# Air Quality

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## I. INTRODUCTION

In recent years, worldwide public concern over deteriorating air quality and the associated local and global impacts has grown significantly. The impacts on human health could be the most drastic since human lungs, containing very sensitive tissues, receive daily around 15Kg of air compared to 2.5Kg of water and 1.5Kg of food. Moreover, polluted air spreads over long distances and can practically not be avoided. Also, the global impact of pollution-related phenomena such as global warming has been proven to have alarming consequences. This has led governments and local authorities, mainly in industrialized countries, into taking these issues more seriously and hence establishing various emissions limits and standards and implementing mitigation measures to reduce the pollution of the air down to bearable levels.


Concerns related to air quality degradation arise in several quite distinct contexts, often requiring separate legal and other policy responses and actions. By far the most important problem is ambient air – the air people breathe outside buildings and, more broadly, the air in the tropospheric layer. Next are the two global concerns related to the stratosphere: climate change caused by excessive green house gases emissions; and the depletion of the ozone layer protecting life from UV radiation reaching the earth from the sun. Finally, there is the problem of indoor air pollution and odour that may impose a lethal health risk which is sometimes neglected by environ-

TABLE 1 **RECENT STATISTICS FROM THE ARAB COUNTRIES (FOR YEARS 2002-2004)**

| Country | Population in 2007 [1] | Number of Vehicles per 1000 inhabitants [2] | Capital | Capital Population | Number of Vehicles in the Capital [3,4] |
|---|---|---|---|---|---|
| **Algeria** | 33,857,913 | 87 | **Algiers** | 1,980,000 | 600,000 |
| **Bahrain** | 752,647 | 322 | **Manama** | 162,000 | 280,000 |
| **Egypt** | 75,497,914 | 30 | **Cairo** | 9,600,000 | 2,000,000 |
| **Iraq** | 28,993,376 | 50 | **Baghdad** | 5,750,000 | 1,000,000 |
| **Jordan** | 5,924,247 | 47 | **Amman** | 1,147,447 | 471500 |
| **Kuwait** | 2,851,144 | 357 | **Kuwait** | 32,400 | 900,000 |
| **Lebanon** | 4,099,114 | 434 | **Beirut** | 2,012,000 | 300,000 |
| **Libya** | 6,160,481 | 234 | **Tripoli** | 1,150,000 | 1,243,418 |
| **Morocco** | 31,224,136 | 53 | **Rabat** | 1,620,000 | 254,674 |
| **Oman** | 2,595,132 | 150 | **Muscat** | 24,769 | 316,786 |
| **Qatar** | 840,634 | 378 | **Doha** | 340,000 | 252,959 |
| **Saudi Arabia** | 24,734,532 | 336 | **Riyadh** | 4,087,152 | 985,000 |
| **Syria** | 19,928,518 | 50 | **Damascus** | 1,614,500 | 250,000 |
| **Tunisia** | 10,327,285 | 71 | **Tunis** | 728,453 | 550,000 |
| **UAE** | 4,380,439 | 193 | **Abu Dhabi** | 552,000 | 212,686 |
| **Yemen** | 22,389,172 | 47 | **Sana'a** | 1,747,627 | 823556 |

Sources: 1. Abdalla, 2006 ; 2. United Nations, 2007 ; 3. NationMaster, 2008 ; 4. PCBS

mentalists as it does not affect nature. Recent studies conducted by national and international organizations, including the World Bank, have indicated that the annual cost of all aspects of air quality degradation is substantial and could constitute up to around 2% of GDP in developed countries and more than 5% in developing countries. These costs include mortality, chronic illness, hospital admissions, lower worker and agricultural productivity, IQ loss, and reduction of visibility. Up to 800,000 premature deaths, and up to 1 million pre-natal deaths have been estimated as one consequence of air pollution globally (Abdalla, 2006).

Table 1 presents a list of Arab countries with statistics about the population densities of each country, the number of vehicles allocated for every 1,000 inhabitants, i.e. the car ownership rate. According to these two sets of statistics, the total number of vehicles in a country is estimated. The population of the capital city for each country is also presented, together with the number of vehicles in each capital.

The car ownership rate indicates the reliance of each Arab state on the transport sector, and is to a certain extent related to the economic standing of the country. Table 2 correlates energy consumption with the national GDP. Here also the recorded figures are much related to the levels of urbanization and economic development in individual countries. Energy consumption per GDP in developing countries, in general, is higher than that of more advanced nations, and this is interpreted sometimes as indicating the inefficient use of energy through the reliance on old technologies for energy conversion, including the transport sector. This gap, however, has been narrowed as indicated in table 2. It is also worth highlighting that some Arab countries have witnessed a drop in relative consumption between 1990 and 2003.

TABLE 2 **ENERGY CONSUMPTION PER GDP IN TONES OF OIL EQUIVALENT (toe) PER MILLION CONSTANT 2000 INTERNATIONAL $**

| Country | 1990 | 2000 | 2003 |
|---|---|---|---|
| **Algeria** | 174.2 | 177.2 | 176.8 |
| **Bahrain** | 666.8 | 582.5 | 559.4 |
| **Egypt** | 197.8 | 189.3 | 201.4 |
| **Jordan** | 286.1 | 276 | 253.1 |
| **Kuwait** | .. | 566 | 481 |
| **Lebanon** | 366.8 | 339.1 | 327 |
| **Morocco** | 84.0 | 101.1 | 96.4 |
| **Oman** | 233.3 | 311.1 | 361.6 |
| **Saudi Arabia** | 353.1 | 426 | 448 |
| **Sudan** | 364.3 | 244.2 | 266.7 |
| **Syrian Arab Rep** | 350.8 | 322.2 | 294.3 |
| **Tunisia** | 149.5 | 126.9 | 123.3 |
| **United Arab Emirates** | 530.9 | 535 | 481.3 |
| **Yemen** | 332.6 | 345 | 335.9 |
| ***Developed Countries*** | *219.1* | *221.1* | *211.8* |
| ***Developing Countries*** | *300.0* | *230.1* | *224.3* |

Source: EarthTrends

## II. EMISSIONS IN THE ARAB WORLD

Most countries in the region, and in particular the capitals and other major cities, suffer from different degrees of air pollution. About 90 percent of total emissions of carbon monoxide (CO) in Arab countries is due to transportation activities. It is estimated that Arab countries emit collectively about 16 million tons/year of CO (El Raey, 2006). The Arab vehicle fleets emit 1.1 million tons/year of nitrogen oxides ($NO_X$). Between 70 and 80 percent of total hydrocarbon (HC) emissions originate from the transportation sector, and play an important role in the formation of photochemical oxidants. Lead, used as an additive in petrol, still accounts for more than half of total lead atmospheric emission in the Arab countries and almost 100 percent in urban areas. Diesel engines also emit sulphur dioxides ($SO_2$) and fine particulate. Stationary sources, such as thermal power plants, refineries, smelters, fertilizers plants, cement manufacturing, and water desalination plants also significantly contribute to air quality deterioration. Industrial compounds and manufacturing facilities emit gases such as $CO_2$, methane, Volatile Organic Compounds (VOCs) and nitrogen oxide ($NO_X$). In the Gulf Cooperation Council (GCC) countries total atmospheric emission loads are about 3.85 million tones per year, made of 28% CO, 27% $SO_2$ and 23% particulates (UNEP, 1999).

Recent studies have indicated that the Gulf countries emit about 50% of the total of Arab countries' (254 million metric tons of carbon) emissions of $CO_2$. A summary of various regional emissions is presented in Table 3.

TABLE 3 **ARAB COUNTRIES ANNUAL EMISSIONS (1000 TONS) FROM THE TRANSPORT SECTOR, AND THE PERCENTAGE THIS REPRESENTS OF TOTAL EMISSIONS**

| | $SO_2$ | $NO_x$ | TSP | CO | HC |
|---|---|---|---|---|---|
| **Road Transport** | 200 (5%) | 1,100 (37%) | 120 (10%) | 16,000 (<90 %) | 3,000 (<80 %) |

Source: El Raey, 2006

Recent reports have included several Arab countries amongst the top 50 countries with highest CO2-emitting power sectors (Center for Global Development, 2007). These are Saudi Arabia (75,900,000 tons and ranked 22nd), Egypt (45,000,000 tons, and ranked 30), Kuwait (19,000,000 tons and ranked 48th), and Algeria (17,700,000 tons and ranked 49th).

Table 4 shows the changes in the carbon dioxide per capita emissions over the past 3 decades. In most listed countries a substantial increase has been recorded between 1980 and 2003. These figures are also compared to the Middle East and World averages. These figures clearly indicate the wide variations amongst regional nations in energy consumption intensities and patterns. In general, GCC and other oil-exporting nations have emissions rates higher than the world average.

TABLE 4 **THE ARAB REGION'S NATIONAL PER CAPITA $CO_2$ EMISSIONS FROM THE CONSUMPTION AND FLARING OF FOSSIL FUELS**

| Region/Country | 1980 | 1990 | 2000 | 2003 |
|---|---|---|---|---|
| **Algeria** | 0.94 | 0.90 | 0.75 | 0.70 |
| **Bahrain** | 6.11 | 7.68 | 8.66 | 9.13 |
| **Egypt** | 0.27 | 0.44 | 0.46 | 0.53 |
| **Iraq** | 1.04 | 1.03 | 0.88 | 0.78 |
| **Jordan** | 0.67 | 0.85 | 0.84 | 0.85 |
| **Kuwait** | 6.12 | 3.48 | 8.15 | 8.16 |
| **Lebanon** | 0.58 | 0.40 | 1.24 | 1.17 |
| **Libya** | 2.83 | 2.74 | 2.21 | 2.77 |
| **Mauritania** | 0.10 | 0.13 | 0.33 | 0.29 |
| **Morocco** | 0.21 | 0.24 | 0.28 | 0.29 |
| **Oman** | 0.88 | 1.90 | 2.33 | 2.17 |
| **Qatar** | 16.37 | 10.54 | 12.64 | 10.78 |
| **Saudi Arabia** | 4.79 | 3.53 | 3.39 | 3.74 |
| **Somalia** | 0.05 | 0.04 | 0.03 | 0.02 |
| **Sudan** | 0.05 | 0.04 | 0.05 | 0.07 |
| **Syria** | 0.52 | 0.81 | 0.86 | 0.80 |
| **Tunisia** | 0.36 | 0.43 | 0.56 | 0.57 |
| **United Arab Emirates** | 8.09 | 10.99 | 12.61 | 14.45 |
| **Yemen** | 0.21 | 0.25 | 0.15 | 0.14 |
| ***Middle East Average*** | *1.43* | *1.48* | *1.76* | *1.89* |
| ***World Average*** | *1.12* | *1.11* | *1.07* | *1.11* |

Source: EIA World Carbon Dioxide Emissions from the Use of Fossil Fuels

Table 5 shows the net thermal electric power (in kilowatt hours - kWh) generated from thermal power plants in the Arab region. The presented figures show that the increase in demand for electricity in some countries has been higher than the world average. It should also be noted that the vast majority of the operating power plants are thermal, and mostly driven by fuel oil derivatives.

Recently, several electric utilities in the region have begun to use natural gas for thermal power generation. The amounts of emissions associated with generated power could be deduced from the emission rates from typical power plants as shown in Table 6.

The electric power sector in the region has the following common characteristics:

- Typical energy conversion efficiencies in the range of 30-35%.
- In most countries, the power sector is entrusted to a state-controlled monopoly for the generation, transmission, and distribution of electricity. This trend has been recently changed in some countries.
- Consequently, the limited available state financial resources, the future size of investments, and uncertainty about the future become major obstacles in any technology updating process.
- Fuel used for electricity generation is mostly being subsidized by the governments, and this leads to a significant undervaluation of electricity prices, causing misleading and distorted market signals provided to producers and consumers alike.
- Traditional electricity planning in these countries has focused on expanding supply resources to meet anticipated demand growth.

TABLE 5 NET THERMAL POWER PRODUCTION [BILLION kWh]

| Region/Country | 1980 | 1990 | 2000 | 2003 |
|---|---|---|---|---|
| **Algeria** | 6.44 | 15.01 | 23.84 | 27.55 |
| **Bahrain** | 1.55 | 3.28 | 5.92 | 7.30 |
| **Egypt** | 8.56 | 31.53 | 57.97 | 73.99 |
| **Iraq** | 10.05 | 20.12 | 29.41 | 26.23 |
| **Jordan** | 1.00 | 3.41 | 6.90 | 7.47 |
| **Kuwait** | 8.82 | 19.37 | 30.88 | 37.41 |
| **Lebanon** | 1.78 | 2.13 | 6.95 | 8.63 |
| **Libya** | 4.53 | 15.79 | 14.57 | 17.81 |
| **Mauritania** | 0.06 | 0.11 | 0.12 | 0.13 |
| **Morocco** | 3.43 | 7.90 | 12.16 | 15.46 |
| **Oman** | 0.90 | 5.02 | 8.56 | 13.74 |
| **Qatar** | 2.28 | 4.53 | 8.59 | 11.29 |
| **Saudi Arabia** | 20.45 | 64.90 | 118.62 | 143.82 |
| **Somalia** | 0.11 | 0.25 | 0.27 | 0.27 |
| **Sudan** | 0.47 | 0.52 | 1.19 | 2.06 |
| **Syria** | 1.20 | 5.61 | 20.67 | 25.14 |
| **Tunisia** | 2.60 | 5.16 | 9.88 | 11.48 |
| **United Arab Emirates** | 5.90 | 16.06 | 37.55 | 46.57 |
| **Yemen** | 0.47 | 1.56 | 3.21 | 3.85 |
| **World Total** | **5,588.54** | **7,137.85** | **9,255.70** | **10,438.90** |

Source: EIA World Carbon Dioxide Emissions from the Use of Fossil Fuels

In general, no account has been given to global initiatives related to the sustainability of the sector.

- Subsequently, insufficient investments have been made into critical areas such as energy conservation and load management, system optimization and loss reduction, renewable energy, and fuel substitution, and others.

## III. POLLUTION LEVELS IN SOME ARAB COUNTRIES

According to the 2006 Yearbook of the UNEP Global Environmental Outlook (GEO), the urban growth rates in the region were very rapid; the urban population increased from 38% of the total in 1970, to 63% by 2005. In the same period, the urban share in the Mashreq sub-region (Iraq, Jordan, Lebanon, the Occupied Palestinian Territories and Syria) increased from 52% to 65%. By 2030, the urban population in West Asia is projected to reach 143 million. The concentration of population in urban areas has resulted, among other problems, in increased air pollution.

According to the yearbook, cities such as Sana'a, Damascus, Cairo, Baghdad and Manama among other major cities in the region suffer air pollution levels that sometimes exceed WHO guidelines. Although few countries monitor air pollution levels systematically, available data and reports indicate that the main sources include industrial processes, inappropriate disposal of solid and hazardous waste, vehicle emissions and the burning of oil in electric power generation.

TABLE 6 TYPICAL EMISSION FROM POWER PLANTS [g/kWh]

| Fuel type | CO | $CO_2$ | $SO_2$ | $NO_x$ | VOC |
|---|---|---|---|---|---|
| Natural gas | 0.2 | 490 | 0.004 | 1.5 | 0.025 |
| Fuel oil | 0.19 | 781 | 5.1 | 1.5 | 0.05 |
| Coal | 0.11 | 1,060 | 5.5 | 2.4 | 0.01 |

Source: EPRI

TABLE 7 **AIR POLLUTION IN CAIRO**

| Pollutant | Standard (ug/m³) | Peak values |
|---|---|---|
| **$PM_{10}$** | 70 (annual) | 300 |
| **$SO_2$** | 150 (24 hour) | 351 |
| **$NO_2$** | 150 (24 hour) | 164 |
| **Ozone** | 120 (8 hour) | 380 |
| **CO** | 10mg/m³ (8-hour) | 34 |
| **Pb** | 1 (annual) | 1.6 |

Source: EIA World Carbon Dioxide Emissions from the Use of Fossil Fuels

In what follows, a brief statistical overview is offered about pollutants concentration in major cities and urbanized regions in the Arab world.

### *Egypt*

It has been estimated that Egypt's emissions of greenhouse gases (GHG) figure is around 0.6% of estimated total world emissions. Measurements inside urban areas and close to industrial complexes have sometimes recorded pollution levels higher (sometimes 6 to 8 times) than the limits set by Environmental Law 4 (ratified in 1994). Egypt has an average concentration of $SO_2$ of around 69µg/m³ of (compared to the WHO standard of 50µg/m³) (Anderson, Loeb, Nasralla, 2001; El Raey, 2006). The peak levels recorded, however, are much higher than recorded averages. High particulates concentrations are generally caused by the climatic conditions and winds blown from the desert. Measurements, however, also showed that smaller particulates that cause major health problems are generated from industrial complexes and power plants. These particle levels are also accompanied by high sulphur concentrations, an indication of the burning of fossil fuels in these complexes. Levels of $PM_{10}$ have reached 580µg/m³ in Cairo and 450µg/m³ in Alexandria. A sample of recorded concentration levels of various major air pollutants in comparison to national standards is shown in Table 7.

### *Syria*

The transport sector in Syria causes around 70% of urban air pollution. The concentration of $PM_{10}$ in Damascus is estimated at 749µg/m³ in highly congested traffic areas and 333µg/m³ in residential zones (El Raey, 2006). This is due to the fossil fuel combustion in industrial complexes in and around the city, and is also attributed to the generally old and poorly- maintained vehicles fleet, quality of transport fuel, and high reliance of diesel- driven microbuses for public transport in major cities (Haffar, 2004).

Diesel stoves are the second biggest polluters (Kurze 2004). They also strongly contaminate the air with sulphur dioxide. There is hardly a private household in Damascus that does not use diesel (*Mazut*), for heating in the cold months from November to March. The stoves, which do not cost more than 25 Euro, can be bought everywhere in town, and *Mazut* is cheap.

### *Lebanon*

The power sector in Lebanon relies almost completely on imported fuel oil to operate its thermal power plants. These plants are regarded as the main source of air pollution in nearby areas, and this has been confirmed by series of measurements conducted mainly by academic institutions and NGOs. Levels of particulates and oxides of sulphur were found to be several times higher than international standards.

Air pollution from the industrial sector is recorded in the vicinity of major cement factories along the Lebanese coast. Particulates and dust are the main effluents from these factories.

The transport sector is the major source of GHG emissions in the country. The motor vehicles fleet of Lebanon constitutes over 1.4 million registered vehicles, 55% of which are more than 15 years old (Chaaban and Chedid 2003). $CO_2$ emissions in 1999 totaled 4,585 Gg (gigagram) compared to around 3,957 Gg in 1994, an increase of around 16% (see table 8). Currently, emissions have topped the 5,000 Gg level.

Lead concentrations in Beirut varied by the end of the 20th century from 0.17 to 4.64µg/m³ with an average value of 1.86µg/m³, and the total TSP concentrations is 166µg/m³. Levels of ozone and smog measured in Beirut were several times higher than the world norms. This has been partially mitigated by the enforcement of law 341 in 2003 that has banned the use of industrial diesel for transport, and also banned leaded fuel.

### *Bahrain*

The transport sector is the main source of pollution in Bahrain, according to air quality tests (Sami and Khonji, 2006). In one such air quality test, air monitoring equipment was set up in each of Bahrain's five governorates; the results revealed a significant increase in pollutants associated with vehicle emissions over the past 10 years – particularly nitrogen oxides and ozone gas. These increases were attributed primarily to vehicle exhaust and industrial emissions, petrol vapours and chemical solvents – as well as natural sources – emitting $NO_X$ and volatile organic compounds, which form ozone.

Levels of sulphur dioxide ($SO_2$), which is pumped into the atmosphere by industries such as petroleum refineries, cement manufacturers and metal processing facilities, have been relatively stable in Bahrain at under 5ppb (parts per billion) over the last 10 years. There were spikes upwards to 10ppb in 1998 and 9ppb in 2002, but the figure currently stands at 7ppb. $SO_2$ also contributes to respiratory illness and acid rain. However, Bahrain's air quality tests showed that certain parts of the country are more polluted than others.

The amount of low-level $O_3$ in Bahrain is 51ppb, whereas $NO_X$ concentration has risen from 15ppb 10 years ago, reaching a peak of 30ppb in late 2002. $CO_2$ emissions from the transportation sector represent only 5.6 percent of the total $CO_2$ emissions in Bahrain (Sami and Khonji 2006).

### *Algeria*

Urban air pollution in Algeria is caused by the transport sector in the large cities of Algiers, Oran and Constantine; by burning municipal

waste; and by heavy industries in Annaba, Skikda, and Gazaouet. Such pollution has triggered on a yearly basis 353,000 cases of bronchitis, 544,000 asthma attacks and could be a cause behind 1,500 cases of lung cancer. Morbidity and mortality were evaluated in terms of DALYs (Disability Adjusted Life Years). It was estimated that 157,000 DALYs a year are lost because of outdoor air pollution and 88,820 are lost annually due to indoor air pollution (METAP, 2003). The environmental cost mounts to around 0.9% of national GDP.

The annual concentration of $PM_{10}$ in Algiers is about 50µg/m$^3$ (SMAP RMSU 2004), and the ozone concentration is 180µg/m$^3$. $SO_2$ concentration is 360µg/m$^3$, and $NO_X$ is 400µg/m$^3$,

TABLE 8 **MAJOR GREENHOUSE GAS EMISSIONS FROM THE TRANSPORT SECTOR IN LEBANON, IN Gg**

| GH Gas Source | $CO_2$ | $NO_X$ | CO | NMVOC | $SO_2$ |
|---|---|---|---|---|---|
| **Civil aviation** | 6.02853 | 0.0255 | 0.00851 | 0.00425 | 0.001872 |
| **Road transportation** | 3,949.839 | 34.824 | 447.193 | 83.8708 | 2.67669 |
| **Navigation** | 1.2564 | 0.02734 | 0.0182 | 0.00364 | 0 |
| **Total Transport (1994)** | 3,957.124 | 34.877 | 447.220 | 83.879 | 2.679 |

Source: Lebanon Ministry of Environment 2001 (State of the Environment Report)

TABLE 9 EMISSIONS FROM THE TRANSPORT SECTOR IN TETUAN IN TONS/YEAR

| NVOC | $CH_4$ | CO | $CO_2$ | $NO_x$ | $SO_x$ | $N_2O$ | $PM_{10}$ |
|---|---|---|---|---|---|---|---|
| 503.09 | 19.26 | 4,681.4 | 286,634 | 489.93 | 1,656.6 | 2.96 | 31.06 |

Sources: World Bank 2003; National Environment Observatory of Morocco 2001

whereas CO concentration is 10,000µg/m³. A quantity of 180 tons lead/year is emitted in the streets of the capital. Other cities also suffer from air quality degradation but at smaller scale.

### *Jordan*

A recent study has been conducted to assess vehicular emissions of carbon monoxide and hydrocarbons for gasoline-driven motor vehicles in the Greater Amman Area in order to provide the government with the basic information necessary for updating and developing new vehicular exhaust emissions standards. It was found that the incompliance rates of CO and HC to limits specified in Traffic Law no. 14/1984 were 40% and 25% respectively. Motor vehicles age was found to be the most important factor affecting vehicular emission levels. Old motor vehicles were found to emit double the CO amount and triple the HC amount emitted by new automobiles. Additionally, public transport vehicles were found to contribute to higher CO and HC emission levels than those of private cars. The total $CO_2$ emissions in the country were estimated at around 5.18 million tons, 2.3% of which were attributed to the power sector (UNESCWA, 2001).

Zarqa is home to 52% of the country's industries. Phosphate accumulation and emissions from local refineries are among the governorate's major environmental problems. The area also is affected by emissions from the nearby thermal power plant, industrial wastewater, and the dust from brick and stone quarries.

### *Saudi Arabia*

The air pollution problem in the Riyadh region is mainly attributed to the nearby refineries, power plants, and to transport. Sulphur dioxide is the main air pollutant emitted from the refining processes. The main source of sulphur dioxide emission is the hydrogen sulphide incinerator. There are no apparent serious environmental problems with any other air effluents. In Riyadh the following concentrations were reported: $SO_2$ concentration is 23.8µg/m³ (Spektor, 1998), whereas the concentration of ozone is 53.4µg/m³. Average interior CO concentrations (inside vehicles) during non-peak traffic times ranged from 10 to 25 parts per million (ppm). Also, lead concentrations have exceeded international norms.

### *Morocco*

Sources of air pollution are the industrial and mining, transport, and agriculture sectors. In Rabat, fine particulates (less than 3µm in diameter) have an annual average of 243µg/m³ (World Bank 2003; National Environment Observatory of Morocco 2001). $PM_{10}$ levels ranges between 70 and 123µg/m³, $CO_2$ concentrations reach 144µg/m³, $SO_2$ concentrations vary between 8 and 144µg/m³ depending on the region inside the city. Data from Tetuan city is also summarized in Table 9.

A correlation has been found between air pollution and health needs in a number of cities. Mortality, for example, has increased by 2% due to the increase of $PM_{10}$ concentrations by 22µg/m³.

### *Palestine*

Although air pollution may not be as severe an environmental issue as the pressures on water and land resources, it still poses a threat to the local community. The main problem is the lack of monitoring stations and therefore reliable data, and the institutional capacity to interpret data and take appropriate action. Air quality in the region is generally on the decline, largely due to lack of relevant regulations, proper solid waste disposal and the lack of control over industrial and transport-related emissions. Another important factor is the growing population, using an expanding fleet of vehicles running on diesel and leaded fuel (El Raey, 2006). Some parts of the West Bank are downwind from industrial zones, and these further reduce ambient air quality.

### *UAE*

Air pollution exists in the UAE in the larger cities such as Abu Dhabi, Dubai and Sharjah. One source is wind-blown sand; the incidence and scale of this problem varies according to the time of year. The anthropogenic sources of air-pollution in the UAE, and mainly in Dubai, are mostly the construction sector, which kicks up a lot of dust, and the ever increasing traffic. According to the State of the Environment report, the $CO_2$ emissions rate in the UAE has increased from around 80.8 million tons in 1990 up to over 94 million tons in 2002.

In Abu Dhabi, $NO_2$ concentrations are between 250-270µg/m$^3$ (Abu Dhabi Environment Ministry), $SO_2$ concentrations are between 100-150µg/m$^3$. In the Al Ain region, $NO_2$ concentrations inside the city reach 230µg/m$^3$, while $SO_2$ concentrations reach its maximum in Al Ain Centre around 60µg/m$^3$. Typical concentration levels in Mussafah and Ruwais are shown in Table 10.

### *Yemen*

The capital city of Sana'a, located at an altitude of around 2300m, suffers from extensive air pollution emitted mainly from the transport, electric power, and energy-intensive industries located in and around the city. The transport sector has witnessed a large growth. According to a recent UN study (Chaaban, 2004), the transport sector in Sana'a constitutes over 100,000 personal vehicles, added to it around 40,000 small taxis, and 70,000 minibuses. There is a heavy reliance on diesel for transport because its cost is almost 50% that of petrol. The fleet is very old and poorly maintained. The pollutant concentrations are estimated to be several times higher than the levels set by norms and standards.

### *Tunisia*

In Tunisia, the electric power and transport sectors are the major contributors to air pollution, at 31% and 30%, respectively. Samples of pollutant concentrations in Ben Arous (Tunis) in the year 2000 are shown in the Table 11.

## IV. INITIATIVES TO REDUCE AIR POLLUTION

There exists a wide scope of mitigation options and strategies for air pollution abatement. The feasibility of these options varies from one country to another depending on the social and economic welfare of each nation. However, options like setting air quality standards, establishing air monitoring networks, increasing awareness among citizens as well as decision makers, and allocating sufficient funding could be adopted in most Arab countries. Each country has conducted steps and set regulations aiming at solving the air quality problem. In what follows is a brief overview of selected countries.

### *Lebanon*

A technology needs assessment has been conducted for all economic sectors for GHG mitigation (Chaaban and Chedid, 2002). The transport sector was analyzed under six options. These are the promotion of mass transport, improving the

TABLE 10 **CONCENTRATIONS IN MUSSAFAH AND RUWAIS (UAE)**

| Pollutant | Mean concentrations in Mussafah (µg/m$^3$) | Mean concentrations in Ruwais (µg/m$^3$) |
|---|---|---|
| $NO_x$ | 83.7 | 28.9 |
| NO | 20.2 | 4.8 |
| $NO_2$ | 52.8 | 21.7 |
| $SO_2$ | 14.7 | 17.2 |
| $H_2S$ | 9.7 | 4.1 |
| CO | 0.6 | 0.3 |
| $O_3$ | 41.4 | 90.8 |
| $PM_{10}$ | 135.0 | 28.9 |

Source: Abu Dhabi Environment Ministry

TABLE 11 **AIR POLLUTION CONCENTRATIONS IN BEN AROUS, TUNISIA**

| Pollutant | Concentration in µg/m$^3$ |
|---|---|
| $SO_2$ | 104 |
| $O_3$ | 86 |
| $NO_2$ | 178 |
| CO | 3143 |
| $H_2S$ | 77 |
| $PM_{10}$ | 226 |

Source: Japan International Cooperation Agency

TABLE 12 **SUMMARY OF TECHNOLOGY OPTIONS RANKING IN THE TRANSPORT SECTOR**

| Option | Overall Score |
|---|---|
| Promoting mass transport | 78.20 |
| Improving technical status of the fleet | 76.50 |
| Switching to alternative fuels (NG) | 73.75 |
| Improving traffic management | 69.30 |
| Environmental standards and regulations | 68.50 |
| Urban planning and land use | 62.50 |

Source: Chaaban and Chedid 2002

TABLE 13 **SUMMARY OF TECHNOLOGY OPTIONS RANKING IN THE POWER SECTOR**

| Option | Overall Score |
|---|---|
| Electric Interconnection | 82.10 |
| Deployment of Combined Cycles | 80.30 |
| Switching to Natural Gas | 77.40 |
| Partially Switching to Renewable Energy | 77.00 |
| Recycling/phasing out Subsidies | 75.30 |
| Reduction of Transmission losses | 71.10 |
| Demand-Side Management | 70.95 |
| Technology upgrading | 70.55 |

Source: Chaaban and Chedid 2002

TABLE 14 **SUMMARY OF TECHNOLOGY OPTIONS RANKING IN THE INDUSTRY SECTOR**

| Option | Overall Score |
|---|---|
| Switching to Natural Gas | 80.75 |
| Boiler Improvement | 80.30 |
| Energy Efficient Systems | 78.80 |
| Cogeneration | 71.15 |
| Efficient Motors | 70.00 |

Source: Chaaban and Chedid 2002

technical status of the fleet, switching to alternative fuels, improving traffic management, updating and enforcing environmental standards and regulations and finally improving urban planning and land use. The results shown in Table 12 reflect the ranking of these technologies, as obtained from a nation-wide consultation process that included decision makers, experts, NGOs, and others. The scores are also listed to show the margins between individual options.

There is a need to consolidate and enforce programs and policies associated with Law 341/2001 on reducing air pollution from the transport sector. Specifically, in designing and implementing a fuel quality improvement program, and supporting a vehicle inspection and maintenance program. A national strategy for the improvement of fuel quality has targeted a complete lead phase-out in gasoline and the reduction of diesel sulphur content, also banning the use of industrial diesel for small and medium vehicles.

In the power sector, eight options have been found suitable to reduce emissions, mainly GHG gases. Based on the comparative analysis made possible by the ranking tables designed for that purpose, it was found that electricity interconnection is the most important option, followed by combined cycle technology, switching to natural gas and then partial switching to renewable energy.

In the industrial sector, five options were identified. The natural gas option has the highest priority followed by boiler improvement, energy efficient systems, co-generation and finally energy-efficient motors.

### *Egypt*

Initiatives and activities are carried out on both the strategic and operational levels.

On a strategic level, the preparation of an Air Quality Management Strategy is underway, primarily addressing air pollution resulting from the mismanagement of solid waste, as well as pollution abatement from mobile sources. Moreover, an emissions inventory in Greater Cairo including all sources of air pollution, industrial and non-industrial, is to be carried out (EEAA).

On an operational level, a number of activities and initiatives were carried out during 2000/2001 with a particular focus on the Greater Cairo area, where the highest levels of air pollution occur:

1. *Monitoring of Ambient Air Quality:* A comprehensive national air quality monitoring system has been established as part of the Environmental Information and Monitoring Program of the Egyptian Environmental Affairs Agency (EEAA). The

monitoring system measures concentrations of common air pollutants.

2. *Reduction of Vehicle Emissions in Greater Cairo:*
   On-road testing of vehicles with mobile emission analyzers has been enforced in partnership with the Ministry of Interior. Moreover, a network of stationary facilities for emissions testing, operated through the Traffic Department has been identified as the most feasible option for systematic testing of vehicles in the long term. With the objective of demonstrating the feasibility of replacing diesel-fuelled city public transport buses with compressed natural gas (CNG), the introduction of CNG buses into the fleets of the public bus companies of Greater Cairo is currently taking place.

3. *Conversion to the Use of Natural Gas:*
   The conversion of the power plants in the Greater Cairo region from the use of fossil fuels to that of natural gas, was successfully carried out, thereby reducing ambient concentrations of sulphur dioxide.

### *Jordan*

"Horizon 2020" has set the following framework for the country to mitigate air quality degradation:

*Initiative 1:*
*Legal framework*
The primary piece of environmental legislation is Law No. 1 of 2003, which has substituted the Environmental Protection Law of 1995. As a result, many regulations are issued by the government; among them is "The Air Protection Regulation". Clean Draft Act (2000) sets out the responsibilities for determining maximum allowable concentrations.

*Initiative 2:*
*Develop and implement action plans*
Consolidate the institutional set-up for environmental management, particularly on pollution management (monitoring and enforcement). In the same context, enhanced communication and coordination between the involved entities is needed. In addition, the preparation of an inspection program, as well as the mechanism to

monitor the environmental mitigation plans proposed for various industrial units (industrial emissions) and the enforcement of the related articles of the environment law is a priority.

*Initiative 3:*
*Technical capacity*
The capacity to manage integrated environmental management systems and technologies in Jordan is weak, and Jordanian experience with some of the modern systems and technologies used in environmental management programs is limited in the field of air pollution. The improvement of Jordan's technical capacity in this field is thus a key objective.

### *UAE*

The UAE's ban on leaded fuel, which came into force on 1 January 2003, has favorably impacted air quality in the country. These changes began when the Gulf Cooperation Council (GCC) asserted in December 1998 the need for a regional transition towards unleaded fuel. Four years later the UAE phased out leaded gasoline entirely and replaced it with unleaded gasoline (ERWDA- Abu Dhabi Research and Wildlife Management Agency 2005).

In response to the rising concern over the preservation of air quality, ERWDA (now Environmental Agency Abu Dhabi - EAD) embarked on an ambitious air quality management project aimed at monitoring air quality. By the end of 2003, ERWDA conducted an 18 month air quality monitoring and management study for Abu Dhabi. As part of the air quality management effort, 15 fixed and 2 mobile stations were acquired to monitor air quality and pollution.

EAD has completed the second stage of the project, bringing to a close the baseline data collection and assessment process, as well as the analysis of emissions and dispersion of flue gases from industrial stacks and vehicular traffic. The third stage will involve the creation of a full fledged Central Network System and an Air Quality Management System, to operate and continually enhance the equipment to achieve maximum efficient utilization of resources.

Another planned measure is to draw up an action plan to introduce natural gas as a substitute for petrol, especially for specific vehicular categories that are high fuel consumers. Indeed, according to the Environment Agency Abu Dhabi (EAD) report, 20 percent of government-owned vehicles and taxis in the emirate will be converted to run on CNG, which EAD also calls Clean Natural Gas, by 2012. All government diesel vehicles will also be converted to run on Ultra Low Sulphur Fuel (ULSF) with at least Euro III emission limits or equivalent by 2012.

### *Saudi Arabia*

Air quality management in Saudi Arabia is currently concerned with establishing air quality standards for limits on sulphur dioxide, particulates, ozone, nitrogen oxides, carbon monoxide and hydrogen sulphide, and other pollutants (Abu Dhabi Research and Wildlife Management Agency, 2005).

The Kingdom's Meteorology and Environmental Protection Administration (MEPA) has undertaken studies on the hazards of pollution, inventory of pollutants, development of necessary environmental standards and measures to protect air quality. Collaborating with MEPA, Saudi Aramco, the country's largest petroleum entity, also conducts its own air quality monitoring program.

Aramco operates ten Air Quality Monitoring and Meteorology Network stations and fifteen meteorology-only stations throughout the Kingdom. These stations ensure facilities meet national and company air quality standards for limits on major air pollutants.

On the other hand, Saudi air quality has been improved by the introduction of unleaded gasoline in the country in January 2001. Currently, service stations in Saudi Arabia sell lead-free gasoline with the octane boosting additive MTBE (methyl tertiary butyl ether). Leaded gasoline has now been almost eliminated.

### *Bahrain*

The most important legislation was set forth as Amiri Decree No. 7 in August 1980, which formed the Environmental Protection Committee (EPC) and the Environmental Protection Technical Secretariat (EPTS). An Amiri decree-law No. 21 (1996) was enacted with the establishment of an Environmental Affairs agency (EA), an agency under the Ministry of Housing, Municipalities and Environment.

Continuous monitoring of atmospheric pollutants at four geographical locations began in August 1993 (United Nations, 1997). Major pollutants such as $SO_2$, $NO_2$, NO, $O_3$, CO, $H_2S$, HC, and $PM_{10}$ are monitored. Recorded data at each station is transmitted via modems to a central computer system. Various mean values are automatically calculated and compared to acceptable ambient air quality standards. All measured values are available for statistical evaluation. Daily, weekly, monthly and annual reports are utilized in the decision-making process.

There is a joint effort within the GCC to implement an action plan to reduce car emissions and introduce unleaded petrol. A program called "Fume watch", which was introduced in Bahrain in 1994, aimed to report vehicles visibly emitting smoke, followed by an immediate approach to rectify these situations. This program yielded a noticeable improvement.

Recent studies have also suggested that removing subsidies and internationalizing the external costs of electricity generation could lead to resources


use optimization, and would also enhance the stability of the sector (Al-Hesabi, 2004). Electricity tariffs should, according to these studies, reflect the cost of the environmental and health impacts of emissions.

### *Qatar*

The State of Qatar has established guidelines to reduce air pollution in urbanized regions. These are based on the following initiatives:

*Initiative 1:*
*Control of air pollution*
The Supreme Council for Environment and Natural Reserves has developed a network of fixed and mobile air quality monitoring stations in many industrial cities to conduct air quality monitoring activities. These stations provide valuable data related to the major pollutants.

*Initiative 2:*
*Legislation*
By publishing the executive regulations of Law Number 30 of 2002 related to the environmental protection in the country, the norms and standards related to gas emissions became legally binding. Equally, any development projects including industrial projects became subject to environmental impact approval. According to this law, all industrial plants are obliged to monitor their emissions according to norms, standards and conditions agreed upon in advance and subject to a quarterly report.

*Initiative 3:*
*General policies to improve fuel quality*
All transport vehicles use unleaded gasoline. It has also been planned to start in 2005 to produce green diesel produced through converting Natural Gas to Liquefied fuels. This is yet to be fully implemented. A nationwide energy audit is being conducted for the residential sector.

*Initiative 4:*
*Capacity building, information research and development*
Particular efforts are made in Qatar towards building and strengthening national institutional and legal capacities to preserve good air quality. In addition, the importance of creating public awareness of these issues is recognized by parties involved in the dissemination of relevant publications and the implementation of specific programs at the school level throughout the country.

### *Tunisia*

In the Tunisian capital, Tunis, motor vehicles and motorcycles are the main causes of air pollu-

tion. A national control and monitoring program is conducted by the Environment and Management body of the Territory Ministry with the National Environment Protection Agency and CITET ("Centre International des Technologies de l'Environnement de Tunis" – Tunis International Centre for Environmental Technologies) (Japan International Cooperation Agency, 2002). The objective of this program is the preservation of air quality by identification, characterization and reduction of origin of the fixed (industrial emissions) or mobile pollutions.

Five continuous monitoring stations form a first group of national monitoring network that is currently extended to 25 fixed monitoring stations.

### *Syria*

Syria has enacted a multifaceted national action plan for controlling air emissions from various sectors (Kayyal, 2005). The proposed goals include:

1. Phase out leaded gasoline from use by vehicular traffic, and provide incentives for minibuses operating in Tartous, Lattakia and Jableh to also run in rural areas.
2. Enforce vehicular emissions standards and controls, control technical performance of vehicles, and develop appropriate rules and regulations in accordance with international standards for imports with the aim of preventing pollution.
3. Shift towards natural gas as a main fuel for the power sector and for major industrial complexes.
4. Deployment of modern heating systems to replace the old diesel stoves in residential sector.
5. Adhere to a regular and annual vehicles inspection system for monitoring exhaust gas emissions, and provide the necessary technologies for this task.
6. Reduce demand on vehicular transport, adjust peak periods, and substitute the individual vehicular traffic with an integrated modern public transport system.

### *Yemen*

Mitigation strategies sought for the transport sector are classified as:

1. To establish a sampling/monitoring network to assess air quality in Sana'a, in collaboration with UNEP and experts from academic research units.
2. To further rely on cleaner fuel for electricity generation.
3. On the technical side, to improve the technical status of the fleet through regular inspection and maintenance programs, phasing out leaded fuel, adopting cleaner fuels and dual fuels systems using LPG, diesel, and gasoline.
4. On the planning and regulatory sides, to establish modern and reliable mass transport systems, to provide incentives to shift towards unleaded and other cleaner fuels, and to upgrade traffic management systems in major cities.
5. To adopt local and international standards on emissions from industries and ambient air quality and to have these standards enforced.
6. On the awareness side, to publicize the economic cost and health impacts of air quality degradation, to highlight technical and economic benefits of cleaner fuels and technologies, and to conduct public awareness campaigns in collaboration with local media and NGOs.

To conclude, Table 15 shows the current status of diesel fuel in a number of Arab countries and a brief of future plans.

## V. STRATEGIES FOR A MORE EFFICIENT ENERGY SECTOR AND EMISSIONS REDUCTION

### *Electric power sector*

Feasible options include:

1. Reducing the role of governments to achieve sector reform and the elimination/reduction of bills and fuel subsidies to reduce consumption and emissions;
2. Introduction of appropriate tariff structures to encourage consumers to shift their demand off peak intervals, thus reducing the total installed capacities;
3. Improvement of the thermal efficiency through the adoption of new and advanced technologies like combined cycle units;
4. Full utilization of hydropower resources tak-

TABLE 15 **ARAB WORLD'S DIESEL SULPHUR MATRIX**

| COUNTRY | CURRENT STATUS Diesel Sulphur Content (ppm) | COMMENT |
|---|---|---|
| **Algeria** | 900 | No plans to process crude further |
| **Bahrain** | 5,000 (500) | To be reduced to further by 2007, some low sulfur available |
| **Egypt** | 5,000 | No Plans to reduce levels, Standard 10,000 ppm |
| **Iraq** | 10,000 | Actual Standards 25,000 ppm |
| **Jordan** | 9,000 | Actual Standards 12,000 ppm |
| **Kuwait** | 3,500 | Actual Standards 5,000 ppm |
| **Lebanon** | 6,500 (350) | Shift towards green diesel |
| **Libya** | 1,000 | Standards are about 1,500 ppm |
| **Morocco** | 10,000 (350) | Introduction of 350 ppm sulfur diesel on a very limited basis |
| **Oman** | 5,500 | Actual Standards 10,000 ppm |
| **Palestine** | 10,000 | Gets fuel from Jordan which is at 10,000 ppm |
| **Qatar** | 5,000 | Shift towards lower sulfur diesel |
| **Saudi Arabia** | 5,000 | Current Standards 10,000 ppm. Plans to go to 500 ppm by 2007 and 50 ppm in future |
| **Syria** | 6,500 | Actual Standards 7,000 ppm |
| **Tunisia** | 10,000 | Actual Standards 10,000 ppm. Change in 2011 |
| **UAE** | 5,000 | Plans to go to 2,500 ppm in late 2005 and 50 ppm by 2010 |
| **Yemen** | 10,000 | No current Standards. Improvements planned for 2010 |

Source: UNEP 2006

ing into account various relevant environmental and social issues;
5. Deployment of other renewable energy technologies, especially for water heating, on a scale wide enough to impact the national energy situation;
6. Upgrading of the power transmission and distribution networks to minimize losses; and
7. Shifting to less polluting fuels, namely natural gas.

### *Industrial sector*

Options in this category include:
1. Establishment of mandatory building codes that account for energy-efficient designs and operation of commercial buildings;
2. Minimization of heat and power losses and the expanded use of waste heat recovery technologies and automated process controls; especially in energy- intensive industries such as cement, steel, and glass factories.
3. Greater exploitation of cogeneration potential; and
4. Establishment of mandatory standards and evaluation of optimum operating conditions for motor-driven systems.

### *Transport sector*

Options in this category include:
1. Promotion of more efficient vehicle technologies; examples include electric and hybrid electric vehicles;
2. Traffic management in urbanized regions leading to a drop in trip duration and hence reduction in fuel consumption;
3. Improving the technical status of the fleet through strict annual checks;
4. Promotion of public/mass transport; and
5. Promotion of cleaner fuels.

It should be noted that implementing the full range of above-listed actions requires national commitment to strengthening existing institutions engaged in energy efficiency activities or to establishing new ones.

Most Arab countries will need, in addition to their own efforts, assistance from more developed nations to achieve these objectives.

Appropriate economic and institutional reforms would be required to encourage private sector involvement that can attract investments in energy efficient technologies.

## VI. CFC ABATEMENT

Data on chlorofluorocarbon (CFC) emissions from various economic sectors in the region is not readily available. Many countries have benefited from the multilateral funds made available from the Montreal Protocol to establish offices and units whose main objectives are:

- Dissemination of information on ozone issues.
- Development of policies and legislation to ban CFC substances and hence reduce their emissions.
- Establishing data bank information on ozone depleting substances (ODS).
- Providing assistance to industrial sector to phase out ODS consumption.
- Conducting training and awareness programs and workshops.

## VII. NOISE POLLUTION

Noise pollution is not considered as severe as other forms of pollution because it is not as fatal as water pollution or air pollution. Moreover, unlike the other forms of pollution, it can be avoided. The main – and overwhelming – source of noise pollution in urbanized regions is generated by transportation. Governments all over the world have changed their perception of noise pollution over the past 40 years. However, for developing countries including those in the Arab region, this issue remains unaddressed due to political, economic, and technological limitations. In many regional countries, no direct legislative implementations deal with noise pollution, though there are laws and directives aimed at limiting or banning honking during the night hours.

A recent study conducted in Beirut, Lebanon has shown that major roads suffer from periodical high noise pollution levels, reaching up to around 90dB during rush hours. The study also surveyed people living in the vicinities of these roads, and concluded that they generally suffer from problems such as headaches, heart palpitations and learning impairment (Fares, Nehme, Jouni, 2007).

Noise measurements in Amman, Jordan, were carried out at many locations and the results of the investigation showed that the minimum and the maximum noise levels are 46 dBA and 81 dBA during day-time and 58 dBA and 71 dBA during night-time. The measured noise level exceeded the 62 dBA acceptable limit at most of the locations (Jarmah, Al-Omari, Sharabi, 2006).

In Dubai, high traffic generates a high noise level, added to it the amount of noise created at construction sites currently building rail stations, sections of track and depots. Noise pollution is the key focus of an environmental audit launched by the Roads and Transport Authority. Areas being targeted for the audit include the assessment of acceptable operating noise levels (Gulf News, 2006). There will be a focus on efforts to reduce the impact of noise generating equipment used in construction.

Reduction measures generally fall into 3 categories:

### *(i) Control at the source*

These measures can be implemented at the design stage by the manufacturers, and they include fitting sound absorbers in the vehicle to reduce mechanical and engine noises and improving tires design, improving the exhaust noise mufflers especially for trucks and motorcycles, improving the engine design so as to reduce its noise and vibration.

### *(ii) Control in the transmission path*

These measures, usually provided by local authorities, include keeping the noise source (traffic) as far from the residential areas as economically possible, fitting noise barriers (walls) to partially reflect noise waves away from the residents, banning heavy-load trucks (and motorcycles) from operating in residential areas during night hours, and constructing tunnels and underground mass transportation networks.

### *(iii) Control at the recipient*

These measures are in principle similar to those implemented by planners and local authorities; they include building houses away from the traffic and using some insulation systems in the construction such as double-glazing, and building barriers close to the traffic or close to the buildings. Planting trees can also lead to significant noise reduction in addition to the natural beauty they offer. Also, controlling the technical status of personal vehicles could lead to substantial noise reduction.

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