Chapter 1

Ambient Air Quality

Sources of ambient (outdoor) air pollution include natural phenomena such as dust storms, and anthropogenic activity such as emissions from industry, transportation, and households. Exposure to ambient levels of air pollutants, even at low concentrations, is associated with a wide range of adverse health effects in the general population, and particularly in vulnerable populations, including children, pregnant women, individuals with chronic illness, and the elderly[17]. Adverse health effects of air pollution include respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD), cardiovascular morbidity, specific types of cancer, adverse neurodevelopmental effects, adverse birth outcomes, type 2 diabetes, obesity, and cognitive impairments.

Scientific evidence suggests that the major air pollutants associated with adverse health effects are particulate matter (PM) of various diameters (for example: $PM_{2.5}$, which is PM with diameters of up to 2.5 micrometers), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Additional ambient air pollutants, including benzene, formaldehyde, and some polycyclic aromatic compounds, are known human carcinogens[37]. The International Agency for Research on Cancer (IARC) classified outdoor air pollution as carcinogenic to humans (Group 1)[10].

Policy and Regulations

Air Standards and Monitoring

Ambient air quality is regulated under the Clean Air Law, which was approved in 2008 and entered into force in January 2011. Air quality values for different pollutants, which were set by the Ministry of Environmental Protection (MoEP) in collaboration with the Ministry of Health (MoH) and other stakeholders, entered into force in 2013. According to the Clean Air Law, industrial plants are required to obtain emission permits and to reduce emissions based on best available technologies (BAT). In 2016, the MoEP updated the target and environmental standards for ambient trichloroethylene, benzene, cadmium, and formaldehyde, and added environmental standards for ambient 1,3-butadiene and mercury (Table 1)[11].

Ambient Air Quality Standards (μg/m³) in 2017 compared with 2011

Table 1
Source: Israel Ministry of Environmental Protection[11]

Pollutant	2011	2017	World Health Organization (WHO) Guideline Values (2000)
Benzene	5 (annually)	3.9 (daily) - maximum of 7 exceedances 1.3 (annually)	1.7*
1,3-Butadiene	-	0.3 (daily) 0.3 (annually)	-
Cadmium (in PM_{10})	5 ng/m³ (annually)	5 ng/m³ (daily) 5 ng/m³ (annually)	5 ng/m³
Formaldehyde	100 (30 minutes)	15 (hourly) - maximum of 10 hourly exceedances 3.3 (annually)	100 (30 minutes)
Mercury	-	0.6 (hourly) in TSP 0.03 (annually)	1 (inorganic mercury vapor)
Trichloroethylene	1000 (daily)	2 (daily) 2 (annually)	23*

* Based on excess lifetime risk of cancer of 1 in 100,000 persons.

Ambient concentrations of air pollutants are routinely monitored in Israel by a network of 146 air quality monitoring stations that measure criteria pollutants (O_3, SO_2, $PM_{2.5}$, PM_{10}, nitrogen oxides [NO_x], NO_2, carbon monoxide, benzene), and 18 sampling sites that measure non-criteria pollutants (such as volatile organic compounds [VOCs], poly-aromatic-hydrocarbons [PAHs], aldehydes, metals, ammonia, and hydrogen sulfide). The stations are operated by the MoEP, local authorities, municipal environmental associations, the Israel Electric Company, industry and the port authorities. In total, 21 pollutants are monitored, including criteria pollutants and non-criteria pollutants.

In certain locations, there is annual screening of additional contaminants, including dioxins and furans. All measurements are under MoEP quality control and are conducted according to International Organization for Standardization (ISO) standards. In 2016, the MoEP started monitoring black carbon and particles less than 1μm in diameter (PM_1).

National Plan to Reduce Air Pollution in Haifa Bay

Following a 2015 government decision, implementation of the 2015-2020 National Plan to Reduce Air Pollution in Haifa Bay began in 2016. The National Plan, which has a budget of NIS 115.5 million, is expected to reduce industrial air pollution in Haifa Bay by 50%[16,18]. The plan includes designating Haifa Bay a low-emission zone; restricting the use of Haifa's main roads by heavy trucks during rush hour; mandatory vapor recovery systems at gas stations in Haifa Bay; financial support for operating 25 electrical buses and 200 electrical car-share systems in Haifa; compulsory particle traps on polluting vehicles in the city of Haifa; and additional monitoring stations and sampling in the Haifa Bay area[15].

As part of the National Plan, the MoEP, in collaboration with the MoH, published a call for epidemiologic studies and surveys in Haifa Bay, and several epidemiological studies were funded. In addition, the program includes a health outcome monitoring system for infants, school-aged children, and adults. The program, run by the MoH, includes monitoring of type 2 diabetes, asthma, cardiovascular and respiratory diseases, and cognitive outcomes.

Additional Policy and Regulation Issues

The MoEP recently proposed new national standards requiring gas stations to install vapor recovery systems in order to reduce hydrocarbon emissions. The MoEP, in collaboration with the MoH and Ministry of Transportation, is promoting regulations regarding emissions of SO_x, NO_x, benzene, and heavy metals from marine vessels in order to reduce air pollution in harbors and their surroundings.

A significant number of charcoal kilns operating in the Palestinian Authority cause severe ambient air pollution and odor that affect both Palestinian and Israeli residents in the surrounding areas. Following a governmental decision, an inter-ministerial committee (Ministry of Agriculture and Rural Development, MoH, MoEP, Ministry of Economy, Ministry of Finance, and the Israel Electric Corporation) was established in 2015 to address this problem. The committee recommended prohibiting the transfer of raw materials (wood) from Israel to the Palestinian charcoal kilns and the transfer of coal from the Palestinian Authority to Israel[14].

The MoH, in collaboration with the MoEP, the Ministry of Education, and the Ministry of Labor, Social Affairs and Social Services, is promoting a program for directors of educational and welfare institutions to raise awareness regarding severe air pollution events and their health effects. The ministries are working on improving the flow of information to and within the educational and welfare systems in cases of severe air pollution events[19].

In 2016, the MoH and the MoEP, in collaboration with the Israeli Football Association, published guidelines for cancelling professional and semi-professional football games and other competitive sports during extreme air pollution events.

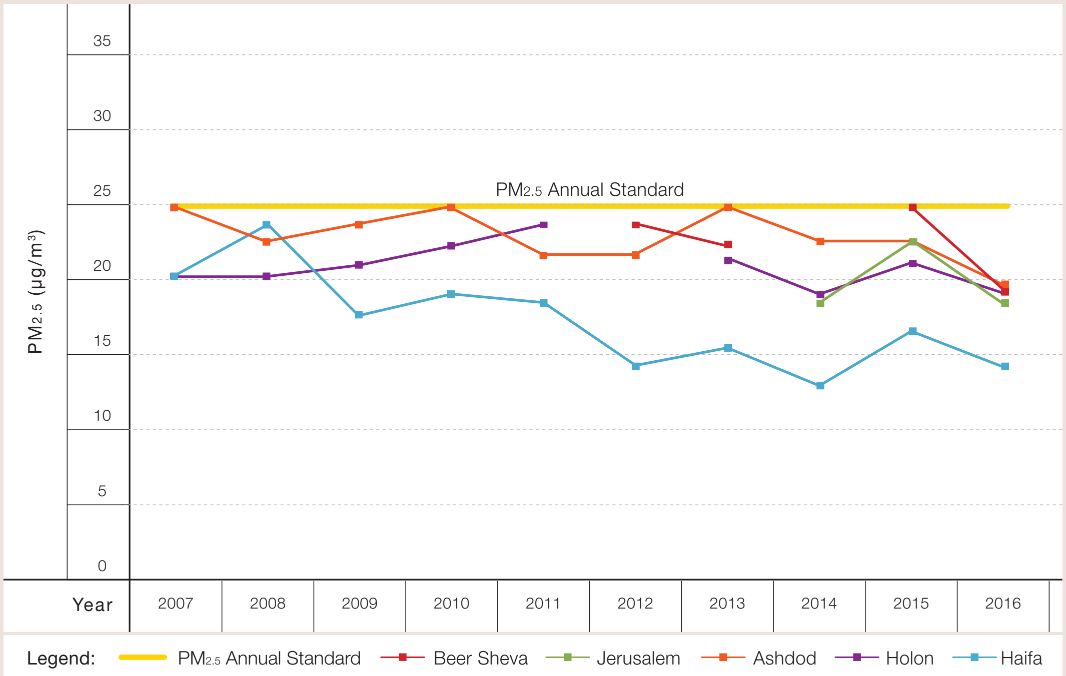
According to a 2017 decision by the National Planning and Building Council regarding urban renewal projects, the minimum distance between small gas stations (up to 4 gas pumps) and sensitive locations, including residences and schools, was reduced from 40 meters to 20 meters.

Data on Air Pollution in Israel

Data from the Pollutant Release and Transfer Register (PRTR) published in 2016 showed a significant decrease in reported emissions of CO_2, NO_x, SO_2, PM, and VOCs (except methane) between 2012 and 2015; for example, a reduction of 34% in SO_2 and NO_x, and of 14% in non-methane VOCs (NMVOC). The significant decrease in SO_2 is due to the improved quality of fuel used in Israel in recent years and the increased use of natural gas for the production of power and in some industrial facilities. However, since 2012, there has been a steady increase in emissions of methane, a potent greenhouse gas(12). Measurements at monitoring stations indicate a decrease in concentrations of $PM_{2.5}$ during the last decade (Figure 1). In 2016, there were 466 measurements that exceeded the environmental standard for daily mean $PM_{2.5}$; many of them were due to meteorological conditions that induced the spread of mineral dust from deserts in Israel's geographical surroundings.

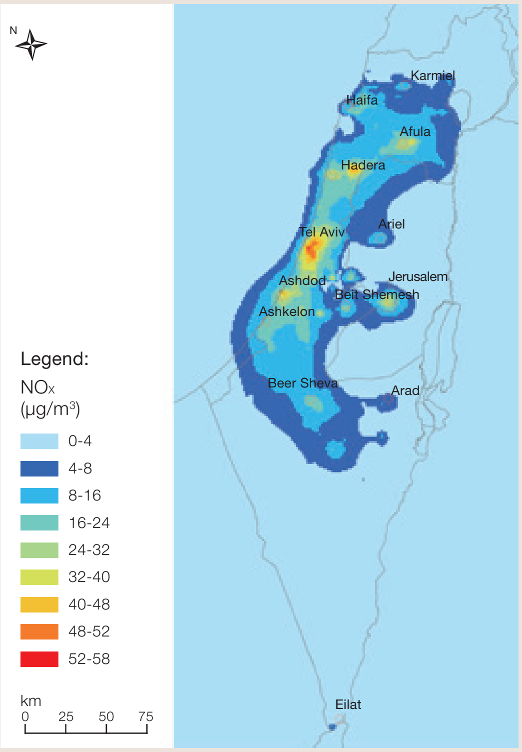
Annual Concentrations of $PM_{2.5}$ (µg/m³) - Trends in Representative Areas, 2007-2016

Figure 1
Source: Israel Ministry of Environmental Protection

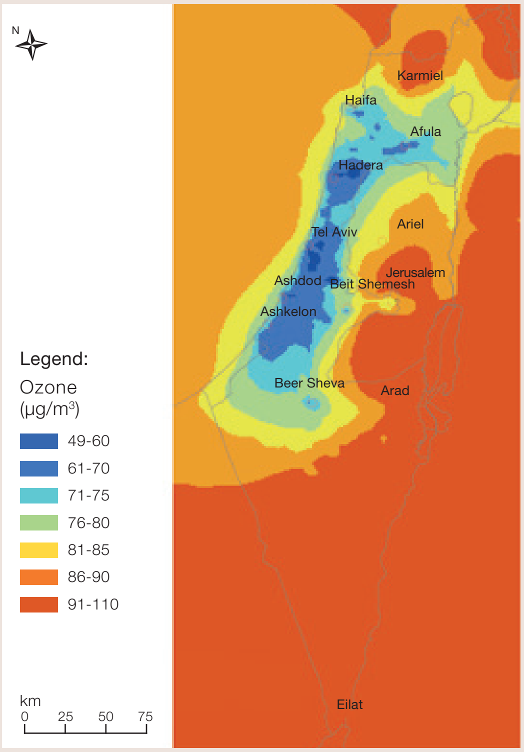


Although NO_x emissions have been decreasing in recent years, relatively high levels have been measured in major cities (especially in Tel Aviv), and in areas adjacent to power plants (Hadera, Ashdod and Alon Hatavor) (Figure 2). Ozone levels have not decreased in recent years. The highest concentrations of ozone are detected in regions far from emission sources, such as Judea, Samaria and the Galilee (Figure 3).

NO_x Concentrations in Israel, Based on Integrated Monitoring and Air Quality Models, 2015



Ozone Concentrations in Israel, Based on Integrated Monitoring and Air Quality Models, 2015



←
Left - Figure 2
Source:
Israel Ministry of Environmental Protection

Right - Figure 3
Source:
Israel Ministry of Environmental Protection

Researchers from the Technion Center of Excellence in Exposure Science and Environmental Health (TCEEH) built an air pollution database for use by the research community. The database includes a variety of data, such as air pollutant monitoring and meteorological data.

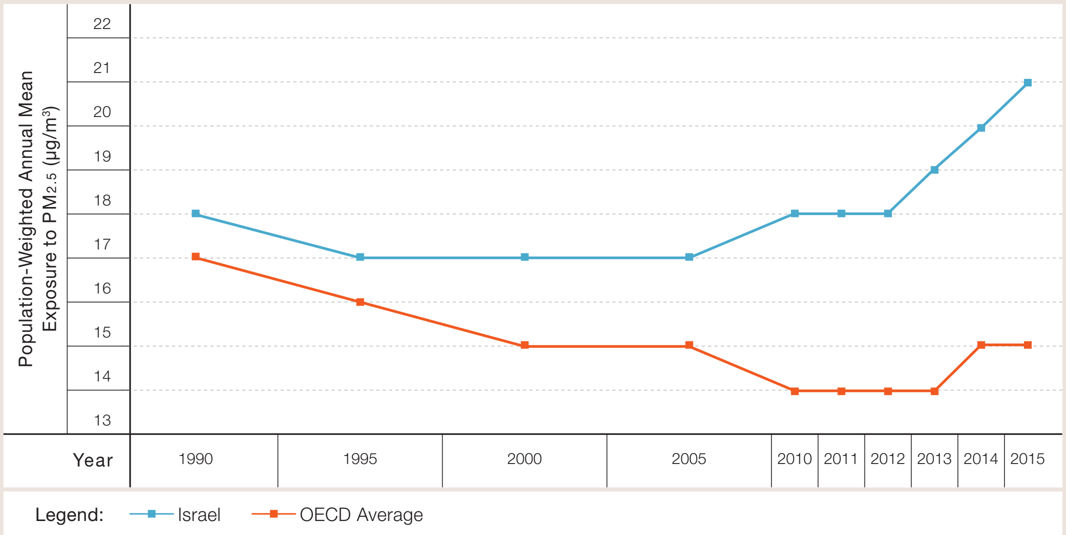
Data on Disease Burden and Costs Associated with Air Pollution in Israel

According to the Global Burden of Disease database, the number of deaths attributed to PM exposure in Israel decreased between the years 2000 and 2015 from a rate of 29 per 100,000 people in 2000 to a rate of 26.5 per 100,000 people in 2015[8]. However, due to population growth, the absolute number of deaths rose during these years from 1,740 to 2,133. According to this database, exposure to $PM_{2.5}$, as calculated using population-weighted concentrations, rose in Israel over the past 25 years, and rose at a faster rate than the Organization for Economic Co-operation and Development

(OECD) average during the past decade (Figure 4). This increase is attributable to higher exposure in populated areas. The fact that the population in Israel is concentrated in highly polluted areas partly explains why the rate of increase is higher than the OECD average[32]. It should be noted that air pollution data in the Global Burden of Disease database are based on ground measurements and satellite observations, and that there is room for additional analyses in Israel.

Population-Weighted Annual Mean Exposure to $PM_{2.5}$ in Israel and the OECD Average, 1990-2015

Figure 4
Source:
State of Global Air[32]



According to an OECD Environment Directorate published in 2017, there were 2,240 deaths in Israel due to air pollution in 2015, and an overall increase in the mortality rate as a result of air pollution between 2010 (238 per million) and 2015 (265 per million). The report estimated the cost of mortality due to air pollution in 2015 at $7.3 billion[27].

In 2016, MoH researchers analyzed the association between exposure to $PM_{2.5}$ and the risk of a wide range of adverse health outcomes, including respiratory and cardiovascular disease, cancer, diabetes, and low birth weight. The researchers used the WIDE Model (entailing a comprehensive and broad examination of respiratory / cardiovascular diseases) and estimated that exposure to $PM_{2.5}$ in 2015 led to 1,908 deaths, 348,039 hospitalization days, and a cost of $1.03 billion (Table 2)[7].

Deaths and Hospital Days due to $PM_{2.5}$ Exposure in Israel and the Associated Costs, 2015

Table 2
Source:
Ginsberg et al., 2016[7]

	Estimated $PM_{2.5}$ Costs and Effects According to the WIDE Model (percent of total)
Deaths	1,908 (4.3%)
Hospital Days	348,039 (6.7%)
General Hospital Costs	$318,918,656 (7.1%)
Total Health Costs	$1,027,757,036 (4.6%)

Research on Ambient Air Pollution in Israel (Published 2014-2017)

Exposure

Researchers from TCEEH and the Hebrew University of Jerusalem developed a system for predicting air pollution, using a land use regression (LUR) statistical model, and demonstrated that the model can be used to determine historical NO_x concentrations due to on-road vehicles from 1961 to 2011 - even before measurements were available[23].

In 2016, TCEEH researchers showed that signals from GPS transmitters mounted on vehicles can be used as a proxy for traffic emissions, and to develop maps with very high spatiotemporal resolution of concentrations of primary air pollutants, which can be used for exposure assessment[2].

In 2017, TCEEH researchers showed that studies on air pollution exposure that rely solely on residential address may result in exposure misclassification, and that accounting for daily commuting may be important in some circumstances[30,31].

Researchers from Ben-Gurion University of the Negev (BGU) examined the spatiotemporal distribution of PM during dust storms in southern Israel, in the city of Beer Sheva, and found variance in PM concentrations in different parts of the city. Higher concentrations were found in areas of the city closer to dust sources[21].

Researchers from BGU and TCEEH, together with colleagues from Harvard University and NASA, developed a model for assessing air pollution ($PM_{2.5}$ and PM_{10}) using hybrid models that include satellite information[20].

Biochemical Effects

In 2016, Weizmann Institute of Science and BGU researchers showed that repeated exposure to PM suppresses pulmonary defense mechanisms, resulting in lipid and protein oxidative damage[28].

In a study published in 2016, BGU researchers demonstrated that exposure to PM_{10} is associated with increased levels of serum glucose, hemoglobin A1c, low-density lipoprotein and triglycerides, and decreased levels of high-density lipoprotein, especially among people with diabetes[39].

In 2015, researchers from BGU showed that NO_2 and SO_2 exposure is associated with a small, yet statistically significant, increase in serum glucose levels[40].

Respiratory Diseases

BGU researchers found in 2014 that daily PM_{10} concentrations were extremely high during dust storm days, and that there is a positive association between dust storms and rate of hospitalization for COPD exacerbation. The effect increased with age and was higher in women. The researchers concluded that short-term exposure to natural PM_{10} during dust storms increases the risk of hospitalization for COPD exacerbation[33].

In 2015, researchers from the Hebrew University of Jerusalem and the University of Haifa showed that sandstorms lead to an increase in PM_{10} concentrations, which results in increased hospital admissions due to respiratory conditions[(5)].

Researchers from Tel Aviv Sourasky Medical Center showed in 2015 that exposure to $PM_{0.1}$ (ultrafine particulate matter with diameters measuring less than 0.1 micron) correlates with high levels of respiratory symptoms and airway inflammation in children with asthma[(1)].

In a paper published in 2015, BGU researchers noted an increased risk of asthma medication purchase associated with mild dust storms. The risk observed for hospitalization was more pronounced among the rural Bedouin population in southern Israel[(42)].

In a paper published in 2016, BGU researchers demonstrated that natural PM (for example, due to dust storms) increased the risk of hospitalization for pneumonia, particularly among patients above the age of 65 and cardiac patients[(35)].

A study published in 2015 by researchers from the Hebrew University of Jerusalem, BGU, and Clalit Health Services suggested that residential proximity to a hazardous industrial site may contribute to hospital admissions for respiratory illnesses in early childhood[(24)].

In a paper published in 2015, Hebrew University of Jerusalem researchers noted an increased risk of hospitalization for respiratory infections related to residential exposure to traffic-related air pollution among girls ages 5 to 14 and boys ages 0 to 4. The findings indicate possible differential associations between traffic-related air pollution and pediatric hospitalization among boys and girls in different age groups[(25)].

In 2015, University of Haifa researchers published a review of studies on the respiratory effects of air pollution in Israel. The researchers found contradictory results in the various studies, specifically in studies that investigated the association between PM_{10} and asthma, and attributed these discrepancies to different research methodologies and different types of data[(9)].

Cardiovascular Diseases

Researchers at BGU published a paper in 2015 demonstrating that exposure to PM_{10} and $PM_{2.5}$ is associated with a higher risk of ischemic stroke in adults under the age of 55[(41)].

BGU researchers showed in 2015 that exposure to non-anthropogenic PM is associated with cardiovascular morbidity, and that the most vulnerable groups were older women and Bedouins. These findings provided evidence of an association between air pollution (NO_2), weather, and visits to hospital emergency departments for headaches. The researchers suggest that short-term increases in air pollution may trigger headaches in various ways - for example, by increasing pulmonary and systemic inflammation, increasing blood coagulability, and altering endothelial function[(34,36)].

Cancer

In a paper published in 2017, TCEEH, Hebrew University of Jerusalem and Tel Aviv University researchers showed that chronic exposure to traffic-related air pollution may constitute an environmental risk factor for cancer among post-myocardial infarction patients. A 10-ppb increase in mean NO_X exposure was associated with a higher risk of cancer, in particular lung, bladder, kidney and prostate cancer[4].

Pregnancy and Birth Outcomes

BGU and MoH researchers published findings in 2016 demonstrating an association between in utero exposure to ambient air pollution and proliferation of umbilical cord blood cells. Specifically, lower cell proliferation (CP) of umbilical cord blood cells was associated with exposure to ambient ozone levels, 1-4 days before delivery; with exposure to increased $PM_{2.5}$ or PM_{10}, 5-6 days before delivery; and with exposure to carbon monoxide (CO) levels on the delivery day and the previous day[26].

In 2015, researchers from BGU and the MoH studied a population of pregnant Bedouin women and found that exposure to NO_2 had an impact on minor congenital malformations, while major congenital malformations depended mostly on the household environment[22].

A study published in 2014 by researchers from the Gertner Institute for Epidemiology and Health Policy Research, in collaboration with the Weizmann Institute of Science and Tel Aviv University, indicated a possible association between exposure to air pollution (PM_{10} and NO_x) and the risk of congenital malformations, specifically in the circulatory system and genital organs. Additionally, the researchers identified a possible adverse effect of exposure to SO_2 and ozone on assisted reproductive technology (ART) pregnancies[6].

Mortality

A study published in 2017 found that the transition from coal or high sulfur oil to natural gas led to a reduction in SO_2 and $PM_{2.5}$ concentrations in Tel Aviv, Haifa, and Ashdod. A meta-analysis that combined results from the three cities showed a statistically significant reduction in cardiovascular events (-13.3%), and a borderline significant reduction in total mortality (-19%) following the transition to natural gas[38].

Current Research on Air Pollution in Israel: Assessing Exposure and Health Outcomes

- In the framework of the National Plan to Reduce Air Pollution in Haifa Bay, a number of epidemiological studies including birth cohorts will be funded. Additional studies will examine the association between air pollution and asthma and cancer in army recruits, and the costs associated with the air pollution-related burden of disease.

- Researchers from the Hebrew University of Jerusalem, the Technion, Shahal Medical Services, and Rabin Medical Center are using telemedicine data to examine associations between acute cardiovascular events and ambient PM levels (measured at monitoring stations).

- Researchers from the Hebrew University of Jerusalem, TCEEH, and BGU are studying the association between exposure to various air pollutants during pregnancy and the risk of autism spectrum disorder.

- BGU researchers are studying the association between adverse birth outcomes and exposure to ozone in the Negev (southern Israel); and the association between maternal exposure to PM_{10} and infections in the infant's lower respiratory tract during the first year of life.

- TCEEH researchers are participating in an international consortium on air-quality micro-sensing units (personal sensors) and are conducting research on this technology in the Haifa area.

- BGU researchers are examining the association between personal/indoor exposure to air pollution (NO_2, $PM_{2.5}$ and black carbon) and blood sugar levels among healthy people and among people with type 2 diabetes.

- Researchers from the Hebrew University of Jerusalem, TCEEH, and the MoH are studying the association between exposure to PM and thyroid hormone levels in newborns.

- Tel Aviv University researchers are developing a system to distinguish among various sources and levels of air pollution in urban areas, using satellite remote-sensing techniques.

- BGU researchers are developing a model for high-resolution daily temperature forecasts that will enable a more precise assessment of exposure in both urban and rural areas. This model will be used together with a model for assessing $PM_{2.5}$ exposure, to examine the association between these factors and various birth outcomes, including low birth weight, premature birth, premature rupture of membranes (PROM), congenital malformations, and pre-eclampsia.

Progress since 2014

In *Environmental Health in Israel 2014*, the major challenges highlighted in the field of ambient air pollution included the need for updating target and air quality standards; developing a strategy for the regular sampling of contaminants that are not monitored continuously; reducing ambient concentrations of PM_{10} and ozone in metropolitan areas; improving the spatial distribution of monitoring air stations in Israel; and integrating transport and land use planning.

Significant progress has been made in updating target and air quality standards (for benzene, 1,3-butadiene, cadmium, formaldehyde, mercury, and trichloroethylene). The spatial coverage of the air quality monitoring network and the range of sampled contaminants improved following the addition of eight air quality monitoring stations since 2014 and the monitoring of two additional pollutants (black carbon and PM_1) in 2016. There was some progress in reducing ambient concentrations of PM_{10}, NO_2, and SO_2, and a slight decrease in $PM_{2.5}$, but no progress was made in reducing ambient ozone. There has been little progress in integrating transport and land use planning.

Major Challenges

In the past decade, there has been a significant increase in the scope and depth of research on ambient air pollution and its health effects in Israel. This research has highlighted the unique characteristics of air pollution in Israel. Data from the numerous epidemiological studies conducted in Israel should be utilized to assess the disease burden from air pollution and the costs it entails.

Research on, and the monitoring of, transboundary air pollution using source apportionment techniques will provide a better understanding of the relative roles of various sources and of the appropriate measures required to reduce pollution. Due to high background concentrations of certain air contaminants, Israel will probably be unable to reach target levels through national actions (within its borders) alone. Source apportionment techniques are also vital for evaluating measures to reduce local pollution. An economic analysis of the cost of environmental pollution in Israel published in 2017 showed geographic variation in the sectors driving major air pollution costs. In the Haifa District, the energy sector was responsible for 75% of the air pollution costs, while in the Tel Aviv and Jerusalem districts, transportation was the dominant sector, responsible for 83% and 71% of the costs, respectively(13).

Following a government decision in 2015, significant efforts and resources were directed at reducing ambient air pollution in Haifa Bay. It is important to designate additional urban areas in Israel as low emission zones, and to reduce the burden of disease associated with air pollution not only in "hot spots" but also in areas with average pollution levels. There is a need to improve the methods for evaluating exposure levels to air pollution and to produce a more accurate calculation of the burden of disease and the costs attributed to the range of actual exposure across the population.

Traffic is a major source of air pollution, but not enough resources are being invested in public transportation. The number of cars purchased annually in Israel continues to increase (according to the Central Bureau of Statistics, 272,000 private vehicles were purchased in Israel in 2017). There is a need to increase investments in public transportation and to adopt innovative measures to reduce traffic, for example, by creating a social infrastructure for car sharing. Reducing traffic and the number of privately owned vehicles would undoubtedly contribute to improving ambient air quality. The National Plan to Reduce Air Pollution from Transportation, approved in 2016 and budgeted at NIS 260 million, is expected to lead to improvements in 2017-2018.

Despite noteworthy reductions in emissions in Israel in recent years, there are still over 2,000 deaths attributable to air pollution in Israel every year(27). The costs associated with air pollution exceed $7 billion annually. In 2013, the government approved a National Program to Reduce Air Pollution, but the program was only partially funded. Although some parts of the program have been fully implemented (for example, encouraging the use of public transportation in workplaces and quantifying emissions of respirable particles from quarries), other major parts have yet to be implemented (for example, scrapping old private cars, promoting the purchase of buses powered by natural gas, and taxing fuels differentially)(3). An analysis of the burden of disease in Israel and its related costs could provide guidelines to help policymakers and decision makers optimally allocate funds to reduce air pollution(29).

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