Appendices

Appendix A: Risk Summary Sheets

Overview

This appendix contains risk summary sheets for 14 environmental health risks in the United Arab Emirates, as shown in Table A.1. The risk estimates shown in these summaries functioned as preliminary estimates for this study. Because the estimates given here were based on early and incomplete information, they are superseded by the results detailed in the preceding chapters.

The 14 risk summary sheets summarize the scope of each risk, describe what is known about the risks from the exposure generally and specifically within the UAE, and provide an overview of what has already been done in the UAE to manage the risk of the exposure. These risk summary sheets were the primary means of educating participants in the risk-ranking workshops (described in detail in Chap. 2) about environmental health risks in the UAE. The first page of each risk summary sheet includes a table with estimates of the environmental health risks in the UAE. The risk summary sheets have been reformatted from their original four-page format to fit this report. Notes on how calculations were performed for each risk are also included.

Definitions of Risk Attributes

Number of Deaths per Year. This is the average number of deaths expected per year among residents in the UAE based on a lifetime of exposure.

Chance in a Million of Death per Year for the Average Resident. This is the average annual lifetime risk of death for a randomly chosen resident in the UAE.

J. MacDonald Gibson et al., *Environmental Burden of Disease Assessment*, Environmental Science and Technology Library 24, DOI 10.1007/978-94-007-5925-1,

Table A.1 List of risk summary sheets found in Appendix A

The risk to the average resident is simply the estimate of deaths per year in the UAE divided by the population.

Chance in a Million of Death per Year for the Resident at Highest Risk. For some hazards, certain people are known to be more exposed or more susceptible than others. Examples include susceptibility of infants and the elderly to pulmonary effects of outdoor air pollution. For some of the hazards, however, the risk to the most exposed resident is the same as the risk to the average resident because residents who might be more exposed or more susceptible cannot be easily identified.

Greatest Number of Deaths in a Single Episode. Some environmental hazards kill only one person at a time, whereas other hazards can kill a group of people all at once. For instance, people who die from chronic low-level exposure to radon gas will die one at a time, but an industrial accident releasing toxic gases could claim many lives at once. This statistic represents the greatest number of people who could plausibly be killed in a single event involving a given hazard. In estimating this statistic, we have tried to account for the fact that major incidents tend to be much less frequent than smaller incidents.

Illness or Injury. Many environmental hazards present nonfatal risks. These risks vary in both duration and severity. The risk summary tables describe four categories of cases of nonfatal illness or injury per year expected among UAE residents resulting from one year of exposure to a given hazard. These four categories are defined in Table A.2.

Time between Exposure and Health Effect. Some hazards, such as poison, have immediate impacts, whereas hazards such as asbestos have effects years into the future.

Table A.2 Categorization used to describe nonfatal risks

Duration	More severe	Less severe
Long term (>3 months)	Serious chronic conditions, often involving hospitalization. Examples: loss of limb; mental retardation requiring continuous care; blindness; infertility; nonfatal cancer; chronic migraine; disfiguring burns; any condition requiring long-term institutional care; permanent damage to lungs, liver, kidney, or heart resulting in more than 20% loss of organ function	Long-term conditions not requiring hospitalization, except emergency room. Examples: joint damage; loss of finger; mild mental retardation; scars and burns affecting movement; permanent damage to lung, liver, kidney, or heart resulting in less than 20% loss of organ function
Short term (<3 months)	Serious acute conditions requiring hospitalization. Examples: meningitis, pneumonia, severe asthma or allergic attack, compound fracture, severe food poisoning	Conditions that might require medical care, but no hospital admission, and that involve the loss of at least 1 day of work or otherwise restricted activity. Examples: acute infectious disease without hospital stay (e.g., cold, flu, earache), mild food poisoning

Quality of Scientific Understanding. There are two sources of uncertainty in estimating risks for the residents of UAE. One involves how well scientists know the relationship between exposure to a hazard and its resulting health impacts. The other involves how well we can predict exposure of UAE residents to a particular hazard. This statistic characterizes the former. For instance, scientists still do not know whether exposure to electromagnetic fields from power systems causes cancer, but scientists understand very well the physical and biological processes leading to injury from exposure to lead. Three categories are used to rate scientific understanding: high, moderate, and low.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects both uncertain scientific understanding about the risk and uncertainty about the extent of exposure or susceptibility of UAE residents to the particular hazard. The table entry gives the amount of uncertainty in deaths, illness, and injury, expressed qualitatively with respect to other risks assessed in this report. Three categories are used to rate uncertainty: high, moderate, and low.

Ability of Residents to Control Exposure. This statistic characterizes the degree to which people can control their own exposure to a given hazard. Some hazards that UAE residents encounter can be avoided partly or entirely by measures that individuals can take on their own. For instance, people not wishing to incur risks from coastal recreational water can choose not to bathe in the ocean. Three categories are used to rate this controllability: high, moderate, and low.

Outdoor Air Pollution

Summary

Major causes of outdoor air pollution in the UAE include transportation, energy refineries and factories, desalination plants, and seasonal dust and sandstorms. Transportation is a particularly large source of outdoor air pollution in Dubai, which has the largest concentration of vehicles in the country. These activities release several pollutants into the air, including particulate matter, ozone, carbon monoxide, sulfur oxides, nitrogen oxides, heavy metals, and the resultant smog. Breathing these pollutants increases risks for mortality, lung cancer, chronic obstructive pulmonary disease, asthma, and other respiratory illnesses that may develop years or even decades after prolonged exposure.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	400	1,400	2,600
Chance in a million of death per year for the average resident	90	300	600
Chance in a million of death per year for the resident at highest risk	Not reported	Not reported	Not reported
Greatest number of deaths in a single event	1	Not reported	4,000
Illness or injury			
More serious long-term cases per year	Not reported	Not reported	Not reported
Less serious long-term cases per year	Not reported	Not reported	Not reported
More serious short-term cases per year	Not reported	Not reported	Not reported
Less serious short-term cases per year	Not reported	Not reported	Not reported
Other factors			
Time between exposure and health effects	Immediate (asthma) to 30 years (cancers, lung disease)		
Quality of scientific understanding	Moderate		
Combined uncertainty in death, illness, and injury	High		
Ability of resident to control exposure to hazard	Moderate		

Exposure to outdoor air pollutants depends on proximity to busy roadways and industrial sources like power plants and refineries, length of time spent outdoors, and an individual's level of physical exertion. The very young, the very old, pregnant women, individuals who spend a large amount of time outdoors, and individuals with pre-existing health conditions such as heart or lung disease are the most vulnerable to disease and mortality risks from outdoor air pollution.

What Is Known About the Risk from Outdoor Air Pollution?

Air pollution affects the air quality and health of people living close to pollution sources. Because pollutants can also be transported through the atmosphere over long distances, air pollution may impact health on a broader local or regional scale. The principal pollutants of concern worldwide, and likely also in the UAE, are particulate matter and ground-level ozone, as well as lead and combustion-related air pollutants.

Particulate matter, or PM, consists of solid and liquid particles in air. Fine particles are those that are 2.5 μm or smaller in diameter ($PM_{2.5}$) and coarse particles are particles 10 μm or smaller in diameter (PM_{10}). PM_{10} can reach the upper part of the airway and lungs and cause an increase in respiratory illness and death. $PM_{2.5}$ particles are inhaled more deeply into the lungs and have been linked with poor lung function, aggravation of asthma, respiratory problems, infant mortality, lung cancer, and increased risk of death from cardiovascular and respiratory disease. Sandstorms may provide a source of exposure to particulate matter and may transport dust contaminated with toxic metals, fungi, and bacteria. Exposure to sandstorms has been linked to higher childhood asthma rates and increased hospital admissions related to heart disease.

Ozone at the ground level is the primary component of smog. Short-term effects of ozone include lung inflammation, respiratory symptoms, an increase in hospital admissions for asthma, and an increase in mortality. Smoking worsens these health effects, especially for those with asthma. The mortality risks associated with ozone may be exacerbated in the summer, when ozone levels are higher.

Lead is a toxic heavy metal that is absorbed through inhalation, drinking, and eating. Lead affects kidney function, blood pressure, gastrointestinal symptoms, sexual development, and the brain. Although leaded gasoline was phased out of the UAE in 2003, the health effects of lead may persist for decades because lead-contaminated soil can be spread through windblown dust and sand.

Combustion-related air pollutants such as those generated by the transportation, power, and industrial sectors, including carbon monoxide, nitrogen dioxide, and sulfur dioxide, all have short- and long-term health effects, including respiratory symptoms, worsening symptoms in people with asthma, decreased lung and exercise capacity, and death from cardiovascular and/or respiratory disease. Chronic exposures to nitrogen dioxide and sulfur dioxide can also affect lung development, increase respiratory illnesses, and worsen asthma in children.

What Is the Exposure to Outdoor Air Pollutants in the UAE?

The primary sources of outdoor air pollution in the UAE are transportation, oil and gas production, power plants, and numerous industrial processes. Increases in car ownership and gas consumption, demand for natural gas and oil used for electricity, and desalinated water generation have contributed to rising levels of outdoor air pollution. According to a report by the U.N. Environment Programme, vehicular emissions are the main source of outdoor air pollution in the Middle East. Driven by increased vehicle ownership, the UAE has witnessed an enormous increase in vehicle travel over the past few years. Given the easy mobility of outdoor air pollution, it is also quite possible for the UAE to experience pollution from neighboring countries that blow into the Emirates. Across the region, sulfur dioxide and nitrogen oxide emissions have been steadily increasing in many locations, and these increases are expected to affect outdoor air pollutant levels in the UAE.

$PM_{2.5}$ and PM_{10} are emitted from combustion sources such as diesel-powered engines, power generation, and wood burning. PM_{10} also comes from windblown dust or soil, and construction activities. PM is also formed in the atmosphere from chemical reactions of gases such as sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds.

Ozone is formed in the atmosphere as a result of chemical reactions between volatile organic compounds and nitrogen oxides in the presence of sunlight. Therefore, ozone is at its highest concentrations when sunlight is most intense during midday and summer months. Combustion products such as sulfur dioxide, carbon monoxide, and nitrogen dioxide arise from transportation, power, and industrial emissions. Transportation emissions were also a major source of lead exposure during vehicular combustion of leaded gasoline. Exposure to lead is also believed to be related to the resuspension of lead-bearing dust in the air, which is spread by wind, vehicle motion, or human activities.

What Has the UAE Already Done About the Risk from Outdoor Air Pollution?

The first binding regional enforcement regarding air pollution in the region was the Convention on Long-range Transboundary Air Pollution, signed in 1979 and entered into force in 1983. Despite the Convention's lengthy existence, the party countries are still building monitoring and regulatory capacity. Additional UAE initiatives include:

- A zero-flaring strategic objective by the Abu Dhabi National Oil Company to reduce the burning off of waste gas, oil, and hydrocarbons
- A transition to natural gas in power plants and desalination plants to reduce carbon dioxide emissions
- The phase-out of leaded gasoline by January 2003
- Newly developed guidelines that limit the amount of air pollution generated by quarries and associated crushing plants

For Abu Dhabi emirate, the Environment Agency–Abu Dhabi (EAD) has planned, or has already implemented, several initiatives to reduce outdoor air pollution, including:

- Creating an air quality monitoring and management network, including one central, two mobile, and ten fixed air stations covering the emirate, as well as site evaluations to evaluate and implement adherence to the agency's regulations on air quality

- Continuing air quality management by EAD along with the Norwegian Institute for Air Research from 2008 to 2012, which includes implementing noise and air quality management, developing sector-specific emission limits (e.g., for power and transportation sectors) and establishing an online data reserve of outdoor air quality measures from the monitoring network
- Replacing 20% of vehicle fleets with compressed natural gas vehicles by 2012
- Switching the emirate's diesel fuel supply to ultra-low-sulfur diesel by 2015
- Employing environmental impact assessments for air quality management
- Pushing the power sector to rely more on natural gas
- Exploring more stringent controls for the oil and gas sector
- Continuing efforts to reduce emissions from other sources

Notes on Outdoor Air Pollution Risk Calculation

Number of Deaths per Year. We calculated the number of deaths in UAE adults over age 30 and for infants under 1 during 2007 that were attributable to two outdoor air pollutants, $PM_{2.5}$ and ozone, by using the following equation representing a widely accepted function of outdoor air health impacts (Ostro 2004):

$$Mortality = Baseline\ mortality\ rate \times Population \times \left(1 - e^{(-\beta \times \delta C)}\right)$$

Where: β = the concentration-response coefficient for $PM_{2.5}$ or ozone
δ*C* = the difference between theoretical background concentrations and 2007 monitored outdoor levels of PM_{10} or ozone from anthropogenic sources in Abu Dhabi emirate (Whitford 2008)

Since $PM_{2.5}$ levels were not monitored across the UAE, we used the annual average of 10 monitoring stations in Abu Dhabi. For PM_{10} we assumed a $PM_{2.5}$ to PM_{10} ratio of 0.35 for an arid desert region where there is a greater proportion of PM_{10}, based on data from the World Health Organization (Ostro 2004). To calculate δ*C*, the background $PM_{2.5}$ concentration was assumed to be 7.5 $\mu g/m^3$ (Pope et al. 2002). For ozone, we used the annual average ozone concentration averaged over 10 monitoring stations in Abu Dhabi emirate. We considered a background concentration of 20 parts per billion (ppb) to be reasonable. β values indicating the percent increase in adult mortality per 1.0 $\mu g/m^3$ increase in annual average $PM_{2.5}$ or 1.0 ppb increase in daily average ozone were determined based on U.S. data from Pope et al. (2002) and Bell et al. (2004), respectively, and it was assumed that they applied to the UAE as well. β values for percent increase in infant mortality per 1.0 $\mu g/m^3$ increase in annual average $PM_{2.5}$ were obtained from Woodruff et al. (2006). Prior studies that examined mortality in adults older than age 30 and this study based at-risk population on the assumption that 60% of the population in the UAE is over age 30. Baseline adult mortality rate (2.16 deaths/1,000), population (4.44 million) data from 2007, and birth rates in the UAE were determined from the Central Intelligence Agency World Factbook (2008). The infant population and baseline mortality rate is based on data from the UAE Health Statistics Yearbook for 2006, which is published annually by the UAE Ministry of Health (2007). Low and high estimates were derived from 95% confidence intervals around the β values (Pope et al. 2002; Bell et al. 2004; Woodruff et al. 2006). We summed the attributable deaths calculated from the formula, assuming no correlation in exposure and attributable risks for $PM_{2.5}$ and ozone, based on the low correlation rates found between PM_{10} and ozone (Bell et al. 2004), although it is not entirely clear that the effects of PM_{10} and ozone found in epidemiologic studies are perfectly separable and additive. To calculate the lowest mortality estimate, we assumed 100% correlation between the mortality risk of $PM_{2.5}$ and mortality risk of ozone so that there was no additional risk from ozone separate from that of $PM_{2.5}$ alone. For the highest mortality estimate, we assumed zero correlation between the mortality risk of $PM_{2.5}$ and mortality risk of ozone so that each pollutant acted independently to confer risk for mortality. This was the sum of the highest estimate for $PM_{2.5}$ and highest estimate for ozone. We recognize that the summation method is a simplification given that the bounds for each risk estimate were calculated for 95% confidence intervals around each specific pollutant. We express the low and high estimates to a single significant figure given our assumptions such as correlation between $PM_{2.5}$ and ozone, the ratio of $PM_{2.5}$ to PM_{10}, the estimation of background levels, the sparse coverage of air quality monitors within Abu Dhabi, lack of monitoring data across the entire UAE, use of annual instead of daily ozone levels, and use of population-based data from the U.S. that may not necessarily have the same distribution of variables that influence mortality risk as in the UAE.

Chance in a Million of Death per Year for the Average Resident. This is the average annual risk of death for a randomly chosen resident of the UAE as a result of exposure to a given hazard for 1 year. This figure is calculated by taking the number of deaths over the total population of the UAE from 2007, per one million individuals. We note that although the dose-response coefficients from epidemiologic literature apply to infants and adults over age 30, this is applied to the entire population, therefore potentially underestimating the chance of death for the average resident of any age.

Chance in a Million of Death per Year for the Resident at Highest Risk. For outdoor air pollution, the residents at greatest risk are smokers, approximately 25% of the male population. Smokers are more at risk than nonsmokers due to the synergistic effect between smoking and other air pollutants. The chance in a million for the high-risk group, then, is calculated by assuming all the deaths occur in the high-risk group: number of deaths divided by the high-risk population per million individuals. The Central Intelligence Agency World Factbook (2008) estimates a 2.74 male-to-female ratio among adults, which we applied to the 2007 mortality estimates above.

Greatest Number of Deaths in a Single Episode. Some of the hazards kill only one person at a time, whereas other hazards can kill a number of people at once. The low estimate of the number of deaths from a single event of acute outdoor air pollution poisoning is assumed to be one. The high estimate would be a Bhopal-like disaster (Broughton 2005), in which case approximately 6,000 residents might be affected. We assumed that a catastrophic, large-scale disaster occurring in the UAE would be more similar to a London-fog-scale disaster than a Bhopal-scale disaster, as industrial sites are located away from cities, and thus failure would affect fewer residential areas. An estimated 4,000 people died in the London fog, or "Great Smog of 1952" (Trivedi 2002). Historically, the Bhopal industrial disaster and London fog were the two largest-impact events resulting from outdoor air pollutant exposures. However, there were important differences in the geographical and chemical contexts surrounding these two events, compared with those that might occur in the desert environment of the UAE, in which there are no equivalently large chemical plants similar to those in Bhopal or coal-burning pollution such as was involved in the cold fog in London. Thus, similar events with equivalent magnitudes of mortality in the UAE are highly unlikely to occur.

Time between Exposure and Health Effect. Some hazards, such as exposure to ozone, have fairly immediate impacts, whereas hazards such as lead exposure have health effects that do not manifest until years or decades into the future. Exposure to PM has been associated with both short- and long-term mortality.

Quality of Scientific Understanding. There are two sources of uncertainty in estimating risks for the UAE population. One involves how well scientists know the relationship between exposure to a hazard and its resulting health impacts. The other involves how well we can predict the exposure of UAE residents to a particular hazard. This statistic characterizes the former. For instance, scientists still do not know whether exposure to electromagnetic fields from power systems causes cancer, but scientists understand very well the physical and biological processes leading to injury from auto accidents. Three categories are used to rate scientific understanding: high, moderate, and low. In the case of outdoor air pollution, exposures to some hazards (e.g., particulate matter or lead) are very well understood, while others (e.g., volatile organic chemicals) are much less characterized. As a whole, outdoor air pollutants are moderately characterized since it is often not clear which pollutants in the ambient mix are causing the poor health outcomes. For instance, in combustion products, it is clear that PM_{10} poses a serious mortality risk, but the evidence is less clear for nitrogen oxides. These are often co-pollutants, and the research does not always make distinctions at the specific pollutant level.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects uncertainty in both the scientific understanding of the risk and about the extent of exposure or susceptibility of UAE residents to the particular hazard. The table entry gives the amount of uncertainty in deaths, illness, and injury, expressed qualitatively with respect to other risks in UAE.

Ability of Resident to Control Exposure. Some hazards that UAE residents encounter can be avoided partly or entirely by measures they can take on their own. For instance, they can choose to stay indoors on heavy pollution days or wear filtering masks when they exercise. Three categories are used to rate this controllability: high, moderate, and low.

Indoor Air Pollution

Summary

Indoor air pollutants are found in a number of forms, including environmental tobacco smoke, combustion by-products, volatile organic chemicals, particulate matter, radon, asbestos, heavy metals such as lead and mercury, and mold and other biological pollutants. Exposure generally occurs through inhalation and may result in a wide range of health conditions, ranging from acute and chronic respiratory conditions (e.g., sinusitis, asthma) to cancers of the respiratory tract (e.g., lung cancer).

Risk attribute	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	60	200	300
Chance in a million of death per year for the average resident	20	50	70
Chance in a million of death per year for the resident at highest risk	30	100	140
Greatest number of deaths in a single event	1	7	10
Illness or injury			
More serious long-term cases per year	Not reported	0	Not reported
Less serious long-term cases per year	Not reported	3,000	Not reported
More serious short-term cases per year	Not reported	300,000	Not reported
Less serious short-term cases per year	Not reported	200	Not reported
Other factors			
Time between exposure and health effects	Immediate (nausea, asthma) to 30 years (lung cancer, mesothelioma)		
Quality of scientific understanding	Moderate		
Combined uncertainty in death, illness, and injury	High		
Ability of resident to control exposure to hazard	High		

The amount of pollutant exposure differs drastically based on several factors:

- Patterns of indoor use of consumer products such as cigarettes, aerosol sprays, pesticides, particleboard, and treated textiles
- Amount of time a person spends indoors and proximity to sources
- Extent of ventilation within the occupied space
- Individual variation in vulnerability to indoor pollutants

The health risks associated with indoor air pollutants can be reduced by limiting the use of products containing harmful compounds; controlling dust generation; regular inspection and maintenance of equipment such as water heaters, dehumidifiers, and heating, ventilation and air-conditioning systems; and most importantly, ensuring adequate ventilation. Smokers, the very young, the very old, pregnant women, and individuals with pre-existing respiratory problems are the most vulnerable to the health effects of indoor air pollutants. Although there is currently little specific information on indoor air exposures in the United Arab Emirates, it is the subject of a major, two-year epidemiologic study in 2008–2010.

What Is Known About the Risk from Indoor Air Pollution?

Environmental tobacco smoke, also called secondhand smoke, is a major source of indoor air pollution and consists of a complex mixture of more than 4,000 chemicals, of which 50 are known or suspected carcinogens. Secondhand smoke contributes to lung cancer, pneumonia, bronchitis, ear infections, asthma, obstruction of peripheral arteries, low birth weight, sudden infant death syndrome, changes to the body's immune system, and aggravation of existing respiratory and cardiovascular disease.

Combustion by-products consist of a variety of chemicals, such as carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter, which arise from combustion sources such as stoves, ovens, water heaters, furnaces, and fireplaces. The health effects of these chemicals include respiratory tract irritation, pneumonia, worsening asthma symptoms, increased heart rate, asphyxiation, and decreased lung function.

Volatile organic compounds such as formaldehyde, benzene, and perchloroethylene (widely used in dry cleaning) are emitted from many household products such as paints, solvents, building materials, aerosol sprays, adhesives, furnishings, and pesticides. Exposure to these pollutants can result in eye and upper respiratory irritation, rash, headache, vomiting, asthma, and damage to the liver, kidneys, and central nervous system.

Radon is an odorless, colorless, tasteless, and naturally occurring radioactive gas that originates from the radioactive decay of radium. Radon becomes harmful when it is trapped in buildings (particularly basements) lacking adequate ventilation. Exposure to radon is the leading cause of lung cancer among nonsmokers and the second leading cause of lung cancer after smoking in the United States.

Asbestos is a naturally occurring mineral that has been used in numerous applications, including thermal system insulation, acoustic insulation, and tiles and shingles in many buildings. Exposure, which occurs when asbestos-containing material degrades or is damaged, is associated with several lung diseases, including asbestosis (primarily from occupational exposures), lung cancer, and mesothelioma.

Airborne lead indoors comes primarily from chipped or flaking paint in homes with leaded paint and from intrusions of leaded-gas emissions from outdoor air. Lead is a potent neurotoxin, exposure to which results in cognitive and developmental deficits, particularly in children.

Airborne mercury exposure occurs primarily through phenylmercuric acetate, present in latex paint. Mercury can cause serious and permanent nerve and kidney damage, rapid heartbeat, irritability, withdrawal, memory loss, peeling of skin on the hands and feet, leg pain, difficulty with fine motor control, sleeplessness, and headaches.

Mold and other biological pollutants such as mildew, dust mites, and animal dander can cause infections, allergic reactions, asthma, and nonspecific respiratory symptoms.

What Is the Exposure to Indoor Air Pollutants in the UAE?

Exposure depends on the type of pollutant, the amount of time that individuals are indoors, and the degree of risk-reduction measures already in place to limit harmful exposures. There is currently little specific information on indoor air exposures in the UAE. Based on data from other industrialized countries, however, individuals residing in more urban, industrialized areas of the UAE are more likely to spend the majority (90%) of their time indoors (U.S. Environmental Protection Agency 1994; Kaynakli and Kilic 2005), use more consumer products that emit pollutants, and may have higher exposures than residents in other industrialized countries.

Environmental Tobacco Smoke. The health and lifestyle survey conducted in the UAE during 2000 (Badrinath et al. 2002) found that at least one person smoked inside the house in over a third of households. Indoor smoking was more frequent in urban areas than rural areas, potentially because of the increased time spent indoors in urban areas.

Asbestos. In most structures, asbestos is unlikely to pose significant health risk. However, this source of indoor air pollution risk may increase in the future as asbestos begins to degrade in buildings constructed before the 2006 UAE federal ban on asbestos production and use (Kelly 2007). In addition, asbestos materials are still being used in migrant workers' housing and illegal home additions.

Airborne Lead and Mercury. Whether and how much lead- or mercury-based paint has been used historically in the UAE is not reported. Studies on indoor lead exposure in the UAE focus on occupational exposure in lead workers. Thus, there is little empirical evidence on which to base standards or develop regulations for nonoccupational indoor or ambient exposure to lead in the UAE.

Mold and Other Biological Contaminants. Mold is a risk whenever humidity levels are regularly above 40–50%. Coastal areas of the UAE experience average levels of ambient humidity between 50 and 60% year-round, peaking at 90% during the summer.

Radon. Publicly reported monitoring data are not available for exposure to radon. Based on the health effects and experiences in other countries, the health effects of exposure to radon in the UAE warrant further study.

What Has the UAE Already Done About the Risk from Indoor Air Pollution?

Smoking in public places was banned effective June 2008 in Sharjah (except in private homes). Other emirates have imposed similar restrictions. This action will to lower exposure to secondhand smoke in public places.

Asbestos importation, production, and use in the UAE were banned in 2006. Prior to this regulation, the UAE developed several federal and local (Dubai) regulations and laws concerning the production, management, and handling of asbestos by occupational asbestos workers and the management and discarding of asbestos during abatement.

Sick building syndrome and the health effects of indoor air pollutants have been addressed indirectly through a new initiative to implement green building guidelines by the Environment Agency–Abu Dhabi (EAD). Sick building syndrome refers to symptoms among a group of people in a building temporarily associated with being in that building. Symptoms include eye irritation, stuffy nose, inability to concentrate, headache, nausea, and feeling tired.

In addition to the new EAD green building initiative, the government of Dubai issued a requirement in October 2007 that all new buildings be constructed with green technologies that comply with globally accepted standards of certification, including the LEED rating system (Leadership in Energy and Environmental Design) used by the U.S. Green Building Council. Old buildings will have to use clean technologies and comply with the same standards.

Notes on Indoor Air Pollution Risk Calculation

Number of Deaths per Year. This is the average number of deaths expected per year among the population of the UAE as the result of lifetime exposure to indoor air pollution. The low and high mortality estimates are extrapolated from U.S. data by scaling the estimated deaths proportionally to population size. High estimates for secondhand-smoke-related deaths are from the National Cancer Institute's (1999) estimates. Baseline mortality rate (2.16 deaths/1,000) and population (4.44 million) data from 2007 were determined from the Central Intelligence Agency World Factbook (2008). The high and low estimates of risk show the range in absolute terms. The "best" estimate is based on figures reported for deaths due to secondhand smoke by Mokdad et al. in 2004.

Chance in a Million of Death per Year for the Average Resident. This is the average annual risk of death for a randomly chosen resident of the UAE as a result of exposure to a given hazard for 1 year. This figure was calculated by taking the number of deaths from indoor air pollution divided by the total population of the UAE from 2000 and dividing by 1 million.

Chance in a Million of Death per Year for the Resident at Highest Risk. For indoor air pollution, the residents at greatest risk are women, who tend to be in the home more and are generally in charge of the cooking, in addition to smokers, who represent approximately 25% of the male population. Smokers are more at risk than nonsmokers due to the synergistic effect between smoking and some pollutants. The chance in a million for the high-risk group is calculated by assuming all the deaths occur in the high risk group: number of deaths divided by high-risk population over 1 million.

Greatest Number of Deaths in a Single Episode. Some of the hazards kill only one person at a time, whereas other hazards can kill a number of people all at once. The low estimate of death from a single event of acute air pollution poisoning (such as from a natural gas leak or carbon monoxide poisoning) would be one for a single person, seven family members living in the same household for the median urban UAE, or 11 for a large family living in one household (Badrinath et al. 2002). We assumed that most gas leaks or other events are not likely to extend beyond one apartment or house, even if the others are attached, because the spaces have separate ventilation systems and are separated by walls and hallways. That is, we assumed that acute residential indoor air pollution exposures are fairly contained and localized to a household.

Illness or Injury. All of the hazards of indoor air pollution also present nonfatal risks, which vary in both duration and severity. The table describes four categories of cases of nonfatal illness or injury per year expected among the average residents of the UAE. The less serious, long-term morbidity stems mainly from the onset or exacerbation of asthma in children due to secondhand-smoke exposure, of which there are an estimated 200,000 cases in the United States (National Cancer Institute 1999). Less serious, short-term illnesses are dominated by allergies to molds, dust, and other biological pollutants. The UAE figure is based on the Asthma and Allergy Foundation of America's estimate[1] that the allergies of approximately 20 million of the 50 million American allergy sufferers are attributable to indoor molds, dust, and biological pollutants. We assumed that UAE residents experience allergies at similar levels and applied that attributable fraction to cases of allergies among UAE residents. Health-care facility visits due to asthmatic episodes or other acute respiratory distress are counted as more serious, short-term morbidity, and in the United States there are an estimated 15,000 hospitalizations annually. Because of a lack of reporting of morbidity numbers for indoor air pollutants other than secondhand smoke, each of these three figures contains a high level of uncertainty. To calculate our figures, we scaled the number of illnesses in the United States to the population of the UAE. Both the United States and the UAE have a similar percentage of their population under age 15 (around 20%, according to the Population Reference Bureau 2007).[2] Because these estimates have high uncertainty due to a lack of reported data, we only reported "best" estimates, which serve as an order of magnitude approximation of the number of illnesses in each category.

Time between Exposure and Health Effect. Some hazards, such as exposure to allergens—mold, dust, etc.—have immediate impacts, whereas hazards such as asbestos have effects that do not manifest for years or decades.

Quality of Scientific Understanding. There are two sources of uncertainty in estimating risks for the UAE population. One involves how well scientists understand the relationship between exposure to a hazard and its resulting health impacts. The other involves how well we can predict the exposure of UAE residents to a particular hazard. This statistic characterizes the former. Three categories are used

[1] http://aafa.org/index.cfm

[2] http://www.prb.org/DataFinder.aspx

to rate scientific understanding: high, moderate, and low. In the case of indoor air pollution, exposures to some hazards (e.g., secondhand smoke, particulate matter, or asbestos) are very well understood, while others (e.g., volatile organic chemicals and combustion products) are much less characterized. It is often unclear which pollutants in the mix of all indoor air pollutants are causing poor health effects since they are frequently correlated, and existing research does not always make distinctions at the specific pollutant level.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects both uncertain scientific understanding about the risk and uncertainty about the extent of exposure or susceptibility of UAE residents to the particular hazard. The table entry cites the amount of uncertainty in deaths, illness, and injury, expressed qualitatively with respect to other risks in UAE.

Ability of Resident to Control Exposure. Some hazards that UAE residents encounter can be avoided partly or entirely by measures they can take on their own. For instance, residents can increase ventilation in their home, install high-efficiency particulate air filters, or use cleaner-burning fuels for cooking and heating. Three categories are used to rate this controllability: high, moderate, and low.

Occupational Exposures in Agriculture

Summary

Agricultural workers can be exposed to a number of hazardous contaminants and relatively hazardous working conditions. The most serious hazard is exposure to pesticides. The effects from exposure can be acute or chronic, or both. Depending on the particular chemical and the level and duration of exposure, pesticides have been associated with respiratory, dermal, gastrointestinal, and reproductive problems; various types of cancer; and effects on the central nervous system.

Farming is a relatively new industry in the United Arab Emirates, and the workforce is relatively uneducated and may not be adequately trained in the use of pesticides. In general, the risk can be reduced by lowering the level of exposure to toxic substances through better practices, decreased use, and/or using less hazardous alternate substances.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	0	65	100
Chance in a million of death per year for the average worker	0	340	525
Chance in a million of death per year for the worker at highest risk	0	>340	>525
Greatest number of deaths in a single event		1	

(continued)

(continued)

Risk characteristic	Low estimate	Best estimate	High estimate
Illness or injury			
More serious long-term cases per year	0	15	~20
Less serious long-term cases per year	0	20,000	~120,000
More serious short-term cases per year	0	20,000	<120,000
Less serious short-term cases per year	0	20,000	~120,000
Other factors			
Time between exposure and health effects	Immediate to 10–30 years		
Quality of scientific understanding	Moderate		
Combined uncertainty in death, illness, and injury	Moderate		
Ability of worker to control exposure to hazard	High		

What Is Known About Occupational Risk for Agricultural Workers?

Exposure to agricultural contaminants is dependent on the amount and type of contaminants present/utilized, and the level of protection used, and the hygiene practiced.

Agricultural workers may be exposed to a number of toxic substances. Sources of hazardous substances in the agricultural environment include fertilizers, pesticides, engine exhausts, solvents, dusts, microbes, and endotoxins. Evidence suggests that the effects of these exposures can be seen in elevated rates of cancer, including leukemia, non-Hodgkin's lymphoma, multiple myeloma, soft-tissue sarcoma, and cancers of the skin, lip, stomach, brain, and prostate among farmers worldwide (Blair and Zahm 1995). However, due to the numerous exposures and general complexities of the diseases, a clear cause-and-effect relationship can be difficult to establish. Immune system deficiencies and other acute and chronic health problems may also result from these exposures.

The primary toxic substances of concern for agricultural workers are pesticides. Exposure can occur via direct inhalation, ingestion, or skin contact, or through contact with or ingestion/inhalation of contaminated soil, water, and/or food in the farming environment. Skin is considered to be a significant route of absorption (Zhang et al. 1991). The primary health concerns from exposure to these pesticides are effects on actions of the central nervous system that control heart rate, breathing rate, and intestinal functioning. Health effect symptoms associated with these chemicals, even at low levels include headaches, dizziness, weakness, sweating, stomach cramps, and vomiting. Pesticide exposure also is recognized as an important contributing risk factor to cancer development, including cancers of the prostate, pancreas, and liver (Jaga and Dharmani 2005). Agricultural workers throughout the world are a high-risk group for developing cancer from pesticide exposure. Farm worker exposure to pesticides has also been linked to Parkinson's disease (Gorell et al. 1998).

Dust and chemicals other than pesticides (e.g., fertilizers) also cause health effects. High morbidity and mortality rates from respiratory diseases are observed for agricultural workers as well (Linaker and Smedley 2002). More serious (but more rare) illnesses include hypersensitivity pneumonitis and respiratory infections. Skin effects, ocular problems, and reproductive risks may also result from pesticide exposure. On the other hand, some nonpesticide farm exposures may have a protective effect against allergies, asthma, and respiratory sensitization.

Exposure to pesticides can often be reduced by education/information, wearing protective clothing/equipment, and improvements in hygiene practices, but it may be difficult or impossible to completely eliminate exposure. Alternatively, usage of fewer or different chemicals on crops can reduce risk.

What Is the Exposure to Contaminants for Agricultural Workers in the UAE?

The UAE agricultural sector employed 193,000 people, or 6.8% of the workforce, in 2006 (UAE Ministry of Economy 2006). The primary crops include dates, green fodder, vegetables, citrus fruits, and mangos. In addition, the UAE agricultural sector raises livestock in the form of goats, sheep, camels, cows, horses, and poultry. Agricultural production has increased from 15,000 ha in 1971 to approximately 260,000 ha in 2007 and now accounts for more than 7% of land in the UAE (UAE Interact 2007).

Farming is a relatively new industry in the UAE. The workforce is relatively uneducated and has often not been trained in the use of pesticides (Gomes et al. 1999). The specific chemicals used, the frequency of use, and the general practices (as well as the types of crops, soil, and pests) appear to be fairly homogeneous within a geographic region of the UAE and differ widely between different geographic regions (Gomes et al. 1997). Based on publicly reported statistics from 1994 to 1995, 4,095 and 3,558 tons of pesticides were used in the UAE, respectively (Beshwari et al. 1999a, b). Given the increase in agricultural production, updated statistics would be useful. However, there is no publicly available information on the complete list of pesticides used in the UAE, including in which regions, on which crops, and in what amounts they are used.

In terms of conditions and practices, as of 1999 only a minority of UAE farm workers used protective equipment and had been trained properly to minimize their exposure to pesticides (Gomes et al. 1999). For example, the mostly expatriate agricultural workforce is not likely to be able to read the warning labels on pesticide containers. They may be completely unaware of the risks and not inclined to seek protective equipment (or medical treatment for exposure) even if they are, due to their lower status. Storage of pesticides near or in living quarters, lack of protective equipment by a majority of workers, lack of knowledge of the risk of exposure, and lack of training in pesticide use and application has been documented in the UAE (Gomes et al. 1999).

What Has the UAE Already Done About Occupational Risk for Agricultural Workers?

Despite generally high levels of government involvement in agriculture, recent federal and regional regulations related to pesticides, and indications that pesticide awareness and safe practices among farm workers are improving, there remain a number of steps that can help improve agricultural worker safety in the UAE.

Farmers in the UAE face considerable challenges related to climate, and, accordingly, the government provides much assistance, including granting land and supplying pesticides. As such, the government is in an excellent position for both knowledge and control of risk to agricultural workers. Research on biological control methods as alternatives to pesticides, such as introduction of predator species or use of insect pheromones to inhibit insect populations, is encouraged and supported by the government. Interest in organic farming is increasing in the UAE. The government has a number of experimental organic farms and recently certified the first privately owned organic farm (UAE Interact 2007).

The federal government has passed a number of regulations relevant to the use of pesticides in the UAE. For example, at least 93 separate pesticides have been outlawed or banned (Al Asram 2006). In addition, the manufacture and formulation of pesticides is prohibited in the UAE. In addition, in 2004, the National Consultative Council urged monitoring the import of pesticides and setting measures to prevent hazardous chemicals from reaching the local markets. Regionally, Abu Dhabi Municipality registered 597 products in 2004, and pesticides require registration and import permits. There are also regulations for return of excess or expired pesticides and efforts to minimize the amount of pesticide waste generated.

As noted, evidence indicates there is little awareness of pesticide risks among UAE agricultural workers and that use of protective measures and good hygiene are not common (Gomes et al. 1999). However, this literature is dated, and this situation may have improved in recent years. For example, according to the Environment Agency–Abu Dhabi, a recent survey conducted to gauge environmental awareness and behavior among the general public in Abu Dhabi indicated that most farmers were aware of the precautions and problems with pesticide use and that the level of self-protective behaviors correlated with the level of awareness.

Notes on Occupational Hazards from Agriculture Risk Calculations

Number of Deaths per Year. This is the average number of deaths expected per year among the agricultural population in the UAE as the result of lifetime exposure to pesticides. In the absence of specific data for the UAE, we used information for the United States related to lung cancer risk among agricultural workers exposed to chlorpyrifos (Lee et al. 2004). For details on how we determined these numbers among agricultural workers, see the "Illness or Injury" section below. In short, the numbers reported here are the lung cancer cases from this exposure that are expected to result in death (the remaining annual lung cancer cases are tabulated as "more serious long-term cases per year").

Chance in a Million of Death per Year for the Average Agricultural Worker Related to Pesticide Exposure. This is the average annual risk of death for a randomly chosen agricultural worker in the UAE as a result of exposure to a given hazard for one year. This is based on the number of deaths (65 and 102 for best and high estimates, respectively) and the total population of 190,000.

Chance in a Million of Death per Year for the Agricultural Worker at Highest Risk. In the absence of publicly available information regarding heterogeneities in the farm work population, we estimated this to be greater than or equal to the risk for the average worker.

Greatest Number of Deaths in a Single Episode. This is the greatest number of deaths resulting from a single cancer case (one).

Illness or Injury. Exposure to pesticides through agricultural employment presents a nonfatal risk of inhibition of the action of acetylcholinesterase in nerve cells. This risk is a less serious, short-term detriment to neurotransmission (manifesting itself as sweating, pinpoint pupils, leg weakness, and other effects). Other chronic problems such as respiratory symptoms, skin disorders, etc., would be less serious, long-term impacts. For the high estimate for both of these less serious risks, we assumed that all agricultural workers not wearing protective clothing would be subject to these risks. Based on percentages of unprotected workers in Gomes et al. (1999), if all workers not wearing gloves, coveralls, or scarves were at risk of these less serious health problems, the number of workers at risk would have been ~125,000, ~124,000 and ~118,000 (~60–65% of 193,000 total), respectively, in 2007 (i.e., ~120,000). This is the worst-case scenario. The low estimate is that no UAE agricultural workers are at risk despite exposure. The best guess is based on the percentages of agricultural workers actually manifesting symptoms of exposure compared with a comparable control group. Across all symptoms in the study, an average of 13% more farm workers experienced symptoms of exposure relative to the control group in Bener et al. (1999) and 10% more experienced symptoms in Beshwari et al. (1999a, b). This implies ~26,000 and ~19,000 farm workers, respectively; we accordingly listed ~20,000 as the best guess number for less serious long- and short-term cases based on these estimates. We then assumed that the number of more serious short-term cases would be less than the numbers estimated for the less serious cases.

For more serious long-term cases, we used these base numbers of 20,000 and 120,000 assumed to be exposed to pesticide (of a total of 193,000 farm workers in the UAE) and assumed an incidence of lung cancer that is 2.18 times the incidence in lung (and bronchus) cancers among men in the United States for this fraction of the agricultural worker population. This is based on exposure to chlorpyrifos in the United States among "highly exposed" farm workers and their increases in incidence of lung cancer relative to the general population (Lee et al. 2004). Approximately 0.04% of men in the United States were diagnosed with lung (and bronchus) cancer in 2008 (American Cancer Society 2008), which implies that ~0.08% of highly exposed male farm workers could be similarly diagnosed in the UAE. So for the best estimate, the number of cancer cases would be ~0.08% of the 20,000 most "highly exposed" workers plus ~0.04% of the balance of workers, 173,000 (i.e., (20,000 × 0.00081) + (173,000 × 0.00037) = ~80). For the high estimate, the number of cancer cases would be ~0.08% of the 120,000 most "highly exposed" workers plus ~0.04% of the balance of workers, 73,000 (i.e., (120,000 × 0.00081) + (73,000 × 0.00037) = ~125). This is the total number of cancer cases per year. We further assumed 82% of these 80 and 125 farm workers diagnosed each year would die based on U.S. percentages of lung cancer deaths relative to lung cancer diagnoses in 2008, giving best and high estimates of number of deaths per year of ~65 and ~102, respectively. The balance of the cases will be the best and high estimates of the "more serious long-term cases," or 15 and 23, respectively.

Time between Exposure and Health Effect. This is highly dependent on the exposure and the particular effect. Pesticide impacts on the nervous system (i.e., inhibition of the action of acetylcholinesterase in nerve cells) would have an immediate impact. Longer-term illness such as cancer would manifest on a multiyear timeframe (i.e., 10–30 years).

Quality of Scientific Understanding. There are several sources of uncertainty in estimating risks for the UAE population. One involves how well scientists know the relationship between exposure to a hazard and its resulting health impacts. The other involves how well we can predict exposure of UAE residents to a particular hazard. This statistic characterizes the former. In this case, the causality between pesticide intake and acetylcholinesterase inhibition is well-established, but the exact correlation between dose and response is less so. Similarly, the relationship between cancer and pesticide exposure is known, but the exact dose-response ratio is unclear due to a number of factors, including the frequent presence of multiple pesticide exposures. Three categories are used to rate scientific understanding: high, moderate, and low.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects both uncertain scientific understanding about the risk and uncertainty about the extent of exposure or susceptibility of UAE residents to the particular hazard. Sources of uncertainty specific to data in the UAE include: (1) lack of knowledge of the types and distribution/amounts of pesticides used across agricultural sites, (2) lack of knowledge of the current level of worker education and protection measures, and (3) unknown quantitative levels of exposure in the UAE. The table entry gives the amount of uncertainty in deaths, illness, and injury, expressed qualitatively with respect to other risks in UAE. The combined uncertainty is a weighted average of uncertainties in risks of death and injury.

Ability of Worker to Control Exposure. Some hazards that UAE workers encounter can be avoided partly or entirely by measures they can take on their own. For instance, they can wear personal protective equipment and practice good hygiene. However, clearly the risk cannot be completely eliminated due to the nature of the job and proximity to high concentrations of the hazardous substance relative to the general population. Three categories are used to rate this controllability: high, moderate, and low.

Occupational Exposures in Industry

Summary

Industrial workers in the United Arab Emirates may face numerous occupational hazards that increase the risk of death, injury or illness. These exposures differ according to industry, production methods, specific task(s) within each industry, and use of personal protective equipment. Health outcomes differ depending on individual characteristics and behaviors such as age, gender, and smoking status, in addition to the variation in individual vulnerability to exposures. Occupational-noise-induced hearing loss due to long-term exposure to high noise levels is the most prevalent irreversible industrial disease (Smith 1998). Workers may also be exposed to volatile organic compounds, crystalline silica, aluminum dust, cement dust, metalworking fluids, and heat stress.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	5	10	20
Chance in a million of death per year for the average industrial worker	1	2	5
Chance in a million of death per year for the industrial worker at highest risk	75	150	300
Greatest number of deaths in a single event		Not reported	
Illness or injury			
More serious long-term cases per year	Not reported	0	Not reported
Less serious long-term cases per year	Not reported	21,000	Not reported
More serious short-term cases per year	Not reported	28,000	Not reported
Less serious short-term cases per year	Not reported	30,000	Not reported
Other factors			
Time between exposure and health effects	Immediate (dermatitis) to 30 years (silicosis)		
Quality of scientific understanding	High		
Combined uncertainty in death, illness, and injury	High		
Ability of worker to control exposure to hazard	High		

What Is Known About the Occupational Risk for Industrial Workers?

In the UAE, industries that are associated with the greatest occupational hazards are oil and gas production, metal manufacturing, and cement making. Other risks are present due to exposure to asbestos, hot environments, and noise in the workplace.

In oil and gas production and distribution, the greatest health risks tend to result from exposure to volatile organic compounds (e.g., benzene), hydrocarbons, and inorganic chemicals (e.g., hydrogen sulfide) that are produced during petroleum treatment. Much of the exposure to these compounds occurs through inhalation and skin contact. The main health effects that are correlated with oil refinery and oil distribution jobs are skin cancer, mesothelioma, and leukemia, although the evidence for leukemia is not as strong. In addition, the assorted health effects associated with exposure to airborne chemicals can include cancer, respiratory irritation, damage to the nervous system, and hearing loss.

Aluminum smelter and steel workers are exposed to polycyclic aromatic hydrocarbons such as benzene-soluble material and benzo(a)pyrene, both of which are strongly associated with carcinogenic processes at the cellular level and increased risk for bladder and lung cancer. Aluminum workers also are exposed to aluminum dust, which can result in eye and respiratory tract irritation. Chronic exposure affects shortness of breath, weakness, and cough. Stainless steel workers are also exposed to hexavalent chromium and metalworking fluids, which can lead to increased cancer risks as well as respiratory and skin diseases.

Cement industry workers are exposed to cement dust, which has been linked with skin problems, lung functioning, and respiratory tract disorders such as chronic obstructive pulmonary disease, although not all studies have reported these associations. Portland cement, the most common type of cement used worldwide, is caustic and abrasive and is used as a strong adhesive in concrete, mortar, plaster, grout, stucco, and terrazzo. It contains a trace amount of hexavalent chromium, which is toxic to the skin and lungs. Cement workers are also exposed to crystalline silica, which has been known to cause silicosis and chronic obstructive pulmonary disease.

Other industrial exposures include occupational asbestos exposure, which occurs primarily in mining and construction; very hot environments, which have serious health implications, particularly heatstroke; and exposure to noise pollution, which has been most commonly associated with hearing impairment as well as hypertension and high blood pressure.

What Is the Exposure to Industrial Occupational Hazards in the UAE?

Oil and Gas Industry. While it is a major contributor to gross domestic product of the UAE and the other Gulf Cooperation Council countries, the oil and gas industry only employs about 1% of the workforce for those countries. This does not include people who work in transportation and distribution of oil and gas products, who may experience more serious exposures from petroleum-associated risks described above. Because the UAE has a strict no-flaring policy, in which oil and gas refineries are prohibited from burning off excess natural gas that arises from the refining process, there is a reduced presence of combustion-related carbon dioxide at the ambient and occupational-exposure levels.

Metals Manufacturing. Aluminum production is the UAE's main industry other than oil, and the Dubai Aluminum Company plant, owned by the Dubai government, provides 12% of Dubai's gross domestic product and 50% of nonoil-related revenues (UAE Ministry of Public Works 2006). Lung functioning was examined in a small group of Dubai iron foundry workers who were exposed to dusts, fumes, and gases (Gomes et al. 2001). Certain jobs (furnace and fabrication) with the highest concentrations of exposure had higher rates of respiratory symptoms. Smoking did not modify the health outcomes associated with exposure to dusts, fumes, and gases within the iron foundry workers. In addition, researchers found that noise levels in the iron foundry exceeded 90 decibels and the thermal stress index was high (Gomes et al. 2002). Workers at the iron foundry had higher rates of visual defects, hearing disability, and muscle cramps than workers at a bottling company. Although linkages between individual exposure and health were not examined, there were dose-response relationships between working in a location with higher noise exposures and hearing loss, and working in a location with higher heat exposure and muscle cramps.

Cement Industry. By 1998, there were a total number of nine cement factories throughout the UAE. Eight produced Portland cement, and one produced white cement. These factories currently employ 2,999 workers (UAE Ministry of Public Works 2006).

There have been at least two occupational studies of cement workers in the UAE. In one study, workers mainly reported chronic cough, bronchitis, burning and itching eyes, headache, and fatigue (Abou-Taleb et al. 1995). Another UAE occupational study found higher rates of cough, phlegm, wheezing, shortness of breath, sinusitis, bronchitis, asthma, poorer lung function, and obstructive respiratory disease in cement workers than in unexposed retail sales workers (Al Neaimi et al. 2001). Smoking increased the risk of decreased lung function. These workers reported that noise and dust were the primary exposures. Factory workers, factory supervisors, and machine operators who were directly involved in the production process were exposed to higher concentrations of dust than machine maintenance workers, although these subgroups did not differ in the extent to which dust was associated with respiratory health, suggesting the dust was pervasive across the factory. There were no dust controls or noise abatement systems in place, and workers did not wear any protective equipment, although some used a head cloth to cover their nose and mouth to protect them from dust exposure.

What Has the UAE Already Done About the Occupational Risk for Industrial Workers?

Governmental regulatory agencies in the UAE have established several federal maximum exposure guidelines for all industrial operations, including those for lead, silica, and asbestos. The law also provides guidelines for screening, routine monitoring and reporting of the health of all workers, setting exposure limits for certain occupational exposures, and providing training, education, and protective equipment in the workplace to prevent exposures. No public reports were found that assess the impact or status of implementation of this recent law. However, such studies may prove to be an important part of future risk management efforts.

While multinationals and the oil companies in the UAE have established guidelines for using personal protective equipment, small private sector businesses frequently operate under hazardous conditions. However, the Ministry of Environment and Water recently released guidelines that limit the amount of noise pollution and set standards for health and safety practices for the 90 quarries and associated crushing plants located in Fujairah and Ras Al Khaimah (2008).

Workers who are semi-skilled or unskilled tend to accept hazardous working conditions as part of the job, since they are being paid better than in their home countries. The UAE federal government faces challenges in establishing regulations and safety guidelines for numerous small companies, as well as internationally-owned or managed private companies.

Notes on Occupational Exposures in Industry Risk Calculations

Number of Deaths per Year. The total number of deaths was calculated using the attributable fractions of deaths related to asthma and chronic obstructive pulmonary disease (COPD) from workplace airborne pollutants (e.g., silica and asbestos in mining, construction, manufacturing) in the World Health Organization's Eastern Mediterranean B (EMR-B) region in 2000 (Driscoll et al. 2005). Driscoll et al. estimated that 12% of total asthma deaths (18% of male deaths) and 11% of COPD deaths (17% of male deaths) were attributable to workplace exposures for the total population in the EMR-B region (of which the UAE represents 1.56%). Using these attributable fractions for both males and females, we estimated the number of workplace deaths by applying these fractions to the WHO-reported asthma and COPD deaths for the UAE (121 in 2000). This conservatively yielded a low estimate of 15 workplace-attributed asthma and COPD deaths or about 22 deaths if we considered that the majority of those working in dangerous jobs in the UAE are men. We then added work-related air pollution deaths to cancer deaths reported by Driscoll et al. (2004). An estimated 1,000 cancer deaths in the EMR-B region are workplace attributable, yielding another 16 deaths when scaled to the UAE fraction of the total EMR-B population. Finally, if approximately 14% of the workforce was in industry in 2007 (UAE Ministry of Economy 2008a) and we assumed the disease burden was spread evenly over the entire workforce, then there should have been approximately six deaths due to industrial exposures in 2007. This assumes that the exposures were the same for UAE as they were across the EMR-B region, and the same from when the estimates were produced (2000) to 2007. It also assumes that workers have the same distribution of confounders (e.g., smoking, age, and pre-existing health conditions) and same distribution of occupations in the EMR-B as they do in the UAE. The estimate for males and females is low because it does not account for other risks encountered in the workplace such as deaths from accidents or cancer. It is also an underestimate since the majority of deaths and illnesses are more likely to be concentrated in industry and construction, rather than evenly spread throughout the workforce. Occupational-exposure-related mortality often has a long latency period after exposure and the high turnover rate of exposed workers would mean that the exposed population is greater than the current worker population. Thus, we have likely underestimated the mortality risk to the extent that there is high turnover in the industrial sector in the UAE. The best estimate available is provided using attributable fractions from Driscoll for males since men make up the vast majority of industrial workers in the UAE. No studies with data on mortality risks from occupational exposures other than airborne pollutants in the UAE exist. Lung cancer and leukemia risk resulting from occupational carcinogenic exposures is not expected to exceed the mortality estimates due to occupational airborne exposures based on the relative magnitude of lung cancer and leukemia deaths to asthma and COPD deaths (Driscoll et al. 2004). Thus we provide a high estimate that is twice the mortality burden from airborne pollutants in the workplace.

Chance in a Million of Death per Year for the Average Worker. The number of deaths was applied to calculate the chance of death per million workers for a randomly chosen UAE resident in 2007 (4.44 million total, according to the Central Intelligence Agency World Factbook 2008). Industrial workers made up 430,440 workers, or 14% of the total population of workers (3,096,000), in 2007, according to the UAE Ministry of Economy's Annual Social and Economic Report (2008).

Chance in a Million of Death per Year for the Worker at Highest Risk. The chance in a million for death in a worker at highest risk assumes that this death rate is applied for older male workers above age 40. Since there are no studies that report risk for all UAE workers with varying characteristics, we used the rate of 15.5% of workers who were 40 and older and smokers from a sample of 304 randomly chosen cement industry workers in the UAE (Abou-Taleb et al. 1995). There were 433,440 industrial workers in the UAE in 2007 (UAE Ministry of Economy 2008a). Thus, the denominator for individuals at highest risk is $0.155 \times 433{,}440 = 67{,}200$. The chance of death in a million industrial workers is therefore the number of deaths (see section above) divided by 67,200.

Greatest Number of Deaths in a Single Episode. Some hazards kill only one person at a time, whereas other hazards can kill a number of people all at once. A catastrophic event such as a chemical poisoning or accident (chemical explosion) within a factory would lead to the greatest number of deaths in an occupational setting. Thus, we assumed the largest estimate is for a chemical poisoning or accident in the largest oil and gas refinery and the lowest estimate for a small iron foundry. The best estimate would be for an event at an oil and gas refinery because this is the most common type of industry in the UAE.

Illness or Injury. Exposure to industrial pollutants also presents nonfatal risks. These morbidity risks vary in both duration and severity. The table describes four categories of cases of nonfatal illness or injury per year expected among average industrial workers in the UAE. Occupational-related asthma and COPD are classified as more serious long-term cases. Overall, 15% of asthma cases are thought to be due to occupational dust exposure (Driscoll et al. 2004), and the rate increases to 29%

for men. However, publicly reported figures for asthma and COPD prevalence in the UAE population are not available. Thus, the reported estimates here stem from excess illnesses reported by Bener et al. (2001) for industrial workers in the UAE.

There are no comparable risk estimates for other more serious long-term cases such as cancer or less serious short-term cases such as hypertension from noise exposure in the literature that can be combined with the Bener et al. extrapolated data in a valid way. Using the rates found in Bener et al. (2001) we calculated morbidity risk by averaging the excess illnesses reported for each category and applying them to the total industrial population, which is 14% of 3,096,000 total workers in 2007 (UAE Ministry of Economy 2008a). Bener's population of industrial workers included construction workers (estimated at 60% of the study sample industrial workforce), so we have removed them from the population to calculate morbidity among industrial workers not involved in construction work. Bener's study had fairly small sample sizes and only included workers in Abu Dhabi emirate. Thus, these estimates contain a high level of uncertainty if we assume the same distribution of morbidity risk across workers across all emirates and if we apply these morbidity numbers to the population of industrial workers in the UAE in 2007 (UAE Ministry of Economy 2008a). Further, it is important to note that the level of uncertainty varies to the extent that many of these occupational-related illnesses are co-occurring.

Time between Exposure and Health Effect. Some hazards, such as exposure to chromium in cement dust, have immediate impacts such as dermatitis, whereas hazards such as asbestos or silica exposure have effects that do not manifest for decades.

Quality of Scientific Understanding. There are two sources of uncertainty in estimating risks for the UAE working population. One involves how well scientists understand the relationship between exposure to a hazard and its resulting health impacts. The other involves how well we can predict the exposure of UAE residents to a particular hazard. This statistic characterizes the former. Three categories are used to rate scientific understanding: high, moderate, and low. In the case of industrial exposures, our quality of understanding is high since most health effects are well characterized due to the observation of occupational versus population-based exposure levels, dose-response effects, and the mitigation of effects after removal of workers from the industrial workplace.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects both uncertain scientific understanding about the risk and uncertainty about the extent of exposure or susceptibility of UAE workers to the particular hazard. The table entry cites the amount of uncertainty in deaths, illness, and injury, qualitatively with respect to other exposures in industry.

Ability of Worker to Control Exposure. Three categories are used to rate this controllability: high, moderate, and low. Many hazards that UAE industrial workers encounter can be avoided partly by using personal protective equipment and following safety guidelines for reducing risk of exposure, accidents, and resulting health risks. UAE Federal Law 8 specifies regulations for providing personal protective equipment. Thus, we classify a worker's potential ability to control his or her exposure to be moderate, if provided the necessary personal protective equipment and education for reducing exposures. It is important to note, however, that given the high exposure levels found in industrial factories, it is impossible to avoid exposure entirely even with the use of personal protective equipment because of errors in protection use, take-home exposures, and other routes of exposure. Moreover, most workers are uneducated and not made aware of the health risks associated with industrial exposures. Workers may not be in a position to demand safe working conditions and protective equipment from their employers if their employers do not comply with federal regulations.

Occupational Exposures in Construction

Summary

Construction workers face numerous occupational risks from breathing dust and debris, skin contact with dangerous chemicals, and exposure to dangerous levels of heat and noise. The 500,000 construction workers in the United Arab Emirates face serious risks of developing chronic obstructive pulmonary disease (COPD) and asthma from breathing dust on the job, as well as stomach cancer, lung cancer, and mesothelioma from asbestos exposure. Construction workers experience significantly higher pneumoconiosis mortality due to silica and asbestos. There are several less serious dangers from noise pollution, heat stress, skin contact with chromium in cement, and allergies due to biological pollutants such as pollen and dust.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	10	15	30
Chance in a million of death per year for the average construction worker	2	3	6
Chance in a million of death per year for the construction worker at highest risk	100	150	300
Greatest number of deaths in a single event		Not reported	
Illness or injury			
More serious long-term cases per year	Not reported	0	Not reported
Less serious long-term cases per year	Not reported	33,000	Not reported
More serious short-term cases per year	Not reported	43,000	Not reported
Less serious short-term cases per year	Not reported	47,000	Not reported
Other factors			
Time between exposure and health effects	Immediate to 30 years		
Quality of scientific understanding	High		
Combined uncertainty in death, illness, and injury	High		
Ability of construction worker to control exposure to hazard	High		

Construction workers face the most risk when they are uninformed about the dangers of exposure at their worksite, when their employers do not provide or enforce measures to reduce dust and chemical exposures, or when they are unable to self-pace their work or use other self-protection measures. The recently revised UAE labor law outlines several federal regulations across all types of occupations to monitor occupational exposure-related health, ensure safe work environments, protect against exposures, and provide education in the workplace.

What Is Known About the Occupational Risk for Construction Workers?

Construction workers are exposed to a number of pollutants in the course of their work that can cause asthma, COPD, pneumoconiosis, heat stress, and other diseases. Many of these are due to inhalation of dusts and pollutants, while others are due to exposure by skin contact.

By the nature of their work outdoors, construction workers are exposed to outdoor air pollutants such as particulate matter and gaseous combustion products, which can lead to the risk of health conditions such as asthma, lung cancer, and COPD.

Construction workers can be exposed to biological irritants such as pollens, insects, or fungi; natural dusts such as asbestos, crystalline silica, or coal; and chemical agents such as chlorofluorocarbons, alcohols, metals, salts, and welding fumes. Exposures differ among workers depending on whether they are engaging in new construction, renovation, or demolition. For renovations or demolitions, construction workers may be exposed to more fungi, mold, and asbestos.

Exposure to asbestos can cause numerous health problems, including asbestosis, fibrotic lesions on lining of the lungs, lung cancer, and mesothelioma. However, one study of Finnish construction workers showed that asbestos exposure had a significant influence on mesothelioma but not on lung cancer. In addition, construction workers exposed to asbestos are also at higher risk of stomach cancer.

Construction workers can be exposed to respirable crystalline silica when working with rock, concrete, or masonry. Crystalline silica is classified as a suspected carcinogen by the International Agency for Research on Cancer and also increases the risk for lung infections such as tuberculosis, as well as COPD and rheumatoid arthritis.

Construction workers also experience an increased risk for a chromium allergy from skin contact with water-soluble chromium present in cement. Although the allergy is not a serious illness, it is uncomfortable. In addition to hexavalent chromium in cement, construction workers are also exposed to plasters, epoxy resins, hardeners, and solvents that can cause skin problems and other health issues.

There is a risk of heat stress morbidity for construction workers working outdoors in the heat of the desert, especially during the summer and afternoon. The most serious health problem associated with working in a hot environment is heatstroke, in which an individual becomes mentally confused, delirious, and perhaps experiences convulsions. Some research suggests workers who are allowed to self-pace their work are better able to regulate their core body temperature (Brake and Bates 2002).

Noise pollution is a common exposure in construction, where workers often use loud machinery. Ironworkers, masons, and carpenters are most affected by high noise levels. Ironworkers, carpenters, and electricians experience the most variability in noise. Exposure to noise pollution has been most commonly associated with hearing impairment.

In construction, there is also the risk of catastrophic exposure events that kill multiple workers, mainly chemical poisonings that occur in confined spaces. In a survey of such accidents in the United States, 62% of the observed fatalities could have been prevented by enforcing a standard for adequate ventilation and risk communication for small spaces.

In addition to substances mentioned above, construction workers are also exposed to wood dusts, acids, organic solvents, isocyanates, metals, and fumes such as those from welding, each with very different toxicological properties and diverse health risks such as airway inflammation, asthma, dermatitis, and cancer.

What Is the Exposure to Health Risks for Construction Workers in the UAE?

The number of construction workers in the UAE has more than doubled, from 287,000 in 2000 to 650,160 in 2007, or 21% of the total labor force. The UAE construction workforce is expected to continue increasing as the UAE carries out its development plans. A number of large-scale endeavors, such as the eco-cities of Masdar in Abu Dhabi and Xeritown in Dubai, and numerous off-shore islands, are slated to begin construction by 2010, which will likely require an increased population of construction laborers, as well as associated skilled labor.

No empirical studies of the health effects due to exposures in construction work in the UAE have been published. One study on the respiratory health of UAE cement factory workers indicated higher levels of cough, phlegm, breathing difficulty, sinusitis, and bronchitis among exposed workers (Al Neaimi et al. 2001). Construction workers mixing cement may face the same risks as workers in the cement factory but probably to a lesser scale. Health effects due to cement dust exposure in construction workers are probably even smaller than those from smoking, which was a greater contributor to respiratory symptoms than cement dust exposure in the factory.

What Has the UAE Already Done About the Risks for Construction Workers?

Federal Law 8 was passed in 1995 to govern safety in all occupations in a general manner. No other laws specifically address the protection of UAE construction workers in such areas as regulations for concrete and masonry work, steel erection, tunnels, caissons, cofferdams, the use of explosives, and power transmission and distribution. The law was updated in 2007 to provide guidelines for screening, routine monitoring, and reporting of the health of all workers; setting exposure limits for certain occupational exposures; and providing training, education, and protective equipment in the workplace to prevent exposures. Companies that do not provide their workers with personal protective equipment violate the law, and the law states that equipment should be supplied along with instruction to protect workers from risks.

In addition to Federal Law 8, the UAE Ministry of Labor enacted a resolution in 2006 to reduce the risk of heat stress in construction workers. This resolution states that construction workers are not allowed to work between 12:30 and 3 p.m. during the months of July and August. Firms violating the rule could be fined and denied new work permits for three additional months.

The main problems with construction site safety in the UAE include the lack of orientation for new employees, education about hazardous exposures, and access to medical information. The lack of employer-provided training about normal safety procedures translates to higher exposures, more accidents, and higher risk of health conditions due to chemical and biological dangers in the workplace.

Aside from general occupational exposure guidelines provided in Federal Law 8, no other publicly available federal regulation exists to ensure the protection and safety of construction workers. The Abu Dhabi Executive Council is considering new laws to ensure construction site safety, harsher penalties for companies that do not follow those laws, and increased numbers of inspectors responsible for monitoring building site safety standards. As of 2008, proceedings are under way to design a federal legal framework for the construction industry.

Notes on Occupational Exposures in Construction Risk Calculation

Number of Deaths per Year. The total number of deaths in construction was calculated using the same method as the total number of deaths in industry, described in detail in the previous risk summary sheet. Since approximately 21% of the workforce was in construction in 2007 (UAE Ministry of Economy 2008a) and we assumed the disease burden was spread evenly over the entire workforce, then there should have been approximately eight deaths due to construction-related exposures in 2007.

Chance in a Million of Death per Year for the Average Construction Worker. The number of deaths is used to calculate the chance of death for a randomly chosen UAE construction worker (total 650,160 in 2007) per one million workers.

Chance in a Million of Death per Year for the Construction Worker at Highest Risk. The chance in a million for death in a worker at highest risk assumes that this death rate is applied for older male workers above age 40. Since there are no studies that report risk for all UAE workers with varying characteristics, we used the rate 15.5%, or workers who were 40 and older and smokers, from a sample of 304 randomly chosen cement industry workers in the UAE (Abou-Taleb et al. 1995). There were 650,160 construction workers in 2007 (UAE Ministry of Economy 2008a). Thus, the denominator for individuals at highest risk is $0.155 \times 650{,}160 = 100{,}800$. The chance of death in a million is therefore the number of deaths (see section above) divided by 100,800, per million residents.

Greatest Number of Deaths in a Single Episode. Some hazards kill only one person at a time, whereas other hazards can kill a number of people all at once. A catastrophic event such as a large construction site accident would lead to the greatest number of deaths in a construction setting. Thus, we assume the largest estimate for a construction accident would be an entire construction team and the smallest a single person. However, deaths due to construction-related pollutants are likely to be small since the most likely causes of death among construction workers (e.g., in the United States) are falls, electrocutions, and motor vehicle accidents (Jackson and Loomis 2002).

Illness or Injury. The table describes four categories of cases of nonfatal illness or injury per year expected among the average worker in the UAE. Occupational-related asthma and COPD are classified as more serious long-term cases. Overall, 15% of asthma cases are thought to be due to occupational dust exposure (Driscoll et al. 2004), and the rate increases to 29% for men. However, publicly reported figures for asthma and COPD prevalence in the UAE population are not available. Thus, the reported estimates here stem from excess illnesses reported by Bener et al. (2001) for construction workers in the UAE. Since Bener's study had fairly small sample sizes, these estimates are highly uncertain. To calculate morbidity attributable to construction-related exposures, we took an average of the excess illnesses reported for each category and applied them to the total industrial population (UAE Ministry of Economy 2008a). Then we estimated that construction-related morbidity made up 60% of the illnesses, as construction workers were approximately 60% of the "industrial" workforce studied by Bener et al.

Time between Exposure and Health Effect. Some hazards, such as exposure to chromium in cement dust, have immediate impacts such as dermatitis, whereas hazards such as asbestos or silica exposure have effects that do not manifest for decades.

Quality of Scientific Understanding. There are two sources of uncertainty in estimating risks for the UAE working population. One involves how well scientists understand the relationship between exposure to a hazard and its resulting health impacts. The other involves how well we can predict exposure of UAE residents to a particular hazard. This statistic characterizes the former. Three categories are used to rate scientific understanding: high, moderate, and low. In the case of construction-related exposures, the quality of our understanding is high since most health effects are well characterized due to the observation of occupational versus population-based exposure levels, dose-response effects, and the mitigation of effects after removal of workers from the construction workplace.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects uncertain scientific understanding about the extent of exposure or susceptibility of UAE workers to the particular hazard. The table entry cites the amount of uncertainty in deaths, illness, and injury, expressed qualitatively with respect to other exposures in industry. The combined uncertainty is a weighted average of uncertainties in risks of death and injury.

Ability of Worker to Control Exposure. Three categories are used to rate this controllability: high, moderate, and low. Many hazards that UAE industrial workers encounter can be avoided partly by using personal protective equipment and following safety guidelines for reducing risk of exposure, accidents, and resulting health risks. Federal Law 8 specifies regulations for providing personal protective equipment. Thus, we classify a worker's potential ability to control his or her exposure to be moderate, if provided the necessary personal protective equipment, and education for reducing exposures. It is important to note that it is impossible to avoid exposure entirely even with the use of personal protective equipment because of errors in protection use, take-home exposures, and other routes of exposure that are not protected. Moreover, most workers are uneducated and not made aware of the health risks associated with construction-related exposures. Workers may not be in a position to demand safe working conditions and protective equipment from their employers if their employers do not comply with federal regulations.

Drinking Water Contamination

Summary

Access to clean drinking water is essential for health. However, drinking water quality is a serious problem worldwide. Problems with drinking water are seen more often in developing countries than in industrialized countries like the United Arab Emirates. Drinking water hazards include microbial contamination that can lead to diarrheal diseases, compounds that may cause acute toxicity, compounds that may cause cancer, and radiological contamination. The UAE has established drinking water quality guidelines that are comparable to international guidelines, and a World Health Organization (WHO) estimate of risks associated with water, sanitation, and hygiene indicates that these risks in the UAE are comparable to those in other industrialized nations.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	0	Not zero but low	147
Chance in a million of death per year for the average citizen	0	Not zero but low	33
Chance in a million of death per year for the citizen at highest risk	0	Not zero but low	33
Greatest number of deaths in a single event		1	
Illness or injury			
More serious long-term cases per year	0	0	Not reported
Less serious long-term cases per year	0	0	Not reported
More serious short-term cases per year	0	Not zero but low	Not reported
Less serious short-term cases per year	Not reported	Not zero but low	Not reported

(continued)

(continued)

Risk characteristic	Low estimate	Best estimate	High estimate
Other factors			
Time between exposure and health effects	Immediate to 10–30 years		
Quality of scientific understanding	High		
Combined uncertainty in death, illness, and injury	High		
Ability of resident to control exposure to hazard	Moderate		

What Is Known About the Risk from Contaminated Drinking Water?

Drinking water can be contaminated in several different ways. These include microbial, chemical, and radiological contamination. The amount of these hazards in drinking water depends significantly on the source of the drinking water and how it is processed (including disinfection), stored, and distributed, such as via piping (tap water), bottles, or directly from surface waters or wells.

Poor water quality and sanitation take a heavy toll on public health, particularly in developing nations and on the health of children. This is due mostly to microbial contamination in drinking water, which is the focus of many water quality guidelines and standards. Lack of safe drinking water contributes to a variety of intestinal infections that can cause malnutrition and anemia in children. Chronic diarrheal disease can also exacerbate malnutrition. Early childhood malnutrition, anemia, and associated diarrheal disease can permanently affect brain development and cognitive ability.

While microbial contamination is the largest public health threat of water for drinking and sanitation, chemical contamination can be a major health concern in some cases. WHO lists guideline values for nearly 200 chemicals, ranging from naturally occurring arsenic and fluoride to synthetic chemicals found only in industrial settings. However, it neither practical nor necessary to test water for all of the chemicals that could cause health problems. Most potential water contaminants occur rarely, and many result from human contamination in limited areas, only affecting a few water sources. Water can be chemically contaminated through natural causes (e.g., arsenic and other elements) or through human activity (e.g., nitrate, heavy metals, pesticides resulting from agriculture or industry). This contamination can have significant effects.

Drinking water also can be contaminated by radioactivity. The contribution of drinking water to overall radioactive exposure is very small and is principally due to the presence of naturally occurring elements in the uranium and thorium decay series. Groundwater typically contains more radioactivity, such as from radon, than surface water does, so a country that receives most of its drinking water from desalination sources is likely at low risk for radiological contamination.

What Is Known About the Risk from Contaminated Drinking Water in the UAE?

The Gulf Coast countries, including the UAE, have the lowest supplies of fresh water per capita in the world. In the past, most drinking water in the UAE came from groundwater and a few surface water sources, both natural and anthropogenic. Recently, however, the groundwater extraction rate has become unsustainable, and desalinated water has become the main source of drinking water, either through piping (tap water) or as bottled water. Desalinated water meets 95% of the domestic water demand in Abu Dhabi emirate; however, it is unclear if this figure is representative of the rest of the UAE. The UAE is currently the world's largest consumer of bottled water per capita.

Bottled water has been reported to present additional risk due to contaminants in the bottles being introduced to the water during storage. A 2007 study in the UAE showed 100 parts per billion (ppb) of bromate (a potentially carcinogenic by-product of a particular desalination process used in the UAE) at one desalination and bottling plant, whereas the WHO recommends consumption of no more than 10 ppb at any time. The Environmental Agency–Abu Dhabi has recognized the risk posed by bromates in all drinking water sources and has taken steps to reduce bromate levels in water production plants to below the WHO-recommended level.

Microbial contamination is another potential risk posed by bottled water, as with other water sources. One study of UAE commercial bottled-water samples showed that 75% of 20-l bottles were contaminated by 10 different species of bacteria. However, this study did not calculate the health risk of this contamination, nor did it determine the source of the contamination.

There is some concern that desalination (i.e., demineralization) results in drinking water that is lacking in essential nutrients. The potential risk of consuming desalinated drinking water appears to be twofold: (1) this water may lack essential dietary ions, and (2) desalinated water could cause potentially harmful compounds to leach from distribution and storage systems. The literature on the health effects associated with long-term consumption of demineralized water is inconclusive because of factors that confound the mechanisms of harm. In the first case, essential ions may be obtained from other dietary sources. In both cases, reintroduction of essential ions to desalinated water could reduce the risk.

It is unclear whether blending or reintroduction of ions is performed routinely in the UAE. Bottled water labels and some information from two desalination plants (Ruwais and Fujairah) provide some indication of such practices from the UAE. Thus, data on the actual level of essential ions in tap and bottled water and the overall nutritional health of the country are needed to better assess the specific risk faced by the UAE.

Groundwater drinking sources may present risks not posed by desalinated or bottled water. Of 228 water samples collected in Abu Dhabi in 2005, 80% had concentrations of nitrate that exceeded the emirate's guideline limit. For most people, consuming small amounts of nitrate is not harmful, but even short-term exposure to high levels of nitrate can cause health problems for infants.

An additional potential risk to drinking water is the possibility of contamination from oil spills at desalination plants.

WHO has estimated the combined risks of water, sanitation and hygiene for the UAE and other countries. Based on data from 2002, WHO estimated that 200 deaths are caused in the UAE each year by this combined risk. This accounts for approximately 2% of all deaths in the UAE. However, no deaths in 2002 in the UAE were attributed to diarrheal disease, parasitic infections, or malnutrition; water-related deaths were attributed mostly to drowning.

What Has the UAE Already Done About the Risk from Contaminated Drinking Water?

Without information about specific exposures to contaminants in drinking water in the UAE, it is difficult to provide an estimate of risk from drinking water to either the general population or to specific, potentially sensitive populations. However, one might approach the question of risk by comparing the UAE's water quality guideline criteria against the established guidelines of other nations. The guidelines from other countries include both mandatory and recommended water quality criteria. The UAE guidelines generally compare well to those of other industrialized countries: they are at or below levels that other countries have declared to be of low risk. There are some potential drinking water contaminants for which most other countries have established guidelines but the UAE does not, including bromate, acrylamide, epichlorohydrin, and vinyl chloride, which pose cancer risks as well as some risk of acute toxicity. However, the UAE has stated that concentrations of any water constituents not included in their quality guidelines should be governed by the internationally accepted WHO guidelines.[3] Therefore, if UAE water quality is monitored and its guidelines are enforced, it is likely that the overall risk from drinking water in the UAE will be low.

Notes on Drinking Water Risk Calculation

The figures in the table are based on 2002 WHO data for reported mortality and morbidity due to the combined exposures of water, sanitation, and hygiene (WSH) (Prüss-Üstün et al. 2008).

Number of Deaths per Year. WHO reported a total of 200 WSH-related deaths in the UAE in 2002, and it reported the UAE population that year as approximately three million. Of those deaths, 100 were due to drowning. The Central Intelligence Agency World Factbook (2008) reports a UAE population of 4.4 million.

[3]Utilizing the water quality standards of other countries or international organizations is a standard practice. A number of countries make available their national drinking-water standards, which can serve as points of reference when developing national drinking-water standards.

Extrapolating 2002 WSH-related deaths, not including drowning, to the 2007 population results in an upper-bound estimate of 147 WSH-related deaths. This estimate is considered high for drinking-water risks because the WSH grouping includes more than just drinking water. In fact, WHO reported no deaths due to diarrheal, parasitic, or other similar diseases that might often be linked to drinking water, so the low estimate for deaths per year is zero. However, the WHO data did not include deaths from cancer due to WSH problems. Because water quality data and information about the disinfection and distribution of water in UAE is unreported, it is possible that some risk exists due to long-term consumption of carcinogens such as arsenic or chlorination by-products in drinking water. The best estimate of "not zero but low" reflects this uncertainty.

Chance in a Million of Death per Year for Residents. This estimate is similar for low- and high-risk populations because these populations are not easily distinguished for drinking water without further characterization of the water sources, contaminants, and distribution. These figures are based on the number of deaths per year described above and calculated for the 2007 population.

Illness or Injury. Most drinking-water-related illnesses are gastrointestinal illnesses of short duration. For 2004, WHO reported that the UAE has among the world's lowest rates of illness due to inadequate WSH (WHO 2009). Therefore, in the absence of reported information about water quality in the UAE, it is estimated that the risk of illness due to drinking water is probably not zero, but low.

Time between Exposure and Health Effect. Most health effects related to drinking water are acute and occur within days, but some contaminants may be carcinogenic and not exert effects for more than 10 years.

Quality of Scientific Understanding. Much is known about water quality, and this knowledge has supported the development of water quality standards in many nations. However, some uncertainty exists about specific cause-and-effect relationships, including, for example, the potential health effects of chlorination by-products and of chemicals present in water bottles.

Ability of Resident to Control Exposure. Drinking water is a basic requirement, and some residents may have little control over its sources or quality. However, some risk avoidance is possible when residents are able to choose water sources or provide additional treatment such as home filtration or boiling.

Coastal Recreational Water Pollution

Summary

As in many other countries with ample coastline and favorable climate, bathing (e.g., swimming) in the sea is a popular form of recreation in the UAE. However, using the UAE's coastal waters for recreation may pose some health risks as a result of exposure to contamination by pathogenic bacteria and viruses as well as chemical pollution from storm water runoff and industrial wastewater. The association between bathing in contaminated recreational water and illness is difficult to establish, but some studies have indicated such a link may exist. Indeed, many nations have established guidelines for recreational water quality as a safeguard against the possibility of illness. The most likely illnesses to result from coastal bathing include short-term gastrointestinal, skin, or ear, nose, and throat infections.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	0	0	147
Chance in a million of death per year for the average resident	0	0	33
Chance in a million of death per year for the resident at highest risk	0	0	33
Greatest number of deaths in a single event		1	
Illness or injury			
More serious long-term cases per year	0	0	0
Less serious long-term cases per year	0	0	0
More serious short-term cases per year	0	Not zero but low	Not reported
Less serious short-term cases per year	0	Not zero but low	Not reported
Other factors			
Time between exposure and health effects	Immediate		
Quality of scientific understanding	Low to moderate		
Combined uncertainty in death, illness, and injury	High		
Ability of resident to control exposure to hazard	High		

What Is Known About the Risk from Coastal Recreational Water Pollution?

The most commonly reported health effects are diseases caused by bathing in recreational waters that are contaminated with bacterial and viral pathogens. Pathogens often come from discharge of sewage into coastal water, storm water runoff from agricultural lands, and contact with other people who may be sick or carriers of pathogens. The risk of disease depends on which pathogens are present, which in turn depends on the source of pollution.

The most frequently reported adverse health outcome associated with exposure to contaminated recreational water involves intestinal illnesses and diarrhea (such as gastroenteritis). Coastal water pollution has also been associated with acute febrile respiratory illness (AFRI), which presents symptoms similar to influenza. AFRI is a more severe health outcome than the more frequently seen (and self-limiting) gastrointestinal symptoms. Little evidence supports an association between the quality of recreational water and other, nonintestinal-related health effects, such as those associated with the skin, ears, or eyes (Prieto et al. 2001).

Some studies have suggested a link between illness and exposure to recreational waters, although the links discovered have been of varying strength. For example, one study included interviews with 1,858 bathers seven days after they were at a beach in Spain and asked about respiratory, gastrointestinal, eye, and ear symptoms, as well as fever. Incidence rates of gastrointestinal, skin, and respiratory tract symptoms were higher in bathers than those who visited the beach but did not bathe, but the differences were not significant.

Another study conducted in the United Kingdom over four summers compared 548 bathers ("bathing" being defined as total immersion of the head) to 668 beachgoers who did not bathe (Fleisher et al. 2006). This study found that rates of gastroenteritis were significantly higher in the bathing group. Further, concentrations of fecal streptococci found in chest-deep water correlated in a dose-response fashion with illness. It was not suggested that these bacteria caused the illnesses, but they seemed to be a good indicator.

However, the association between bathing in coastal waters and illness is not definitively confirmed. While some studies, including those mentioned above, have shown an association between beach bathing and illness, it has also been found that nonbathing-related factors such as the ingestion of foods related to transmission of gastroenteritis may complicate estimations of swimming risk. The possibility that illness may be associated with bathing even in clean waters has also been proposed. Moreover, another study points out that a possible differential health status of bathing and nonbathing groups could be responsible for their choice of beach activities; this difference may result in an underestimation of bathing-associated risk if individuals chose not to swim due to an existing illness. Therefore, it is difficult to associate levels of illness directly with the amount of time a person spends bathing in coastal waters.

What Is Known About the Risk from Coastal Recreational Water Pollution in the UAE?

Monitoring of coastal water quality in the UAE indicates periodic episodes of contamination. One study found a seasonal contamination in UAE coastal waters (and the few creeks that feed them), where bacterial numbers peaked from April to May, followed by a dramatically sharp decrease in the summer months and a minimum in August (Banat et al. 1998). This was followed by a second peak in October and a subsequent drop during winter. More importantly, total and fecal coliforms fluctuated in numbers at different sites depending on several factors, including the presence of nearby drains and wastewater outlets or recreational areas. This study concluded that these coastal areas had a small degree of microbial pollution.

Coastal waters in the UAE may also be contaminated by wastewater streams from industrial processes that discharge to the sea. These include, for example, discharge from petroleum processing industries and from power generation (and concurrent desalination) plants. A review of one petroleum refinery at Al Ruwais found that its discharge included high biochemical oxygen demand and chemical oxygen demand levels as well as polyaromatic hydrocarbons and phenolic compounds in the major wastewater streams. Polychlorinated biphenyls were also detected in some waste streams. At this refinery (likely as with others), dilution of the wastewater with process cooling water serves as the main treatment approach before the effluent wastewater is disposed into the sea (samples taken from the sea where bathing may occur were not conducted as part of this study). This study suggested that primary as well as secondary treatment units are thought to be essential and strongly recommended to ensure pollutant levels are below UAE standards for marine discharge. However, the study did not include an assessment of the risk posed by this wastewater stream.

An additional potential risk to bathers in Arabian Gulf coastal waters is the potential for contamination from oil spills. Given the large amount of oil transport that takes place in the Gulf, accidental oil spills are unfortunate realities, there more than in any other body of marine water in the world. While limited data have been reported on the distribution of such spills and resulting contamination, it is also recognized that much more data collection is required to support any risk estimation. It is unclear, for example, if oil spills have affected coastal areas during times of sea bathing; large spills would likely deter sea bathing for aesthetic reasons, but smaller amounts of pollutants that are not obvious via sight or smell could pose some risk.

What Has the UAE Already Done About the Risk from Coastal Recreational Water Pollution?

Most measures to control beach pollution focus on preventing sewage from contaminating recreational coastal waters. However, the limited evidence available from cost-benefit studies of point-source pollution control suggests that direct health benefits alone rarely justify the proposed investments and may be ineffective, particularly in cases where pollution results from other sources. While some limited studies have been performed, more complete monitoring data is necessary to describe the extent of coastal pollution in the UAE. Furthermore, reports are lacking on the steps taken to control such pollution in the UAE.

Notes on Coastal Recreational Water Risk Calculations

Number of Deaths per Year. WHO reported a total of 200 deaths related to water, sanitation, and hygiene (WSH) in the UAE in 2002 (WHO 2006). Of those, 100 were due to drowning. Extrapolating 2002 WSH-related deaths, not including drowning, to the 2007 population would result in a high estimate of 147 WSH-related deaths. This estimate is considered high for coastal bathing illness-related risks, because the WSH grouping includes more than coastal bathing. In fact, WHO reported no deaths in the UAE in 2002 due to diarrheal, parasitic, or other similar diseases that might often be linked to coastal bathing, and the expected potential illnesses are generally self-limiting infections. Therefore, the low and best estimate for deaths per year is zero. However, the WHO data also reported approximately 100 drownings in the UAE in 2002, and this number is the basis for the high estimate (extrapolated to the 2007 population of 4.4 million as reported by the Central Intelligence Agency World Factbook). Because data are unreported on coastal water quality and about which residents bathe and how often, the additional risk of illness cannot be accurately estimated.

Chance in a Million of Death per Year for Residents. These figures are based on the number of deaths per year due to drowning and extrapolated to the 2007 population.

Illness or Injury. Most reported coastal-bathing-related illnesses are gastrointestinal illnesses of short duration. For 2002, WHO reported disability-adjusted life years (DALYs) related to WSH causes for the UAE (WHO 2006). These causes included diarrheal diseases and other infectious diseases. It is likely that few of these illnesses were caused by coastal bathing, but no studies documenting coastal water exposure or associated illnesses in the UAE have been reported. DALYs due to parasitic diseases were not reported from WSH-related causes except for trachoma, which is unlikely to be transmitted by coastal bathing. Therefore, in the absence of reported information about water quality in the UAE, it is estimated that the risk of illness due to coastal bathing is not zero but is probably low.

Time between Exposure and Health Effect. Most coastal bathing-related illnesses are gastrointestinal illnesses of rapid onset and short duration.

Quality of Scientific Understanding. Some epidemiologic studies have correlated illnesses with coastal water quality. While the pathogenicity of microbial contaminants sometimes found in coastal waters is well documented, the direct cause-effect relationship between bathing and illness is less well established.

Ability of Resident to Control Exposure. Residents may choose not to bathe in coastal waters.

Exposure to Residential Soil

Summary

Threats to health from residential soil may exist in the UAE due to industrial sources and poorly regulated waste disposal. Pollutant exposures include heavy metals and trace elements, inorganic compounds, aromatics, hydrocarbons, and pesticides. Pollutants in residential soil can be brought into homes via dirty shoes, agricultural produce, or the wind. Exposures are fairly simple to remedy by removing shoes at the door, washing or peeling fruits and vegetables, and keeping doors and windows shut if it is particularly dusty outside. The exact sources and magnitude of possible soil contamination has not been reported.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year		Not reported	
Chance in a million of death per year for the average resident		Not reported	
Chance in a million of death per year for the resident at highest risk		Not reported	
Greatest number of deaths in a single event		Not reported	
Illness or injury			
More serious long-term cases per year		Not reported	
Less serious long-term cases per year		Not reported	
More serious short-term cases per year		Not reported	
Less serious short-term cases per year		Not reported	
Other factors			
Time between exposure and health effects	10–30 years		
Quality of scientific understanding	Moderate		
Combined uncertainty in death, illness, and injury	High		
Ability of resident to control exposure to hazard	High		

Exposures in children are often much higher than in adults due to children's tendency to spend more time on the ground in playgrounds or parks. Additionally, even if they receive less absolute pollution than adults, it is often greater on a scale relative to weight.

What Is Known About the Risk from Residential Soil?

There are many different possible contaminants in residential soil: heavy metals and trace elements, inorganic compounds, aromatics, hydrocarbons, pesticides, and others. Of those, some of the most dangerous to human health and development (and most common) are heavy metals (which particularly affect young people), hydrocarbons, and pesticides.

Heavy metals can include lead, cadmium, mercury, and arsenic. Lead can come from cars burning leaded gasoline or from industrial sources and presents risk through inhalation or ingestion via the food chain. Cadmium can often come from incorrect disposal of nickel-cadmium batteries, industrial sources, or application of fertilizers and sewage sludge to farmland; however, the main pathway for exposure among non-smokers is through ingestion of food that takes up the cadmium in the soil. Mercury and arsenic are also usually from industrial sources—particularly nonferrous smelting and energy production from fossil fuels—or could just be prevalent in soil naturally.

Hydrocarbons (particularly polycyclic aromatic hydrocarbons) are known to be animal carcinogens and mutagens, although specific characterization of their effects on humans from soil exposure has not been quantified. Hydrocarbons in the soil and water most often come from industrial sources and other combustion processes, such as heating or cooking.

Pesticides, depending on their concentration, can cause a number of health outcomes such as diarrhea, nausea, vomiting, rash, ocular irritation, anxiety, dizziness, headache, muscular pain, memory loss, fatigue, shortness of breath, insomnia, and contact dermatitis. Pesticides can enter the home by blowing in on contaminated dirt or by being transferred from produce.

Research on residential soil exposure suggests that children may be more affected by chemical exposure because their systems are still developing (with more porous bones and membranes). Additionally, they spend more time in the dirt than their adult counterparts. Further, by bodyweight, their exposure is relatively larger. This is certainly true for lead and hydrocarbons. However, in a study of arsenic exposure in children living near a pesticide factory, no significant correlation was shown between soil arsenic levels and levels of arsenic measures in the children's urine.

Mitigation measures for exposure to contaminated soils include wiping shoes on a mat outside the house and leaving shoes near the door, vacuuming and mopping, minimizing carpeting, keeping windows and doors closed on windy days, and washing agricultural products.

What Is the Exposure to Residential Soil in the UAE?

Multiple threats to health from residential soil may exist in the UAE, but the exact nature of the contamination and degree of human exposure is not known because reported data do not provide the information needed to assess the associated health risks.

According to a July 2008 news release by the Environment Agency–Abu Dhabi (EAD), there are six extremely large, unregulated landfills outside of Abu Dhabi that the government plans to begin cleaning up (Kwong 2008). The landfills may contain medical, chemical, household, industrial, construction, and agricultural waste, and even, at one site, discarded military weapons. The largest site is Al Dhafra, which is 16 km^2 and receives 20,000 tons of waste daily. Another 8 km^2 landfill in Al Gharbia receives 1,800 tons of municipal and 5,000 tons of construction waste daily. Additionally, there are numerous small-scale landfills near smaller settlements that also lack appropriate waste treatment facilities. Although the exact nature of the chemical exposures due to these fills is unclear, they are known to contain oil sludge that can lead to hydrocarbon and heavy metal contamination of the soil.

Additionally, there has been widespread and fairly unregulated use of pesticides, particularly organophosphates and carbamates, which have been shown to be a significant health risk to farmers working with them and significant sources of occupational agricultural cancer. However, it is not clear to what extent these pollutants are transferred to nonagricultural areas.

There have not been any large-scale oil spills in the UAE, but there have been a number of minor ones, mainly in ports. Although the UAE deals harshly with oil spills and promptly cleans them up, the efficiency of cleaning operations is not clear. Beaches are especially dangerous in this regard because people generally lie in the sand and are more likely to ingest contaminants or absorb them through the skin.

What Has the UAE Already Done About the Risk of Residential Soil Exposure?

There has been some research into bioremediation of crude oil-contaminated soils in the UAE, and EAD plans to clean up landfills, but beyond that, there has been no significant movement to address the problem of residential soil exposure.

Eating Contaminated Seafood

Summary

Eating seafood has documented health benefits, but it also exposes people to risk if the fish contains hazardous contaminants. These contaminants include pathogens, which can be eliminated with proper handling and preparation, and toxic metals and organic compounds, which cannot be removed in preparation. Depending on the chemical and the level of exposure, toxic substances can have effects on cognition, the immune system, and neurological functions and may cause cancer. The effects can be long-term and are generally the result of consuming contaminated fish over a long time period. Furthermore, pregnant women may be at risk because of possible health effects of mercury on fetuses. People can reduce these risks by limiting the amount of fish they eat.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	0	4	10
Chance in a million of death per year for the average resident	0	2	3
Chance in a million of death per year for the resident at highest risk	0	>2	>4
Greatest number of deaths in a single event		1	
Illness or injury			
More serious long-term cases per year	0	7	15
Less serious long-term cases per year	0	27,000	67,000
More serious short-term cases per year	0	0	0
Less serious short-term cases per year	0	0	0
Other factors			
Time between exposure and health effects	Immediate to 10–30 years		
Quality of scientific understanding	Moderate		
Combined uncertainty in death, illness, and injury	Moderate		
Ability of resident to control exposure to hazard	High		

Note: Fatalities and serious long-term cases are due to the carcinogenicity of dioxins in seafood. Less serious long-term cases are due to the effects of mercury consumption on fetuses/unborn children

What Is Known About the Risk of Eating Contaminated Seafood?

The two types of contaminants that may be found in seafood are human pathogens and toxic substances. Exposure to contaminants in seafood is dependent on two factors: the amount of fish consumed; and the level of contamination in the fish consumed.

Typical human pathogens found in fish are *Clostridium botulinum* type E, which causes slurred speech and muscle weakness as symptoms of muscle paralysis, and *Vibrio parahaemolyticus*, which causes acute gastrointestinal effects such as diarrhea, nausea, vomiting, abdominal cramps, and sometimes fever. These health risks can be minimized or eliminated through proper handling (i.e., using proper refrigeration and good hygiene practices) and making sure the fish is thoroughly cooked before eating.

Toxic substances such as mercury (as methylmercury) and other metals (e.g., cadmium, nickel, and lead), PCBs, and dioxins present potential concern for consumption of seafood because they tend to bioaccumulate in fish and other aquatic animals, can have long-term health effects, and cannot be removed by preparation methods such as cleaning and cooking. The levels of these contaminants in seafood depend on their concentrations in the aquatic environment and on the lifespan, diet, and level of fatty tissue of the fish themselves; mercury contamination is highest in fish that are highest in the food chain, and dioxins are fat soluble and therefore increase with fatty tissue content.

Many metals are naturally occurring, but chronic overexposure can lead to adverse health effects. For example, toxic levels of cadmium and nickel can cause dizziness, headache, vomiting, vertigo, and intestinal irritation. Excessive amounts of lead can cause anemia, renal tubular nephrosis, diminished intellectual capacity and developmental delays in children, headache, drowsiness, and gastrointestinal upset. Exposure to mercury can cause pulmonary, brain, kidney, liver, and gastrointestinal damage. Methylmercury at high concentrations can induce sensory abnormalities, paresthesias, and ataxia in adults, and can delay cognitive and neuromuscular development in children. PCBs and dioxins have been found to impair the immune system and neurological functions. Depending on the substance, bioaccumulation can occur in fish tissue (especially in larger or older fish), as well as in the tissue of humans who consume them. Even so, the health benefits from fish consumption often outweigh the risk of adverse health effects.

What Is the Exposure to Contaminants in Seafood in the UAE?

Because seafood holds an important place in the diet of many residents in the UAE, consumption levels are relatively high compared with the world average. According to one source, the apparent per capita fish consumption in the UAE was 24 kg per year in 2005, including both citizens and noncitizens. Other sources indicate higher consumption levels for UAE citizens, namely that the average UAE citizen consumes 33 kg of fish per year; and up to 90% of UAE citizens consume fish at least once a week. UAE citizens typically eat rabbit fish, grouper, mullet, sea bream, and shrimp.

Studies of contamination in seafood off the UAE coast indicate that the UAE has relatively low metal contamination in its domestically produced fish. Regional studies also indicate a comparatively low level of an even wider range of contaminants. However, studies are limited and dated, and changes in domestic industries and patterns in urbanization affect pollution that reaches fish. No data are publicly available for contaminant levels in shrimp, commonly consumed in the UAE. However, shrimp is generally relatively low in mercury and is not an "oily" fish so it also will have relatively low levels of dioxins. Approximately 50% of seafood in the UAE is imported, mainly from India, Thailand, Oman, Pakistan, Tanzania, China (both mainland and Taiwan), Uganda, Malaysia, Iran, and Yemen. There is no publicly available information on the levels of contaminants in imported fish, nor on any systematic governmental monitoring of either domestic or imported seafood contamination.

There is no publicly available information on specific industrial sources of mercury and/or dioxins in the UAE, or monitoring data from industrial waste and emissions in the UAE. The Environment Agency–Abu Dhabi has recently reported that mercury levels were nondetectable in Abu Dhabi coastal waters and that PCB levels were lower than 0.4 ppm at all sites except one (at 1 ppm). However, it is difficult to predict the levels of contaminant in fish tissue based on concentrations in the water, making direct studies of fish tissues necessary to assess exposure. Therefore, in the absence of additional current and specific seafood contamination data, it is advisable for pregnant women to limit intake of older/predatory fish, and for pregnant women and the general population to limit consumption of oily fish to two and four servings per week, respectively.

What Has the UAE Already Done About the Risk of Contamination in Seafood?

A number of actions and activities have been initiated in the UAE and the region to protect water from pollution, especially oil spillage. In particular, the UAE has:

- Established the Federal Environmental Agency in 1993 to set federal plans and policies that prevent pollution, specifically addressing the marine environment
- Established relevant laws to regulate dumping in and around the marine environment
- Participated in regional organizations and ratified a number of conventions with the goal of protecting the marine environment (e.g., the Regional Organization for the Protection of the Marine Environment; the London Convention)
- Formed public and private organizations to protect the environment from pollution
- Conducted experimental studies to find out the effects of oil on certain fish
- Given instructions to fishermen on careful handling of fuel and avoiding spills

Currently, most of the UAE regulations regarding oil spills are responsive, not preventive, and no specific regulations are targeted at seafood safety protection.

An overview of environmental regulations and food control infrastructure indicates a need to:

- Strengthen relevant regulations on water pollution and seafood safety control
- Establish a comprehensive framework for integrated planning and management of the coastal zone at the federal level
- Establish a system to classify and assess the potential risks associated with seafood consumption and encourage the development of national monitoring or surveillance schemes for contaminants that cover seafood
- Enhance the emergency response to accidents such as oil spills or power plant and/or industrial discharges

Notes on Eating Contaminated Seafood Risk Calculations

Number of Deaths per Year. This is the average number of deaths expected per year among the population of the UAE as the result of lifetime exposure to contamination in seafood. Assuming proper handling and preparation of seafood, this number is zero from pathogens. In fact, consumption of seafood is known to decrease a number of health risks, including coronary heart disease, which may actually enhance quality and length of life. The risk of death reported herein is related to the carcinogenicity of dioxin exposure. The details of this calculation are described below in the "Illness or Injury" section. In brief, the numbers reported here are the cancer cases resulting from this exposure that are expected to end in death in a given year (the remaining annual cancer cases are tabulated as "more serious long-term cases per year").

Chance in a Million of Death per Year for the Average Resident. This is the average annual risk of death for a randomly chosen resident of the UAE as a result of exposure to a given hazard for one year. Again, this number is related to dioxin exposure, and average consumption levels are assumed for this calculation.

Chance in a Million of Death per Year for the Resident at Highest Risk. Higher-risk residents would be those with higher levels of consumption of oily fish or higher-risk groups such as children. Lacking specific knowledge of the distribution of fish consumption across the population and lacking a scientific basis for cancer risk assessment across different demographic groups, we have simply estimated these numbers to be equal to or greater than for the average resident.

Greatest Number of Deaths in a Single Episode. This is the greatest number of deaths resulting from a single cancer case, or one.

Illness or Injury. Exposure to dioxins causes a risk of cancer, which was used as the estimate for more serious long-term cases of illness. Because the use of PCBs has largely been banned and contaminant levels have been decreasing over the past few decades, we focused on the risks associated with dioxin exposure.

The best estimate assumes moderate levels of oily fish consumption, and the high estimate assumes higher levels of oily fish consumption. However, because these values are uncertain due to the absence of specific information on dioxin/PCB contamination of seafood in the UAE, data are based largely on U.S. and U.K. information, as detailed in the following paragraphs.

The implied average contamination level of fatty fish (<6 ng dioxins/kg fish), as well as the proportion of total fish consumption which is fatty fish (<25%) assumed herein was based on U.K. information for the best estimate values for the best estimate values (Scientific Advisory Committee on Nutrition 2004). An assumption of 50% of total seafood consumption being fatty fish yielded the high estimate values. A body weight of 65 kg (143.3 lbs) was assumed in both cases. Exposure was then determined as follows:

$$Exposure = \left(Oily\ fish\ (g)/day\right) \times \left(Contaminant\ in\ fish\left(\mu g/g\right)\right) \\ \div \left(Body\ weight\left(kg\right)\right)$$

This exposure was then multiplied by the carcinogenicity, which for dioxins was established by the U.S. Environmental Protection Agency (EPA) as 1.56×10^5 per mg/kg-day (1999), and divided by a typical lifespan of 70 years to yield the percentage of the population in a given year expected to be diagnosed with cancer. The values used are summarized in the table below.

Dioxin in seafood exposure for the UAE: "More Serious Long-Term Cases per Year" and "Fatalities" calculations

Estimate	Assumptions	Exposure, µg/kg-day	Percentage of population with cancer annually
Best	Oily fish consumption: 15 g/day (i.e., 23% of total consumption) Contamination: 5.8 ng/kg	1.5×10^{-6}	3.3×10^{-4}
High	Oily fish consumption: 21 g/day (i.e., 50% of total consumption) Contamination: 5.8 ng/kg	3.2×10^{-6}	7.1×10^{-4}

These percentages of the total population were used to determine the number of annual cancer cases: 11 and 25 people per year for the lower and higher levels of oily fish consumption, respectively. Based on U.S. statistics (American Cancer Society 2008), it was assumed that ~40% of the annual number of cases would result in death in a given year; this allowed calculation of the expected number of deaths per year (best estimate = 4, high estimate = 10), as well as the chance in a million of death for the average resident. The remaining cancer cases that did not result in death in a given year were tabulated as the "more serious, long-term illnesses" (i.e., 60% of the 11 and 25 annual cancer cases, or 7 and 15 cases for the best and high estimates, respectively).

Exposure to mercury through consumption of contaminated fish presents a nonfatal risk to the offspring of mothers who consume this contaminated fish during pregnancy. This risk is a more serious long-term detriment to cognitive development. The high estimate is that all newborns of both citizens and noncitizens in the UAE (i.e., all residents of the UAE) are at risk for cognitive impacts related to methylmercury exposure.

The best estimate is that only Emirati newborns are at risk due to the relatively higher levels of fish consumption by citizens relative to noncitizens. The impact on cognitive ability is immediate and lifelong. Details of the calculation follow.

The reported mercury contaminant levels were used to determine whether the reference dose is being exceeded, that is, whether or not consumption of fish is risky for the average UAE citizen. The exposure calculation performed was as follows:

$$Exposure = \left(Fish(g)/day\right) \times \left(Contaminant\ in\ fish\left(\mu g/g\right)\right) \div \left(Body\ weight\left(kg\right)\right)$$

The estimates reported in the table below are based on the assumption that all of the average 24 or 33 kg of annual fish consumed has the minimum and maximum level of contamination, respectively, indicated in the above table. They also assume a bodyweight of 65 kg. The ranges presented below represent (1) the lowest observed level of contamination and the lower estimated consumption level and (2) the highest observed level of contamination and the higher estimated consumption level. The exposure level was then compared with the reference dose, and the results of the comparison are shown in the third column.

The reference dose established for pregnant women is 0.1 μg/day (U.S. National Research Council 2000; U.S. EPA 2004). Note that while average levels of contamination are low compared to U.S. numbers, the fact that fish consumption levels are ~3.5–5 times higher than they are in the United States puts all citizen and resident births (under the "best estimate" and "high estimate" cases, respectively) at risk for at least some cognitive impact.

Determination of "less serious long-term cases per year" was based on the scenarios in the table below. The "low estimate," "best estimate," and "high estimate" were determined for both average UAE residents and citizens separately, with assumptions detailed below.

Mercury in seafood exposure for the UAE: "Less-Serious Long-Term Cases per Year" calculation

Exposure scenario	Assumptions	Exposure, μg/kg/day	Exceeds reference dose?
Low, resident	Fish consumption: 66 g/day Contamination: 0.036 μg/g	0.036	No
Low, citizen	Fish consumption: 90 g/day Contamination: 0.036 μg/g	0.050	No
Median, resident	Fish consumption: 66 g/day Contamination: 0.072 μg/g	0.072	No
Median, citizen	Fish consumption: 90 g/day Contamination: 0.072 μg/g	0.099	Approximately equal
High, resident	Fish consumption: 66 g/day Contamination: 0.11 μg/g	0.11	Yes
High, citizen	Fish consumption: 90 g/day Contamination: 0.11 μg/g	0.15	Yes

Assuming that 1 μg/kg/day of exposure to mercury results in 10 μg of mercury per gram of maternal hair, and that the IQ loss associated with mercury exposure is −0.2 points per μg mercury per gram maternal hair, the risk for each of these exposure levels can be quantified (Cohen et al. 2005). For example, "low exposure" in children born of Emirati women would be expected to result in a loss of approximately 0.1 IQ points, whereas "high exposure" would result in a loss of approximately 0.3 points. Note that Cohen states that the range of IQ point impacts is 0–1.5 IQ points per μg mercury per gram of maternal hair and that this range is large relative to the uncertainty in other numbers in our analysis. So, the magnitude of the cognitive impacts of these exposure levels is quite uncertain.

Based on the UAE census of 2005, the average annual number of births for UAE residents (i.e., both citizens and noncitizens) is approximately 67,100 births per year, and the average annual number of births for citizens is approximately 26,800 births per year (UAE Ministry of Economy 2008a).

Time between Exposure and Health Effect. The fatal and more serious long-term effects from dioxin, namely cancer, may take many years to appear. As noted, cognitive impacts from mercury are immediate and persistent.

Quality of Scientific Understanding. There are several sources of uncertainty in estimating risks for the UAE population. One involves how well scientists know the relationship between exposure to a hazard and its resulting health impacts. The other involves how well we can predict exposure of UAE residents to a particular hazard. This statistic characterizes the former. For instance, scientists still do not know the exact impacts on cognition from prenatal exposure to methylmercury (e.g., the range of possible loss of IQ related to exposure is very large), but scientists understand very well the physical and biological processes leading to injury from auto accidents. In the case of dioxin exposure, the current available evidence suggests that dioxins may cause cancer in humans. Three categories are used to rate scientific understanding: high, moderate, and low.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects both uncertain scientific understanding about the risk and uncertainty about the extent of exposure or susceptibility of UAE residents to the particular hazard. Sources of uncertainty for mercury exposure in the UAE in particular include: (1) the distribution of consumption levels across the population, (2) the distribution of fish types, (3) the contamination levels in all types of fish consumed, and (4) the contamination of imported fish. For dioxin exposure in the UAE, the uncertainty is greater due to a lack of publicly available information on the dioxin contamination levels, in addition to these other factors. The table entry gives the amount of uncertainty in deaths, illness, and injury, expressed qualitatively with respect to other risks in UAE.

Ability of Resident to Control Exposure. Some hazards that UAE residents encounter can be avoided partly or entirely by measures they can take on their own. For instance, decreasing the total amount of fish consumption, or more advisably, limiting certain types of fish in the diet (especially for high-risk groups such as women of childbearing years) are well within an individual's control. Three categories are used to rate this controllability: high, moderate, and low.

Eating Contaminated Fruits and Vegetables

Summary

Eating fruits and vegetables has documented health benefits, but it also exposes people to risk if the fruits and vegetables contain hazardous contaminants. The two primary potential contaminants are human pathogens, which can be eliminated or greatly reduced with proper handling and preparation, and pesticides. Assuming fruits and vegetables are not exposed to pathogens in production, there is no risk from this contaminant. The washing and/or peeling of uncooked produce reduces this risk, as does cooking. Assuming the UAE is following standard practices for pesticide use similar to those, for example, in the United States and the United Kingdom, there is minimal acute risk and virtually no chronic risk from pesticide exposure via consumption of fruits and vegetables in the UAE.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	0	0	Low but nonzero
Chance in a million of death per year for the average resident	0	0	Low but nonzero
Chance in a million of death per year for the resident at highest risk	0	0	Low but nonzero
Greatest number of deaths in a single event		1	
Illness or injury			
More serious long-term cases per year	0	0	0
Less serious long-term cases per year	0	0	Low but nonzero
More serious short-term cases per year	0	0	0
Less serious short-term cases per year	0	0	<35,000–89,000
Other factors			
Time between exposure and health effects	10–30 years or immediate		
Quality of scientific understanding	Moderate		
Combined uncertainty in death, illness, and injury	Low		
Ability of resident to control exposure to hazard	High		

What Is Known About the Risk of Contaminants in Fruits and Vegetables?

Cooking fruits and vegetables eliminates virtually any risk of exposure to pathogens, but when fruits and vegetables are eaten raw, the risk of exposure to pathogens depends on handling in production and in preparation. The most common pathogens of concern are *Salmonella* and *E. coli*; these are generally only a problem if they are introduced during production (e.g.), in use of nondisinfected reclaimed water. Pathogens of particular concern for pregnant women due to possible harm to the unborn child, such as *Toxoplasma gondii* (which can cause miscarriage or eye and brain damage to child), *Listeria monocytogenes* (which can cause stillbirth, miscarriage, or physical retardation in child), and aflatoxins (which can cause growth faltering in child after birth), can also be virtually eliminated with thorough washing, peeling, and/or cooking.

The main toxic substances of concern in fresh produce are pesticides that typically come from the organophosphate and carbamate chemical groups. The primary health concerns from exposure to these pesticides are effects on actions of the central nervous system that control heart rate, breathing rate, and intestinal functioning. Organophosphates produce chronic effects (i.e., it takes 4–6 months to return to normal functioning after exposure), and carbamates cause acute effects (i.e., it takes 48–72 h to return to normal). Health effect symptoms, even at low levels, associated with these chemicals are headaches, dizziness, weakness, sweating, stomach cramps and vomiting. Studies on the carcinogenicity related to these pesticides are limited, and in most cases these pesticides are not considered carcinogens. Exposure to pesticides can often be reduced by washing and peeling food prior to consumption, but contaminants may remain even after such preparation.

What Is the Exposure to Contaminants in Fruits and Vegetables in the UAE?

Exposure to contaminants depends on both the amount of fruits and vegetables consumed and the level of contamination in the fruits and vegetables consumed.

The average UAE citizen consumes 124 kg of fruits and 113 kg vegetables per year (~340 and 310 g per day, respectively) (Dehghan et al. 2005). This is comparable to consumption levels in the United States and Europe and exceeds the minimal recommendation of more than 400 g/day of fruit and vegetables by the (World Health Organization 2008). The percentage of UAE citizens who report consuming cooked vegetables and fresh fruit 6 or 7 days a week is 50 and 45%, respectively; only 8 and 10% report rarely or never consuming vegetables and fruit, respectively (Dehghan et al. 2005).

The main fruit in the traditional UAE diet is dates, which continue to be a relatively important part of the diet. However, the modern diet of UAE citizens also includes a broader range of fruits and vegetables.

Fruit and vegetable production in the UAE includes dates, green fodder, vegetables, and fruit (mainly citrus and mangoes). The country produces 100% of the dates it consumes and 50–60% of fruits and vegetables. Tomatoes are also a major crop, and all salad crops are produced domestically for much of the year. Import bans and government incentives and subsidies encourage domestic production.

There is some publicly available data regarding pesticide residues on fruits and vegetables in the UAE (for Abu Dhabi) and in the region. Of 185 samples collected for one study in Abu Dhabi between 1998 and 2001, eight samples exceeded the recommended maximum residue limits (MRLs) of target pesticides; another study analyzed 26 samples for numerous pesticides and found that three samples (of the same vegetable, corn) exceeded MRLs for one of the pesticides, pirimicarb.

The types of pesticides used, and the quantitative residue levels of those pesticides that remain on fruit and vegetables, do not appear to be publicly available for other emirates. Also, while information on banned pesticides is publicly available, there is no publicly available list of all pesticides in use.

Numerous pesticides have been banned from entry into the UAE. But because imports account for a significant fraction of fruit and vegetables in the UAE, exposure to some of these pesticides may nevertheless occur. However, based on one recent study, assuming even a very homogenous diet (for example, a diet that consisted entirely of potatoes exclusively imported from the United States), less than 1% of the population would be exposed to levels of a given pesticide that would exceed the acute reference dose (in this example, the acute reference dose for aldicarb). Given that diets in general are much more diverse and given that only 50–60% of vegetables are imported, no citizens are likely to be exposed to risky levels of a given pesticide, either acute or chronic. However, note that the effects of combinations of pesticides are generally unknown, so these are not considered here even though they may well impact health.

There is no publicly available information regarding ongoing, systematic governmental monitoring of pesticide residues on either domestically produced or imported fruits and vegetables.

What Has the UAE Already Done About the Risk of Contaminants in Fruits and Vegetables?

The Federal Environmental Agency was established in 1993 to set federal policies, specifically addressing human health and agricultural crops. The UAE government has passed a number of regulations on the use of pesticides in the UAE. For example, at least 93 pesticides have been banned as a result. Additionally, the manufacture and formulation of pesticides is prohibited in the UAE, and only pesticides registered by the Ministry of Environment and Water (formerly the Ministry of Agriculture and Fisheries) can be imported and used. There is no publicly available information on established "best practices" for minimization of pesticide residues on fruits and vegetables.

Local municipalities also conduct monitoring activities. For example, in 2002 the Pesticide Residue Analysis Section at the Food and Environment Control Centre of Abu Dhabi Municipality found that 68% of tested samples of locally grown vegetables had no unacceptable levels of pesticide residues, but 25% were found to have quantities above the MRL. Results were better for samples of locally produced fruits: 45% were found to have no unacceptable levels of pesticide residues and none were above the legal acceptable level (UAE Interact 2007).

Individual emirates have food control agencies to establish rules and regulations for handling and standards for contaminant levels. In addition to those agencies, there are a number of additional steps that can be taken in the UAE to reduce pathogen contamination of fruits and vegetables. In particular, standards should be established for farming practices, including the use of reclaimed water. Washing and proper hygiene is important in order to minimize the risk of pathogens from fruits and vegetables in the home; this includes separation of food items to avoid cross-contamination, thorough cooking, and proper refrigeration. These efforts are particularly important for pregnant women. In terms of processed fresh fruits and vegetables, standards for handling and production facilities are appropriate, and worker training is essential.

Notes on Eating Contaminated Fruits and Vegetables Risk Calculations

Number of Deaths per Year. This is the average number of deaths expected per year among the population of the UAE as the result of lifetime exposure to contamination in fruits and vegetables. Assuming proper handling and preparation, this number is zero due to pathogen exposure. In fact, consumption of fruits and vegetables is known to decrease a number of health risks and may actually enhance quality and length of life. The high estimate of "low but nonzero" is based on possibly carcinogenic effects of exposure to pesticide residue; the number cannot be exactly calculated due to lack of information on carcinogenicity and limited sample size.

Chance in a Million of Death per Year for the Average Resident. This is the average annual risk of death for a randomly chosen resident of the UAE as a result of exposure to a given hazard for 1 year. Again, this number is zero for pathogens. The high estimate of "nonzero" is based on the possibly carcinogenic effects of exposure to pesticide residue; the number cannot be calculated due to lack of information on carcinogenicity and limited sample size.

Chance in a Million of Death per Year for the Resident at Highest Risk. The number is estimated as zero for pathogens. The high estimate of "nonzero" is based on the possibly carcinogenic effects of exposure to pesticide residue; the number cannot be calculated due to lack of information on carcinogenicity and limited sample size.

Greatest Number of Deaths in a Single Episode. The number is estimated as zero.

Illness or Injury. Exposure to pesticides through consumption of contaminated fruits and vegetables generally presents a nonfatal risk of inhibition of the action of acetylcholinesterase in nerve cells. This risk is a less serious, short-term detriment to neurotransmission, manifesting itself as sweating, pinpoint pupils, leg weakness, and other effects. While pesticides can also have long-term effects and have been linked to cancer and other life-threatening problem, there is no evidence that eating fruits and vegetables alone exposes an individual to sufficient quantities of pesticides to experience a risk of these impacts. As such, the "less serious short-term cases" table entry refers to cases of nonfatal illness or injury per year expected among residents of the UAE related to acute pesticide exposure. The high estimate assumes that 92% of residents (i.e., all except the 8% who say they "rarely" consume vegetables) are consuming large amounts of a single crop (namely, that all of their vegetable intake is of a single type on which a single type of pesticide is used, and this being one of the two most contaminated vegetables that we surveyed: either a parathion-methyl-contaminated vegetable from the UAE or an aldicarb-contaminated potato from the United States) and are therefore exposed to acute risk with the same probability of a given sample of that crop exceeding acceptable limits for acute exposure (one sample in 100). So the numbers in the range presented here are 2.6 and 1%, for the two contaminants respectively, of the 92% of the total population. Further, we assume no reduction in pesticide residue due to washing, peeling, and/or cooking. As this is clearly the absolute worst-case scenario and not highly plausible, the best estimate is that no UAE citizens will be at risk for acute exposure due to both diversity of diet and proper handling of produce. Even in the worst case, acute impacts from pesticides at these relatively low levels are reversible.

One set of samples (parathion-methyl-contaminated vegetables from the UAE) may indicate that chronic reference doses are being exceeded based on the median value of all the samples. However, since only a range of all sample residues is given in the reference to which we had access, without the average or even the total number of samples included, we are unable to state this with confidence. As such, we have stated only that the high estimate for the less serious long-term cases is "nonzero." Access to the details of the results of the study would presumably allow this number to be estimated to a specific nonzero (or even zero) value.

Time between Exposure and Health Effect. Long-term illnesses such as cancer would, in theory, manifest on a multiyear timeframe (i.e., 10–30 years). Short-term nervous system impacts from pesticide exposure would be immediate.

Quality of Scientific Understanding. There are several sources of uncertainty in estimating risks for the UAE population. One involves how well scientists know the relationship between exposure to a hazard and its resulting health impacts. The other involves how well we can predict exposure of UAE residents to a particular hazard. This statistic characterizes the former. In this case, the causality between pesticide intake and acetylcholinesterase inhibition is well-established, but the exact correlation between dose and response is less so. Three categories are used to rate scientific understanding: high, moderate, and low.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects both uncertain scientific understanding about the risk and uncertainty about the extent of exposure or susceptibility of UAE residents to the particular hazard. Sources of uncertainty specific to data in the UAE include: (1) lack of knowledge of the distribution of consumption levels across the population, (2) lack of knowledge of the distribution of produce types consumed, (3) unknown levels contamination in all types of produce consumed and across all regions of the UAE, and (4) unknown levels of contamination and proportion of imported produce. The table entry gives the amount of uncertainty in deaths, illness, and injury, expressed qualitatively with respect to other risks in UAE.

Ability of Resident to Control Exposure. Some hazards that UAE residents encounter can be avoided partly or entirely by measures they can take on their own. For instance, they can wash and peel fruits and vegetables that might have pesticide residues. However, the risk cannot be completely eliminated due to the potential of the pesticide to contaminate other parts of the fruit or vegetable, and there is nutritional value in eating vegetable peels. Three categories are used to rate this controllability: high, moderate, and low.

Electromagnetic Fields

Summary

Electromagnetic fields (EMF) are produced by an electric charge or current, such as those found in power cords to household appliances or as a result of high-voltage power lines. The strength of both electric and magnetic fields drops off steeply with distance from their source.

The science linking exposure to EMF to health effects remains unconvincing. The only biological impact for which there is any correlation is childhood leukemia, but no cause and effect relationship has actually been shown. Therefore, these findings remain controversial, earning extremely low frequency (ELF) magnetic fields the International Agency for Research on Cancer's "possibly carcinogenic in humans" classification.

Currently there is scant information available on the typical EMF levels for different locations in and around the United Arab Emirates, workplaces, schools or residences. According to the Dubai Electricity and Water Authority, the utility does not allow buildings constructed within 50 m of high-voltage power lines, which are thought to be particularly strong producers of magnetic fields.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	0	0.16	3.9
Chance in a million of death per year for the average resident	0	0.06	1.4
Chance in a million of death per year for the resident at highest risk	0	0.21	5.0
Greatest number of deaths in a single event		1	
Illness or injury			
More serious long-term cases per year	0.5	2	14
Less serious long-term cases per year	0	0	0
More serious short-term cases per year	0	0	0
Less serious short-term cases per year	0	0	0
Other factors			
Time between exposure and health effects	10–30 years		
Quality of scientific understanding	Low		
Combined uncertainty in death, illness, and injury	Low		
Ability of resident to control exposure to hazard	Moderate		

What Is Known About the Risk of Exposure to Electromagnetic Fields?

Electromagnetic fields occur both naturally and from anthropogenic sources. Electric fields occur whenever an electric charge is present, even if a device is not on. Magnetic fields, on the other hand, are only created when an electric current is flowing, such as when an appliance is switched on. A higher current drawn through the device will produce a stronger magnetic field. Electric fields may be easily shielded by objects such as buildings, whereas magnetic fields are not as easily blocked.

The frequency or its corresponding wavelength is the characteristic that defines how much energy the electromagnetic field will contain. Fields that do not have enough energy to break molecular bonds are called "nonionizing" radiation. The fields produced by modern technology, including radio and television antennas, microwave ovens, and electricity all fall into this spectrum. Since the radiation from these fields declines rapidly with distance from the source, typical human exposures to EMF are generally in the ELF range, as classified by the World Health Organization.

Although controlled experiments have shown that exposure to very strong, high frequency levels of EMF can cause biological effects such as nerve and muscle stimulation, those levels have not typically been found in the community at large. Thus, most attention from the public health sector has focused on ELF-EMF, the form of EMF to which humans are most typically exposed. For ELF-EMF, the connection between exposure and biological effect is more tenuous. The World Health Organization (WHO) recently reviewed all of the scientific research on ELF-EMF and found there to be little statistically significant correlation with disease (World Health Organization WHO 2007b).

Many health effects have been studied, including childhood and adult cancers; mental health outcomes such as headaches, anxiety, suicidal intentions, and depression; reproductive problems, including spontaneous abortions, low birth weight, and congenital malformations; and other immunologic and neurological outcomes. Individuals reporting "electromagnetic hypersensitivity" and depression have inconsistent reactions under controlled exposure environments, and there is no accepted biologic mechanism that supports a hypersensitivity reaction. None of the outcomes mentioned above support an association between ELF-EMF exposure and disease.

Childhood leukemia is one health outcome for which the evidence of a causative link from EMF remains highly controversial. Human studies have consistently shown a pattern of a twofold increase in childhood leukemia associated with average residential EMF exposure. On a worldwide basis, this translates into 100–2,400 additional cases per year that could be attributable to ELF-EMF exposure. A 2,000 study by the Electric Power Research Institute shows a potential connection between contact current and childhood leukemia (Brain et al. 2003). This is related to the way homes in the United States are grounded (usually to pipes) and only affects children while they are bathing. Although it is not a constantly present danger, it is—in contrast with ambient EMF—a significant physical threat to children.

International research on health effects from EMF exposure is now focused more prominently on the potential effects from mobile phone use. Although research in this area is at an early stage, thus far the overall evidence does not point to any excess risk from that source, and sophisticated computer models of the head show that the energy absorbed from a mobile phone is not in excess of current guidelines.

What Is the Electromagnetic Field Exposure in the UAE?

Many sources in the everyday environment contain ELF-EMF. In the outside environment, common sources include high-voltage power lines and various utility substations and antenna base stations. In the indoor environment, sources include any household appliance, including computers, mobile phones, electric blankets, air conditioners, microwave ovens, electric shavers, etc. It is also unclear how UAE residences are grounded or how children bathe, so it is not certain whether contact current is a significant concern.

Currently there are no known surveys or studies that have been conducted in the UAE to document typical residential, school, workplace, or other exposures. The Dubai Water and Electricity Authority and other utilities in the UAE have taken some measurements just within proximity to their equipment, and the highest level measured immediately outside of the 50-m radius of the high-voltage power lines was below levels associated with reported health effects.

There are, however, new high-voltage power lines being planned to connect all the emirates into a single power grid. This could mean a growing population that could potentially be affected by EMF radiation in the future.

What Has the UAE Already Done About the Risk from Electromagnetic Fields?

Although short-term ELF-EMF exposure guidelines exist in the United States and other nations to protect workers and the public from acute exposure, no long-term exposure guidelines have been set internationally because of the weak evidence on the links of ELF-EMF to health effects. Different countries have radically different codification of EMF protection. For instance, Turkey regulates frequencies between 10 kHz and 60 GHz, while Italy regulates 50 Hz to 300 GHz. However, according to the WHO, Turkey and Israel are the only two Middle Eastern countries that have EMF regulations. In 2002, the UAE passed a federal law that regulates ionizing radiation, but currently there are no laws regulating nonionizing radiation levels such as EMF.

As of 2008, the UAE had taken limited action to assess EMF exposure for its population. This risk assessment found no evidence that the government either had developed risk communication materials or had undertaken efforts to prepare baseline measurements of EMF to begin to understand the typical levels to which the population is exposed.

Notes on Electromagnetic Fields Risk Calculations

Number of Deaths per Year. This is the average number of deaths expected per year among the population of the UAE as the result of lifetime exposure to extremely low frequency electromagnetic field radiation (ELF-EMF). The high and low estimates of risk show the range in absolute terms. The high and best estimates come from WHO estimates that ELF-EMF could be responsible for 0.2 (best) to 4.9% (high) of leukemia deaths worldwide. The number of annual deaths from leukemia in the UAE is approximately 81 (WHO 2007a). The low estimate is 0 because it has not been proven definitely that EMFs influence mortality at all.

Chance in a Million of Deaths per Year for the Average Resident. This is the average annual risk of death for a randomly chosen UAE resident as a result of exposure to a given hazard for 1 year. The risk to the average resident is the number of deaths in the UAE due to EMFs divided by the entire population of the UAE, according to WHO's GBD figures.

Chance in a Million of Death per Year for the Resident at Highest Risk. For some hazards, certain residents are known to be more exposed or more susceptible than others. For EMF, children are thought to be most at risk, so the calculation here is the number of deaths attributed to EMF divided by the population of children under the age of 15 from UAE population data, approximately 26% of the total population.

Greatest Number of Deaths in a Single Episode. There are not really any large-scale acute incidents of EMF exposure, especially since the proposed mechanism for health effects is low-level exposure over extended periods. Thus, we estimate that the most likely number to die in an "episode" is zero, but since the mechanism for mortality is not well understood, the greatest number of people could alternately be a single person.

Illness or Injury. The main illness risk from EMF is leukemia. We applied the risk of contracting nonfatal leukemia to the estimated 2005 population of the UAE.

Time between Exposure and Health Effects. Science is unsure of the mechanism for health effects and thus also unclear about the time between exposure and effect. However, the estimates are mainly around a decade for children and possibly longer for adults.

Quality of Scientific Understanding. There are two sources of uncertainty in estimating risks for the UAE population. One involves how well scientists know the relationship between exposure to a hazard and its resulting health impacts. The other involves how well we can predict exposure of UAE residents to a particular hazard. This statistic characterizes the former. For instance, scientists still do not know whether exposure to EMF from power systems causes cancer, but scientists understand very well the physical and biological processes leading to injury from auto accidents. Three categories are used to rate scientific understanding: high, moderate, and low.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects uncertain scientific understanding about the risk the extent of exposure or susceptibility of UAE residents to the particular hazard. The table entry gives the amount of uncertainty in deaths, illness, and injury, expressed both qualitatively with respect to other risks in the UAE.

Ability of Resident to Control Exposure. Some hazards that UAE residents encounter can be avoided partly or entirely by measures they can take on their own. For instance, in the case of ELF-EMF exposure, residents can avoid living near power lines, or they can take household measurements and spend less time in rooms with high EMF or arrange the power switches in their rooms to minimize EMF. Three categories are used to rate this controllability: high, moderate, and low.

Ambient Noise

Summary

Noise is unwanted sound that results from many activities. In urban settings, common sources of noise include airplanes, trains, trucks and automobiles, construction and demolition activity, and industrial facilities. The most obvious effect from high noise levels is hearing impairment and its associated interference with general communication. Other impacts from continued noise exposure include cardiovascular effects and sleep disturbances. In a 2006 ambient noise survey (Muskett and Bohler 2006), the noise level at monitoring sites in Abu Dhabi appears to be in excess of national and international standards, raising the concern that residents may be exposed to ambient noise pollution. But no systematic studies have been done to assess the noise levels in other emirates.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	0	Nonzero but low	Not reported
Chance in a million of death per year for the average resident	0	Nonzero but low	Not reported
Chance in a million of death per year for the resident at highest risk	0	Nonzero but low	Not reported
Greatest number of deaths in a single event		1	
Illness or injury			
More serious long-term cases per year		Not reported	
Less serious long-term cases per year		Not reported	
More serious short-term cases per year		Not reported	
Less serious short-term cases per year		Not reported	
Other factors			
Time between exposure and health effects	Weeks to months		
Quality of scientific understanding	Low		
Combined uncertainty in death, illness, and injury	High		
Ability of resident to control exposure to hazard	Moderate		

What Is Known About the Health Risks of Noise Pollution?

The effects of noise on health are complex and remain poorly understood. It is believed that the effects of noise exposure depend on both the level of sound as well as the length of time to which an individual is exposed. The most obvious impact of noise exposure relates to hearing loss, however there are a wide array of other identified health effects that raise concerns. The best way to describe the health effects of noise exposure is to separate what is currently described in the occupational setting as opposed to the community or "environmental" setting.

Occupational noise exposure measured over an 8-h period shows that at 75 dBA (*A* represents a weighting filter that has been widely adopted for environmental noise measurement) and lower, even prolonged exposures over many months or years will not result in noise-induced hearing impairment. However, environmental noise standards are much lower than occupational requirements because they also factor in the issue of annoyance and other quality-of-life issues. The U.S. Environmental Protection Agency (EPA) and the World Health Organization (WHO) have recommended standards between 30 and 70 dBA depending on the area of concern (e.g., industrial, commercial, or residential).

It has been much more difficult to measure and link the health effects of noise in the environmental than in the occupational setting. Measurable occupational impacts associated with noise, such as hearing loss and hypertension (though less definitively) are not documented at levels of noise typically measured over an average day in a community environment. Many effects in an environmental setting are more closely linked with annoyance and quality-of-life issues, rather than with primary health effects such as hearing damage. The major issues relate to interference with speech and the impact on sleep, which may have numerous secondary effects, including stress, loss of productivity, increased fatigue, mood changes, decreased cognitive performance, and an increase in accidents.

The literature has shown mixed results of a causal relationship between noise and serious health problems such as heart disease and hypertension. Some literature suggests that chronic noise exposure, even at low levels, has the potential to cause chronic stress hormone increases in humans that accelerate the aging of the myocardium and vascular walls. There is scant information available regarding which type of noise might have an effect (e.g., noise that is continuous versus noise that pulses on and off) and the length of exposure required to produce such effect. In addition, in many cases, individuals adopt coping strategies that may reduce the impact of noise over time and thereby reduce the potential associated health effects. Certain subgroups—in particular, fetuses and children, the elderly and those that already have pre-existing conditions such as high blood pressure—may be more vulnerable to noise in community settings.

What Ambient Noise Exposure Levels Are Documented in the UAE?

In 2006, the UAE conducted an ambient noise survey of various sources around Abu Dhabi, which helped provide baseline data for levels in the city. The noise level in Abu Dhabi appears to be in excess of national and international standards, and residents may be at risk from one or more of the health effects described above. Much of the available information about environmental noise exposure levels in the UAE is based upon the Abu Dhabi noise strategy document (Muskett and Bohler 2006). According to this report, road traffic is the major source of noise in urban Abu Dhabi, while industrial noise is more localized, affecting areas with heavy industry (e.g., power stations and oil refineries). Aircraft noise appears to be confined to the regional area of the airport, and construction zones vary by what is being built and how long it takes to construct.

A review of the 2006 Abu Dhabi noise survey shows that large areas of Abu Dhabi city experience noise levels primarily due to road traffic in excess of 65 dBA, the noise level above which research shows a significant percentage of the population will be disturbed. The measurements in this survey were only done for 15-min intervals, and it is not certain what the time weighted averages would be. Noise levels measured away from traffic were generally documented at much lower levels. Given these baseline results, it is likely that in many parts of Abu Dhabi city and other regions within the emirate, residents are being exposed to noise substantially in excess of established national and international standards and are therefore experiencing many of the primary and secondary health effects described for environmental noise exposure. However, insufficient data are available to document the health effects, or to document noise levels in other emirates.

What Has the UAE Already Done to Reduce the Risk of Noise Exposure?

There are minimally developed noise regulations in Abu Dhabi and elsewhere in the UAE. Inspection and enforcement procedures are also limited. However, the Environment Agency–Abu Dhabi has drafted recommended standards, drawn from international guidelines. These guidelines will be used to evaluate and guide new development proposals and direct future noise management issues in the UAE.

The table below presents a brief comparison of noise-level guidelines across three types of areas in different countries. (The UAE values are recommended in a draft regulation.) In general, the UAE values are lower than those in other countries and may reflect the UAE's preference for stricter criteria for allowable noise levels.

Comparison of International Guidelines for Noise in Residential, Industrial, and Commercial Areas

	Residential areas[a]			
Country	Day	Night	Industrial areas[a]	Commercial areas[a]
UAE	40–60	30–50	50–70	45–65
U.S. (EPA)[b]	45–55		70	60
Japan	55	45	50–60	50–60
India (Delhi)	50	40	70–75	55–65
Malaysia	55–60	45–50	70	65
Global (WHO)	55	50	70	70

[a]Measured in decibels (dB); the range of maximum acceptable levels are reported, due to variation in guidelines between federal versus local governments *within* a country and/or the definition of 'area type' *by* a country

[b]In 1981, the noise regulation authority of the United States shifted from the federal to the state level. However, the Noise Control Act of 1972 and the Quiet Communities Act of 1978 remain in effect. U.S. numbers reflect the federal guidelines

Currently, a strategy is in place to establish a framework for the management of noise in Abu Dhabi emirate through 2015. The first phase of this strategy entails the collection of sufficient noise monitoring and mapping data as a baseline for implementing further noise control management and action plans in the future. Once that data is collected, the noise management approaches will consider:

- Introduction of traffic management schemes to restrict heavy vehicles traveling through noise-sensitive areas at certain times of the day
- Use of acoustic barriers to protect noise-sensitive buildings
- Establishment of quiet zones around sensitive buildings such as hospitals and schools
- Restricting noise-generating industry to specific zones, away from residential or other noise sensitive development

Notes on Ambient Noise Risk Calculations

Number of Deaths per Year. Although recent studies conducted by European researchers have shown a relationship between noise exposure and premature deaths in Europe, the evidence is not strong. Overall the literature has shown mixed results of a causal relationship between noise and serious health problems such as heart disease and hypertension.

More Serious Long-Term Cases per Year. This reflects the heart attack cases attributable to road traffic in UAE annually only. We used the following formulas (Babisch 2006) to calculate the illnesses cases:

$$AR = \frac{RR-1}{RR} \times 100$$

$$PAR\% = \frac{P_e}{100} \times \frac{RR-1}{P_e/100 \times (RR-1)+1} \times 100$$

$$PAR = PAR\% \times N_d$$

Where:

AR = Attributable fraction

RR = Relative risk (odds ratios are estimates of the relative risk)

$PAR\%$ = Population attributable risk percentage

P_e = Percentage of the population exposed

PAR = Absolute numbers of affected subject

N_w = Number of subjects with disease occurrence

The relative risks of exposure to different noise levels were estimated by Babisch (2006).

The WHO estimates that 20% of the population worldwide is annoyed by road noise, and we used this percentage as the low estimate for the UAE population exposed to traffic noise. Considering that the population of the UAE is overwhelmingly urban, with more than 90% of people living in cities, at the high end we assumed that 85% of UAE population is exposed. This is roughly the population of Abu Dhabi, Dubai, and Sharjah in total. The UAE population in 2008 was 4,621,399 (UAE Ministry of Economy 2008b).

In the United States, there are 900,000 annual heart attack cases, which represent about 0.3% of the whole population (Centers for Disease Control and Prevention 2009). We assumed that the occurrence in the UAE is similar, based on the understanding that currently the trend of such diseases in UAE as diabetes, hypertension, and heart attack is very like that in developed countries, as a consequence of higher living standards.

Using the above formulas, relevant data, and assumptions, we got the following numbers for noise level between 70 and 75 dBA:

$$AR = \frac{RR-1}{RR} \times 100 = \frac{1.19-1}{1.19} \times 100 = 15.97$$

$$PAR\%(Low) = \frac{P_e}{100} \times \frac{RR-1}{\frac{P_e}{100} \times (RR-1)+1} \times 100 = \frac{20}{100} \times \frac{1.19-1}{\frac{20}{100} \times (1.19-1)+1} \times 100 = 3.66$$

$$PAR\%(High) = \frac{P_e}{100} \times \frac{RR-1}{\frac{P_e}{100} \times (RR-1)+1} \times 100 = \frac{85}{100} \times \frac{1.19-1}{\frac{85}{100} \times (1.19-1)+1} \times 100 = 13.90$$

$$PAR(Low) = PAR\% \times N_d = 3.66\% \times (4,621,399 \times 0.3\%) = 507$$

$$PAR(High) = PAR\% \times N_d = 13.90\% \times (4,621,399 \times 0.3\%) = 1,927$$

Risk estimation (Risk of myocardial infarction due to road traffic noise) low/high

Average noise level during the day (dBA)	Percentage of population exposed	Relative risk	Attributable fraction	Population attributable risk percentage PAR%	Number of subjects per year
<60	80/15	1.00	0.00	0.00	0
>70–75	20/85	1.19	15.97	3.66/13.90	500/1900

Time between Exposure and Health Effect. Some health effects, such as hypertension, can be fairly immediate, whereas health effects such as hearing loss or heart diseases may not manifest for years or decades into the future.

Quality of Scientific Understanding. The effects of noise on health are complex and remain poorly understood.

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects both uncertain scientific understanding about the risk and uncertainty about the extent of exposure or susceptibility of UAE residents to the particular hazard.

Ability of Resident to Control Exposure. The main sources of noise in the UAE are road traffic, industry, aircraft, and construction. People living close to these sources generally cannot control their exposure.

Global Climate Change

Summary

The Earth is warming, as evidenced by increasing air and ocean temperatures, widespread melting of ice and snow, and rising global average sea levels. The increase in the global average temperature since the mid-twentieth century is very likely caused by the increased concentration of greenhouse gases (GHG), such as carbon dioxide, methane, and nitrogen oxides, in the atmosphere. There is a scientific consensus that the primary reason for this increase is human activities—the combustion of fossil fuels, including coal, oil, and natural gas. Evidence is mounting that climate change has been associated with heat-related deaths and disease; deaths and illnesses from extreme climate-related events such as flooding and droughts; and malnutrition, diarrheal diseases, and infectious diseases. The risks of climate change can be managed by a combination of international and local government policies, such as reductions in carbon emissions, and by community and individually adaptive strategies.

Risk characteristic	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	0	20	50
Chance in a million of death per year for the average resident	0	6	13
Chance in a million of death per year for the resident at highest risk	0	6	13
Greatest number of deaths in a single event		1	
Illness or injury			
More serious long-term cases per year	0	0	0
Less serious long-term cases per year	0	0	0
More serious short-term cases per year	0	0	0
Less serious short-term cases per year	0	54,000	110,000
Other factors			
Time between exposure and health effects	Immediate to 30 years		
Quality of scientific understanding	Low		
Combined uncertainty in death, illness, and injury	Moderate		
Ability of resident to control exposure to hazard	Low		

What Is Known About the Potential Health Risks of Climate Change?

Over the next 50–100 years, global warming is projected to be five times greater than what has been experienced over the last 25 years. Importantly, it is predicted that the effects of global warming will not be uniform and will affect various populations and regions of the world differently. Because hot regions of the world suffer more from temperature increases, the regions most seriously affected by climate change will be Africa and the poorer areas of the Eastern Mediterranean and Southeast Asia.

Weather can have a major influence on human health in a number of ways, including the direct effects of extreme events such as heat waves, floods, and storms; the indirect effects of infectious diseases; and the limited availability of clean freshwater, which can cause many diseases, and food, which can lead to malnutrition and starvation.

The table below presents the potential pathways through which climate change may affect human health.

Potential pathways through which climate change may adversely impact human health

Direct impacts	Intermediate factors	Potential human health effects
Increasing temperature and heat waves		Heat-related mortality and disease, cardiovascular and respiratory diseases
Affecting precipitation	Food production (yield)	Malnutrition
Increasing extreme climate-related events	Ozone concentration increasing, air pollution	Air pollution related mortality and illness such as respiratory diseases
Hurricanes, wildfire, droughts, floods, etc.	Microbial contamination and transmission in food and drinking water	Diarrheal diseases, infectious diseases, water- and foodborne diseases, vector- and rodent-borne diseases
	Sea level rising	Mortality and injury from flooding, malaria during droughts, health-related problems with displaced populations

However, uncertainty remains with direct attribution of these health consequences to climate change. If climate change progresses, its effects on weather can result in cascading health consequences. The extent to which climate change affects human health in one region/nation is determined by the baseline conditions of the exposure, a population's vulnerability to changes in climate, as well as the capacity of populations to respond to change.

What Are the Current and Predicted Impacts of Global Climate Change on Health in the UAE?

The United Arab Emirates' arid and semi-arid regions are considered moderately to highly vulnerable to the effects of climate change, which are expected to affect temperatures, extreme climate-related events, precipitation, water resources, and sea levels. In turn, these effects can then have a serious impact on public health through the various pathways shown above. No studies on deaths or diseases directly attributable to climate change in the UAE have been done, but the UAE's baseline climate-sensitive diseases (malaria, diarrhea, and malnutrition) are at comparatively low levels that are similar to those in developed countries, and the health effects of climate change through this path might be limited. However, climate change may pose moderate to high risks to the UAE population's health condition, as potential deaths or illnesses associated with climate change could include heat-related illness, respiratory symptoms, vector-borne infectious diseases, and deaths during flooding.

An increase in temperature and decrease in precipitation may influence the UAE's freshwater supply. Currently the entire UAE population (both urban and rural) has sustainable access to improved drinking water sources, and drinking water quality is good. However, the UAE's water supply has been a critical issue due to its arid climate, fast population growth and economic development, and expanding agricultural activities. Higher average temperatures and greater evaporation will worsen the condition of the UAE's water supply, which is largely produced by the desalination of sea water, a process that consumes a large amount of energy and is responsible for large amounts of carbon dioxide.

Rising sea level is a significant risk for the UAE's coastal zones, which comprise approximately 1,318 km of coastline, with 85% of the population living within 100 km of the coast. This large coastal population is likely to be particularly vulnerable to floods, as are many buildings and industrial facilities (including oil and gas) that operate along the coast.

What Has Already Been Done About Climate Change in the UAE?

Because the climate system is affected by global emissions of GHGs, the UAE does not have the ability to control the climate change it will experience. By taking action to reduce its own emissions, the UAE, as an energy-exporting nation, can set an important example on climate-change mitigation efforts for its neighbors as well as other nations around the world.

There are generally two approaches for countries to prevent or lessen the negative impacts of global climate change on its people: address the drivers of climate change, or mitigate the effects. The UAE has focused on the first approach by taking a number of steps:

Shifting away from high-energy processes. The major source of GHG emissions is the burning of fossil fuels, and the UAE is one of the major emitters of GHG per capita, ranking fourth in the world. The UAE is actively trying to shift away from high-energy processes and is also transitioning to natural gas, which produces less carbon dioxide per unit energy than oil.

Participating in international treaties and coordinated efforts to set targets to reduce emissions. The UAE hosted the first World Summit on Energy for the Future in January 2008. It also ratified the Kyoto Protocol in January 2005, which aims at reducing global emissions of GHG to 5% below 1990 levels during the period 2008–2012.

Developing clean energy technologies and alternative energy source. For example, a "green city"—Masdar City in Abu Dhabi—will be built in 8 years and will be mostly powered by solar energy. Another example began in January 2008 when Abu Dhabi announced a $15 billion initiative to develop clean energy technologies using hydrogen.

Promoting research and developing preparedness plans for future defined risks. The UAE has published its initial national communication to the United Nations, conducted its own GHG inventory, defined methods to improve data quality, and identified vulnerabilities and adaptation options.

Setting improved efficiency standards. The UAE outlined "greener" building codes and appliance standards in its report to the United Nations.

Despite taking the above actions, the UAE still needs a national and regional strategy for climate change to deal with the various health consequences, especially those caused by increasing temperatures, shrinking fresh water supply, and sea level rise.

Notes on Global Climate Change Risk Calculations

We calculated the fatalities and cases of illness due to climate change based on the relative risks estimated by McMichael et al. (2004). The following health effects (mortality/morbidity) are estimated because (1) they are sensitive to climate change; (2) it is important to predict these outcomes in the future; and (3) data are available:

- Mortality: deaths from cardiovascular disease and from floods (inland and coastal floods)
- Morbidity: malnutrition, malaria, and diarrheal diseases

Number of Deaths per Year. This is the average number of excess deaths (from cardiovascular disease and floods) among the UAE population as a result of exposure to global climate change. To calculate this number, we assume that (1) deaths attributable to climate change are distributed proportionally to the populations across all EMR-B countries; (2) UAE accounts for 1.87% population in all EMR-B countries; and (3) the annual deaths from cardiovascular disease and floods in the region are constant. The low estimates are zeroes, reflecting the most optimistic scenario under which the UAE completely adapts to the change.

We used the following formula to calculate best and high estimates of excess deaths from cardiovascular disease and floods attributable to climate change:

$$\textit{Excess deaths due to climate change} = \textit{Numbers of current death} \times (\textit{Relative risk} - 1)$$

Relative risks under three climate scenarios for EMR-B region are estimated by McMichael et al. (2004). These data are presented in the table below.

Relative risks for EMR-B region, 2005

Climate change scenario	Cardiovascular disease			Inland floods/ landslides			Coastal floods		
	Low	Mid	High	Low	Mid	High	Low	Mid	High
s550[a]	1.000	1.001	1.001	1.00	1.98	2.49	1.11	1.22	1.45
s750[b]	1.000	1.001	1.002	1.00	2.37	3.09	1.12	1.24	1.48
Unmitigated[c]	1.000	1.001	1.003	1.00	2.41	3.15	1.16	1.31	1.63

[a]The future exposure scenario that assumes GHG emission reduction achieving stabilization at 550 ppm CO_2-equivalent by 2170

[b]The future exposure scenario that assumes GHG emission reduction achieving stabilization at 750 ppm CO_2-equivalent by 2210

[c]Unmitigated emission trends

For our calculations, we assumed unmitigated emission trends. We used the “mid estimates of relative risks” to calculate our best estimates and high estimates of relative risks to calculate our high estimates.

The number of cardiovascular disease deaths in 2002 in the UAE was 369 per 100,000 population, and we have assumed this death rate to remain constant (WHO 2006). The 2005 UAE population was 4,104,695. Therefore the number of cardiovascular disease (CVD) deaths in 2005 in UAE is 15,144.

The annual incidence of deaths per 10,000,000 population in 2000 in all EMR-B countries caused by floods, in the absence of climate change, was 13.8 for inland floods and landslides and 0 for coastal floods. The population of the EMR-B region in 2000 was 139,070,000 (United Nations Population Division 2000).

Examples of calculations:

Excess CVD deaths due to climate change (high) = 15,144 × (1.003–1) = 46
Excess CVD deaths due to climate change (best) = 15,144 × (1.00 –1) = 16
Excess deaths from inland floods/landslides due to climate change (high) = (13.8 × 13.9) × (3.15–1) × 1.87% = 8
Excess deaths from inland floods/landslides due to climate change (best) = (13.8 × 13.9) × (2.41–1) × 1.87% = 6
Excess deaths from coastal floods due to climate change (high and best) = 0

Chance in a Million of Death per Year for the Average Resident. This is the average annual risk of death for a randomly chosen UAE resident as a result of exposure to global climate change. We calculated this number by dividing “number of deaths per year” by the total population (in millions) of the UAE in 2005.

Chance in a Million of Death per Year for the Resident at Highest Risk. This is the average annual risk of death for a UAE resident at highest risk as a result of exposure to global climate change. We assumed it is the same with chance of death for the average resident.

Greatest Number of Deaths in a Single Episode. This is the greatest number of deaths resulting from a single cardiovascular disease case, or one.

Illness or Injury. These are cases of nonfatal illness or injury per year expected among the UAE population resulting from the exposure to climate change. Three types of illnesses are estimated using the same method described above: malnutrition (more serious long-term), malaria (less serious long-term), and diarrhoeal diseases (less serious short-term). Data are given as follows.

Relative Risks for EMR-B Region, 2005

	Malnutrition			Malaria			Diarrhea		
Scenario	Low	Mid	High	Low	Mid	High	Low	Mid	High
s550	1.00	1.01	1.03	1.00	1.00	1.00	0.99	1.02	1.04
s750	1.00	1.03	1.06	1.00	1.00	1.00	0.99	1.02	1.04
Unmitigated	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.03	1.06

The numbers of baseline cases of malnutrition, malaria, and diarrheal diseases in 2002 estimated by WHO in all EMR-B countries were 585,000, 363,000, and 96,324,000, respectively.

Time between Exposure and Health Effect. Some health effects, such as diarrheal diseases caused by microbial contamination, have fairly immediate impacts, whereas health effects such as malnutrition may not manifest for years or decades into the future.

Quality of Scientific Understanding. Climate change may affect human health via many mechanisms. The extent of health impacts depends on the magnitude of climate change that occurs, the links that are identified between climate and public health, and the ability of people to adapt to climate change and avoid its effects. But scientific understanding is improving, with the publication of the Intergovernmental Panel on Climate Change's Fourth Assessment Report in 2007 (IPCC 2007).

Combined Uncertainty in Deaths, Illness, and Injury. This statistic reflects both uncertain scientific understanding about the risk and uncertainty about the extent of exposure or susceptibility of UAE residents to the particular hazard.

Ability of Resident to Control Exposure. Climate change is a global issue and the UAE as an individual country does not have the ability to control the climate change that it will experience. Although to some extent human beings have the ability to adapt to temperature change, the hazards cannot be removed or avoided. Extreme events such as flooding and wildfire cannot be controlled by individuals.

Stratospheric Ozone Depletion

Summary

The depletion of the ozone layer, which protects the planet from potentially damaging amounts of ultraviolet (UV) radiation reaching the surface, is the source of numerous adverse health effects caused by increased exposure to ultraviolet radiation. Substances including chlorofluorocarbons (CFCs), halons, methyl bromide, and hydrochlorofluorocarbons (HCFCs), which are used for air-conditioning and refrigeration systems, have been shown to deplete the ozone layer if released into the air.

Risk attribute	Low estimate	Best estimate	High estimate
Fatalities			
Number of deaths per year	16	20	24
Chance in a million of death per year for the average resident	6	8	10
Chance in a million of death per year for the resident at highest risk	7	9	11
Greatest number of deaths in a single event		1	

(continued)

(continued)

Risk attribute	Low estimate	Best estimate	High estimate
Illness or injury			
More serious long-term cases per year	2,100	2,600	3,200
Less serious long-term cases per year	4,600	5,700	6,900
More serious short-term cases per year	800	1,000	1,200
Less serious short-term cases per year	4,700	5,800	7,000
Other factors			
Time between exposure and health effects	Immediate to 30 years		
Quality of scientific understanding	High		
Combined uncertainty in death, illness, and injury	Low		
Ability of resident to control exposure to hazard	High		

As the ozone layer is depleted, more ultraviolet radiation from the sun passes through the atmosphere. The health effects of increased exposure to ultraviolet radiation include cancers of the skin and eyes, cataracts, corneal damage, reduced resistance to infectious diseases, and the diminished effectiveness of vaccines. In response to this risk, 190 countries, including the UAE, signed the Montreal Protocol to formalize international agreement on plans to phase out the production and consumption of ozone-depleting compounds. However, the recovery of the ozone layer remains uncertain because it is dependent on the continued international agreement and commitment to limit emissions of these harmful substances into the atmosphere.

What Is Known About the Risk of Increased UV Exposure as the Result of Ozone Depletion?

Increased exposure to UV rays due to ozone depletion can lead to a variety of harmful health effects, from sunburn to malignant cancers. Acute exposure of the skin to UV rays causes sunburn. The amount of exposure depends on the amount of protective pigment in the skin, genetic factors and the level of UV-B radiation, the most harmful part of the UV spectrum, contained in the sun exposure. Longer-term exposure may also cause wrinkling, thinning, and loss of elasticity in the skin.

UV radiation may also cause nonmalignant or malignant skin cancer by altering important genes that control cell division and cell death. Exposure to radiation can cause both malignant and nonmalignant cancers, with nonmalignant carcinomas occurring at highest frequencies in Caucasians living in sunny environments. These are generally fairly easily treated and are rarely fatal. The malignant form of skin cancer, although much more dangerous, occurs at a much lower frequency than the other, nonmalignant forms of skin cancer. Some evidence suggests that melanomas are correlated with acute sunburns and high exposures during childhood. It should be noted, however, that the rate of some nonmalignant cancers has been increasing in most countries over time, and in a pattern correlated with regions affected by ozone depletion.

UV radiation also has varying effects on the human eye, depending on the type of exposure (acute and intense versus chronic and lower-level intensity). The effects from ozone-depleting chemicals broadly falls into the latter category and the resulting concern is for the development of cataracts, which may be irreversible and ultimately lead to blindness if not corrected. Because cataracts are so highly associated with advanced age and certain diseases such as diabetes, there have been few studies that have been able to distinctly correlate any additional impacts from UV exposure.

Immune effects have also been documented by UV exposure in numerous ways. "Antigen-presenting cells" of the immune system, which are present in human skin, are responsible for bringing invading microorganisms into the lymph nodes, where the immune response begins. Damage to these cells by UV radiation can limit or alter this response. Also, UV-B radiation has been shown to stimulate cell mediators and activate chemical responses that increase immune suppression instead of activation. While it is not clear how this ultimately affects the response to diseases in humans, there is some evidence to show it increases both the susceptibility and severity of infections and reduces the effectiveness of vaccines. This remains an area of important research.

What Are UV Exposure Levels in the UAE?

Because the ozone layer is mainly depleted around the Earth's poles, ultraviolet radiation exposure due to ozone depletion varies by the latitude of the area of study. The UAE lies within the low latitudes or "tropics," which experience a lower risk gradient due to ozone depletion for harmful UV exposure than those closer to the polar regions. However, although the increase in UV exposure is smaller in the UAE than in northern latitudes, the baseline level of exposure is higher because of the angle of the sun and relatively shorter layer of atmosphere they must pass through for most of the year. Additionally, the clear, hot weather in the UAE increases the likelihood of more high UV radiation days in the region, as compared to other parts of the world where air pollution and clouds significantly reduce the radiation that reaches the ground.

The nature of ozone depletion means that the quantity of different wavelengths of radiation reaching Earth increase by different amounts. Because of this, levels of UV-B radiation have not changed significantly for the tropics (23°N to 23°S). Even though levels of UV-B radiation have surpassed pre-1980 levels in other regions, they still have not reached the overall levels experienced by the UAE.

Despite these risks, there is also a risk of too little UV exposure, especially for women in the UAE. A large portion of the population spends much time indoors in factories and businesses, and too little sun exposure can result in a vitamin D deficiency, which can cause skeletal diseases such as rickets, osteomalacia, and osteoporosis, as well as possibly even decreased immunity to cancer and autoimmune disorders such as multiple sclerosis or Type 1 diabetes.

In the UAE, twice as many men as women are affected by diseases and deaths related to excess UV radiation. This could be partially because, according to a UAE study, many Muslim women spend the bulk of their time indoors or under conservative dress. These women, if they work, are also more likely to work indoors, rather than in some of the more manual-labor-intensive jobs.

Risks in the UAE are particularly high for migrant workers, who tend to make up the bulk of those working outdoors. However migrants also tend to have darker skin, which mitigates their risk to some extent. Because the UAE population is primarily comprised of darker skinned populations (with less than 10% identified as ethnicities with fair skin), the risk for skin cancers in this population is relatively lower than for fairer-skinned populations.

What Has the UAE Already Done to Reduce the Risks of UV Exposure?

It is hoped that if emissions are controlled on a global scale, the ozone layer will return to normal around the year 2050. The UAE is complying with its role as an international participant in the Montreal agreement to reduce emissions. Currently, there is no production of ozone-depleting substances in the UAE. Import and consumption of ozone-depleting substances remained stable between 1990 and 2001 in the UAE, with 448 tons of CFCs consumed in 1990 and 423 tons in 2001. Since then, there was a phaseout of 50% of these substances by 2005. As of 2007, CFCs and halons should have reached 85% below 1989 levels in Abu Dhabi and the UAE. The phaseout of these substances should be complete by January 2010 when the UAE will ban all imports of ozone-depleting substances.

Until the ozone layer has been restored, behavior modification is very effective at reducing human exposure to excess UV rays. However, in the UAE most of the population already covers up their entire body except for hands and faces. Much of the population already employs protective measures against UV exposure such as wearing sunscreen, covering skin with clothes, wearing sunglasses, and reducing exposure during the hottest part of the day. All are effective means of protection from the sun's harmful rays. Although it is unknown whether the UAE has implemented any specific educational campaigns to reduce the public's exposure to the sun, these approaches have been shown to be successful and if necessary, may be further tailored to fit the specific cultural norms of the UAE.

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Appendix B: How to Use the *UAE Environmental Burden of Disease Model*

This appendix provides a brief overview of the software package *Analytica* and instructions on how to open the *UAE Environmental Burden of Disease Model*, view input and output variables, view model results, and edit variables.

Overview of the Analytica *Software*

Analytica is a powerful forecasting software package and a visual tool for creating, analyzing, and communicating decision models. You will need to have *Analytica* (version 4.1 or higher) installed on your computer to open, view, and edit the *UAE Environmental Burden of Disease Model*. It is available from Lumina Decision Systems at http://www.lumina.com. A free download is available for viewing and running models (*Analytica Player*); however, note that the normal *Analytica* software is needed should you wish to directly edit variables, nodes, or internode relationships. The *UAE Environmental Burden of Disease Model* itself is available by request from the Department of Environmental Sciences and Engineering at the University of North Carolina–Chapel Hill. For additional details, please contact the department directly.

Viewing and Editing the Model in Analytica

Opening the Model

The model can be opened in two ways: (1) by double-clicking the icon for the model file, or (2) by selecting the *File* pulldown menu at the top left of the *Analytica* application window, then selecting the *Open Model* tab. A directory browser dialog appears, from which you can locate the model file. Figure B.1 shows the top-level diagram window that appears when the model is opened.

The first seven nodes at the left of the diagram depict the seven modules that calculate the burden of disease attributable to seven environmental health risks in the UAE for this project. The last node depicts the module that contains definitions and descriptions of all the global variables in the model.

The burden of disease calculation results can be viewed directly from the top-level diagram window shown in Fig. B.1. To view the disease burden estimates from a risk module, click that module's corresponding *Calc* button. A *Result* window will appear, showing mean values of the burden of disease estimates in table format. It may take a few seconds or longer—depending on your computer's CPU model and speed—for the window to open as the model computes the results. The *Result* window can also display the statistics of an estimate, such as its minimum and

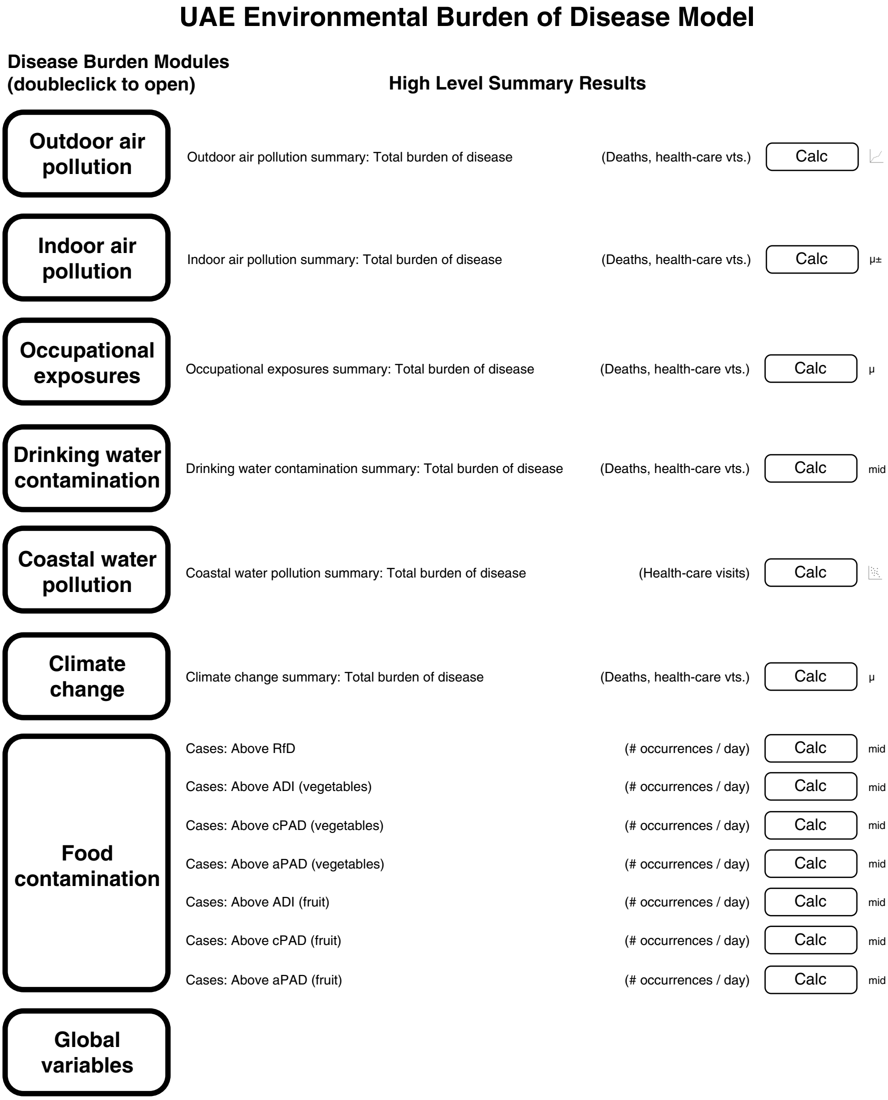

Fig. B.1 Top-level diagram window of the *UAE Environmental Burden of Disease Model*

maximum values, and results can alternatively be viewed in graphical format. (See the section below on viewing result tables and graphs for more details.)

Opening Modules

To see details of an environmental risk module, double-click the module node in the top-level diagram window. This opens the next level of detail of the model.

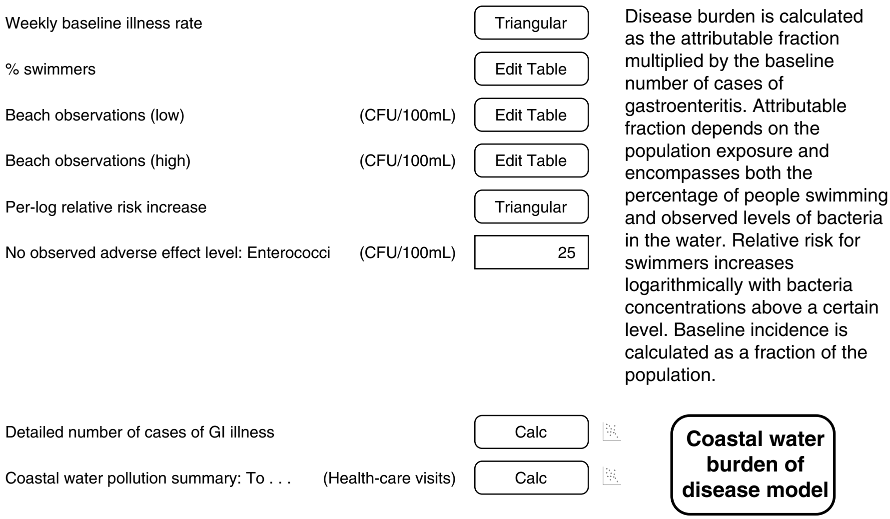

Fig. B.2 Top-level diagram window of the ***Coastal Water Contamination*** module

For example, double-clicking the ***Coastal Water Contamination*** module opens the diagram window seen in Fig. B.2.

This diagram window shows the input nodes (the first six rows on the left side) and the output nodes (the last two rows on the left side) of the ***Coastal Water Contamination*** module. It also contains a brief description of the method used to estimate the disease burden in this module (upper right) and a module node that contains the details of the model (lower right).

Most of the seven modules have submodules that depict the calculation of the disease burden attributed to various contaminants in a risk area. For example, the ***Indoor Air Pollution*** module has eight submodules, such as ***Benzene***, ***Formaldehyde***, etc. Double-clicking a submodule node opens a diagram window that depicts input and output nodes similar to the one shown in Fig. B.2.

Viewing a Variable

To view an input or output variable, double-click its node, which will open an *Object* window that shows the attributes of an object, commonly including its class (e.g., chance, objective, etc.), identifier (a unique name of up to 20 characters assigned to a variable), title, units, description, definition, value, inputs (if the variable has input variables), outputs (if the variable is an input variables of other variables), and others such as sources and references. Users can manage the display of attributes of a variable in its object window, for example, by creating user-defined attributes. This can be done by using the attributes dialog. To open the attributes dialog, select *Attributes* from the *Object* menu. You can display optional attributes, create new attributes, and rename an attribute.

For example, double-clicking the first input variable, ***Weekly baseline illness rate***, opens its *Object* window, which shows the variable's class (*chance*, which means the variable is uncertain and its definition contains a probability distribution), identifier (Weekly_baseline_illn), title (Weekly baseline illness rate), description, definition (triangular (8 m, 0.014, 0.024)), value (0.01506), outputs (Baseline_cases2), references, and units (percentage).

To view the value of a variable from the diagram window shown in Fig. B.2, click the colored button in a node. For example, in Fig. B.2 above, clicking the *Triangular* button next to ***Weekly baseline illness rate*** opens an *Object Finder* showing that the variable has a triangular distribution with a minimum value of 8 m (i.e., 8×10^{-3}; *Analytica* uses the suffix "m" for 10^{-3}), a mode value of 0.014, and a maximum value of 0.024. When the input variable consists of a table, the button is shown as *Edit Table* (rows 2, 3, and 4 in Fig. B.2). Click the button to open the table, and view the values in the table. More details of viewing and editing a multidimensional table are discussed below in the section on viewing and editing multidimensional tables. In the case that a variable has only a single value, such as the variable ***No observed adverse effect level***: enterococci in Fig. B.2, the value is shown directly in the button.

Viewing Result Tables and Graphs

To open a *Result* window for an output node, such as the node ***Detailed Number of Cases of GI Illness*** in Fig. B.2, simply click its *Calc* button. It may take a few seconds or longer for the window to open as the model computes the results. When you open the *Result* window, the default view is set to display the mean values of the burden of disease estimates as a table. You may use the controls in the upper-left corner of the *Result* window to change the view of the results. Specifically, click the [1.2] button to display the result as a table or the [graph] button to display the result as a graph.

Most of the variables defined in the *UAE Environmental Burden of Disease Model* have an uncertain or probabilistic value. As a result, the model computes the mean values and ranges of its output variables. The *Result* window offers seven uncertainty views, including the *mid* value (for variables that have a certain or deterministic value) and six ways to display a *prob* value (including *Mean Value*, *Statistics*, *Probability Bands*, *Probability Density*, *Cumulative Probability*, and *Sample*, for variables that have an uncertain or probabilistic value). Click the [mid▾] button in the upper-left corner of the *Result* window to open the uncertainty view menu and select an option.

Editing an Input Variable

The current version of the model estimates the disease burden attributable to the seven primary risk areas in the UAE based on the best available data we could find when the model was developed. In cases when UAE data were not available, the model relies on data from other countries. Therefore, the model should be updated as new information becomes available. A key advantage of this computer-based model is that the values of input variables can be easily refined to incorporate new information, and the model will generate new predictions accordingly.

To begin editing a variable, select the *Edit Tool* in the navigation toolbar at the top of an *Analytica* window by clicking it (when the file is opened, *Analytica* automatically selects the *Browse Tool* , which does not allow editing). The edit tool will be highlighted to show that it is selected, and the cursor will switch from to an arrow.

Use the steps to view a variable described above to open its *Object* window. Double-click the *Definition* attribute and then type in the new values of the input variable. If the input is in table format, double-click the *Edit Table* button to open the *Edit Table* window. Now you can edit the input values in cells. To replace the value in a cell, select the cell, click three times to get a cursor in the cell, and then type. Press *Enter* to accept the value and to select the next cell, or click in another cell. When you are done editing, click to accept all the changes you have made. If you close a table, it also accepts the changes unless you click to cancel changes you have made to the table since you opened it or last clicked. Click to open the *Result* window to see the new estimates based on updated input values.

You may also copy and paste the data in a table directly from or to a spreadsheet. For further assistance with editing a table in *Analytica*, please refer to the "Editing a table" section in the *Analytica User Guide* (Lumina Decision Systems 2008).

Multidimensional Tables or Graphs

As mentioned at the beginning, one of the key advantages of *Analytica* is that it allows users to create and manage multidimensional tables. Many of the input and result tables in the *UAE Environmental Burden of Disease Model* have more than two dimensions. For example, the input variable ***% Swimmers*** in the *Diagram* window in Fig. B.2 has three dimensions identified by three indexes (in *Analytica*, an index is the identifier of a dimension of a multidimensional table): Population Category, Emirate, and Month. The output variable ***Detailed Number of Cases of GI Illness*** also has the same three indexes. In an *Edit Table* window or a *Result* window, the index selection area is the top part of the window, in which there are two buttons. The first button shows which index goes down the rows, and the second shows which index goes across the columns. If the table has too many dimensions to display directly, the index selection area also shows the indexes that are currently not displayed in the table (these are called a slicer index in *Analytica*). For example, in the *Edit Table* window of the ***% Swimmers*** variable, if the two buttons are *Emirate* and *Month*, and the textbox next to the slicer index ***Population Category*** says *Tourist*, it means that the current table displays the values corresponding to each emirate and each month for the population category *Tourist*. Press for a popup menu from which you can select the other value of the slicer index: *Resident*. Click or to switch the slicer value between *Tourist* and *Resident*.

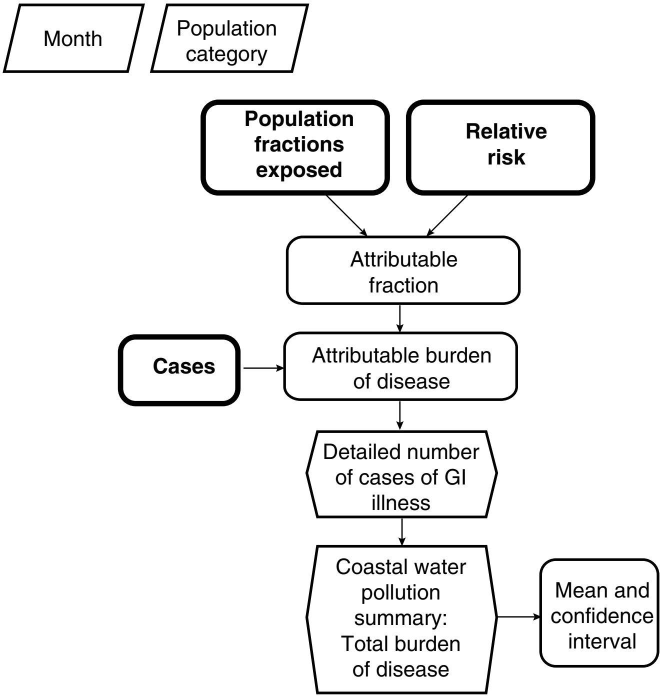

Fig. B.3 Influence diagram of the ***Coastal Water Contamination*** module

Viewing the Influence Diagrams of the Model

Each top-level diagram in the burden of disease model, such as the one shown in Fig. B.2, contains a module node that depicts the details of the model (e.g., the ***Recreational Water Burden of Disease*** module in Fig. B.2). Double-clicking the node opens an influence diagram showing details of the model as depicted in Fig. B.3.

An influence diagram in *Analytica* is a qualitative representation of a model that shows the variables and their dependencies. The rounded nodes with thick outline (i.e., the nodes ***Cases, Population Fractions Exposed***, and ***Relative Risk***) are modules that include separate influence diagrams. Double-clicking a module node will open its influence diagram. The parallelogram-shaped nodes (i.e., the nodes ***Month*** and ***Population Category***) depict the index variables that are used to define dimensions of tables in the model. The two hexagon-shaped nodes depict objective variables. Lastly, the remaining three rounded nodes depict general variables.

The arrows in an influence diagram that link two nodes are influence arrows. The *Analytica User Guide* states that "an influence arrow from variable A to variable B means that the value of A influences B because A is in the definition of B" (Lumina Decision Systems 2008). In this case (the influence diagram in Fig. B.3), the two arrows from ***Population Fractions Exposed*** and ***Relative Risk*** to ***Attributable***

Fraction mean that the fraction of each population exposed to coastal pollution through swimming and the relative risk of gastroenteritis for those exposed to microbial coastal pollution both affect the fraction of disease attributable to coastal water contamination. Therefore, when those values change, it changes the attributable fraction estimates.

The influence diagram shown in Fig. B.3 illustrates the essential qualitative structure of the model used to compute the disease burden attributable to an environmental health risk. The influence diagrams and details underlying the structure, including numbers and mathematical formulas, are described in the corresponding chapters of this report.

Overview of the *Global Variables* Module

The ***Global Variables*** module depicts the variables that are used by more than one module in the model. Some index variables, such as the ***Emirate*** index (a list of the seven emirates in the UAE), are used in most of the seven modules since we estimated the disease burden in each emirate wherever possible. This module also depicts the population data (the node ***Population***) and the baseline health data (the module node ***Baseline Health Endpoints***, including mortality and hospital visits due to various causes) used in different modules in the model. In order to reduce the complexity of the model, we did not link the input values of the population and baseline health endpoints in this module to the modules that use them as inputs. Instead, we list the data in the ***Global Variables*** module as references for users. Therefore, changing the values in the ***Global Variables*** module will not change the values used by the model to compute the results. Users need to go to an individual module to change input values.

Further Assistance

The purpose of these brief instructions is to get users started using the computer-based *UAE Environmental Burden of Disease Model*. Individual chapters in this report describe the details of the methods, assumptions, and data used in each module in the model. The *Analytica User Guide* also contains more detailed information about the software itself. It can be accessed from within the software by pressing the function key F1 at any time.

Reference

Lumina Decision Systems. 2008. *Analytica user guide*.

Appendix C: Model Input Parameters

Table C.1 Exposure variables, values, probability distribution functions (PDFs), and sources of data for each risk factor considered in this study

Outdoor air pollution									
		Mean annual average concentration by emirate[a]							
Exposure variable	Unit	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Sources of data
Measurement-based approach									
PM_{10}	μg/m^3	107.2	105.6	104.1	105.6	109.0	105.4	104.3	Detailed PM (PM_{10} and $PM_{2.5}$) data in 2007 were obtained from 10 monitoring stations, and detailed ozone data in 2007 were obtained from seven monitoring stations. All stations are located in Abu Dhabi emirate
$PM_{2.5}$	μg/m^3	37.5	36.9	36.4	37.0	38.1	36.9	36.5	
Ozone: Daily avg.	ppb	29.1	28.5	28.5	28.5	28.5	28.5	28.5	
Ozone: Daily 1-h max	ppb	50.9	50.2	50.2	50.2	50.2	50.2	50.2	
Community Multiscale Air Quality Modeling System (CMAQ)-based approach									
PM_{10}	μg/m^3	33.5	31.8	33.9	38.1	42.6	39.1	36.6	Concentration estimates from CMAQ modeling by the UNC air quality team
$PM_{2.5}$	μg/m^3	14.0	14.0	14.1	14.2	14.3	13.9	13.5	
Ozone: Daily 1-h max	ppb	60.7	68.9	67.8	68.8	70.2	65.3	67.1	

[a] 1,409 grid cells (resolution: 55 km^2) were created across the UAE to represent the spatial variations of pollutant concentrations (the numbers of grid cells in each emirate: Abu Dhabi–1,164; Dubai–79; Sharjah–55; Ras al Khaimah–51; Umm al Quwain–18; Ajman–75; and Fujairah–37). Pollutant concentrations in each grid cell are lognormally distributed and characterized by a mean and a standard deviation. The mean concentration and standard deviation in each grid cell are estimated using two different approaches: measurement-based and CMAQ model-based

Indoor air pollution			
Exposure variable	Unit	PDF/exposure category	Sources of data
PM_{10}	µg/m³	Lognormal (92.8, 144.9)	18 studies[a] worldwide, including countries such as the United States, Belgium, Austria, India, Korea, and China
$PM_{2.5}$	µg/m³	Lognormal (30.6, 34.36)	26 studies[a] worldwide, including countries such as the United States, Belgium, Singapore, Austria, Italy, Greece, Switzerland, Finland, Czech Republic, France, and Mexico
Benzene	µg/m³	Lognormal (9.5, 9.46)	8 studies[a] worldwide, including countries such as the United States, the United Kingdom, China, Korea, and some European countries
Formaldehyde	µg/m³	Lognormal (47.4, 36.2)	12 studies[a] worldwide, including countries such as the United States, Canada, Japan, Riyadh, Saudi Arabia, China, Turkey, and some European countries
Radon	Bq/m³	Abu Dhabi city: lognormal (13.8, 6.6); Sharjah: triangular (8, 50.3, 164)	Measured radon concentration data from the emirates of Abu Dhabi and Sharjah were obtained for this analysis. The data from Abu Dhabi consisted of 202 measurements in 111 residential dwellings. The data from Sharjah were provided only as a mean, a minimum value, and a maximum value
Environmental tobacco smoke (ETS)		Exposed to secondhand smoke in a residential environment, or unexposed; uniform (0.15, 0.75)	
Mold		Exposed to mold in a residential environ ment, or unexposed; uniform (0.05, 0.5)	
Incense use		Exposed to incense use in a residential environ-ment, or unexposed; citizens: uniform (0, 0.9); noncitizens: uniform (0, 0.5)	

[a]See Appendix D for details on mean concentration estimates

Occupational exposures		
Exposure variable	Exposure category	Sources of data[a]
Carcinogens[b] and leukemogens[c]	Background, low, and high. High exposure refers to exposures above the relevant U.S. Permissible Exposure Limit (PEL), and low exposure below it. The WHO estimates that in Eastern Mediterranean Region B countries, 50% of the workforce is exposed to carcinogens at high level and 50% at low level	Driscoll et al. (2004b). Estimated proportion of UAE workforce exposed to each carcinogen or leukemogen within each economic subsector was derived from the Carcinogen Exposure (CAREX) database (FIOH 2006)
Particulate matter	*Asthma:* Exposure and relative risk categorized by occupational group including administration, technical, sales, agriculture, mining, transportation, manufacturing, and services	Driscoll et al. (2004a)
	Chronic obstructive pulmonary disease: Background (includes combined proportions of workers in trade, finance, and services), low (agriculture, electricity, and transportation), medium/high (mining, manufacturing, and construction)	Korn et al. (1987)
	Asbestosis and silicosis: 100% attributable fraction	Driscoll et al. (2004a)
Noise	Moderately high (85–90 dB(A)) and high (>90 dB(A))	Concha-Barrientos et al. (2004)

[a]The proportion of the UAE workforce in each occupational group or economic subsector by gender was derived from the UAE Ministry of Economy
[b]Asbestos, arsenic, beryllium, cadmium, chromium, diesel fumes, nickel, and silica
[c]Benzene and ethylene oxide

Drinking water contamination			
Exposure variable	Unit	PDF/exposure category	Sources of data
Trihalomethanes (THMs)	μg/L	Normal (30.08, 13.57)	Statistical summary of drinking water samples taken in Kuwait (Al Mudhaf et al. 2009)
Microbial contamination		WHO defined water quality scenarios: Scenario II – Population having access to improved water supply and sanitation services in countries where more than 98% of the population is served by those services Scenario Vb – Population having access to improved water supply but not served with improved sanitation in countries which are not extensively covered by those services (less than 98% coverage), and where water supply is not likely to be routinely controlled	Fewtrell et al. (2007)

Coastal water contamination										
			Range of 12-month observed beach concentrations							
Exposure variable	Unit	Exposure category	Abu Dhabi	Dubai	Sharjah	Ajman	Umm Al Quwain	Ras Al Khaimah	Fujairah	Sources of data
Enterococci	CFU/100 mL	Low	0–5	0–10	0–5	0–5	0–5	0–5	0–5	Observed 2006 concentrations, Al Raha Beach, EAD
		High	0–250	0–500	0–250	0–250	0–250	0–250	0–250	Observed 2006 concentrations, Abu Dhabi public beach, EAD

Produce and seafood contamination			
Exposure variable	Unit	PDF/range	Source of data
Methylmercury in seafood	mg/kg	Triangular (0.033, 0.068, 0.098)	Kosanovic et al. (2007), data from 3 sampling points on UAE coast

(continued)

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Produce and seafood contamination				
Exposure variable	Unit	PDF/range		Source of data
Pesticide residue on vegetables and fruit	mg/kg	Vegetables	Fruit	The range refers to maximum residue levels (MRL) on various vegetables or fruit. Strict adherence to MRLs is assumed
Acephate		0.02–50	0.02	
Bifenthrin		0–2	0–3	
Bromopropylate		0–1	0–2	
Chlorfenvinphos		0	0	MRL data from Codex Alimentarius Commission for all pesticides except those listed below: • MRL data from EC (European Commission) and ESFA (European Food Safety Authority) for acephate, bifenthrin, bromopropylate, dimethoate, quintozene, cyhalothrin, methamidophos, procymidone, vinclozlin, methadathion, chlorpyrifos • MRL data from USDA/FAS (MRLDatabase.com) for malathion
Chlorpyrifos		0–20	0–3	
Dichlorvos		0	0	
Dimethoate		0–2	0–5	
Ethion		0	0	
Fenitrothion		0	0–0.5	
Cyhalothrin		0–1	0–0.2	
Malathion		0–8	0–8	
Methamidophos		0–2	0.01–0.5	
Methidathion		0.02–0.1	0–5	
Phenthoate		0	0	
Pirimicarb		0–20	0–3	
Procymidone		0–50	0–5	
Quintozene		0–0.1	0.02	
Vinclozolin		0–30	0.05–10	

Table C.2 Relative risk and sources of data for each risk factor considered in this study

Exposure variable	Unit	Health endpoint	Relative risk	Sources of data
Outdoor air pollution				
PM_{10}	μg/m³	All-cause mortality due to short-term exposure	Percentage increase in incidence per 1 μg/m³: Normal (0.08, 0.001)	Mortality: Ostro (2004)
		Respiratory mortality in children <5 due to short-term exposure	Normal (0.166, 0.007)	Morbidity: Ostro and Chestnut (1998)
		Respiratory health-care facility visits due to short-term exposure	Normal (0.084, 0.0019)	
		Cardiovascular disease health-care facility visits due to short-term exposure	Normal (0.03, 0.0031)	
$PM_{2.5}$	μg/m³	All-cause mortality due to long-term exposure in adults > 30	Percentage increase in incidence per 1 μg/m³: Normal (0.6, 0.2)	Pope et al. (2002)
		Cardiopulmonary mortality due to long-term exposure in adults >30	Normal (0.9, 0.3)	
		Lung cancer mortality due to long-term exposure in adults > 30	Normal (1.4, 0.5)	
Ground-level ozone	ppb	Total non-accidental mortality due to short-term exposure	Percentage increase in incidence per 1 μg/m³: Normal (0.052, 0.0128)	Bell et al. (2004)
		Cardiovascular and respiratory mortality due to short-term exposure	Normal (0.064, 0.017)	Bell et al. (2004)
		Respiratory mortality in adults >30 due to long-term exposure	Normal (0.4, 0.1)	Jerrett et al. (2009)

(continued)

Table C.2 (continued)

Exposure variable	Unit	Health endpoint	Relative risk	Sources of data
		Respiratory health-care facility visits due to short-term exposure	Normal (0.34, 0.06)	Levy et al. (2001)
Indoor air pollution				
PM_{10}	μg/m³	Asthma in children < 6	Lognormal (mean = 1.06, standard deviation = 0.0255) per 10 μg/m³	McCormack et al. (2009)
$PM_{2.5}$	μg/m³	Asthma in children < 6	Lognormal (mean = 1.03, standard deviation = 0.0204) per 10 μg/m³	McCormack et al. (2009)
Benzene	μg/m³	Asthma in children < 6	Lognormal (mean = 1.085, standard deviation = 0.0141) per 10 μg/m³	Rumchev et al. (2004)
Formaldehyde	μg/m³	Asthma in children < 6	Lognormal (mean = 1.003, standard deviation = 0.0005) per 10 μg/m³	Rumchev et al. (2002)
Radon	Bq/m³	Lung cancer mortality	Lognormal (1.0008, 1.000255) per Bq/m³	Darby et al. (2006)
		Lung cancer		Darby et al. (2006)
Environmental tobacco smoke (ETS)		Cardiovascular disease mortality	Male: Normal (1.25, 0.112) Female: Normal (1.35, 0.087)	Hill et al. (2007)
		Lung cancer mortality	Male: Normal (1.1, 0.255) Female: Normal (1.2, 0.204)	Cardenas et al. (1997)
		Lung cancer	Normal (1.25, 0.051)	Boffetta (2002)
		Cardiovascular disease	Normal (1.25, 0.041)	He and Whelton (1999)
		Lower respiratory tract infection in children <6	Normal (1.57, 0.148)	Li et al. (1999)
		Asthma in children <18	Normal (1.48, 0.816)	Vork et al. (2007)
		Leukemia	Normal (2.28, 0.576)	Kasim et al. (2005)
Bio-aerosols (mold)		Asthma in adultsx	Normal (1.54, 0.2704)	Jaakkola et al. (2002)
		Asthma in children 6–12	Normal (1.35, 0.0765)	Antova et al. (2008)
Incense use		Respiratory tract cancer mortality and morbidity	Normal (1.8, 0.306)	Friborg et al. (2008)

Occupational exposures			
Occupational carcinogens and leukemogens	Lung cancer mortality and morbidity	*Background*: 1 *Low exposure*: Normal (1.21, 0.0148) *High exposure*: Normal (1.77, 0.0316)	Driscoll et al. (2004b); (2005); Steenland et al. (1996, 2003); Nurminen and Karjalainen (2001)
	Leukemia mortality and morbidity	*Background*: 1 *Low exposure*: Normal (1.9, 0.15) *High exposure*: Normal (4, 0.2)	Steenland et al. (2003); IARC (1997); Lynge et al. (1997); Driscoll et al. (2004b)
	Malignant mesothelioma	A relative risk for malignant mesothelioma in exposed versus non-exposed population is not available since mesothelioma does not occur in populations that have not been exposed to asbestos. It has been estimated in the literature that 90% of mesothelioma in males and 25% in females is related to occupational exposure to asbestos.	Nurminen and Karjalainen (2001); Steenland et al. (2003)
Particulate matter	Asthma mortality and morbidity	Occupation group	Karjalainen et al. (2001, 2002); Kogevinas et al. (1999); Driscoll et al. (2004a)
		Administration Male: 1 Female:1 *Technical* Male: Normal (1.05, 0.0357) Female: Normal (1.06, 0.0204) *Sales* Male: Normal (1.1, 0.0663) Female: Normal (1.13, 0.0255)	

(continued)

Table C.2 (continued)

Exposure variable	Unit	Health endpoint	Relative risk	Sources of data
			Agriculture Male: Normal (1.41, 0.3112) Female: Normal (1.41, 0.3112) *Mining* Male: Normal (1.95, 0.2296) Female: Normal (1, 1.5408) *Transportation* Male: Normal (1.31, 0.0459) Female: Normal (1.22, 0.0459) *Manufacturing* Male: Normal (1.56, 0.0459) Female: Normal (1.33, 0.0306) *Services* Male: Normal (1.53, 0.1226) Female: Normal (1.41, 0.0255)	
		Chronic obstructive pulmonary disease (COPD) mortality and morbidity	*Background*: 1 *Low exposure* Male: 1.2 Female: 1.1 *High exposure* Male: 1.6 Female: 1.4	Korn et al. (1987); Driscoll et al. (2004a)
		Asbestosis and silicosis	100% attributable fraction (asbestosis and silicosis are almost solely caused by occupational exposure to asbestos and silica, respectively)	Driscoll et al. (2004a)

Noise	dB(A)	Hearing loss	Age groups *15–29 years* Moderately high (85–90 dB(A)): 1.96 High (>90 dB(A)): 7.96 *30–44 years* Moderately high: 2.24 High: 5.62 *45–59 years* Moderately high: 1.91 High: 3.83 *60–69 years* Moderately high: 1.66 High: 2.82 *70–79 years* Moderately high: 1.66 High: 2.82	Concha-Barrientos et al. (2004)
Climate change				
Heat exposure		Cardiovascular disease mortality and morbidity	Climate change scenario (Projection year) *UnmitB* 2007: Triangular (1, 1.001, 1.003) 2020: Triangular (1, 1.003, 1.005) 2030: Triangular (1, 1.003, 1.007) *S750* 2007: Triangular (1, 1.001, 1.002) 2020: Triangular (1, 1.002, 1.004) 2030: Triangular (1, 1.002, 1.004) *S550* 2007: Triangular (1, 1.001, 1.001) 2020: Triangular (1, 1.001, 1.003) 2030: Triangular (1, 1.002, 1.004)	McMichael et al. (2004)

(continued)

Table C.2 (continued)

Exposure variable	Unit	Health endpoint	Relative risk	Sources of data
Drinking water contamination				
Trihalomethanes (THMs)	μg/L	Bladder cancer (mortality and morbidity)	*Relative risk method: Drink chlorinated water versus not*	Morris et al. (1992)
			Male: Normal (1.24, 0.1378)	
			Female: Normal (1.17, 0.07143)	
			Relative risk method: Increasing RR with increasing exposure	Villanueva et al. (2003)
			Male:	
			(Exposure levels)	
			0: 1	
			0–1: 1	
			1–5: Normal (1.1, 0.0918)	
			5–25: Normal (1.26, 0.1071)	
			25–50: Normal (1.25, 0.1071)	
			>50: Normal (1.44, 0.1224)	
			Female: 1	
		Rectal cancer	Male: Normal (1.24, 0.1939)	
			Female: Normal (1.1, 0.102)	
		Colon cancer	Male: Normal (1.09, 0.1429)	
			Female: Normal (1.19, 0.1327)	
Microbial contamination		Gastroenteritis mortality and morbidity	Scenario II: Uniform (1, 4)	Fewtrell et al. (2007)
			Scenario Vb: Uniform (7.2, 10.2)	
Coastal water contamination				
Enterococci	CFU/100 mL	Gastroenteritis	Increase in relative risk for every log increase in enterococci concentration: Triangular (1.00, 1.34, 1.75)	Wade et al. (2003)

Produce and seafood contamination					
Methylmercury in seafood	mg/kg/day	Reference Dose (RfD): 0.0001			U.S. EPA (2002)
Pesticide residue on vegetables and fruit		Acceptable daily intake (ADI)	Chronic population adjusted dose (cPAD)	Acute population adjusted dose (aPAD)	ADI from WHO; cPAD, aPAD from U.S. EPA (1997, 2009)
Acephate		0.005	0.0012	0.005	
Bifenthrin		0.015	0.015	0.015	
Bromopropylate		0.030	0.2	0.2	
Chlorfenvinphos		0.002	0.0007	0.0007	
Chlorpyrifos		0.010	0.0003	0.005	
Dichlorvos		0.004	0.0005	0.008	
Dimethoate		0.010	0.0022	0.013	
Ethion		0.002	0.0005	0.001	
Fenitrothion		0.005	0.0013	0.130	
Cyhalothrin		0.020	0.001	0.005	
Malathion		0.020	0.07	0.140	
Methamidophos		0.004	0.0001	0.0001	
Methidathion		0.001	0.0015	0.0015	
Phenthoate		0.003	0.003	0.003	
Pirimicarb		0.020	0.02	0.020	
Procymidone		0.100	0.035	0.035	
Quintozene		0.007	0.003	0.003	
Vinclozolin		0.070	0.0012	0.006	

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Appendix D: Literature Review for Indoor Air Concentrations

At the time Chap. 5 was written, observational data on indoor air quality only were available for radon. Hence, for the other indoor air pollutants evaluated in the chapter, means and standard deviations of indoor air contaminant observations were collected from an exhaustive literature review (Tables D.1, D.2, D.3, D.4, and D.5, below), then used in the *UAE Environmental Burden of Disease Model* to simulate potential indoor concentrations in the UAE (see Appendix C). This appendix lists the studies included in the review.

Table D.1 PM_{10} input concentration data

References	Location	Notes	Mean (µg/m³)	Standard deviation (µg/m³)
Leaderer et al. (1999)	Virginia, connecticut	Air-conditioned homes, summer	28.9	18.7
		Non-air-conditioned homes, summer	33.3	14.2
		Kerosene heater, winter	44.36	30.37
		No kerosene heater, winter	25.71	21.12
Stranger et al. (2009)	Belgium		28.9	27.2
Breysse et al. (2005)	Baltimore	72-h samples from bedroom	56.5	40.7
		Smoking households	71.2	46.7
		Nonsmoking households	37.7	18.8
Simons et al. (2007)	Baltimore	Suburbs	23	17
		Inner city	57	41
Komarnicki (2005)	Vienna	Indoor, day	61	32
		Indoor, night	45	23
		Outdoor, day	34	11
		Outdoor, night	37	23
Williams et al. (2003)	North Carolina		27.7	19.6
Liu et al. (2003)	Seattle		14.1	6.6
			12.6	7.8
			19.4	11.1
			16.2	11.3
Suh (2003)	Los Angeles	Winter	30.6	21.2
		Summer to fall	29	14.7
Keeler et al. (2002)	Detroit		52.2	30.6
Williams et al. (2000)	Baltimore	Summer	13.5	5.9
Long et al. (2000)	Boston		19.4	12.7
Abt et al. (2000)	Boston		19.6	16.1
Rojas-Bracho et al. (2000)	Boston	Winter	37.3	23.2
		Summer	28.3	25.4

(continued)

Table D.1 (continued)

References	Location	Notes	Mean (μg/m³)	Standard deviation (μg/m³)
Khillare et al. (2004)	India	Summer	178.8	14.91
		Summer	171.19	12.32
Jo and Lee (2006)	Korea	Winter, lower floor	35	33
		Summer, lower floor	36	17
		Winter, higher floor	36	99
		Summer, higher floor	33	19
Houyin et al. (2005)	Beijing	Smoker's home	122	
			97	
Cheng et al. (2007)	Guiyang City, China	Smoking	130	35.6
		Nonsmoking	106	24.4
Lung et al. (2003)	Taiwan	Incense burning, unventilated room	723	
			601	
			385	
		Incense burning, ventilated room	178	
			136	
			119	

Table D.2 $PM_{2.5}$ input concentration data

References	Location	Notes	Mean (μg/m³)	Standard deviation (μg/m³)
Leaderer et al. (1999)	Virginia and Connecticut	Air-conditioned homes, summer	18.7	13.2
		Non-air-conditioned homes, summer	21.1	7.5
		Kerosene heater, winter	29.97	23.58
		No kerosene heater, winter	17.43	23.63
Stranger et al. (2009)	Belgium	Houses 1–15	36	13
		Houses 16–19	41	31
Baxter et al. (2007)	Urban Boston	Indoors	20.3	12.5
Breysse et al. (2005)	Baltimore	μg/m³	45.1	37.5
Simons et al. (2007)	Baltimore	Suburbs	12	8.6
		Inner city	45	37
Meng et al. (2005)	California		16.2	9.4
	New Jersey		20.1	15.5
	Texas		17.1	12.7
See et al. (2007)	Singapore	Cooking (μg/m³)	38.8	14.9
		Indoors	18.2	5.2
		Incense	142.6	16.3
		Cigarettes	227.2	37.3
Sarnat et al. (2002)	Boston	Spring–summer	12.5	7.1
		Fall–winter	7.2	2.5

(continued)

Table D.2 (continued)

References	Location	Notes	Mean (μg/m³)	Standard deviation (μg/m³)
Komarnicki (2005)	Vienna	Day	44	21
		Night	44	22
Wallace et al. (2006)	North Carolina	Indoors	19.4	16
Allen et al. (2007)	Seattle		8.25	2.31
Suh and Koutrakis (2004)	Los Angeles		17.6	11.4
Williams et al. (2003)	North Carolina		19.3	8.4
Liu et al. (2003)	Seattle	COPD patients	8.5	5.1
		Healthy	7.4	4.8
		Asthmatic	9.2	6
		Coronary	9.5	6.8
Suh (2003)	Los Angeles	Winter	16.9	11.7
	COPD patients	Summer–fall	18.1	11.1
Keeler et al. (2002)	Detroit		34.4	21.7
Long et al. (2000)	Boston		11.9	9.8
Abt et al. (2000)	Boston		13.9	15.2
Lachenmyer and Hidy (2000)	Birmingham, Alabama	Summer	16.1	9.6
		Winter	11.2	5.4
Rojas-Bracho et al. (2000)	Boston	Winter	17.2	13
		Summer	17.7	14.9
Wallace et al. (2003)	Seven U.S. cities		27.7	35.9
Simoni et al. (2004)	Italy	Urban winter	67	38
		Urban summer	47	20
		Rural winter	76	35
		Rural summer	50	21
Gotschi et al. (2002)	Athens, Greece		35.6	29.4
	Switzerland		21	16.7
	Finland		9.5	6.1
	Czech Republic		34.4	28.7
Zmirou et al. (2002)	France	Grenoble	28.7	26.3
		Paris	25.3	18.7
		Nice	20	10.2
Brown et al. (2008)	Boston	Winter	10.1	4.6
		Summer	12	7.3
Cortez-Lugo et al. (2008)	Mexico City	Winter	35	20
		Spring	31	15
		Summer	26	13
		Fall	26	13

Table D.3 Benzene input concentration data

References	Location	Notes	Mean (μg/m³)	Standard deviation (μg/m³)
Kim et al. (2001)	Birmingham, U.K.		13.9	13.8
Wallace (1996)	Virginia (winter 1987)	Day, living room	9.9	8.4
		Day, kitchen	11	16
		Night, kitchen	15	13.2
	Virginia (summer 1987)	Day, living room	6.5	5.7
		Day, kitchen	5.5	4.9
		Night, kitchen	6.5	7.3
	Virginia (summer 1990)	Day	13	21.9
		Night	18	28.5
	Virginia (winter 1991)	Day	26	23.7
		Night	24	23.9
	Virginia (spring 1990)	24-h	4.7	7.6
Sax et al. (2004)	New York	Winter	5.3	4.7
		Summer	1.7	1.2
	Los Angeles	Winter	4.9	2.8
		Fall	15	6.2
Van Winkle and Scheff (2001)	Chicago		4.1	4.8
Guo et al. (2003)	Hong Kong		4.4	2.5
Son et al. (2003)	Seoul, Korea		43.7	36.9
	Asan, Korea		20.3	12.6
Batterman et al. (2007)	Michigan		2	1.9
Bruinen de Bruin et al. (2008)	European Union cities		3.2	2.1
	Helsinki		1.7	
	Leipzig		1.3	
	Brussels		2.7	
	Arnhem		1.9	
	Budapest		5	
	Dublin		2	
	Nijmegen		1.5	
	Athens		6.5	
	Nicosia		6.3	

Table D.4 Formaldehyde input concentration data

References	Location	Notes	Mean (μg/m³)	Standard deviation (μg/m³)
Quackenboss et al. (1989)	United States		32	14
			47	27
Sax et al. (2004)	New York	Winter	12	4.7
		Summer	21	11
	Los Angeles	Winter	21	11
		Fall	16	6.2

(continued)

Table D.4 (continued)

References	Location	Notes	Mean (μg/m³)	Standard deviation (μg/m³)
Sherman and Hodgson (2004)	United States	New homes	40	15
Gilbert et al. (2005)	Canada		39	22.4
Park and Ikeda (2006)	Japan	New homes:	120.1	100.5
		1st year	134	93
		New homes: 2nd year	112	105
		New homes: 3rd year	86	58
		Older homes: 1st year	88	115
		Older homes: 2nd year	89	107
		Older homes: 3rd year	90	98
Al Rehaili (2002)	Saudi Arabia		29.5	2.5
			20.9	2.5
			20.9	4.9
			25.8	3.7
			34.4	9.8
			27	7.4
			28.2	11.1
			24.6	3.7
			4.9	17.2
			3.7	7.4
Gilbert et al. (2006)	Quebec City		32.7	15.3
Bruinen de Bruin et al. (2008)	Helsinki		28.6	9.3
	Leipzig		18.6	13.4
	Brussels		19.5	3
	Arnhem		30.7	17.8
	Budapest		24.4	8.2
	Dublin		14.4	4.9
	Nijmegen		30.1	24.2
	Athens		24.1	12.9
Guo et al. (2009)	Hong Kong		112.3	90.3
Li et al. (2008)	China		60	30
			60	20
			60	40
			40	40
			110	130
Mentese and Gullu (2006)	Turkey		109.3	134.9

Table D.5 Radon concentration data

Emirate	μ (Bq/m³)	Σ (Bq/m³)	Minimum (Bq/m³)	Maximum(Bq/m³)
Abu Dhabi	13.91	7.00	3.5	41.3
Sharjah	50.3	N/A	8	164

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Appendix E: Authors and Contributors

This book represents the synthesis of research carried out by a large, interdisciplinary team from several institutions and multiple nations between June 2008 and June 2011. The lead authors are responsible for weaving together the pieces prepared by the team. Nonetheless, this book would not have been possible without major contributions from each team member. The list below shows contributors to each chapter. Following this list are biographies of all of the authors and contributors

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Chapter 3: Assessing the Environmental Burden of Disease: Method Overview
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Chapter 4: Burden of Disease from Outdoor Air Pollution
Ying Li, Gavino Puggioni, Prahlad Jat, Mejs Hasan, Marc Serre, Kenneth G. Sexton, J. Jason West, Saravanan Arunachalam, Uma Shankar, William Vizuete, Mohammed Zuber Farooqui

Chapter 5: Burden of Disease from Indoor Air Pollution
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Chapter 6: Burden of Disease from Occupational Exposures
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Chapter 7: Burden of Disease from Climate Change
Richard N.L. Andrews, Leslie Chinery, Elizabeth S. Harder, J. Jason West

Chapter 8: Burden of Disease from Drinking Water Contamination
Gregory W. Characklis, Joseph N. LoBuglio

Chapter 9: Burden of Disease from Coastal Water Pollution
Gregory W. Characklis, Leigh-Anne H. Krometis, Joseph N. LoBuglio

Chapter 10: Burden of Disease from Soil and Groundwater Contamination
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Chapter 11: Burden of Disease from Produce and Seafood Contamination
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Author Biographies

Richard N.L. Andrews is professor and chair of the Department of Public Policy at the University of North Carolina–Chapel Hill (UNC), with joint appointments in Environmental Sciences and Engineering and City and Regional Planning, the Curriculum in Environment and Ecology, and the Carolina Institute for the Environment. He earned a bachelor's degree at Yale University in 1966, and both a master's degree in regional planning and a doctorate in environmental policy and planning at UNC. He has written on and taught environmental policy in the United States and elsewhere for more than 38 years, particularly the history of U.S. environmental policy; the National Environmental Policy Act and environmental impact assessment; the use of risk and cost-benefit analysis in government decision-making; the use of environmental management systems by businesses and government; and innovations in energy, environment, and climate change policies. He also has studied environmental policy in Cameroon, the Czech Republic, Nepal, Thailand, and the United Arab Emirates. Andrews serves as a member of the National Research Council's Committee on Human Dimensions of Global Change and its Panel on Addressing the Challenges of Climate Change through the Behavioral and Social Sciences, and the North Carolina Legislative Commission on Global Climate Change. He is a Fellow of the National Academy of Public Administration and of the American Association for the Advancement of Science, and a member of Sigma Xi, the Delta Omega Public Health Honor Society, and the Association for Public Policy Analysis and Management.

Saravanan Arunachalam is a research associate professor at the UNC Institute for the Environment who performs research related to air quality modeling and analyses to better understand the formation of air pollution at local and regional scales. He earned his doctorate and master's degree in chemical engineering from Rutgers University. During the past 10 years, he has received research funding as principal investigator or co-investigator from several federal, state or private organizations, including among others, the U.S. Environmental Protection Agency (EPA), Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), and National Science Foundation. Arunachalam is an expert air quality modeler with extensive experience in developing modeling applications for regulatory support using both existing and evolving regional air quality models. At UNC, he directs the FAA-funded Partnership for Air Transportation Noise and Emissions Reduction Center of Excellence, developing methodologies for performing a non-scale assessment of the impact of aviation emissions on air quality to support health-based risk assessment. His research for the FAA in the recent past has made critical contributions to understanding the impacts of aviation on air quality. Arunachalam is the principal investigator on an Emissions, Meteorological, and Air Quality Modeling Assistance contract with the U.S. EPA in support of developing their regulatory programs. He was the recipient of the 2008 FAA Centers of Excellence Faculty of the Year award.

Angela S. Brammer is a copy editor and graphic designer. She earned her master's degree in entomology and nematology and her bachelor's degree in journalism from the University of Florida. Prior to venturing into self-employment, she was a copy editor for the *Seattle Times*, the *Winston-Salem Journal*, and the *Independent Florida Alligator*. She also has taught journalism at the secondary and undergraduate levels in the United States and English at the secondary level in Japan. Under her advisement, Brammer's students won the Columbia Scholastic Press Association Gold Medal for yearbook and for literary magazine. Brammer also served as editor and graphic designer of the 2010 UAE *National Strategy and Action Plan for Environmental Health*, part of the UAE National Environmental Health Project.

Gary Cecchine is a natural scientist with RAND. He received his doctorate in biology and public policy at the Georgia Institute of Technology and a bachelor's degree in marine science and biology at the University of Tampa. Cecchine's research interests include biology, toxicology, environmental and energy policy, biological and chemical terrorism, sustainability, and management systems. He has a background in national security. Before joining RAND he was a management systems consultant and auditor for Det Norske Veritas and an officer in the U.S. Army. Cecchine's recent projects have involved the role of the military in emergency response, infectious disease and national security, countering bioterrorism threats, occupational health and wellness in the military, and establishing research funding organizations internationally

Gregory W. Characklis is an associate professor in the Department of Environmental Sciences and Engineering at UNC. His primary research interests involve integrated planning of water supply and treatment strategies through the consideration of both engineering and economic criteria. Specific areas of interest include the use of water transfers in mitigating drought risk, the impacts of water quality on resource value and allocation, and developing minimum cost strategies for water-related infrastructure. He also directs several laboratory and field studies that explore the role particles play in pathogen and indicator organism transport, research with particular relevance in the development of water quality models used to evaluate the location and severity of public health risks posed by microbial contamination. Prior to joining UNC, Characklis served as Director of Resource Development and Management at Azurix Corporation, where his responsibilities included assessing the technical and financial merits of water supply development projects throughout the United States, including most of the western states. Before entering the private sector, he spent 2 years in Washington, DC, as a fellow with the National Academy of Engineering, where he co-authored a study on industrial environmental performance metrics for U.S. manufacturers and conducted work related to market-based reform of environmental policy. Characklis earned his doctorate and master's degree in environmental science and engineering at Rice University and his bachelor's degree in materials science and engineering at Johns Hopkins University.

Chidsanuphong Chart-asa is a research assistant and doctoral student in the Department of Environmental Sciences and Engineering at UNC. His dissertation focuses on exposure mapping and environmental risk. Chart-asa earned his master's degree in information management on environment and resources from Mahidol University, Thailand. In 2008 he was granted a full scholarship by the Royal Thai Government to pursue doctoral study in a field that emphasizes environmental impact assessment or related fields. His past research interests have included geographical information systems and natural resource management.

Leslie Chinery earned her master's degree in environmental sciences and engineering at UNC, with a specialization in climate change and transportation policy. She has a bachelor's degree in environmental studies with a concentration in economics from the University of Tennessee. Chinery was a top graduate of the University of Tennessee in 2007 and received the Nissan-World Wildlife Fund Environmental Leadership Award in 2006. Chinery compiled a greenhouse gas emissions inventory of the University of Tennessee–Knoxville campus as an undergraduate honors thesis in 2007. For her master's thesis, Chinery modeled the potential emissions reductions and cost-effectiveness of various changes in the UAE's passenger vehicle fleet.

Aimee Curtright is an associate physical scientist in RAND's Pittsburgh office. She works primarily in the areas of energy and environmental policy and technology assessment. Presently she is working on a number of projects examining the environmental implications and technical challenges to the use of biomass for energy production. She has a doctorate in chemistry from the University of California–Berkeley and a bachelor's degree in chemistry from the University of Miami.

Christopher A. Davidson is the project manager for the UAE National Environmental Health Project at UNC. He puts his engineering and teaching background to work for optimizing the flow, storage, and presentation of information for the project. Davidson holds a master's degree in agricultural and biological engineering and a bachelor's degree in computer engineering from the University of Florida. Related work includes analyzing air quality and agricultural data in the UAE, establishing and maintaining electronic document repositories, and minimizing barriers to understanding scientific data for faculty and graduate students involved in this interdepartmental project.

Zeinab S. Farah earned her doctorate at The London School of Hygiene and Tropical Medicine, University of London, and her bachelor's degree in microbiology, majoring in medical microbiology at the University of East Anglia, United Kingdom. She worked in the medical services in Abu Dhabi for more than 20 years and assumed various responsibilities in the laboratory of one of the major hospitals in Abu Dhabi. In 2008 she was appointed as consultant and in-country coordinator for the UAE National Environmental Health Project at UNC.

Mohammed Zuber Farooqui received his doctorate in environmental engineering from Texas A&M University–Kingsville. His research interests include air quality modeling, emission inventory, meteorology and environmental information systems. Farooqui's dissertation focused on developing an air quality modeling framework for South Texas, and he was subsequently awarded first place for best overall doctoral research efforts in the TAMUS Annual Pathway Student Research Symposium in 2007. His research addresses ambient air quality issues within the UAE, specifically on enhancing estimates of dust emissions due to dust storms within the Arabian peninsula.

Tiina Folley is a research associate in the Department of Environmental Sciences and Engineering at UNC. She earned a master's degree in occupational hygiene from the University of Kuopio, Finland, and a master's degree in public health from UNC as a Fulbright Scholar. Before joining the occupational exposures team at UNC, Folley worked as a researcher at the Department of Food and Environmental Hygiene at the University of Helsinki. Her research interests include exposure assessment in environmental and occupational settings, and her current research involves quantitative modeling of occupational exposures to chemical hazards.

Sandra A. Geschwind is an environmental epidemiologist with more than 25 years of experience in the environmental health field. Her research areas at RAND have spanned studying the impact of endocrine disrupting chemicals on wildlife for the White House Office of Science and Technology Policy to evaluating the effects of pesticide exposures on Gulf War veterans. She is currently involved in helping set environmental health risk priorities for countries within the Middle East. Additionally, she serves as a reviewer for the American Journal of Epidemiology. Prior to her work at RAND, Geschwind led the Cancer Cluster Program at the Connecticut Department of Health. She also spent 5 years as a hazardous waste field investigator for the U.S. Environmental Protection Agency, Region IX. Geschwind earned her bachelor's degree at the University of California–Berkeley and both her master's degree in environmental health sciences and her doctorate environmental epidemiology from Yale University. She has been recognized and received awards for her work by the Environmental Protection Agency and the Agency for Toxic Substances and Disease Registry under the Centers for Disease Control.

Elizabeth S. Harder is a research assistant at UNC. Her research areas include renewable energy, climate change, economics, and energy policy. Previous graduate work included mapping water pollutant concentrations with geographic information systems software, conducting a life cycle analysis of solar photovoltaic energy, and analyzing the barriers of entry for renewable energy in the United States. Harder earned her master's degree in environmental science at UNC. Her thesis research focused on the economic feasibility, energy production benefits, green house gas mitigation, and air quality health benefits for constructing large-scale photovoltaic power plants in Abu Dhabi.

Mejs Hasan earned her master's degree in environmental sciences and engineering and her bachelor's degree in economics at UNC. She taught secondary math for 2 years in Philadelphia. Hasan is interested in geographic information systems, spatial analysis, contaminant flow in water and related health effects, and remote sensing.

Jianhui Hu is a research assistant and a doctoral fellow at the Pardee RAND Graduate School. Hu's research interests are in areas of public health, quality of care, environmental health, disease prevention, and drug abuse and HIV/AIDS. She is especially interested in global health care policies. Hu has been providing research assistance to a variety of health-care projects at RAND, focusing on qualitative research and program evaluation. Hu earned her bachelor's degree in business administration at Renmin University of China and her master's degree in public policy at Pepperdine University.

Prahlad Jat is a graduate research assistant and doctoral candidate in the Department of Environmental Sciences and Engineering at UNC. Jat's research focus is on space and time mapping and analysis of air pollutants, integration of economic and environmental models and the estimation of environmental burden of disease. Currently he works in the Bayesian Maximum Entropy lab on software updates and development. Jat holds a master's degree in biological engineering from the University of Arkansas and a master's degree in energy studies from the Indian Institute of Technology.

Leigh-Anne H. Krometis received her doctorate in environmental sciences and engineering from UNC and her master's degree in biological systems engineering from Virginia Polytechnic Institute and State University. Her dissertation research on the fate and transport of pathogenic microorganisms in urban stormflow won the 2009 Carolina Impact Award in recognition of its potential to protect the health of state residents. Following completion of her postdoctoral work on the *UAE Environmental Burden of Disease Model* in the summer of 2009, Krometis accepted a position as a research assistant professor in the Biological Systems Engineering Department at Virginia Polytechnic Institute. Her current work focuses on improving scientific understanding of the waterborne transport of indicator organisms and pathogens, particularly in support of nonpoint source regulatory programs.

Frederic J.P. Launay is senior advisor to the Secretary General, Environment Agency–Abu Dhabi (EAD). Dr. Launay began his career as a wildlife biologist in Saudi Arabia, where he established protected areas and conducted reintroduction programs for species such as the houbara bustard, Arabian oryx, and various species of indigenous gazelles. Subsequently, he moved to the National Avian Research Centre in Abu Dhabi to lead the organization in its work on the study and conservation of the houbara. In addition to his role at EAD, he also is director general of the Mohammed bin Zayed Species Conservation Fund, United Arab Emirates, and is chair of the International Union for Conservation of Nature/Species Survival Commission (IUCN/SSC) Reintroduction Specialist Group, United Arab Emirates. Launay earned his doctorate in wildlife management and ecology from the Université de Rennes. He earned his master's degree in ecology from the Université Paul Sabatier.

Ying Li is a postdoctoral research associate at the Department of Environmental Sciences and Engineering, UNC. She obtained her doctorate in public policy from UNC and her master's and bachelor's degrees in environmental sciences from Peking University. Her main research interests include environmental risk assessment and health benefits of pollution control policies. Since June 2008, she has been working to assess and prioritize various environmental health risks in the UAE. Her dissertation, which focused on the health benefits of traffic-related particulate matter control policies in Bangkok, was honored with the 2008 Association for Public Policy Analysis and Management Best Dissertation in Asia Award. Li has also won several prestigious academic awards in the past few years, such as the UNC Society of Fellows William Neal Reynolds Fellowship from 2002 to 2007, a student merit award for the Dose Response Specialty Group of Society for Risk Analysis in 2007, and the Graduate Education Advancement Board North Carolina Impact Award in 2008.

Joseph N. LoBuglio is a research specialist working with the Water Institute at UNC. LoBuglio has more than 10 years of experience in environmental management, water supply planning, and drinking water quality and additional expertise in uncertainty analysis and modeling. He has worked for the Massachusetts Water Resources Authority, the agency responsible for drinking and wastewater services in the Boston metropolitan area, helping develop processes for obtaining, managing, and reporting on river and marine water quality data associated with the Boston Harbor Cleanup Project. He has contributed to projects for the North Carolina state legislature promoting North Carolina's economic development through strategic water resource management. His recent work helped frame and analyze policy options for water allocation considering social, ecological, economic, and institutional systems. He has received a bachelor's degree in mechanical and aerospace engineering from Princeton University and a master's degree in aeronautics and astronautics from Stanford University. He is currently pursuing a doctorate in environmental sciences and engineering from UNC. His dissertation focuses on managing uncertainty in water resource and water quality models and means of using uncertain information to facilitate policy decisions. He has been a licensed professional engineer for more than 15 years.

Jacqueline MacDonald Gibson is an assistant professor in the Department of Environmental Sciences and Engineering at UNC. MacDonald Gibson conducts interdisciplinary research on the quantification of risks due to environmental contamination and on the quantitative comparison policy options for controlling environmental risks. She earned dual doctorate degrees from the Department of Engineering and Public Policy and the Department of Civil and Environmental Engineering at Carnegie Mellon University. She was previously a senior engineer at RAND. She also previously was associate director of the Water Science and Technology Board, a unit of the National Research Council of the National Academy of Sciences. In these previous positions, she studied a range of issues at the interface between environmental science and public policy. Research topics included assessment of options for improving potable water service to small U.S. communities, evaluation of regulatory requirements for the remediation of contaminated groundwater, assessment of research priorities for new environmental remediation technologies, evaluation of research on alternative methods for detecting and cleaning up landmines, and evaluation of risk assessment methods for sites contaminated with unexploded military ordnance. She has given briefings on these and other topics to a variety of federal officials, members of Congress and their staffs, and institutional advisory boards. She earned a master's degree from the Department of Civil and Environmental Engineering at the University of Illinois–Urbana-Champaign and a bachelor's degree (magna cum laude) in mathematics from Bryn Mawr College.

Melinda Moore is a public-health physician and epidemiologist who joined RAND as a senior natural scientist in 2005 following a 25-year career in government. She is RAND's associate director for global public health. Her research at RAND has focused on infectious disease surveillance, public-health and pandemic influenza preparedness, global health, military health, and environmental health. She led the RAND collaboration with UNC to develop the *National Strategy and Action Plan for Environmental Health* for the UAE. She is co-leading an ongoing project aimed at developing a tool for local civilian and military disaster preparedness planning and contributing to the development and implementation of the U.S. National Health Security Strategy. Moore earned her medical degree and master's degree in public health from Harvard University and is board certified in pediatrics and preventive medicine. Prior to joining RAND, she served at the U.S. Department of Health and Human Services for 25 years. She has worked in over 50 countries (including Saudi Arabia, Kuwait, Jordan, and the UAE) and lived in the Democratic Republic of the Congo for nearly 5 years. She is a retired medical officer of the U.S. Public Health Service.

Leena A. Nylander-French is a professor of occupational and environmental health at UNC. She obtained her doctorate in occupational and industrial hygiene from the Royal Institute of Technology in Sweden and joined the UNC faculty in 1997. Nylander-French has served as the director of the industrial hygiene program in the National Institute of Occupational Safety and Health Educational Resource Center since 2002. In 2006, she became the director of the Exposure and Biomarkers Research Core under the Center for Environmental Health and Susceptibility in the Gillings School of Public Health at UNC. She is certified by the American Board of Industrial Hygiene and has expertise in exposure assessment, biomarkers, and toxicokinetics. Nylander-French's research and teaching program is focused on understanding the consequences of human exposure to toxic substances. She is particularly interested in the relationship between dermal and inhalation exposure to hazardous environmental or occupational agents and the effect of individual genetic differences on the function of enzymes that detoxify these agents and that affect the development of disease. Nylander-French engages in research projects that are full-scale occupational and environmental studies incorporating both methods development in the laboratory as well as health surveys where individual exposures are monitored using a battery of exposure measurement techniques (inhalation, dermal, and biological monitoring) multiple times over an extended period. Her research group has pioneered approaches to quantitatively measure skin and inhalation exposures to toxicants. Additionally, her group has developed sophisticated exposure modeling tools using mathematical and statistical principles in an effort to standardize and improve exposure and risk assessment.

Sarah Olmstead is an assistant policy analyst at RAND and doctoral fellow at the Pardee RAND Graduate School. She works on a wide variety of topics, including energy and environment issues and conflict prevention. Her dissertation looks at the ways in which water management can affect economic development and local conflict. Prior to joining RAND, Olmstead was employed at the Science and Human Rights Program of the American Association for the Advancement of Science, where she worked on topics such as using geospatial technologies to identify large-scale human rights violations and assessing the effectiveness of transitional justice mechanisms. She also worked with the Parliamentary Monitoring Group and the Black Sash in South Africa and on issues of health and education with the Movimiento de Mujeres Dominico-Haitiana in the Dominican Republic. Olmstead holds a master's degree in physics from the University of Minnesota.

Gavino Puggioni is a postdoctoral researcher at Emory University in the Center for Disease Ecology and the Department of Biostatistics and Bioinformatics. His research interests include spatiotemporal models, stochastic differential equations, Bayesian statistics, environmental applications and econometrics. Puggioni received his doctorate in statistical science from Duke University. Before working for Emory, he was a research associate working with space-time analysis of air and water pollutants at UNC.

Hanine Salem is an associate director for Middle East Development at the RAND Education Unit. Much of her work is concerned with results-oriented public management methods such as strategic planning, organizational performance management and measurement, program evaluation, and quality improvement methods. Prior to joining RAND, Salem was a United National Development Programme Advisor to two Ministers of Administrative Reform in Lebanon. She introduced concepts of organizational performance management and measurement in the Lebanese public sector as well as developed a national performance-based reporting system. Her projects focused on the introduction of modern public management methods that promote transparency and accountability such as organizational performance measurement and strategic performance management. Salem is a doctoral candidate at the University of Strathclyde, where her research focus is on performance measurement and strategic planning in the public sector. She earned her master's degree in business communication from the University of Oklahoma and her bachelor's degree in business administration from Kuwait University.

Uma Shankar has more than 20 years' experience developing aerosol models for multiscale applications in particulate matter air quality and its feedbacks to climate, and has led a number of projects developing and applying CMAQ modeling and its prototype, MAQSIP, under funding from a diverse group of sponsors. Shankar is currently a co-investigator leading the CMAQ modeling studies recently funded by the UAE to support their national environmental health strategy. She participates with NASA contractors on providing training on the use of satellite data in air quality model evaluations through the Community Modeling and Analysis System Center, for which she also serves as research coordinator. She has served on EPA and NASA proposal peer review panels, and reviewed submissions to the Journal of Geophysical Research and Atmospheric Environment. Shankar earned her doctorate in physics at UNC and her master's degree in nuclear engineering at North Carolina State University.

Marc Serre is an associate professor at in the Department of Environmental Sciences and Engineering at UNC. He has a doctorate in environmental space/time geostatistics from UNC. His scientific expertise includes spatiotemporal modeling and mapping of air and water pollutants, exposure analysis and human health risk assessment, temporal geographic information systems, and the numerical development of advanced mapping functions. He has been extensively involved in many research efforts in advanced spatiotemporal modeling of ambient air and water pollution, with wide applications to local, regional, national, and international settings. He currently directs the UNC-BMElab research group at the University of North Carolina, which is dedicated to the numerical development of the Bayesian maximum entropy method of modern geostatistics and its worldwide application to exposure, disease, and risk mapping. As part of this effort, he has been an integral part of the development of a well-known BMElab package of spatiotemporal geostatistics used by scientists and researchers in more than 30 countries.

Kenneth G. Sexton is a research associate professor at UNC, where he earned his master's degree in public health and his doctorate in atmospheric chemistry. His research interests include the atmospheric chemistry of urban systems of nitrogen oxides and hydrocarbons, with a focus on understanding the reactive chemistry producing ozone and other air toxics, using smog chambers. Recent efforts have focused on developing and demonstrating new technological systems to interface smog chambers and in vitro toxicological exposure systems for evaluating the effects of photochemistry on urban air mixtures and the resulting toxic potential for health effects. Recent projects have compared the inflammatory toxicity potential of exhaust from traditional diesel and biodiesel exhaust, the toxicity and fate of 1,3-butadiene and related air toxics and their degradation products, and development of field deployable biological methods for estimating risk from exposure to urban mixtures.

Regina A. Shih is an associate behavioral/social scientist at RAND. Trained in epidemiology, her interdisciplinary research focuses on the influence of particulate matter and the built environment on cardiovascular disease. She previously published research on the relationship between lead exposure and neurological functioning in adults and on the methodological issues of measuring cumulative lead dose. She is currently a co-investigator on a grant from the National Heart, Lung, and Blood Institute to examine the impact of neighborhood socioeconomic status, racial/ethnic composition, economic segregation, and particulate matter air pollution on the incidence of cardiovascular disease among women. Prior to her work at RAND, she was a postdoctoral fellow at the National Institute of Child Health and Human Development, where she helped design the scientific protocol for measuring nonlevel social, structural, and chemical environmental risk factors for poor neurobehavioral and developmental outcomes across the lifespan, for which she received a Director's Merit Award. She teaches measurement methods and structural equation modeling in the Department of Environmental and Occupational Health at the George Washington University School of Public Health and Health Services. Shih earned her doctorate in mental health from the Johns Hopkins Bloomberg School of Public Health and her bachelor's degree in neuroscience from Johns Hopkins University.

Stephanie Soucheray-Grell is an administrative support specialist at UNC. She has been the main assistant to the UAE National Environmental Health Project, as well as the USAID WaterSHED initiative. Before joining the Department of Environmental Sciences and Engineering, Soucheray-Grell worked as a freelance editor and English tutor in Germany, a production assistant for Minnesota Public Radio, and a newspaper reporter. She received her bachelor's degree in English and history from St. Olaf College.

Jens T.W. Thomsen is Section Head, Occupational and Environmental Health, for the Health Authority–Abu Dhabi (HAAD). Thomsen's primary role at HAAD, which he joined in 2007, is to lead and oversee the strategy development, planning, implementation and monitoring and evaluation of public health activities in the areas of occupational and environmental health and safety, injury prevention, and road safety in the community and emirate of Abu Dhabi. His and his team's responsibilities include developing the strategy and action plan for these areas; collecting and analyzing data and statistics; planning, conducting, monitoring and evaluating public health interventions; supporting targeted research; capacity building; developing policies and standards; organizing mass media and community outreach programs; and coordinating with stakeholders. Thomsen is a medical doctor, public health specialist, and German Medical Board-certified specialist in clinical microbiology and infectious disease epidemiology. He is also German and U.S. board-certified in health-care infection control. He holds a master's degree in public health from Emory University, with a major in epidemiology, and has 17 years of medical and public health experience in the United States, Germany, and the UAE.

Chris B. Trent received her master's degree in industrial hygiene from UNC and her bachelor's degree in biology from James Madison University. She is currently pursuing her doctorate in environmental health and risk assessment at UNC. Trent has more than a decade of practical work experience in the environmental and occupational health fields, including numerous years conducting field-level exposure assessments. She has held management positions for nonprofit organizations focusing on overarching programmatic issues in the occupational and environmental health fields. More recently, she worked for the U.S. EPA on issues related to the role of exposure science in environmental health assessments, with specific application to broad programs such as outdoor air quality standards. Trent's research interests include the characterization of exposures and related uncertainties for health-based risk assessments, and capitalizing on the role of science in policy decision-making.

William Vizuete is an assistant professor in the Department of Environmental Sciences and Engineering at UNC. He is an expert on the use of computer models in understanding the role of atmospheric chemistry in the formation of air pollutants. His current research projects include assessing air quality in the UAE and evaluating the regional scale air quality models used by regulators to guide air quality policy in Houston, Texas. He is also the recipient of a Gillings Innovation Lab award to fund a project that uses UNC outdoor smog chamber facilities, biosensors, and atmospheric modeling to understand the changing toxicity of chemically aged atmospheric pollutants. He has developed several advanced diagnostic tools that are currently being used to improve the model's ability to simulate the chemistry of the upper troposphere. He has also worked closely with the UNC Institute for the Environment in developing inputs for and evaluating regional scale atmospheric models. Vizuete received his doctorate and master's degrees in chemical engineering from the University of Texas–Austin and his bachelor's degree in chemical engineering from the University of Missouri–Rolla.

J. Jason West is an assistant professor in the Department of Environmental Sciences and Engineering at UNC, where he performs interdisciplinary research addressing air pollution and climate change. West recently worked as a research scientist at Princeton University and prior to that, at the U.S. EPA in Washington, D.C., under a fellowship from the American Association for the Advancement of Science. He has a doctorate from Carnegie Mellon University, earned jointly between civil and environmental engineering and engineering and public policy, a master's degree in environment and development from the University of Cambridge, a master's degree in civil and environmental engineering from Carnegie Mellon, and a bachelor's degree in civil and environmental engineering from Duke University. West is interested broadly in the relationships between air pollution and climate change and their relevance for environmental science and policy. Using computer models, he has investigated the effects of changes in emissions on global air quality, the international transport and health impacts of air pollutants (focusing on ozone and particulate matter), and the radiative forcing of climate. As a postdoctoral researcher at the Massachusetts Institute of Technology and a visiting scientist at the Mexican National Institute of Ecology, West conducted computer modeling of air pollution and analyzed the integrated mitigation of greenhouse gases and air pollutants in Mexico City. West has also been an expert consultant to the World Bank, studying source apportionment techniques for identifying the sources of urban particulate matter in developing nations. Recently, West's research has emphasized quantification of the climate, air quality, and human health benefits of reductions in global emissions of methane, black carbon, and carbon monoxide.

Henry H. Willis is an expert in environmental and health risk assessment, risk communication, and risk management. He has recently reviewed existing risk assessment tools used across government for managing former U.S. Army lands contaminated with chemicals and unexploded ordnance and developed a focus-group process for incorporating public participation into comparative risk management. He has also led the risk assessment task in the UAE National Environmental Health Project. Willis serves on the editorial board of *Risk Analysis* and is the secretary of the Society for Risk Analysis. He earned his doctorate in engineering and public policy at Carnegie Mellon University and holds a master's degree in environmental science from the University of Cincinnati as well as a bachelor's degree in chemistry and environmental studies from the University of Pennsylvania.

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