking prevalence among students (age 13-15) is 15 percent for males and seven percent for females (WHO, 2000). According to the Lebanon's 1998 Tobacco Control Profile, adult smoking prevalence in Lebanon was 46 percent for males and 35 percent for females –considered the highest among all Arab Countries (Kuwait: 29.6% for males and 1.5% for females; Qatar: 37% for males and 0.5% for females) (WHO, 2000).

Cigarette smoke contains an array of gaseous and particulate compounds that may cause long-term health effects including lung cancer.

These include (in approximate order by mass): CO_2, water, CO, PM, Nicotine, NO_x, HCN, NH_3, CH_2O, PAH, VOC, Phenol and dozens of other well known toxic compounds. Some of these components are present in extremely high concentrations. For instance, cigarette smoke contains much higher concentrations of Carbon Monoxide [CO] (0.5-5% v/v) than the auto exhaust from a well maintained vehicle. Such CO concentration would be lethal if inhaled continuously for ~30 minutes (Jaffe and Chavasse, 1999).

4.1.2.2 Heating Malpractices

Lebanese citizens, especially lower income households, often rely on dirty and inefficient solid fuels for home heating including biomass (wood and crop wastes), polymer products (shredded tires) and other liquid fuels such as cooked oil and Diesel oil. The majority of households using solid fuels burn them in open fires or simple stoves that release most of the smoke into the home. The resulting indoor air pollution is a major threat to health, particularly for women and young children, who may spend many hours close to the fire.

Furthermore, the reliance on solid fuels and inefficient stoves has other, irreversible consequences on health (i.e., damages to the central nervous system), the environment, and economic development. Many health-damaging pollutants, including PM, CO, SO_x, NO_x, Aldehydes, Benzene (C_6H_6), and HC are emitted. Inadequate ventilation, high temperature and humidity levels will increase indoor pollutant levels.

Excessive cigarette smoking

4.2 CURRENT SITUATION

Since 2001, Lebanon's capabilities in air quality monitoring have vastly improved. Although the country still lacks a national, government-driven program for air quality monitoring, several universities and institutions have started to coordinate their air pollution related activities. This section therefore first describes Lebanon's current air quality monitoring capabilities, and then draws on a growing volume of air quality data and publications to reveal a partial assessment of Lebanon's air quality situation.

4.2.1. Preliminary Air Quality Monitoring Program inside and outside GBA

Under a partnership agreement with the Municipality of Beirut, Le Conseil Régional d'Ile de France, and Université Saint Joseph (USJ), a

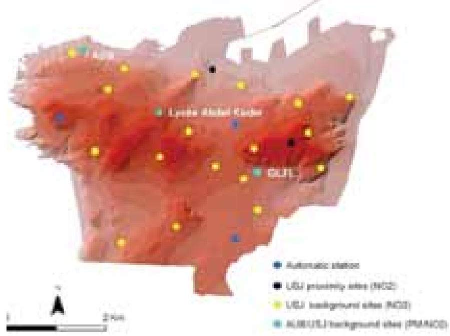
Clear view of Beirut

Preliminary Air Quality Monitoring Program was established in 2003 to provide data on ambient air quality in Beirut. The program installed 23 monitoring stations for sampling and analyzing key air pollutants including (PM_{10}, $PM_{2.5}$, NO_x, SO_x, CO_x, VOC, and O_3), using a variety of fixed and mobile sampling equipment. The program was extended and expanded in 2008 to cover the Greater Beirut Area (GBA), in association with the American University of Beirut (AUB). Specifically, and under the patronage of the Lebanese National Council for Scientific Research (CNRS), faculty members from AUB and USJ joined efforts to establish the Air Quality Research Unit (AQRU). The unit studies air pollutants levels in GBA and their transformations in the atmosphere. Its objectives are to establish a permanent observatory for the continuous monitoring of air quality in Beirut City and initiate an awareness system to appraise the public on air pollution issues and levels (AQRU Brochure, 2009-2010). Accordingly, the upcoming activities of the AQRU will be (1) to develop the Beirut Air Quality Index on air pollution that will be accessed by the public via internet, (2) monitor pollutants outside GBA and (3) monitor emissions from industrial stations (AQRU Conference, 2011). Table 4.5 presents an overview of air quality monitoring stations in Beirut and GBA from 2004 till the present and Figure 4.6 shows their location in Beirut City (NO_2 and PM sampling sites only).

Outside GBA, two institutions, Tripoli Environment and Development Observatory (TEDO) and University of Balamand (UOB), are involved in air quality monitoring. In particular, the observatory started to measure and monitor TSP and PM in 2000 in the region of Al Fayhaa within Tripoli. The University started in 2008 to monitor TSP in the industrial area of Chekaa and Selaata in North Lebanon. Table 4.6 presents an overview on air quality monitoring stations outside GBA. There are no known initiatives in air quality monitoring in the Bekaa Valley and South Lebanon.

For ease of reference, Table 4.7 summarizes key air quality standards in Lebanon, in comparison with EPA and WHO standards and guidelines. The MOE set National Ambient Air Quality Standards (NAAQS) in 1996. The 2005 WHO standards and 2010 EPA standards are similar to the NAAQS for some pollutants (e.g., CO) and more stringent for other pollutants (e.g., SO_2); the 2005 WHO 24hr-standard for SO_2 is 20 µg/m³ while the NAAQS 24hr-standard for SO_2 is 120 µg/m³. Standards for other ambient

Figure 4.6 NO_2 and PM sampling sites in GBA



Source: AQRU Brochure, 2009-2010

Table 4.5 Summary of air quality monitoring stations in GBA

Period	Responsible Unit	Measured Pollutants	Sampling Equipment	Location of Equipment
2003-2008 (Phase 1)	Le Conseil Régional d'Ile de France, Beirut Municipality and USJ	NO_2 and SO_2	Passive Sampling (collection every 14 days)- Radiello Tubes, Passam Tubes	23 sampling sites within Beirut City
		NO_x, SO_x, O_3, CO, VOC and PM_{10}	Automatic station Online analyzers (automatic readings every 15 min)	Mobile lab in Horsh Beirut (pine forest)
2008-Present (Phase 2, on-going)	USJ-AQRU	NO_2 and SO_2	Passive Sampling (collection every 7 days)-	Extension from 23 to 66 sites distributed over the GBA
	USJ-AQRU	PM_{10} and $PM_{2.5}$	Two additional automatic stations – Impactor	College Protestant Français and USJ Huvlein
	AUB-AQRU	PM_{10} and $PM_{2.5}$	High Volume Samplers – Impactors	AUB, Lycée Abdel Kader and Grand Lycée

Sources: Pers. comm with Rawad Massoud (AUB), Maher Abboud (USJ) and Charbel Afif (USJ)

Table 4.6 Air quality monitoring stations outside GBA

Period	Responsible Unit	Measured Pollutants	Sampling Equipments	Location of Equipments
2000 to present	TEDO	TSP, PM_{10}, $PM_{2.5}$	High Volume Sampler Low Volume Sampler	1) Urban station: down town of Tripoli; 2) Peri-urban station: TEDO building
		Benzene, Toluene, Xylene, HF, NO_2, SO_2, and O_3	Passive Sampling- Radiello Tubes	13 monitoring stations (according to Al Fayhaa community towns)
		vehicle exhaust gas emissions: HC, O_2, CO, CO_2	Exhaust gas analyzer	In the alleys of Tripoli City
2008 to present	UoB	TSP	High Volume Sampler	Chekka and Selaata

Sources: Pers. comm Amal Soufi (TEDO), Hanna El-Nakat (UOB) air pollutants such as $PM_{2.5}$ are still lacking in Lebanon. MOE will need to review and update the current NAAQS based on recent air quality monitoring data, the latest national environmental epidemiology studies as well as international standards (see Section 4.5.1 on Draft Law on the Protection of Air Quality).

Table 4.7 Standards for ambient air pollutants

Parameter	NAAQS Maximum levels (µg/m³)	EPA Standards	WHO
Sulfur dioxide (SO_2)	80 (annual) 120 (24hrs) 350 (1hr)	0.03 ppm (Annual) 0.14 ppm (24hrs) 75 ppb (1hr)	20 µg/m³(24hrs) 500 µg/m³ (10 minutes)
Nitrogen dioxide (NO_2)	100 (Annual) 150 (24hrs) 200 (1hr)	53 ppb (Annual) 100 ppb (1hr)	40 µg/m³(Annual) 200 µg/m³(1hr)
Carbon Monoxide (CO)	30,000 (1hr) 10,000 (8hrs)	35 ppm (40 mg/m³) (1hr) 9 ppm (10 mg/m³) (8hrs)	30 mg/m³ (1hr) 10 mg/m³ (8hrs)
Ground-level Ozone (O_3)	150 (1hr) 100 (8hrs)	0.075 ppm (2008 std) (8hrs)	100 µg/m³ (8hrs)
Total Suspended Particles (TSP)	120 (24hrs)	75 µg/m³ (24hrs)	150 µg/m³ (24hrs)
PM_{10}	80 (24hrs)	150 µg/m³ (24hrs)	20 µg/m³ (Annual) 50 µg/m³ (24hrs)
$PM_{2.5}$	NA	15 µg/m³ (Annual) 35 µg/m³ (24hrs)	10 µg/m³ (Annual) 25 µg/m³ (24hrs)

Source: Compiled by ECODIT based on MOE (Decision 52/1-1996), EPA (2010) and WHO (2005)

4.2.2 Concentrations and Composition of Air Pollutants

In recent years, there have been a growing number of scientific studies published in Lebanon addressing air quality. Scientists and ministries (MOE, MOPH) are showing greater interest and commitment to air quality issues. Atmospheric pollutants are extremely variable in space and time, depending on meteorological and topographical conditions (including the urban morphology) and on the spatial distribution of emission sources. The following paragraphs present and analyze a targeted selection of air quality data, covering gaseous pollutants and particulates, from Beirut and outside Beirut.

4.2.2.1 Greater Beirut Area

Sulfur Dioxide in GBA Saliba *et al.* (2006) and Afif *et al.* (2008) studied mean SO_2 concentrations in Beirut in 2005 and 2006. Measurements showed that mean concentrations of 3.1 ppb and 7.1 ppb were below annual WHO guidelines (17.5 ppb) and MOE's environmental limit values pursuant to Decision 52/1 (1996) (30 ppb) –*see values in Table 4.8.*

Spatially, SO_2 concentrations tend to peak in highly urbanized cities or areas affected by industrial activities, while rural or suburban areas tend to show lower levels. Beside local sources, long-range transport can account for an important source of SO_2 in Beirut (Afif *et al.* 2008).Temporally, SO_2 concentrations increase in winter due to the lower height of the mixing layer and higher SO_2 emissions (home heating, slower rate of SO_2 oxidation, etc.). Although Beirut does not appear to have an SO_2 problem, measurements should be extended to other parts of the country and augmented with short-term measurements (in urban, rural areas and especially around thermal power plants) to monitor spikes and assess short-term health impacts. Worldwide, SO_2 values in Beirut are comparable to values recorded in other cities– *see Figure 4.7.*

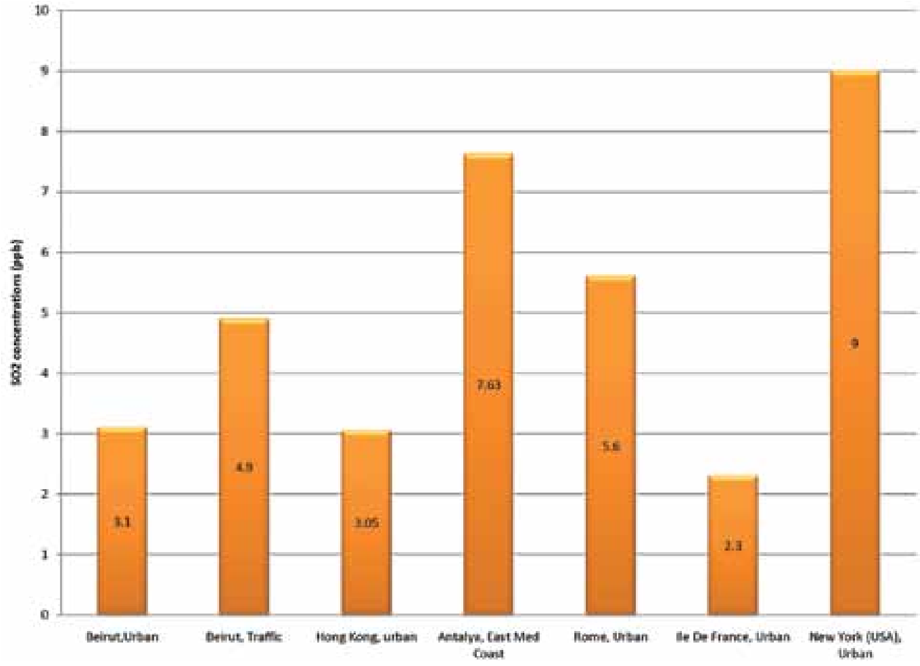
Table 4.8 Mean SO_2 Levels in Beirut

Locations	Sampling Period	SO_2 (ppb)
Beirut, Urban	Dec 2004-Jul 2006 (20 months)	**3.1**
Beirut, Traffic	Summer 2004	4.9
	Winter 2004-2005	9.4
	Mean concentration (2004-2005)	**7.1**
WHO (2005)	Annual guidelines	**17.5**
MOE Decision 52/1 (1996)	Annual guidelines	**30**

Source: Saliba et al. 2006 and Afif et al. 2008

Nitrogen Dioxide in GBA Annual average NO_2 concentration was measured for the first time in 2005 in Beirut City using a city-wide passive sampling network. The main NO_x emission source in Lebanon is traffic (Afif *et al.* 2009). NO_2 concentrations ranged from 17µg/m³ in summer (May 2006) to 178µg/m³ in winter (December 2005), with an annual average concentration of 67µg/m³ (Afif *et al.* 2009), higher than the annual WHO recommended value of 40µg/m³ (WHO, 2005). In 2009 and 2010, AQRU measured annual average NO_2 concentrations in GBA. Reported values for these two consecutive years were 53µg/m³ and 58µg/m³ respectively, also exceeding the WHO standard. It was thus calculated that 93 percent of the population in Beirut are exposed to NO_2 concentrations greater than 40µg/m3 (AQRU Conference, 2011). Chronic exposure to NO_2 can lead serious health effects. To measure short-term concentrations of NO_2 such as hourly averages and concentration peaks, researchers use online analyzers. It should be noted that NO_2 concentrations vary widely during the day, from as low as one µg/m3 to hundreds of µg/m3 depending on climatic conditions and emission sources. Of importance, $SO_{2(g)}$ and $NO_{2(g)}$ are precursors to SO_4^{2-} and NO_3^- in the particle phase.

Figure 4.7 SO_2 levels in different cities around the world



Source: Afif et al. 2008

Smog over Beirut

Carbonyl compounds in GBA In recent years, the toxicity of unregulated pollutant emissions in vehicle exhausts has attracted attention. Formaldehyde (C1), Acetaldehyde (C2), and Propanal/ Acetone (C3) are three carbonyl compounds known to affect human health. They are emitted by primary sources (incomplete combustion of fuels) or by secondary sources through photo-oxidation of VOC (natural or anthropogenic) with OH in the atmosphere, producing HO_2, C1, C2 and C3. Carbonyls and O_3 contribute to the formation of photochemical pollution episodes in summer. Moussa *et al.* (2005) measured lower carbonyl compounds in 2003 and 2004 in two locations in Beirut and found that formaldehyde (C1) and acetaldehyde (C2) were the most common carbonyls *–see carbonyl values in Table 4.9.* Carbonyl levels in the Hamra area were slightly higher than those recorded on AUB Campus. Local anthropogenic emissions mainly vehicle emissions were the predominant source of carbonyl compounds measured in AUB and Hamra. Of importance, carbonyl levels on weekends dropped compared to weekdays.

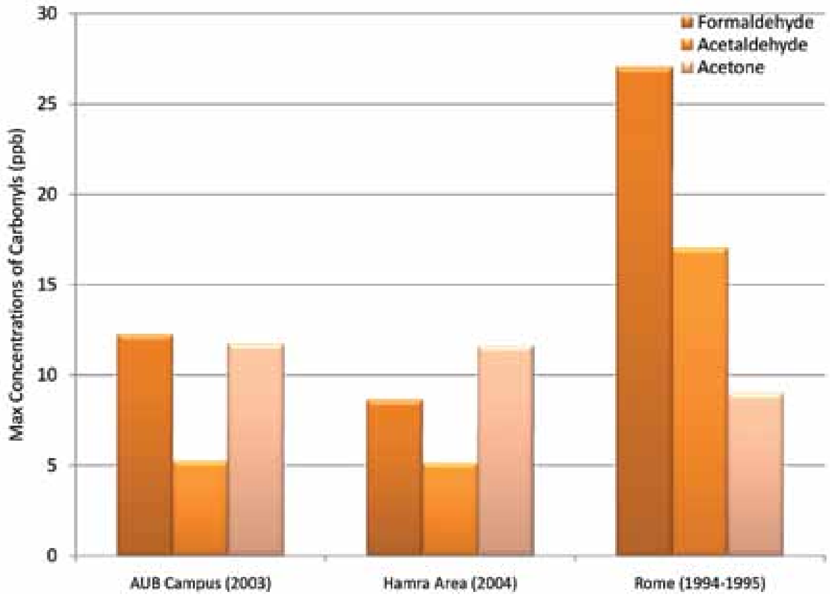
Table 4.9 Concentration of lower carbonyl compounds in Beirut City

Species	*AUB Campus (Jul-Dec 2003) Min-Max*	*Abdel Aziz Street (Aug-Sep 2004) Min-Max*
Formaldehyde (C1) (ppbv)	0.1-12.2	2.4-8.6
Acetaldehyde (C2) (ppbv)	0.02-5.2	0.9-5.1
Propanal (C3) (ppbv)	Max: 0.9	<DL*
Acetone (ppbv)	0.1-11.7	5.8-11.6
Carbon monoxide (CO) (ppmv)	1.1-3	1.1-3

*DL: Detection limit of the measuring device

Source: Moussa et al. 2005

Figure 4.8 Comparison of max carbonyl levels between Beirut and Rome



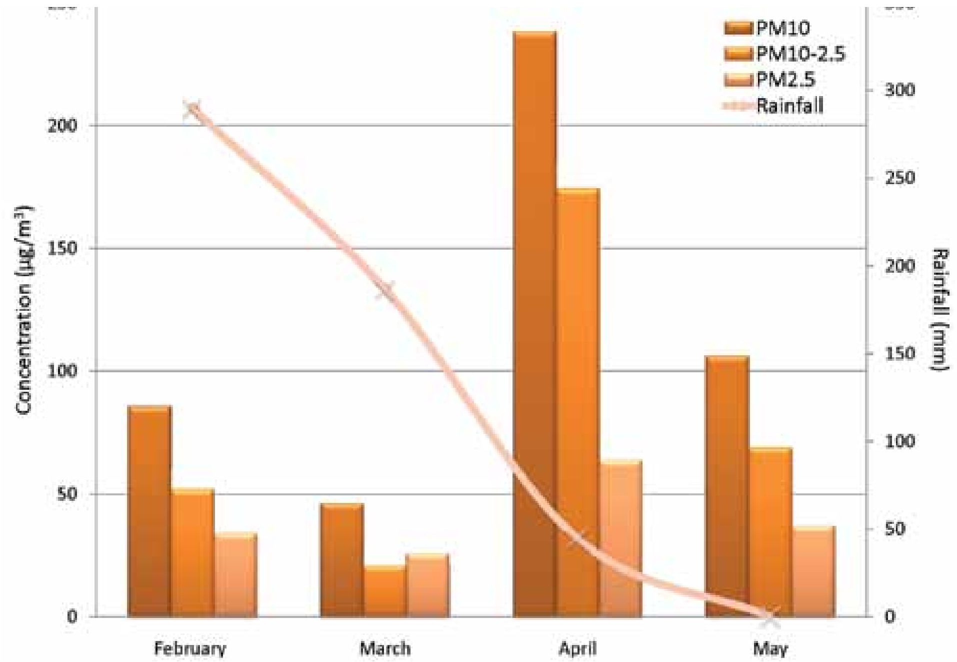
Sources: Possanzini et al. 1996, Moussa et al. 2005

The 2003-2004 urban levels of carbonyl compounds in Lebanon were lower than those recorded in Rome in 1994-1995 *–see comparison of carbonyl levels in Figure 4.8.* In the mid 1990s, European countries (Developed Countries) still used old vehicle technologies, which is therefore a valid comparison period with Lebanon in 2004-2005.

Suspended Particles in GBA (TSP, PM_{10}, $PM_{2.5}$). Population density, the effect of the Mount Lebanon range on the dilution of particulates, recurring dust storms in spring and autumn, as well as emissions from long-range transport, and limited rainfall with long spells of drought have a compounding effect on PM in the atmosphere. Shaka *et al.* (2003) and Saliba *et al.* (2007 -2010) conducted extensive PM sampling and measurement in and around Beirut. *See summary of sampling locations and results in Table 4.9.* In particular, Shaka *et al.* measured PM concentrations (all particle sizes) over a four-month period (February-May 2003). Low PM concentrations during February and March may be attributed to rainfall, whereas the spike in PM concentrations in April may have been caused by annual dust–storms. *See PM concentrations versus rainfall in Beirut City in Figure 4.9.*

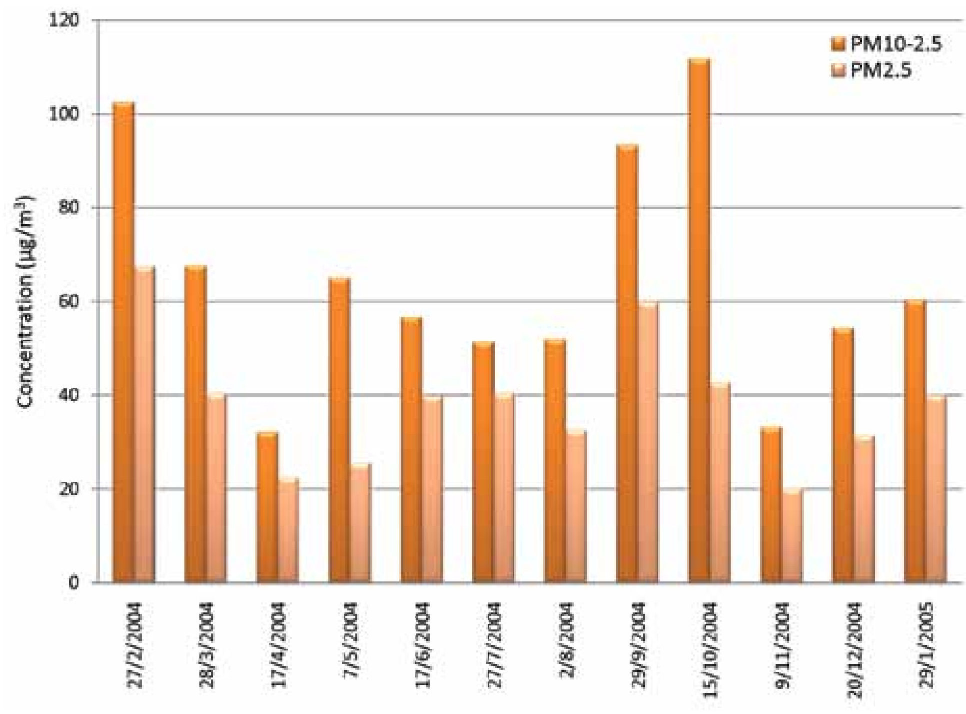
Separately, Saliba *et al.* measured in 2004 PM concentrations in the Borj Hammoud area, one of Beirut's busiest suburbs. The area is characterized by a concentration of residential and commercial activities, day-long vehicle traffic, significant sea-spray exhausts from Beirut harbor operations, as well as some open-air waste burning. The highest concentrations of $PM_{10-2.5}$ were recorded in February, September and October 2004, and were correlated with dust storm episodes coming from Africa and the Arabian Peninsula *–see Figure 4.10*. The average annual concentration of $PM_{10-2.5}$ and $PM_{2.5}$ were 65µg/m³ and 38.5µg/m³ respectively. *See PM levels recorded by Shaka et al. (2003) and Saliba et al. (2007-2010) in Table 4.10.*

Figure 4.9 PM concentration between February and May 2003 in Beirut-AUB



Source: Shaka et al. 2003

Figure 4.10 PM concentrations in 2004-2005 in Beirut-Bourj Hammoud

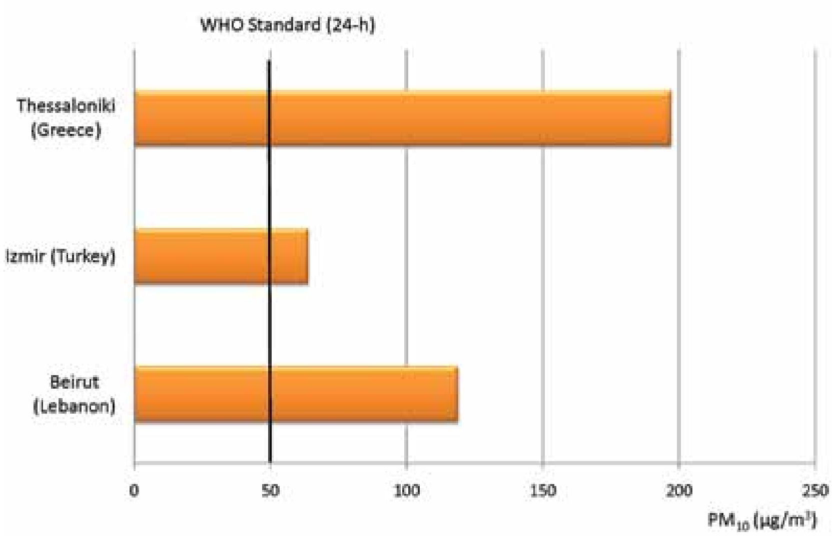


Source : Saliba et al. 2007

Table 4.10 PM levels in Beirut City (listed chronologically by sampling period)

Sampling site	Site description	Sampling period	Mean value during sampling period		Source
			PM_{10}	$PM_{2.5}$	
AUB	Location exposed to different sources of PM (natural & anthropogenic)	2/2003-6/2003 (4 months)	118.9 μg/m³	39.9 μg/m³	Shaka *et al.* 2003
Bliss Street	Urban area and coastal site	3/2003-6/2003 (3 months)	71.34 μg/m³	40.95 μg/m³	Saliba *et al.* 2010
AUB Seagate	Urban area and coastal site	11/2003-3/2004 (4 months)	86.9 μg/m³	-	Saliba *et al.* 2010
Abdel Aziz (Hamra)	Urban area and coastal site	9/2004-12/2004 (3 month)	55.1 μg/m³	-	Saliba *et al.* 2010
Borj Hammoud (Beirut suburb, north)	Urban area, close to Beirut Harbor and a waste facility	1/2004-1/2005 (12 months)	103.78 μg/m³	38.525 μg/m³	Saliba *et al.* 2007
Haret Hreik (Beirut suburb, south)	Urban area affected by post-war reconstruction	12/2006-8/2007 (8 months)	77.1 μg/m³	28.14 μg/m³	Saliba *et al.* 2010
American University	Urban areas	May 2009 -May 2010	54.69 μg/m³	20.18 μg/m³	Saliba & co-researchers, publication in progress
Lycée Abdel Kader			60.77 μg/m³	20.70 μg/m³	
Grand Lycée Franco Libanais			74.69 μg/m³	20.33 μg/m³	
WHO Standards (WHO, 2005)	**Annual average concentrations**		**20 μg/m³**	**10 μg/m³**	

Figure 4.11 PM_{10} Concentrations in Three East Mediterranean Cities



Source: Shaka et al. 2003

PM_{10} variations have different root causes. Near the sea (AUB Seagate in Ain El Mreisseh and Bliss Street in Hamra), high PM_{10} levels were correlated with sea breezes which carry sea salt particles. By contrast, high PM_{10} concentrations in crowded suburbs (Borj Hammoud and Harek Hreik) are not related to wind conditions but to local emissions (dust outbreaks, low precipitation, dust re-suspension, etc.). The main source of $PM_{2.5}$ include combustion processes and photo-chemical reactions combining precursors including $NO_{2(g)}$ and $SO_{2(g)}$ under increased humidity and high solar radiation. In summary, PM_{10} and $PM_{2.5}$ annual levels in all sampling sites in Beirut City exceeded WHO guidelines for PM_{10} (20μg/m³) and $PM_{2.5}$ (10μg/m³). Figure 4.11 compares PM_{10} concentrations in Beirut (Lebanon), Thessaloniki (Greece) and Izmir (Turkey). The most worrisome particles are fine ($PM_{2.5}$) and ultrafine particles (PM_1 and $PM_{0.1}$, yet to be assessed in Beirut City) because they can penetrate lung tissue and cause long-term tissue damage.

Chemical composition of PM in GBA Shaka *et al.* (2003), Kouyoumdjian *et al.* (2006) and Saliba *et al.* (2007) also examined the inorganic composition of aerosol samples in Beirut City (Research into the organic composition of aerosols is on-going *(pers. comm* with Charbel Afif, USJ).

Ionic Compositions and Salts: Ammonium (NH_4^+), Nitrate (NO_3^-) and Sulfate (SO_4^{2-}) ions are the main ionic components of both fine $PM_{2.5}$ and coarse fractions $PM_{10-2.5}$ (Shaka *et al.* 2003). Fine particles which are considered to originate from photochemical reactions hold higher concentrations of the main chemical airborne constituents: Ammonium Sulfates {$(NH_4)_2SO_4$}, ammonium nitrates (NH_4NO_3) and carbonate ions (CO_3^{2-}). Nitrate and Sulfate ions showed higher concentrations in summer due to enhancement of photochemical reactions which facilitates the conversion of NO_2 – SO_2 gases into NO_3^- - SO_4^{2-} respectively and to ammonium sulfates and nitrates. Nitrate is mainly due to local heavy traffic while sulfates are due to local exhaust emissions such as residential heating, Diesel operating buses, etc. and long-range phenomena. Quartz (SiO_2), Kaolinite {$Al_2Si_2O_5(OH)_4$}, typical salts of continental dust coming from Africa, and Calcium carbonate ($CaCO_3$), originating from crustal rocks, were identified to be major species in coarse atmospheric aerosols. Accordingly, Calcium (Ca^{2+}) was dominant in coarse particles along with Chloride (Cl^-) and Sodium (Na^+) resulting from marine aerosols qualified as Eastern Mediterranean Aerosols (Shaka *et al.* 2003, Kouyoumdjian *et al.* 2006).

Elemental Composition: The elemental composition of $PM_{10-2.5}$ and $PM_{2.5}$ was studied in winter, summer, stormy and non-stormy dates, in a populated area of Beirut (Saliba *et al.* 2007)–*see Table 4.11*. Results showed that crustal elements including Ca, Si, K, Ti, Mn and Fe were more abundant in $PM_{10-2.5}$(primary aerosols), increasing in stormy episodes, while enriched elements including S, Cu, Zn and Pb predominated in $PM_{2.5}$ (secondary aerosols). Highly enriched elements like Cu, and Zn, were emitted from worn tires and brakes. S, abundant in both $PM_{10-2.5}$ and $PM_{2.5}$ and originating from local and long range transport, exhibited higher concentrations in the summer season due to high photochemical reactions. It is worth mentioning here that abundance of S in $PM_{10-2.5}$ shows that the aerosol has aged. Chlorine, (Cl), originating from sea salt aerosols and abundant usually in $PM_{10-2.5}$, was found in higher concentrations in $PM_{2.5}$. This can be attributed to waste mass burning (open burning) generating fine particles rich in chlorine during the sampling period.

Table 4.11 Average elemental composition of $PM_{10-2.5}$ & $PM_{2.5}$

	Si (ng/m³)	S (ng/m³)	Cl (ng/m³)	K (ng/m³)	Ca (ng/m³)	Ti (ng/m³)	Mn (ng/m³)	Fe (ng/m³)	Cu (ng/m³)	Zn (ng/m³)	Pb (ng/m³)
$PM_{10-2.5}$	3425.55	814.18	1021.31	369.00	6318.63	154.95	26.64	1898.63	47.27	82.09	78.09
$PM_{2.5}$	38.53	611.00	1755.58	62.78	293.33	17.48	15.75	258.44	14.02	92.30	97.68

Source: Saliba et al. 2007

4.2.2.2 Outside Greater Beirut Area

Outside GBA, air quality data becomes more sketchy and episodic. Most air quality studies outside Beirut have focused on Chekka and Selaata; a region that is infamous for housing large industries including cement plants (Holcim and Cimenterie Nationale) and a phosphate fertilizer industry (Selaata Chemicals Company). The region is also affected by nearby quarries, sea-spray, and long-range transport (secondary aerosols). As described earlier, the Tripoli observatory and the University of Balamand have both implemented air quality monitoring programs in Tripoli and Chekka respectively. Separately, the Lebanese American University (LAU) monitored between September 2002 and February 2004 four criteria air pollutants (PM_{10}, CO, SO_2 and NO_2) in the framework of the USAID-funded project "Air Quality Management and Estimated Health Impact of Pollutants in Urban and Industrial Areas." The program used monitoring stations in five locations in and around the cement industry zone in Chekka and the surrounding Koura villages (Kefraya, Kfarhazir, Fih, and Enfeh). Diffusion and dispersion of pollutants in these areas were also studied according to prevailing and recorded meteorological conditions (Karam & Tabbara, 2004).

Air pollutant levels in Chekka and Koura are presented in Table 4.12 and interpreted below:

- CO: Low levels were recorded in all monitoring locations which is an indication of the absence of inefficient combustion processes.
- NO_2: Relatively low levels were noted in all monitoring locations corresponding to normal transportation and industrial activities. Peak NO_2 levels (from a few hours to a few days) occurred due to irregular

industrial activities and were correlated with a cloud of industrial emissions enveloping the Chekka neighborhood.

- SO_2: Measurements showed significantly high levels during the dry season in the three regions Chekka, Enfeh, and Fih probably due to the smoke plume of the cement factory[3]. However, levels in Chekka were slightly lower than those of Fih and Enfeh.
- PM_{10}: Measurements in the Chekka and Koura region have showed significantly high levels in almost all sampling locations. Chekka showed consistently the highest PM_{10} values, being the closest to all sources of emissions including quarries.

[3] Sulfur is found (6% by weight) in coke and petroleum coke used as fuel in cement kilns.


Large industry in Selaata

Table 4.12 Gaseous pollutants in Chekka and Koura villages

Pollutant	*Concentration range*	*Lebanese Standards MOE Decision 52/1 (1996)*
CO (ppm)	0-2	9.00 (8hr)
NO_2 (ppm)	6.4-10.11	0.053 (annual)
SO_2 (ppm)	0-2*	0.14 (24hrs)
PM_{10} (µg/m^3)	10-450**	80 (24hrs)

* Peaks recorded in Fih and Enfeh; ** Peaks recorded in Chekka

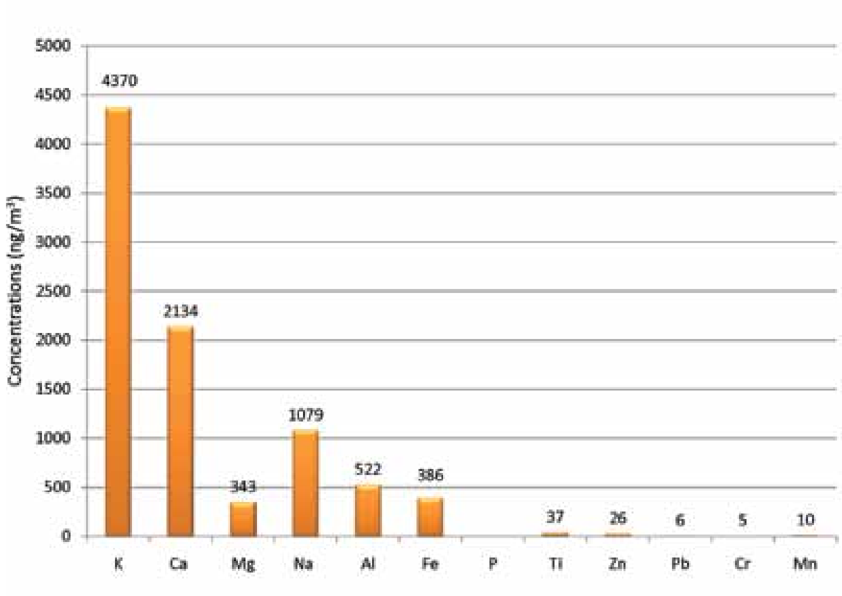
Source: Karam & Tabbara, 2004

Chemical Composition of TSP Kfoury *et al.* (2009) and Yammine *et al.* (2009) investigated the inorganic composition of aerosol samples in Chekka and Selaata. In terms of their ionic composition, NO_3^- had the highest mean concentration linked to gas-particle conversion of NO_2, followed by SO_4^{2-}, Ca^{2+}, NH_4^+ and Cl^- (Kfoury *et al.* 2009, Yammine *et al.* 2010). In terms of their elemental composition, Kfoury *et al.* collected TSP samples in Chekka over a three-month period (August 2008-October 2008). Among all the elements, Potassium (K) was found in highest concentrations, presumably the result of anthropogenic activities. Other crustal elements including Ca, Mg and Fe were detected in lower concentrations *–see elemental composition in Figure 4.12.* Interestingly, average calcium concentration in Chekka (2,134ng/m^3, period Aug-Oct 2008) appear to be lower than values previously reported in Beirut City (6,612ng/m^3; period Feb 2004-Jan 2005), notwithstanding the impact of dust storms in Beirut on Ca concentrations. To determine the influence of industrial activities (cement factories and quarries) on the composition of atmospheric aerosols in Chekka, Kfoury *et al.* (2009) collected samples from two sampling circles. The first circle includes sites near the cement factories (Anfeh, Bdaibhoun, Chekka, Bednayel and Hamat) and the second circle includes sites farther away (Deir alnatour, Fiaa, Kfarhazir, Kelbata and Mseilha). Figure 4.13 illustrates the difference in the elemental and ionic composition of aerosols between the first and second circles.

Calcium concentrations were not affected by emissions from the cement factories (Ca 1st circle ≈ Ca 2nd circle), probably due to low wind activity during the sampling campaign. In general, activities related to the cement industry (not the process itself) including extraction (quarries), crushing and grinding of raw materials as well as cement bagging release particles that are rich in Calcium. Almost similar results were also found for other elements except for Potassium; high Potassium levels were associated to biomass combustion.

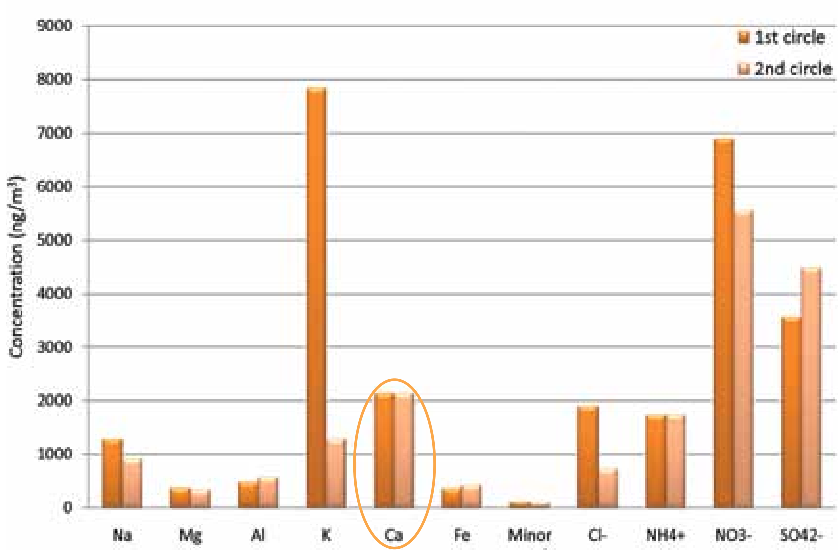
In Selaata, Yammine *et al.* (2009) studied the elemental composition of TSP in seven sampling points near the phosphate fertilizer industry (April-June 2008). Average levels of Na, Mg, Al and K were higher than all sampled sites in Lebanon *–see detailed composition in Figure 4.14*. Phosphorous and Calcium concentrations exceeded 10,500ng/m^3, which is attributed to rocks grinding and other processes.

Figure 4.12 Elemental composition of TSP in Chekka



Source: Kfoury et al. 2009

Figure 4.13 Chemical composition of TSP in Chekka

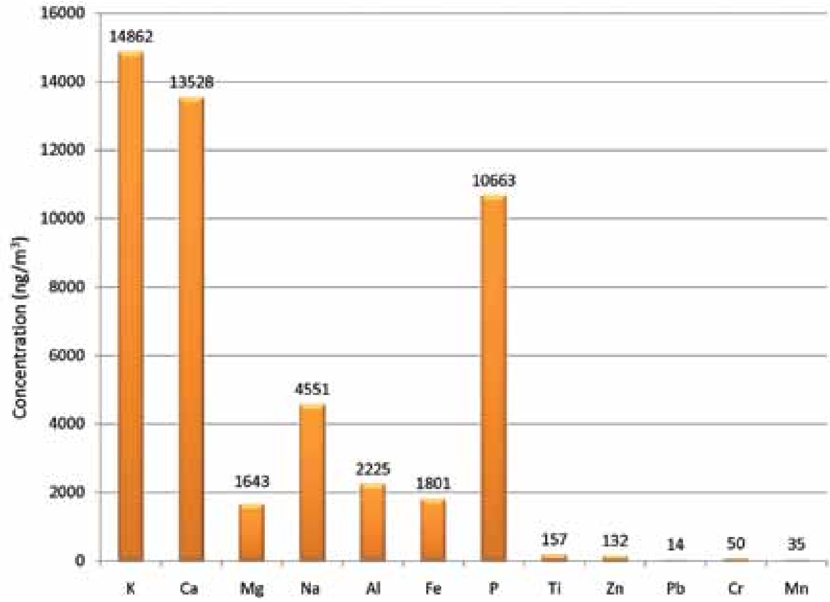


Source: Kfoury et al. 2009

In Tripoli, TEDO has been monitoring air pollutants since 2000. The observatory installed fixed monitoring stations downtown Tripoli (urban) and on the roof of the TEDO building (peri-urban station influenced by sea winds) to monitor TSP, PM_{10} and $PM_{2.5.}$TSP and PM levels downtown Tripoli are aggregated in Table 4.13, covering a six-month period. They also operate 13 passive sampling monitoring stations, distributed across Al Fayhaa's 13 cadastral zones, to monitor benzene, toluene, xylene, HF, NO_2, SO_2, and O_3.

During the sampling period, and out of 105 sampling days, TSP readings exceeded the

Figure 4.14 Elemental composition of TSP in Selaata



Source: Yammine et al. 2010

Box 4.5 Summary of air quality indicators in Lebanon

Pollutants	GBA	Source	Outside GBA	Source
Air quality				
NO_2	58µg/m³	AQRU Conference 2011	6.4-10.11 ppm	MOE-ECODIT 2002
SO_2	3.1 ppb	Afif et al. 2008	0.45-0.7 ppm	
O_3	-	-	115.5 µg/m³	TEDO 2009
PM_{10}	63.38µg/m³	Saliba & co-researchers (in progress)	81.4 µg/m³	
$PM_{2.5}$	20.4µg/m³	Saliba & co-researchers (in progress)	29.1 µg/m³	

Monitoring stations:
GBA 6 automatic stations (PM & gaseous pollutants) and 66 passive sampling stations (NO_2 & SO_2)
Outside GBA 3 Impactors (PM & TSP) and 13 passive sampling stations (NO_2, SO_2 and O_3)

Daily National Standard of 120µg/m³ 25 times (24%). Similarly, PM_{10} values exceeded the Daily National Standard of 80µg/m³ 38 times out of 84 sampling days (45%); compared to the daily PM_{10} WHO standard of 50µg/m³, the number of days would be much higher. Mean $PM_{2.5}$ in downtown Tripoli (34.6 µg/m³) was consistently higher than $PM_{2.5}$ values at the seafront station (23.6 µg/m³), principally due to heavier traffic in downtown Tripoli. Generally, $PM_{2.5}$ values recorded in downtown Tripoli and on the seafront were almost consistently higher than EPA's daily standard for $PM_{2.5}$ (35 µg/m³) as well as WHO's annual standard for $PM_{2.5}$ (10µg/m³). In terms of gaseous pollutants, Table 4.14 summarizes mean levels in 2008 (data from four sampling locations missing / not available). NO_2 are surprisingly low and far below the WHO annual standard for ambient NO_2 (40 µg/m³), as well as mean annual levels reported in Beirut (67µg/m³); an indication that the monitoring equipment could be dysfunctional (i.e., expired Passam tubes).

The previous sections presented a range of air quality data from multiple sources and for different time periods. Box 4.5 consolidates key findings to populate Lebanon's air quality indicators.

Table 4.13 TSP, PM_{10} and $PM_{2.5}$ levels in Tripoli from Jan-Jun 2008

Month	Mean Monthly TSP (µg/m³)	Mean Monthly PM_{10} (µg/m³)	Mean Monthly $PM_{2.5}$ (µg/m³)	
			Downtown of Tripoli	*TEDO building*
Jan 2008	103	80	45	33
Feb 2008	93	79	49	26
Mar 2008	125	NA	23	27
Apr 2008	106	89	31	19
May 2008	83	76	31	19
Jun 2008	100	83	29	17
Mean	**101**	**81.4**	**34.6**	**23.6**
WHO std (daily)	150	50	25	25
WHO std (annual)	-	20	10	10
EPA std (daily)	75	150	35	35

Source: TSP, PM_{10} & $PM_{2.5}$ levels from (TEDO 2009), WHO standards are (WHO 2005) and EPA standard is (EPA 2010)

Table 4.14 Levels of gaseous pollutants in the urban community of Al Fayhaa

Sampling Station	Benzene (µg/m³)	Toluene (µg/m³)	Xylene (µg/m³)	SO_2 (µg/m³)	NO_2 (µg/m³)	HF (µg/m³)	O_3 (µg/m³)
Al Maarad- Mina Street	1	15	40	0.2	2	0.1	157
Tripoli Port	3	70	83	0.2	3	0.2	139
Abi Samra	2	50	64	0.3	1	0.25	90
Al Maloula	3	68	48	0.5	5	0.2	175
Aazmi and Miatayn Street	-	55	62	0.2	4	0.1	101
Mouharam	5	52	102	1	4.3	0.2	90
Al Kornich	2	60	50	0.7	3	0.1	103
Industrial Zone & Saiid Port	1	51	82	0.2	2	0.2	80
Baddawi Street	3	52	65	0.6	6	0.1	105

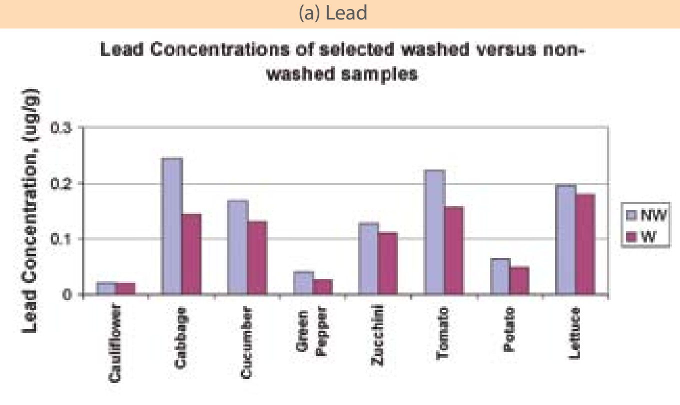
Source: TEDO 2009

Box 4.6 Contamination of agricultural crops

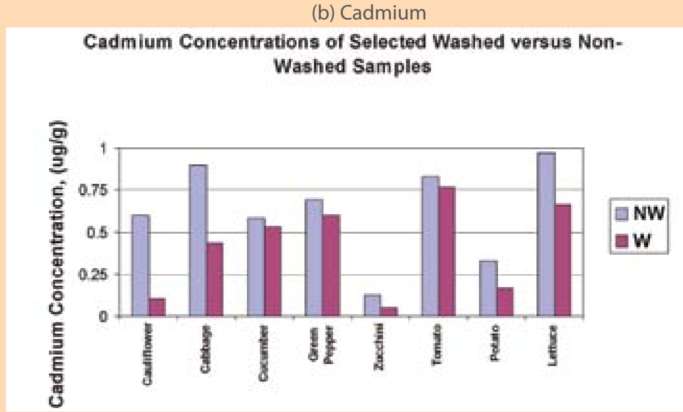
Air pollution can affect agricultural products. In 2009, Al Chaarani et al. investigated the levels of four heavy metals (lead, cadmium, chromium and arsenic) in a large sample of washed and non-washed vegetables (181 samples in total including 66 leafy vegetables, 84 ground vegetables, and 31 below-ground vegetables). The samples were collected from Beirut, Jounieh, Tripoli, and Koura. Heavy metals in ambient air may deposit on the surface of vegetables by adsorption and eliminated by washing whereas heavy metals taken up by the roots from contaminated water or from the soil will enter plant tissue through absorption, are difficult to remove and therefore pose a major health concern. The study showed that, in most cases, concentrations of heavy metals in non-washed vegetables were slightly higher than levels in washed vegetables. Levels of Cr and Ar in non-washed cucumber and lettuce were considerably higher than in washed vegetables *-see test results in figure below.*

Concentrations of four heavy metals in washed and non-washed vegetables

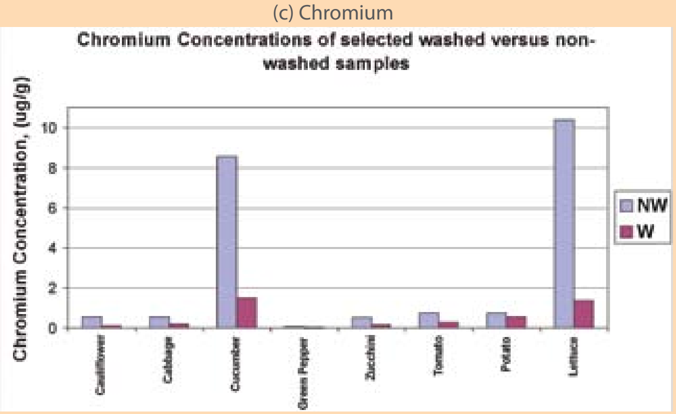
(a) Lead



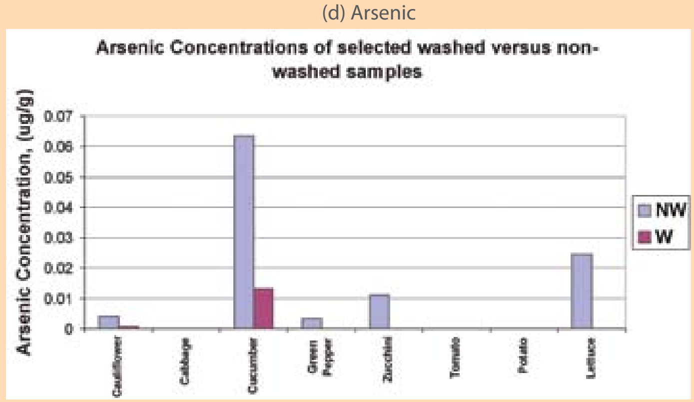
(b) Cadmium



(c) Chromium



(d) Arsenic



Source: Al Chaarani et al. 2009

4.2.3 Odors

Odors are caused by volatilized chemical compounds with low molecular weight (usually NMVOC [aldehydes, acetaldehyde, etc.] and pheromones), nitrogen compounds (amine, ammonia, etc.) and sulfur compounds (Hydrogen Sulfide [H_2S], mercaptans, etc.) that people and animals detect by the sense of olfaction. Intensity of odors depends on their accumulation and dispersion in the atmosphere which is related to climatic conditions (wind speed, wind direction, humidity, ambient temperature, height of the mixing layer, etc.). Olfactometers (electronic nose) measure odor intensity and levels. In Lebanon, although the MOE and municipalities receive regular complaints from citizens related to foul odors (see examples in MOJ/MOE/UNDP, 2010), odor pollution is rarely studied or measured. Major sources of odors in the country stem from poultry farms and slaughterhouses, waste dumps and composting plants as well as open sewers. People who reside in Beirut (or commute daily to and from the capital) often experience a very pungent odor near the areas of Bourj Hammoud and Karantina, which harbor a solid waste sorting and composting facility, a slaughterhouse facility, and the Beirut sea port (unloading and transport of livestock).


View of Bourj Hammoud industrial area

4.3 KEY ACTORS, LAWS AND REGULATIONS

The following sections describe key laws and regulations related to air quality and the environment. Each text cited here is also listed chronologically at the end of this chapter. For a more complete analysis of environmental legislation related to air, please refer to Chapter 9 of SELDAS (EU/UOB/MOE/ELARD, 2005). For a review of environmental jurisprudence cases related to air quality in Lebanon and other countries, please refer to Chapter 9 of SEEL (MOJ/MOE/UNDP, 2010).

4.3.1 Institutional Framework

"Given that air constitutes a basic element of life and a public natural resource, every citizen has the right to enjoy a clean and healthy air so that it does not constitute a hazard to public health and to the quality of life" (MOE, 2005). Safeguarding air quality is a broad and multidimensional endeavor that requires the participation of the public and private sectors *–see Table 4.15.*

4.3.1.1 Ministry of Environment

MOE is responsible for developing Air Quality Standards (AQS), Air Monitoring Programs and Surveillance (AMPS), Pollution Prevention Plans (PPP) in the country for ambient air and national GHG emissions inventories. The ministry has promulgated emission standards for several industries -Decision 8/1-2001 (power plants <300 MW, aluminum industries, etc.) as well as ambient air quality standards -Decision 52/1-1996 (maximum levels and exposure time). The MOE recently issued Circular No. 10/1 (dated 19/3/2011) related to "Monitoring the Operation of Electric Generators". The circular includes technical requirements on how to mitigate air pollutants from power generators (using exhaust systems for trapping air pollutants such as cyclones), control oil and/or fuel leakages (using absorbent materials under generators such as sawdust), and store used oil prior to safe final disposal.

Due to staff shortages and budget constraints, the ministry is only capable of carrying out a limited number of spot checks and/or routine inspections of industry stack and other sources of air pollution, to determine compliance. According to MOE's new organizational structure (Decree no. 2275 dated 15/06/2009), the Service of Environmental Technology includes an Air Quality Department; when adequately staffed and resourced, the department would be better able to carry out routine monitoring and

Table 4.15 Distribution of responsibilities related to air quality

Responsibility \ Party	MOE	MOPH	MOIM	MOEW	MOI	Munici-palities	TEDO–AQRU Others
Ambient Air Quality Standards	X						
Ambient Air Monitoring Programs and Surveillance	X						X
Pollution Prevention Plans	X						
GHG emissions inventories	X						
Inspection of industry & other air pollution sources	X						
Guidelines and regulations for indoor air quality		X					
Vehicle inspection			X				
Air pollutant limits for large power plants (>300MW)				X			
Industry licensing	X	X			X		
Traffic management						X	

Note: The above delineation of responsibilities is not an exhaustive assessment and is subject to change.

analysis of ambient air quality in different areas in Lebanon and update the existing ambient air quality standards.

4.3.1.2 Ministry of Public Health

The Ministry of Public Health (MOPH) is responsible for establishing guidelines and regulations regarding indoor air quality (indoor spaces include workspace, malls, restaurants, etc.). For example, MOPH and the World Health Organization established jointly in 2009 the National Program for Tobacco Control. The program was launched after the GOL signed in December 2005 the WHO Framework Convention on Tobacco Control, to counter the increasing prevalence of smoking in Lebanon, as well as to reduce the burden of tobacco-related diseases, including their impact on human health and economy.

4.3.1.3 Other ministries

In the transport sector, and to reduce vehicle emissions, MOIM contracted in 2004 a national vehicle inspection program to a private Joint Venture (called *mécanique*) on a BOT basis (Build, Operate and Transfer), and for a period of nine years (2004-2013). *Mécanique* built, equipped and is operating five inspection stations on lands owned and provided by the GOL. At the end of the BOT contract period, the firm will in theory hand over the entire operation including infrastructure, buildings and equipment to the GOL (YASA, 2010).

Vehicle inspection includes examination of brakes, lights and emissions from tailpipes. In addition to vehicle safety issues, this inspection aims to reduce emissions from vehicles by adopting the Lebanese pass-or-fail values for CO, CO_2, and HC. A well run inspection program is capable of achieving very significant emission reductions and can be a good starting point for pollution-control.

In the energy sector, the MOEW has prepared tender specifications for transformer oil (they should be PCB-free) and fuel products including limit values for sulfur content in heavy fuel oil (2.5% by weight). To date, there are no emission standards for large power plants (>300MW).

In the industry sector, and according to Law 642/1997 that established the Ministry of Industry (MOI), a permitting committee examines applications received from new and existing industrial establishments. The committee operates under the MOI and brings together representatives from the ministries of Industry, Public Health, Environment, Public Works and Transport including the- Directorate General of Urban Planning (DGUP). The committee can approve new permit applications, as well as renew or cancel existing permits based on environmental, health and safety criteria.

4.3.1.4 Municipalities

Municipalities play a modest role in improving air quality but could do much more, within their mandate, to alleviate air pollution. For example, some municipalities (Hazmieh, Zahleh, etc.) carry out routine inspections of private power generators, making sure they are fitted with appropriate stacks, filters, and noise reduction measures to minimize public nuisance. Other municipalities (Beirut, Tripoli, etc.) are facilitating air quality monitoring programs (but still need to do more to communicate air quality data to citizens). Finally, the municipality and municipal police can also play an important role in traffic management by manning key intersections,

Private power generators are widespread and poorly regulated

installing traffic lights at key locations, enforcing zero-tolerance on double-parking, etc. Collectively, these measures that can ease traffic and help reduce emissions.

4.3.1.5 Other Key Players

Tripoli Environment and Development Observatory (TEDO) was established in 2000 by the Federation of Municipalities of Al-Fayhaa (Tripoli, El-Mina, and Beddawi) and with grant funding from EU's Short and Medium Term Priority Environmental Action Plan (SMAP) Program. The objectives of its air pollution laboratory are to (1) identify air pollutants, (2) prepare inventory of air pollution sources, (3) measure emissions, (4) raise public awareness, and (5) improve urban air quality. Today, long after the initial funding ended, the observatory is formally integrated into the municipal structure of the Federation (COM Decision 18, dated 29/12/2004).

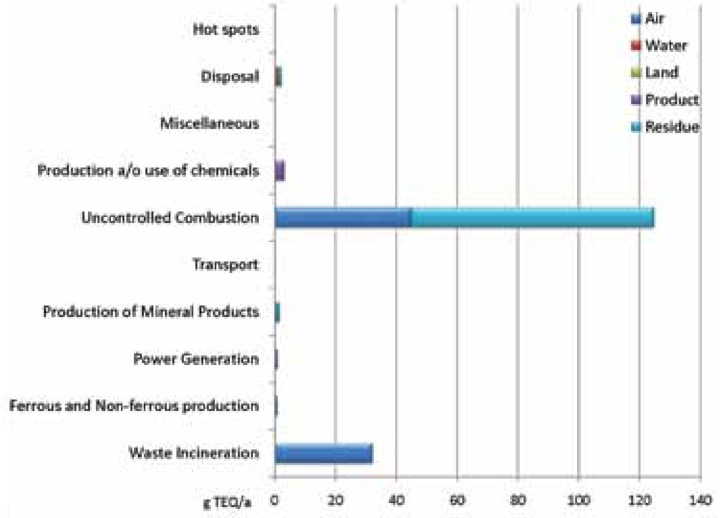
The Lebanese Cleaner Production Center (LCPC) was established by MOE in 2002 with grant funding from the European Commission and the Austrian Government through UNIDO. After an initial hosting period at MOE, the LCPC was relocated to the Industrial Research Institute (IRI) in 2004. The centre is today integrated into the IRI, is part of a global network of National Cleaner Production Centers from 41 countries, and was recently elected as the CPC representative for West Asia. The LCPC was the second center to be established in the Middle East and has been contracted to initiate cleaner production centers in the UAE and KSA. The centre provides assistance to Small- and Medium-Sized Enterprises (SME's) in adopting Cleaner Production measures and sustainable industrial production modes that will reduce consumption of water and energy, decrease pollutants emissions, and effluent loads and waste. In fact, the LCPC chooses industries from each industrial sector, inspects installed equipment, identifies areas of resource inefficiency and proposes the best Cleaner Production option. These services are provided to industrialists free of charge. Subsequent cost implications of implementing the recommendations of the LCPC team are left to the discretion of the industry. For example, a food industry installed a brand new boiler that achieves 85 percent efficiency, up from a previous 40 percent, resulting in much lower emissions. Fuel savings amounted to $25,000 per year. http://www.lebanese-cpc.net/

4.3.2 Multilateral Environmental Agreements

The GOL has acceded to and ratified several multilateral environmental agreements related to (1) phasing out of POPs (see summary in Box 4.7), (2) combating Climate Change (Box 4.8), (3) protecting the ozone layer (see current status in Box 4.9) and (4) controlling tobacco use. Table 4.16 lists key conventions and protocols related to the atmosphere and air, and their implications on Lebanon.

Box 4.7 National Implementation Plans for the Management of Persistent Organic Pollutants

Lebanon was one of 12 countries to conduct a pilot project for handling and managing POPs including (a) dioxins and furans (by-products of combustion activities) (b) pesticides (agriculture), and (c) PCBs (from closed applications such as transformer oil). As part of this regional project, MOE prepared between 2003 and 2006 a *National Implementation Plan for the Management of POPs* with grant funding from GEF and technical assistance from UNEP through UNDP and private consulting firms. To produce the NIP, Lebanon prepared a preliminary inventory of POPs including sources and quantities, and assessed releases of Polychlorinated Dibenzodioxins and Polychlorinated DibenzoFurans (PCDD/PCDF) from various sources and into different media (air, water, land, etc.). This analysis revealed that uncontrolled combustion, so widespread in Lebanon, releases 44.98 gTEQ of PCDD/PCDF annually into the air -*see annual emission levels of PCDD/PCDF per type of activity below.* The NIP identified national challenges in the management of POPs including lack of facilities for the disposal of waste containing or contaminated with POPs; very limited financial and technical resources for remediation of contaminated sites; lack of POPs release monitoring schemes, etc.



Source: National Implementation Plans for the Management of POPs, MOE, 2006

Box 4.8 Climate Change and Lebanon's Second National Communication

Climate Change is one of the major worldwide challenges of our time. It is a growing crisis affecting the global economy, world population health and safety, planet food production, international security, etc. From shifting weather patterns that threaten food production, to rising sea levels that increase the risk of catastrophic flooding, the impacts of climate change are global in scope and unprecedented in scale. Without drastic action today, adapting to these impacts in the future will be more difficult. While developed countries are the largest contributors to climate change, its negative impacts are more severely felt by developing countries including Lebanon; they are more vulnerable because of their high dependence on natural resources and their limited capacity to cope with climate variability and extremes.

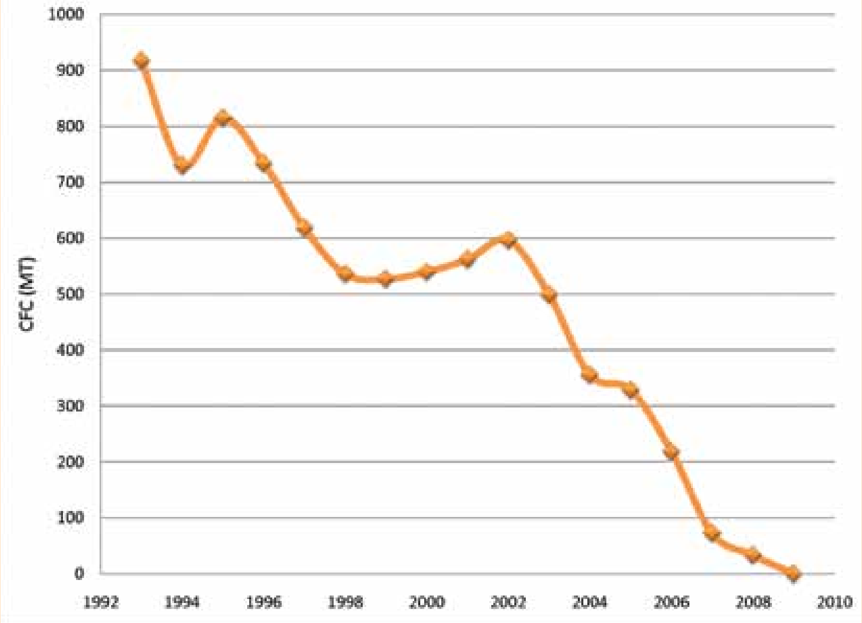
Lebanon's Second National Communication (SNC) to the UNFCCC comes to ascertain that although the country's GHG emissions are insignificant at the global level, Lebanon must prepare for the unavoidable consequences of climate change. The SNC therefore brings forward a set of mitigation and adaptation measures that would allow Lebanon to prepare –*see more details on Lebanon's solution in combating climate change in section 4.5.4*

MOE-UNDP, 2011

Box 4.9 National Ozone Unit: achievements and challenges

In January 1998, MOE and UNDP established the National Ozone Unit (NOU) to meet its obligation under the Montreal Protocol on Substances that Deplete the Ozone Layer. Lebanon has since entered into a $14.3 million agreement with the Multilateral Fund (MLF) for the phase-out of all Ozone Depleting Substances (CFCs, Annex-A, Group-I Substances, Methyl Bromide, Annex E Group-I Substances). The agreement requires Lebanon to completely phase-out CFCs and Halons by 1 January 2010 and Methyl Bromide by 1 January 2015. To achieve the 2010 milestone, the NOU provided technical and financial assistance to about 100 industries (foam, aerosol and refrigeration sectors) in the country, helping them convert their production from ODSs to non-ODSs technology. In practice, this meant that production technology that used CFCs were destroyed, put out of service, and replaced with non-CFC technology. During the period 1998-2010, Lebanon reduced consumption of **CFCs** from 923 tons in 1993 to **zero** consumption in 2010 (see figure). In 2007, on the occasion of the 20th anniversary of the Montreal Protocol, Lebanon has been awarded by the Montreal Protocol "The NOU Best Implementers Award" in appreciation of the government and NOU efforts to make the Protocol's phase-out goals a reality, as well "The Montreal Protocol Exemplary Project Recognition" for the contribution through the Methyl Bromide phase-out public-private partnership.

CFC consumption trend in Lebanon (1992-2010)



Phasing out CFCs did not solve the entire Ozone Depletion problem. While CFC consumption declined, the reliance on alternatives, including Hydrochlorofluorocarbons (HCFCs, such as R-22 and R-141b used in the refrigeration and foam sectors), picked up rapidly. In particular, **HCFC** consumption in Lebanon increased from about 278 MT in 2004 to **826 MT** in 2009 (annual growth of 34% for the past five years). Because HCFCs have a high global warming effect, the Parties to the Montreal Protocol decided at their 19th meeting in September 2007 to freeze the production and consumption of HCFCs in Article-5 countries and accelerate their phase-out (Decision 19/6 of the Meeting of the Parties). In particular, Parties need to freeze production and consumption of HCFCs effective 1 January 2013 to the Baseline Level (average consumption in 2009 and 2010), and then to reduce consumption of HCFCs by 10 percent effective 1 January 2015. The MLF will support the Parties, including Lebanon, to prepare a HCFC Phase-out Management Plan to meet the 2013/2015 control targets. Accordingly, Lebanon prepared and submitted to the MLF a strategy and action plan for compliance with the 2013/2015 control targets in July 2010. With UNDP assistance, MOE is responsible for monitoring the implementation of the HCFCs phase-out plan.

Source: MOE National Ozone Unit, 2011

Table 4.16 Multilateral Environmental Agreements related to the atmosphere and air

Conventions	*Main goals*	*Signature/ Adhesion/ Ratification/ date*	*Implications on Lebanon*
Vienna Convention for the Protection of the Ozone Layer	Framework for the international efforts to protect the ozone layer damaged by ODS including CFCs, HCFCs, halons, methyl bromide	Adhesion by law number 253 (30/03/1993)	See implications under Montreal Protocol
Montreal Protocol on Substances that Deplete the Ozone Layer *and its four amendments*	Protocol to Vienna Convention- Phasing out the production and consumption of substances believed to be responsible for ozone depletion.	Adhesion by law number 253 (31/03/1993)	Phase out the consumption of ODS completely by the end of 2010. The National Ozone Unit (NOU) was established at MOE to assist industries in phasing-ou–ODS
United Nations Framework Convention on Climate Change (UNFCCC)	Framework for the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system	Ratification by law number 359 (11/08/1994)	1) No requirement to decrease national GHG emissions. Lebanon has voluntarily committed to increase Renewable Energy (RE) to 12% by 2020 (Copenhagen 2009). 2) Submit national inventory of GHGs (for baseline years 1994 and 2000, based on the COP decision), assess Lebanon's vulnerability to Climate Change, and propose adaptation and mitigation strategies to reduce GHG emissions (although not an obligation under the UNFCCC) and adapt to the impacts of climate change. .
Kyoto Protocol	Protocol to the UNFCCC Reduction of GHG (CO_2, CH_4, N_2O, SF_6) emissions to levels that would prevent interference with the Climate System.	Raticiation by law number 738 (15/05/2006)	The Clean Development Mechanism (CDM), defined in Article 12 of the Protocol, allows a country (Annex I and Annex B Parties,with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to implement an emission-reduction project in Non-Annex I countries (including Lebanon). Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets.
Stockholm Convention on Persistent Organic Pollutants (POPs)	Framework for the Protection of human health and the environment from POPs, including (a) dioxins and furans (by-products of combustion activities) (b) pesticides (agriculture), and (c) PCBs (closed applications, such as transformer oil)	Signature: 22/5/2001 Accession by law number 432 (08/08/2002)	Eliminate production and import of POPs by 2025; set environmental guidelines and action plan for the use of POPs in the country and release prevention; develop educational and public awareness materials on the effects of POPs; and identify and quantify the main sources of POPs in the country.
WHO Framework Convention on Tobacco Control (WHO FCTC)	Framework for combating the tobacco epidemic and its industry marketing as well as protecting present and future generations from the devastating consequences of tobacco consumption and exposure to tobacco smoke	Ratification by law number 657 (04/02/2005)	A National Program for Tobacco Control (NPTC) was established in 2009 in Lebanon as a result of the GOL signing the FCTC. The NPTC came as a joint program between the MOPH and WHO –See section 4.5.

4.4 SELECTED RESPONSES TO AIR QUALITY ISSUES

Lebanon has made noteworthy strides to reduce air pollution from point sources, but not enough. More is needed from the Government and from individual citizens to limit emissions and abate air pollution impacts. The following sections summarize selected and measurable responses to air quality issues.

4.4.1 Improved Ambient Air Quality Monitoring Programs and Capabilities

Lebanon now has a partial air quality monitoring program. This constitutes the building block for establishing air pollution management strategies in the country. In the last decade, dozens of municipalities and universities started to invest resources in acquiring air quality monitoring instruments and training air quality professionals. These efforts are generating air quality data in Beirut, Chekka, Selaata and Tripoli *–see section 4.2.1 for more details related to inter-agency cooperation*. These monitoring initiatives, although still under-resourced, help define principles for air pollution abatement policies and support the development of a National Air Quality Strategy (MOE/EU/NEAP, 2005u), yet to be developed by MOE (Decree 2275/2009, Article 24).

4.4.2 Partial Implementation of Law 341/2001

One of the primary government responses to Lebanon's air pollution problem was the approval and implementation of Law 341/2001, amended by Law 380 (14/12/2001) and Law 453 (16/8/2002). It has partially curbed air pollution from the transport sector and encouraged the use of less polluting fuels. Specifically, the law banned (1) the import of minivans and buses (<15 passengers + driver) operating on Diesel oil, (2) the import of old and new Diesel engines for private passenger cars and minivans, (3) the use of Diesel in private vehicles, and (4) the use of leaded gasoline in all vehicles. It also made catalytic converters a mandatory requirement in all vehicle categories and reinstated the mandatory vehicle inspection (*mécanique*) for gasoline engines (annual inspection) and Diesel engines (every six months). The total ban on leaded gasoline is an outstanding example of an air pollution reduction measure, with considerable benefits for public health and the environment. However, there has been some debate in recent years over the use of methyl tert-butyl ether (MTBE), an effective substitute of Lead in petroleum products, and its impacts on the environment due to its persistency and mobility.

In the years that followed the promulgation and enforcement of Law 341/2001, private interest groups and legislators recognized a number of deficiencies. This has prompted the GOL to explore avenues for improving and expanding the provisions of Law 341/2001, by reviewing similar laws and experiences in other countries (e.g., United Kingdom, Japan, Korea and China). Years of debate and consultations have yielded a proposed amendment to Law 341/2001 which is expected to be approved by parliament. *See proposed amendments in Table 4.17*. Also, a number of measures have already been adopted by MOF in coordination with MOE including Article 83 of the 2010 proposed budget law (approval pending) which exempts Hybrid cars from customs fees.

Separately, in 2002, the COM enacted Decree 8442 (dated 13/08/2002) which defines standards for gasoline and Diesel oil used in vehicles including their Sulfur content; 0.05% by weight in gasoline 92, 95 and 98 Octane and 0.035% by weight in Diesel oil *–see Chapter 9 for more information on sulfur content in other petroleum products.* While this is a good first step, Lebanon should aim to introduce Ultra Low Sulfur Diesel (ULSD) (>15 ppm). Lower sulfur content will allow the application of newer emission control technologies that will substantially lower emissions from engines.

4.4.3 Emission Control Guidelines

MOE has developed environmental guidelines and limit values for emissions for several industry sectors including Lebanon's cement industry (Decision 8/1 dated 2001). Cement plants pose serious concerns and have been the cause of many complaints received by local municipalities and MOE. Recognizing the need to engage polluters in any air quality monitoring and abatement program, the Ministry has developed a self-monitoring program with each cement plant whereby the industry monitors air emissions on a daily basis and submits monthly reports to MOE for review (Decision 191/1 dated 1997). Subject to resource availability, the ministry conducts random inspection of stack emissions, sometime in response to formal complaints received from nearby residents to community groups *–see for example Batroun Tribunal (Criminal Court) Decision 40/2003 dated 24/2/2003* (MOJ/MOE/UNDP 2010).

4.4.4 Total Phase-Out of CFCs

The Montreal Protocol was established to reverse ozone depletion globally and help parties to the protocol phase-out CFCs and

Table 4.17 Summary of actions and proposed actions in Law 341/2001 and its draft amendment (2010)

Provisions in Law 341/2001	Proposed amendment and additions
Retrieval by GOL of up to 10,000 public license plates (cars including "Taxi" and "Service")	Retrieval by GOL of up to 10,000 public license plates as follows: a) 7500 car plates including "Taxi" and "Service" with an allowance of 9 Million L.B.P for every plate b) 2000 bus plates (15 passengers + driver) with an allowance of 12 Million L.B.P for every plate c) 500 bus plates (>25 passengers + driver) with an allowance of 18 Million L.B.P for every plate
Provide incentives for vehicle owners to renew their public transport fleet (tax cuts and tariff exemption)	Provide incentives (tax cuts, tariff exemption and *mécanique* exemption for first registration) to private and public vehicle owners to switch to hybrid electric, fuel cell/Hydrogen and Natural Gas vehicle
Import ban on minivans operating on Diesel	Import ban on all types of vehicles and engines (civilian and military) including buses (<15 passengers + driver), Pullman, freight cars (weight>3500Kg) and power generators operating on diesel unless they comply with last emission standards: EU Emission Standards (EURO) or equivalent
Set permissible exhaust limit values	Permissible exhaust limit values will be determined by MEW, MoI and MOE
Ban the use of Diesel in minivans and small pick-ups	All Diesel vehicles (locals and foreigners) and engines must comply with EU Emission Standards or equivalent–
NA – new	Ban the operation of Diesel buses (<15 passengers + driver) in urban cities and implement restrictions for their itinerary between urban and rural areas
NA – new	All buses, pick-ups, freight cars and heavy machineries circulating on Lebanese territory must use local fuel to conform with local fuel standards
NA – new	Mandatory inspection of Diesel quality distributed by gas stations
NA – new	Equip MOIM traffic police with special tools to sample and check vehicle fuel quality
NA – new	Standards for fuel quality used in vehicles, industries, will be developed by LIBNOR and based on EU Emission Standards

other ODS. In Lebanon, efforts to reduce ODS consumption achieved stunning success, from 923 tons of CFCs in 1993 down to nil in 2010. The National Ozone Unit at MOE provided technical and financial assistance to about 100 industries helping them convert their production from ODSs to non-ODSs technology *–see Box 4.9 for more information on NOU activities.* On a global scale, chemistry-climate models predict that recovery to pre-1980 Antarctic ozone layer can be expected around 2060-2075 (GEO 4, UNEP, 2007).

4.5 EMERGING ISSUES AND OUTLOOK

In the last decade, the progress that has been made in preventing and controlling air pollution in the country has been achieved through effective multi-stakeholder participation at different scales and mobilization of public-private partnerships.

4.5.1 Draft Law on the Protection of Air Quality

The MOE prepared in 2005 a draft law on the Protection of Air Quality (Clean Air Legislation) within the framework project SELDAS, and after comparing the benefits of developing priority legislation related to water and air pollution. The draft law comprises 34 articles related to ambient air pollution (including fixed and mobile sources), monitoring air pollutants (National Program for Ambient Air Quality Monitoring, National Network for Ambient Air Quality Monitoring, National emission inventory, National report on the Ambient Air Quality), assessment of their levels in the Lebanese atmosphere (Setting Limit Values and Thresholds of Ambient Air Pollutants including CO, NO_x, O_3, Particles, SO_x, NMVOC and Pb, emission limit values of fixed sources, emission limit values of mobile sources, specifications of harmful material in fuel, etc.), prevention, control and surveillance of the ambient air pollution resulting from human activities. This law awaits formal review by the COM and approval by the Lebanese Parliament.

4.5.2 Taxi Fleet Renewal Program

Lebanon should fast-track policies that will renew Lebanon's feeble taxi fleet. A *Taxi Swap to Hybrids and Fuel-Efficient Cars* policy would help rid Lebanon of up to 12,000 old and often dilapidated cars, reduce urban fuel consumption, as well as enhance Lebanon's brand image and green competitiveness. The policy requires a string of government incentives to eligible cars including exemption from customs and excise duties, $2,500 payment against the old car, and full subsidy of loan interest and guarantee of the car loan. *See detailed findings of a feasibility study to renew the urban taxi fleet in Box 4.10 prepared based on the GOL Ministerial Declaration (dated 8/12/2009).*

Box 4.10 Taxi Fleet Renewal Program

In a 2010 study commissioned by the Presidency of the Council of Ministers, Booz & Company articulated a Taxi Fleet Renewal Program for Lebanon and evaluated its feasibility based on three scenarios all of which constitute a voluntary scheme: (1) swap to hybrids, (2) swap to fuel-efficient cards, and 3) swap to fuel-efficient cars and hybrids. The primary objectives of the program were to contribute to a cleaner environment, enhance Lebanon's brand image, increase the net income of taxi owners, and minimize legislative requirements and financial burden for the government.

To date, there are six fuel efficient hybrid cars on the global market of which only one model (Toyota Prius) is marketed in Lebanon. Globally, Hybrid cars represent less than 4 percent of total gasoline cars in circulation. The study determined that the addressable taxi market are 17,000 legal and urban taxis older than 2005. From this pool, the study estimated that about 5,000 taxi owners would be interested by a swap to hybrids (Scenario 1) but that such a swap would cost the GOL $70 million including $16 million in outright payments. Hybrids are expensive ($37K for a Prius + tax) and taxi owners would need to spread the purchase price, plus cost of repairs and battery replacement (every four years) over an 8-year loan period.

With fuel-efficient cars (Scenario 2), the swap program becomes more feasible. Fuel-efficient cars are cheaper (about $14K-$20K + tax) and have a fuel city consumption of 11 liters per 100 km. In particular, the addressable taxi fleet market would increase to 25,000 cars of which an estimated 12,000 cars would be interested in the swap, costing the GOL $57 million including $27 million in outright payments. Much higher affordability of fuel efficient cars and lower maintenance requirement would cut the loan period by half, down to 4 years. To enhance green competitiveness and reduce emissions further, encouraging 12,000 potentially interested taxi owners to choose between hybrid or fuel-efficient cars (Scenario 3) would achieve the best results and cost the GOL $70 million over the coming seven years ($30 million in outright payments and $40 million in forgone revenues).

Source: booz&co. 2010

Old and dilapidated taxi in Beirut

4.5.3 Improving Mass Transport

As discussed in Section 4.1, and in the absence of an efficient mass transport system covering the entire territory, Lebanese citizens rely heavily on their private vehicles for daily commuting. Usually, mass transport systems would include a combination of buses, trolleybuses, trams and trains, rapid transit (metro/subways/ undergrounds, etc) and/or ferries. In Lebanon, rail transport began in the 1890s and continued for most of the twentieth century until it was interrupted by the civil war and associated impacts including widespread infringement on the public domain.

Today, mass transport is limited to low capacity buses (about 24 passengers; compared with trams and trains) that have no dedicated lanes and therefore compete with private vehicles on very congested roads. Most of them are dilapidated and operate on Diesel oil spewing dark plumes on pedestrians, traffic policemen, and street stores. In the GBA, there are two bus networks; one is public (operated by the MOPWT) and one is private (Lebanese Commuting Company). Ticket fares range from LBP750 to LBP1,000 ($0.5-0.7). Lebanon urgently needs to devise and implement a bus fleet renewal program that would encourage the public and the private sector to acquire new buses that run on cleaner fuels. Dedicated bus lanes should also be explored to reduce travel time and build consumer confidence in the public service. This is a priority measure to reduce air pollution and road congestion in cities. It is worth mentioning here that the Directorate General for Land and Marine Transport at MOPWT submitted to the GOL in 2002 a draft transport policy that aims to promote the economic, financial, environmental and social sustainability of the land transport sector in Lebanon. No action was taken by the GOL and the draft policy was never enacted nor approved. Presently, a new draft Law/Strategy on transport is being discussed.

4.5.4 GOL Commitment to Renewable Energy

Phenomenal growth in energy consumption worldwide engenders rapid increases in GHG emissions, accelerated urban growth and infringement on natural areas thereby compromising carbon sinks. Mounting evidence suggests beyond doubt that global warming is occurring and its impacts will intensify in the coming decades. And air pollution is no longer a local issue but a global concern since polluted air masses move long distances. Air pollutants remain suspended in the environment for long periods of time and are carried by winds

Credit: Christian Akhrass

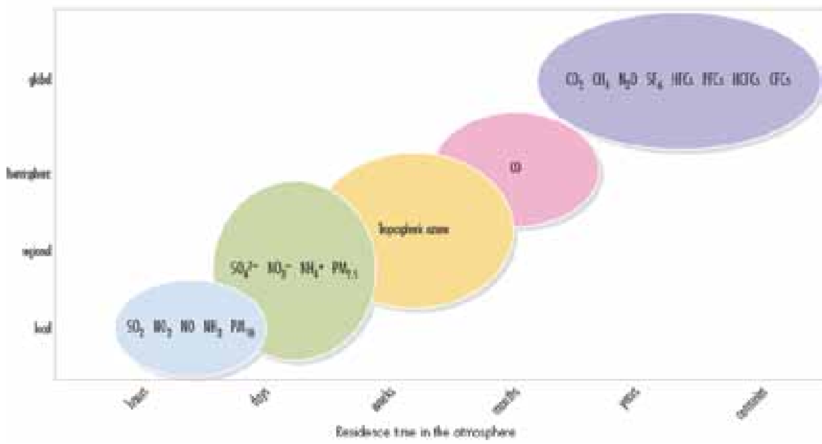
Remains of the defunct national railway in Dahr el Baydar

Public transport buses are old and inefficient (here a graveyard for out of service buses in Mar Mikhail, Beirut) hundreds and thousands of kilometers from their origin –*see lifespan of major air pollutants in the atmosphere in Figure 4.15*.

Lebanon's contribution to global GHG emissions is insignificant. For example, in 2000, CO_2 emissions in the UK reached 553,046Gg compared to Lebanon's 18,507Gg (UNFCCC); the per capita contribution to CO_2 emissions in Lebanon is significantly lower than in the UK (4.6 t of CO_2 per capita per year in Lebanon versus 8.9 t CO_2/capita/year in the UK). Ironically, the smallest contributors to total GHG emissions will be affected by the impacts of global warming the most. In Lebanon, predictions show that global warming will bring significant consequences on water resources (snow melting, drying springs, rainfall intensity and regime, etc.), biodiversity (species loss, agricultural damages, etc.), land resources, public health and major socio-economical systems.

[4]Smoking ban in all hospitals, pharmacies, cinemas, theatres, public transport, sport clubs and schools & universities classrooms.

Figure 4.15 Life-span and spatial scale of major air pollutants in the atmosphere



Source: UNEP-GEO 4, 2007

Beyond its long-term impacts on the environment, global warming is already affecting lifestyles (i.e. nowadays, air conditioners are considered standard home appliances rather than luxury items). The GOL is slowly appreciating the anticipated impacts of global warming on society and so has made a voluntary pledge, and on condition to be supported financially and technically by developed countries, to increase the share of renewable energy in its total energy consumption from 4 to 12 percent by 2020 (A developing country, Lebanon is not required to decrease GHG emissions). This pledge was made at the UNFCCC COP in Copenhagen (Denmark) in 2009. Subsequently, the MOEW prepared a strategy paper (road map) for the electricity sector and included initiatives on how to increase RE harvesting to meet the 12 percent target –*see Chapter 9 for more details on the Policy Paper for the Electricity Sector and RE 2020 target.*

4.5.5 Anti-Smoking Legislation

A National Program for Tobacco Control (NPTC) was established in 2009 to counter the increasing prevalence of smoking in Lebanon, as well as to reduce the burden of tobacco-related diseases including their impact on human health and economy by focusing on raising awareness. However, Lebanon still has one of the weakest tobacco control policies in the Middle East region. The current and most important aim of the NPTC is to advocate for a national law on tobacco control that focuses on advertising bans, smoke-free public places, and warning labels. Advocacy of strong tobacco control policies such as a total smoking ban in indoor places without exemption is supported by other key players including the AUB Tobacco Control Research Group. The anti-smoking law will update and amend ministerial Decree 213/1 (1993)[4] and Decision 394 (1995).

4.5.6 Miscellaneous Initiatives and Greener Lifestyles

Improving air quality is a shared responsibility. The GOL shoulders a lot of responsibility for reducing air pollution from point and non-point sources, but citizens also can make a difference through lifestyle changes. For example, Lebanese citizens and other residents of Lebanon can:

- Participate in reforestation programs (through public or private initiatives) –*see reforestation efforts in Chapter 6.*
- Walk or bike to nearby destinations, whenever possible, while exercising and saving money
- Use mass transportation / public transport whenever possible but avoid transportation that uses air-polluting fuel
- Buy and/or use fuel-efficient vehicles including hybrid cars if possible
- Carpool, the simplest and most common "ride sharing" arrangement –see for example national car pooling initiative www.lebanoncarpooling.com
- Buy local / Lebanese products to reduce transportation costs and air pollutant emissions

Made in Lebanon
صنع في لبنان

- Buy energy-saving devices and appliances

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CITED LEGISLATION RELATED TO AIR QUALITY AND ATMOSPHERE

نوع النص	الرقم	التاريخ	عنوان النص
قرار وزيري الصحة والشؤون الاجتماعية	١/٢١٣	١٩٩٣/٠٣/٠٢	يتعلق بمنع التدخين في الأماكن العامة
قانون	٢٥٣	١٩٩٣/٠٧/٢٢	الإجازة للحكومة الإنضمام إلى معاهدتين متعلقتين بطبقة الاوزون
قانون	٣٥٩	١٩٩٤/٠٨/٠١	إتفاقية الأمم المتحدة بشأن تغير المناخ
مرسوم	٦٦٠٣	١٩٩٥/٠٤/٠٤	تحديد شروط إستعمال سيارات الشحن وسيارات اوتوبيس والمركبات الآلية العاملة على المازوت وكيفية مراقبتها ومستوى المعدل المقبول لكثافة الدخان المتصاعد منها ونوعيته
قرار مجلس النواب	٣٩٤	١٩٩٥/٠١/١٢	التحذير من مضار التدخين
قرار وزير البيئة	١٩١/١	/١٠/١٩٩٧٠٨	تطبيق المذكرة الارشادية لصناعة الاسمنت في لبنان والتلوث البيئي العام الناتج عنها
قانون	١٢٠	١٩٩٩/١٠/٢٥	الإجازة للحكومة الانضمام إلى تعديلات كوبنهاغن المتعلقة ببروتوكول مونتريال حول حماية طبقة الأوزون من المواد المستنفذة لها
قرار وزير البيئة	١/١٥	٢٠٠٠/٠٤/١٣	منع إستيراد وإستعمال مطافيء عاملة بمواد سائلة خاصة بالسيارات والآليات
قرار وزير البيئة	١/٨	٢٠٠١/٠١/٣٠	المواصفات والمعايير المتعلقة بملوثات الهواء والنفايات السائلة المتولدة عن المؤسسات المصنفة ومحطات معالجة المياه المبتذلة
قانون	٣٤١	٢٠٠١/٠٨/٠٦	قانون التخفيف من تلوث الهواء الناتج عن قطاع النقل وتشجيع ألإتجاه إلى إستعمال الوقود الأقل تلوث
قرار وزير البيئة	١/٥	٢٠٠١/٠١/١٢	الشروط البيئية لرخص إنشاء و/أو استثمار محطات توزيع المحروقات السائلة
قانون	٣٨٠	٢٠٠١/١٢/١٤	يتعلق بتعديل بعض مواد في القانون رقم ٣٤١(٢٠٠١) قانون التخفيف من تلوث الهواء الناتج عن قطاع النقل وتشجيع ألإتجاه إلى إستعمال الوقود الأقل تلوث
قانون	٤٤٤	٢٠٠٢/٠٧/٢٩	حماية البيئة
قانون	٤٣٢	٢٠٠٢/٠٧/٢٩	الإجازة للحكومة الإنضمام إلى إتفاقية ستوكهولم للملوثات العضوية الثابتة
قانون	٤٤٨	٢٠٠٢/٠٧/٢٩	الإجازة للحكومة شراء اليات عاملة على المازوت
مرسوم	٨٤٤٢	٢٠٠٢/٠٨/١٣	يتعلق بمواصفات البنزين ٩٢ و ٩٥ و ٩٨ اوكتان من دون رصاص والديزل اويل (المازوت) لاستخدامها في المركبات الآلية
قانون	٤٥٣	٢٠٠٢/٠٨/١٦	تعديل الفقرة (ب) من المادة الثانية من القانون رقم ٣٤١ المعدل بالقانون رقم ٣٨٠ وإلغاء القانون رقم ٤٤٨
قرار وزير البيئة	١/٩	٢٠٠٤/١٢/٠٢	تحديد المسافات الدنيا التي يجب ان تفصل جميع انواع المزارع المنوي انشاؤها و/او استثمارها في المناطق الغير منظمة عن المناطق الآهلة
قانون	٦٥٧	٢٠٠٥/٠٢/٠٤	الإجازة للحكومة الإنضمام إلى إتفاقية منظمة الصحة العالمية الإطارية بشأن مكافحة التبغ
قانون	٧٣٨	٢٠٠٦/٠٥/١٥	الإجازة للحكومة الإنضمام إلى برتوكول كيوتو الملحق بإتفاقية الامم المتحدة الإطارية بشأن تغير المناخ
قانون	٧٥٨	٢٠٠٦/١١/١١	الإجازة للحكومة الانضمام إلى تعديلات بيجين المتعلقة ببروتوكول مونتريال بشأن المواد المستنفذة لطبقة الأوزون
مرسوم	٢٦٠٤	٢٠٠٩/٠٩/١٧	التحكم في المواد المستنفذة لطبقة الأوزون