Chapter 1
Introduction

It is simple, really. Human health and the health of ecosystems are inseparable.[1]

— Gro Harlem Brundtland
Director General, World Health Organization, 1998–2003

We cherish our environment because it is an integral part of our country, our history and our heritage. On land and in the sea, our forefathers lived and survived in this environment… They were able to do so only because they recognized the need to conserve it, to take from it only what they… needed to live and to preserve it for succeeding generations.[2]

— H. H. Sheikh Zayed Bin Sultan Al Nahyan
President of the United Arab Emirates, 1971–2004
Ruler of Abu Dhabi Emirate, 1966–2004

Abstract The environmental burden of disease assessment approach described in this volume is illustrated through its application to the United Arab Emirates (UAE). The UAE occupies 83,600 km^2 along the Arabian Gulf, with an estimated 2011 population of about 7.5 million. The UAE supports a diversified modern economy and, as a result, faces environmental and public health problems similar to those of other industrial nations. The methods we illustrate build upon a series of guidelines on environmental burden of disease assessment published by the World Health Organization beginning in 2003. Although many countries have employed these guidelines to assess the burden of disease due to individual environmental risk factors, the comprehensive environmental burden of disease assessment across multiple exposure pathways and contaminants described in this book is the first of its kind.

[1] Address to the National Press Club, Canberra, Australia, October 17, 2000. Available at http://www.who.int/director-general/speeches/2000/english/20001017_camberra.html.

[2] From Sheikh Zayed in Quotes, UAE Interact, February 11, 2005. Available at http://www.uaeinteract.com/docs/Sheikh_Zayed_in_quotes/18411.htm.

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This project was intended to serve as a model for other nations wishing to conduct similar assessments. The basic methods can be applied to any nation or subnational geographic unit (such as a state or city). Furthermore, much of the information on relationships between exposures to pollutants and the probability of becoming ill is, and will increasingly be, relevant across the globe. These relationships are specified in the *UAE Environmental Burden of Disease Model*, a multilayered computer simulation tool constructed in *Analytica* software. Other countries can adopt this model's structure, along with much of the input data, as a starting point for their own environmental burden of disease assessments. Also relevant to other nations is the process we used to prioritize risks to include in this analysis—a process that involved systematic consultations with environment and health stakeholders. Other nations can save considerable time and resources in carrying out similar assessments by using the approaches and modeling methods described in this book.

Keywords United Arab Emirates • Environmental burden of disease assessment • Environment Agency–Abu Dhabi • UAE Environmental Burden of Disease Model • Environmental risks to public health • Analytica • Multilayered environmental simulation computer modeling

The Purpose of This Report

Civilizations have long understood the inseparable connections between environmental quality and human health. Ancient Assyrian medical texts—dating from 2000 to 1000 BC and unearthed in modern-day Iraq—include numerous passages emphasizing environmental conditions as causative factors in disease. One volume (preserved on a clay tablet) advised, "He must not go into the lowlands by the river or an infectious disease will infect him." Others mention patients exposed to contaminated river water prior to the onset of medical symptoms (Scurlock and Anderson 2005).

Although the ancients understood environmental risks to health in a qualitative sense, the tools to quantify these risks are new relative to the time span of human history (see Box 1.1). Late-twentieth-century research in environmental and health sciences, along with modern computing tools, make it possible to estimate the number of deaths and illnesses attributable to environmental pollution in a population exposed to such pollution. In this book, we show how to combine environmental and public health data, modern literature on environmental causes of disease, and sophisticated computing tools to determine the number of premature deaths and illnesses that could be prevented if exposure to modern pollutants were reduced. The results provide an indication of the pollutants and routes of exposure to these pollutants that induce the greatest health burden in the population under study. Hence, these results can be used to identify high-impact opportunities for improving public health through environmental interventions.

The environmental burden of disease assessment approach described in this volume is illustrated through its application to the United Arab Emirates (UAE).

Box 1.1 Historical Development of Tools for Environmental Burden of Disease Assessment

Quantifying the number of deaths and illnesses attributable to environmental pollution as is carried out in this book would not be possible without (1) an understanding of probability theory, (2) instruments to measure pollutant concentrations in the environment, (3) mathematical relationships (derived from epidemiologic and toxicologic studies) linking these measured concentrations to specific illnesses, (4) baseline public health data, and (5) computing tools that allow simulation of population exposures to pollutants under different scenarios, such as under different levels of pollutant emissions to the environment. None of these tools existed prior to the Renaissance. And, while Renaissance-era discoveries laid the foundation the techniques employed in this book, much of the knowledge underlying the analysis presented here was unavailable before the end of the twentieth century.

Probability theory—which provides the foundation for modern, quantitative risk assessment—is a product of Renaissance-era mathematicians (Bernstein 1996). Prior to the Renaissance, decision-makers faced with risky choices and uncertainties consulted with priests or other religious authorities, rather than employing the tools of probability to quantify risks. In his authoritative history of risk assessment, *Against the Gods: The Remarkable Story of Risk*, Bernstein writes,

> The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk: the notion that the future is more than a whim of the gods. … Until human beings discovered a way across that boundary, the future was a mirror of the past or the murky domain of oracles and soothsayers who held a monopoly over knowledge of anticipated events (Bernstein 1996).

In addition to probability theory, quantitative environmental health risk assessment requires instruments to measure pollutant levels, mathematical relationships linking exposure to measured contaminants to specific health effects (derived from toxicologic and epidemiologic studies), and baseline public health statistics. Before the nineteenth century, a lack of instrumentation for measuring pollutant levels and a lack of systematic public health record-keeping posed a major obstacles to making progress in understanding the relationships between exposure to environmental hazards and disease (Covello and Mumpower 1985). Although the science of toxicology dates to the sixteenth century, when the physician Paracelsus established the fundamental principle of toxicology (the dose makes the poison), and although historians have identified early epidemiologic investigations dating from the sixteenth century, research to quantify the relationship between the dose of a contaminant received and the probability of becoming ill is quite recent (Graham 1995). Covello and Mumpower note, "It is surprisingly easy to forget that it was not until the work of Pasteur in the late 19th century that scientists

(continued)

Box 1.1 (continued)

first began to comprehend adequately the concept of infection or the causal relationship between the environment and biological agents of infectious disease." For chemicals, dose-response assessment emerged in the last quarter of the twentieth century with the "convergence of interest in the carcinogenic effects of radiation and chemicals" (Graham 1995).

A final ingredient for the type of analysis presented in this book is computing tools for simulating human exposure to pollutants at different geographic scales and under different pollution scenarios. Such tools became widely available only with the advent of personal computers toward the end of the twentieth century.

The UAE occupies 83,600 km^2 along the Arabian Gulf (see Fig. 1.1), with an estimated 2011 population of about 7.5 million. The UAE supports a diversified modern economy and, as a result, faces environmental and public health problems similar to those of other industrial nations.

The methods we illustrate build upon a series of guidelines on environmental burden of disease assessment published by the World Health Organization (WHO) beginning in 2003 (Prüss-Ustün et al. 2003). Although many countries have employed these guidelines to assess the burden of disease due to individual environmental risk factors, the comprehensive environmental burden of disease assessment across multiple exposure pathways and contaminants described in this book is the first of its kind.

The UAE launched its environmental burden of disease assessment project with the encouragement of the WHO Centre for Environmental Health Activities in Amman, Jordan, in June 2008. The project was funded through the Environment Agency–Abu Dhabi (EAD) and involved collaboration of many other government agencies in the UAE. In addition to helping the UAE's leaders identify the leading environmental risks to UAE public health as part of a process of updating environmental policies, this project was intended to serve as a model for other nations wishing to conduct similar assessments. Hence, this book fully documents the burden of disease assessment process as implemented in the UAE. The quantitative assessments were conducted by an international team of environment and health scientists commissioned by EAD. We hope this documentation will enable other nations to conduct similar assessments, building on the methods and data we illustrate.

The basic methods in this book apply to any nation or subnational geographic unit (such as a state or city). Furthermore, much of the information on relationships between exposures to pollutants and the probability of becoming ill is, and will increasingly be, relevant across the globe. These relationships are specified in the *UAE Environmental Burden of Disease Model*, a multilayered computer simulation tool constructed in *Analytica* software (version 4.1, Lumina Decision Systems). Appendix B explains how to use this model, and Appendix C documents the model

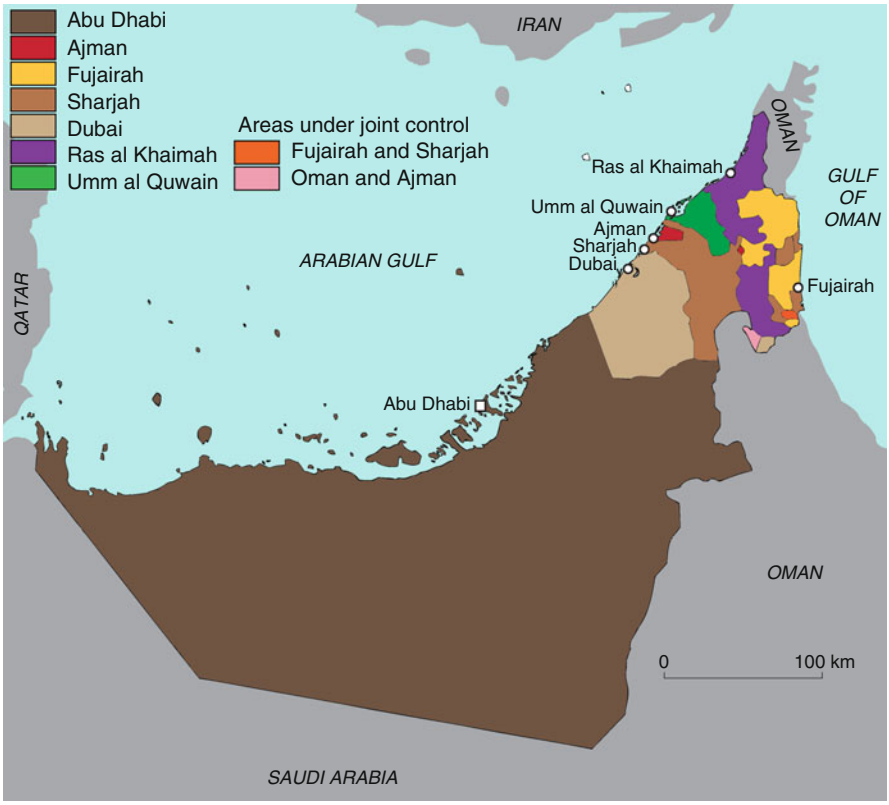

Fig. 1.1 The UAE comprises seven emirates and borders Saudi Arabia and Oman on the Arabian Gulf. From bottom left, the emirates are Abu Dhabi, Dubai, Sharjah, Ajman, Umm al Quwain, Ras al Khaimah, and Fujairah

input parameters. Other countries can adopt this model's structure, along with much of the input data, as a starting point for their own environmental burden of disease assessments. Also relevant to other nations is the process we used to prioritize risks to include in this analysis—a process that involved systematic consultations with environment and health stakeholders. Other nations can save considerable time and resources in carrying out similar assessments by using the approaches and modeling methods described in this book.

How This Book Is Organized

This chapter briefly reviews the rationale for conducting national-level environmental burden of disease assessments. It then provides background information on the UAE and why it serves as a particularly useful case study nation for environmental burden of disease assessment for modern, industrial nations and emerging

economies. Chapter 2, "Prioritizing Environmental Risks to Health," describes the process used to identify the environmental risks to include in this volume. Those priority risks form the basis for the remaining chapters. Chapter 3, "Assessing the Environmental Burden of Disease: Method Overview," documents our general approach for estimating the environmental burden of disease. Each of the eight subsequent chapters examines the estimated burden of disease due to the environmental risks that UAE stakeholders identified as priorities:

- inhaling polluted outdoor air (Chap. 4),
- inhaling polluted indoor air (Chap. 5),
- inhaling or absorbing (via the skin) contaminants or hearing excess noise in workplaces (Chap. 6),
- experiencing excess heat exposure due to global climate change (Chap. 7),
- drinking polluted tap water (Chap. 8),
- swimming in polluted coastal water (Chap. 9),
- ingesting contaminants from polluted soil and groundwater (Chap. 10), and
- eating produce contaminated with pesticides or fish contaminated with heavy metals (Chap. 11).

Each risk chapter includes

- background information on the nature and sources of the environmental problem (in general and in the UAE in particular),
- the expected key health effects of exposure to the relevant pollutants (to humans in general),
- specific details on the construction of the module within the *UAE Environmental Burden of Disease Model* that simulates the risk addressed in the chapter,
- the estimated burden of disease due to that risk factor (including sensitivity and uncertainty analysis),
- information on future data needed to improve the disease burden estimate, and
- overall conclusions.

Chapter 12 ("Applying Environmental Burden of Disease Models to Strengthen Public Policy") summarizes the overall estimates of the environmental burden of disease from all these risks, identifies the leading causes of environmentally related diseases, recommends priorities for collecting data to improve future burden of disease estimates, and discusses important steps for increasing the capacity of UAE institutions to collect additional environmental data and update the burden of disease estimates in the future.

Why Assess a Nation's Environmental Disease Burden?

The motivation for conducting national-level environmental burden of disease assessments emerged from a WHO project to compile global statistics on the incidence, prevalence, survival, and long-term impacts on quality of life of all of the

predominant diseases affecting human populations. The World Bank commissioned this global assessment in the 1980s as a source of impartial information to inform cost-effectiveness analyses of its public health programs (Stein et al. 2007). In 1990, the WHO published its results, Global Burden of Disease 1990. This study provided the first-ever comprehensive global overview of morbidity and mortality due to 130 diseases and conditions. In a retrospective analysis of the project's impacts, a prominent demographer who tracks global trends in population health compared the study's influence to the invention of the microscope:

> Like the microscope, the Global Burden of Disease 1990 [report] brought diseases into much sharper focus. … As a sophisticated measuring device, it could not be ignored by any serious student of epidemiology or development (Preston 2006).

In a brief history of the global burden of disease assessment process, Stein notes that the project's results enabled policymakers—previously frustrated "by fragmented, incomplete, incomparable, and often advocacy-driven health information"—to "directly compare the burden of different diseases, set priorities, and evaluate the cost-effectiveness of their interventions."

Having quantified the global disease burden, the WHO recognized that another layer of information—beyond an understanding of global disease patterns—was needed to inform decisions about strategies to improve global public health. In addition to understanding how disease patterns vary by country and region, policymakers also needed to understand the causes of these diseases, in order to determine the interventions with the greatest potential for improving the human condition. Murray and co-authors, investigators in the global burden of disease project, have written, "Data on disease or injury outcomes alone, such as death or hospitalization, tend to focus on the need for palliative or curative services. Reliable and comparable analysis of risks to health, on the other hand, is key for preventing disease and injury" (Murray et al. 2003).

Subsequently, WHO employed crude population and environmental measures collected at low resolution to develop the first approximation of the global environmental burden of disease. This analysis concluded that environmental risk factors contribute to 24% of the global disease burden (Prüss-Ustün and Corvalán 2007). Subsequently, the WHO identified the need for higher-resolution environmental burden of disease studies (e.g., at the national or subnational level)—ones that would accurately reflect local conditions and recognize the global variation in environmental conditions and baseline disease patterns. As a result, the WHO developed a series of guidebooks with methods for computing the burden of disease for several different environmental risk factors, including outdoor air pollution; indoor smoke from solid fuels; occupational carcinogens, airborne particulates, and noise; solar ultraviolet radiation; climate change; water, sanitation, and hygiene; lead; and mercury (see Chap. 3). The project we document in this book is the first comprehensive national-scale implementation of these guidelines. For some exposure pathways and contaminants, detailed WHO guidelines were not available, and in those cases we adapted the WHO's methods to the particular risk.

A comprehensive environmental burden of disease assessment such as that documented in this book can serve many purposes (Prüss-Ustün et al. 2003):

- ***Prioritizing environmental risks to health***: Governments rarely, if ever, have sufficient financial and other resources to tackle all health risk factors at once or to reduce levels of all contaminants in all media to concentrations known not to cause harm. An environmental burden of disease assessment can identify combinations of contaminants and exposure pathways with the most substantial public health impacts, and this information can be considered in planning which problems to address first. Of course, priority-setting requires not only quantitative information about disease burden but also value judgments because values-based trade-offs are inevitable when deciding to fund some programs but not others, or to emphasize some risks over others. Chapter 2 describes a method for combining the quantitative output of environmental burden of disease assessments with a stakeholder deliberation process in order to set priorities.
- ***Assessing trends in environmental impacts on health over time***: Environmental burden of disease assessments, if performed regularly, can serve as indicators of a nation's progress toward reducing the preventable environmental burden of disease.
- ***Predicting the health benefits of environmental interventions***: Environmental burden of disease assessments also can be used to predict the public health benefits of interventions (e.g., increasing wastewater treatment capacity, promoting fuel-efficient vehicles), to improve environmental quality, and/or reduce human exposure to environmental contaminants. This information, in turn, can be used to compare the costs and benefits of alternative environmental interventions a country may be considering.
- ***Identifying high-risk populations***: If performed at sufficient geographic and population resolution, environmental burden of disease assessments can highlight locations and population subgroups that may be at elevated risk due to environmental exposures, in comparison to the national average. Chapter 4 illustrates this potential by highlighting regions of the UAE at highest risk for health effects brought on by air pollution.
- ***Assessing health under future environmental scenarios***: Building on international research to develop future climate change scenarios, environmental burden of disease assessments can predict how a nation's disease burden may shift in response to global warming; Chap. 7 illustrates such an analysis. These assessments also can be used to illustrate how population behavior changes may affect health risks due to environmental exposures. For example, Chap. 9 illustrates how changing recreational swimming behaviors affects the predicted burden of disease due to exposure to fecal pathogens in contaminated marine waters, and Chap. 11 illustrates how food consumption behaviors affect risks of methylmercury exposure.
- ***Setting environment and public health research priorities***: The process of preparing a comprehensive national environmental burden of disease assessment inevitably reveals gaps in environmental and public health data, as well as in scientific knowledge. Thus, the results can be used to guide decisions about which data collection initiatives and research topics to fund. For example,

Chap. 8 illustrates the need for data on concentrations of microbiological and chemical in the UAE's potable water distribution system, in order to assess more accurately the burden of disease due to drinking water contamination.

- ***Informing environmental and public health policy decisions***: Ultimately, environmental burden of disease assessments provide a tool that governments can use to help chart a path toward sustainable development.

  Despite these benefits, few nations have undertaken environmental burden of disease assessments across multiple exposure pathways, and, as Chap. 2 describes, none has undertaken an analysis as comprehensive as the study presented in this book.

Overview of the UAE

The UAE consists of seven emirates (Fig. 1.1) united under a federal constitution but retaining substantial governance autonomy. Table 1.1 shows population data for the emirates from the end of 2007. The emirate-level population data were obtained from the UAE Ministry of the Economy at the launch of the project described in this book (in June 2008). These estimates were based on the 2005, the most recent confirmed census data in the UAE. Recent (2011) population projections from the UAE National Bureau of Statistics suggest that the net rate of migration into the country may have exceeded previous projections. Accordingly, to estimate the 2011 population, the bureau adopted an exponential growth model, which resulted in the estimated 2011 population of 7.5 million, an increase of 66% over the 2007 estimate. According to the National Bureau of Statistics, the current distribution of this population by emirate is not known because of uncertainty over where expatriates reside:

> The resident data … are classified by place of visa issuance or cancellation, therefore the net migration by emirate does not reflect the actual geographical distribution of the population and efforts are underway to find an alternative methodology depending on other sources to find the estimate of the population by emirate (UAE National Bureau of Statistics 2011).

The analyses presented in this book use the 2007 estimates, which are based on the 2005 census and the population projections available when this project began (in June 2008). Notably, total population estimates for the UAE vary by source. For example, the CIA World Factbook estimates the 2011 UAE population as 5.1 million. These discrepancies reflect the difficulties of conducting an accurate census in a nation with a large transient population. In the UAE, this transient population consists of expatriate workers who fill the demand for the variety of jobs, from construction laborer through financial manager, created by the UAE's economic boom. As is notable in Table 1.1, the majority (81%) of the UAE population consists of expatriate workers.

The UAE formed in 1971 from the Trucial States, a protectorate established by England early in the nineteenth century to protect British trade routes to India (Rizvi 1993). England held power until 1971, when it withdrew from the Arabian Peninsula of its own volition. Until the discovery of oil in Abu Dhabi in 1958, the Trucial States were among the Arab world's poorest inhabitants (Rizvi 1993), with "no

Table 1.1 UAE population, end of 2007

Emirate	Citizens	Expatriates	Total
Abu Dhabi	372,000	1,121,000	1,493,000
Dubai	141,000	1,337,000	1,478,000
Sharjah	143,000	739,000	882,000
Ajman	41,000	183,000	224,000
Umm Al Quwain	16,000	36,000	52,000
Ras Al Khaimah	91,000	131,000	222,000
Fujairah	60,000	77,000	137,000
Total	864,000	3,624,000	4,488,000

Fig. 1.2 Maqta Crossing in Abu Dhabi, 1965, before the building of the first bridge at the site. The sandbar in the distance is the site of downtown Abu Dhabi today (photo courtesy of George Bell, http://maribelecosystems.com/OldAbuDhabiandDubaiPhotos.html)

electrical grid, indoor plumbing, telephone system, public hospital, or modern school" (Walters et al. 2006). Abu Dhabi City, the capital, had no paved roads or even a paved runway for its airport (see the historic image in Fig. 1.2).

In spite of—or perhaps especially because of—its late start toward development, the UAE is an ideal demonstration nation for comprehensive environmental burden of disease assessment. The UAE transitioned from one of the world's poorest to one of the most highly developed nations in less than a generation—a time frame difficult to comprehend even for Emiratis who have lived through this transformation (Fig. 1.3). As a result, the UAE is a microcosm for studying the effects of industrial development on environmental health. In addition, its modern governmental institutions are still evolving—a condition that affords these institutions more flexibility to address environmental problems in creative ways than

Fig. 1.3 Downtown Abu Dhabi, 2011 (photo by Wouter Kingma)

long-established bureaucracies in nations that followed a slower, more traditional development trajectory. As well, care for the environment is a deep-rooted cultural tradition, as illustrated in the quote by the nation's late founder, H.H. Sheikh Zayed Bin Sultan Al Nahyan, on the first page of this chapter. Moreover, the leadership has a history of addressing problems of all sorts—including environmental problems—in innovative ways.

The UAE's Development: A Brief History

When the British withdrew, Sheikh Zayed bin Sultan Al Nahyan united several tribes of the Trucial States to form the UAE. Since then, it has developed at an unprecedented rate, fueled by its oil resources and guided by Sheikh Zayed's ambitious vision. All told, the UAE has about 8% of known global oil reserves and 3.4% of natural gas reserves (Davidson 2009). From the beginning, Sheikh Zayed decided that this vast oil wealth should enhance the living standard of all the new nation's citizens, rather than benefiting only the ruling elite. First priorities for his development vision included establishing modern transportation networks, building homes for all citizens, and educating citizens, who were mostly illiterate when the country was founded (Walters et al. 2006).

As a result of Sheikh Zayed's visionary early investments, only 40 years after its founding the UAE ranks among the top echelon of the world's nations, in the category "very high human development" on the Human Development Index, a United Nations

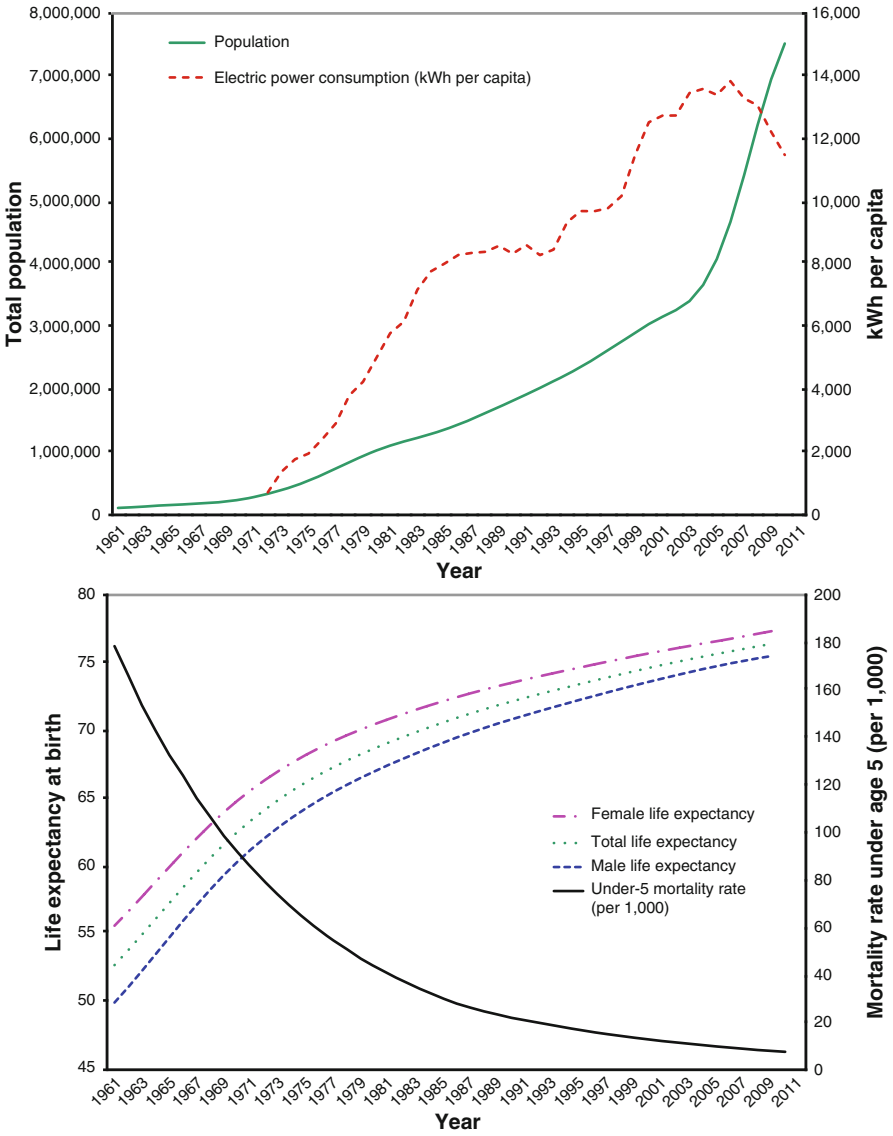

Fig. 1.4 Development in the UAE has led to dramatic population increases (*top*), decreases in infant mortality (*bottom*), and increases in life expectancy (*bottom*). Data adapted from the World Bank Databank (http://data.worldbank.org/country/united-arab-emirates)

measure of prosperity that considers population longevity, educational attainment, and income (Walters et al. 2006). Life expectancy has increased from less than 45 in the 1950s to 75.9 in 2010, and infant mortality rates have plummeted (Fig. 1.4). The UAE's gross national income per capita in 2010 was $59,993—the third highest in the world behind Lichtenstein and Qatar (United Nations Development Program 2011).

Were its wealth concentrated solely in the oil industry, the UAE might not be a useful case study for other nations to emulate in environmental burden of disease assessment, since it would lack industrial diversity and could proceed with simpler solutions to decrease pressure on the environment. However, also due to Sheikh Zayed's vision, the nation's leaders decided early on to broadly diversify the economy, recognizing that oil would not last forever and that relying on oil as the sole basis for development would leave the nation highly vulnerable to oil price shocks (Davidson 2009). Hence, the government invested substantial funds in launching state-owned, export-oriented manufacturing companies in a variety of industries and also developed industrial zones to lure foreign investment. The UAE is home to major industrial facilities that produce metals, plastics, fertilizers, petrochemicals, cement, microelectronics, and many other products. While crude oil revenue accounted for 68% of the UAE's economy in 1975, the oil sector's share of GDP dropped to less than 22% by 1998 (Walters et al. 2006).

The UAE also has invested in amenities to attract tourists and consumers. Abu Dhabi is constructing Middle East versions of the Guggenheim and Louvre, both designed by world-renowned architects. Dubai has constructed deluxe five-star hotels on artificial islands, water parks, indoor snow ski parks, and many other amenities designed to attract tourists. As another marker of the flourishing consumer and tourist culture, the UAE has the highest per-capita square footage of shopping mall space in the Middle East and the second highest in the world (Walters et al. 2006).

Beyond diversifying its industrial base and establishing tourism and consumer infrastructure, the UAE also has invested heavily overseas, as another cushion against oil price shocks. A handful of sovereign wealth funds managed by Abu Dhabi control an estimated $1 trillion in overseas investments, making Abu Dhabi the world's largest holder of sovereign wealth (Davidson 2009). Its sovereign wealth funds are the largest shareholder in Citigroup; own a 75% stake in New York's historic Chrysler building; own 5% of the Italian car manufacturer Ferrari; hold an 8.1% stake in Advanced Micro Devices, the second-largest microprocessor manufacturer in the world; and possess major shares of many other long-established businesses and real estate ventures around the world (Davidson 2009).

The UAE's development has brought improvements in the standard of living of its population more dramatic than anyone likely could have conceived a generation ago. At the same time, however, this transformation has stressed the natural environment and, in so doing, created new risks for public health, as described in detail in Chaps. 4, 5, 6, 7, 8, 9, 10 and 11. The government has recognized these risks, and the study presented in this book represents but one of many initiatives the UAE has adopted in response. Another prominent example is Abu Dhabi's development of Masdar City, a sustainable, zero-carbon-emission city designed to demonstrate renewable and clean energy technologies.

The UAE's Institutional Flexibility

In the 1990s the UAE government began enacting laws and forming institutions to address its newly emerging environmental threats. The Federal Environment Agency was established in 1993, and the first environmental law, Federal Law 24 for the Protection and Development of the Environment, was enacted 6 years later. The law stated as one of its principal goals "control of all forms of pollution and avoidance of any immediate or long-term harmful effects resulting from economic, agricultural, industrial, development or other programmes aiming at improving life standards." The law contained broad provisions for environmental protection, covering air, water, soil, and natural reserves (UAE Federal Government 1999).

Authority to regulate environmental quality was further strengthened with the establishment in 2005 of EAD, expanding the mission of what had formerly been a wildlife protection agency to include a broad range of environmental concerns. In the UAE, unlike in other federations, the wealthier emirates, Abu Dhabi and Dubai, hold considerably more power than the federal government. In fact, Abu Dhabi's revenues heavily subsidize the federal government as well as government functions of the five smaller emirates. As such, EAD, in many respects, is more influential than its federal-level counterpart, and its emergence from what had been a natural resources protection agency signified the growing priority the UAE government was placing on environmental protection, writ large.

Because the UAE's environmental laws and institutions are little more than a decade old, they are still in flux. Agency reorganizations occur regularly. For example, in 2009, the government abolished the Federal Environment Agency and transferred its responsibilities to the new Ministry of Environment and Water. Because they are young, the UAE's government agencies are more nimble than those in many other developed nations and can react rapidly to address problems. By comparison, scholars of environmental policy have cited institutional inflexibility as a major barrier to implementing a more efficient, evidence-based approach to reducing environmental risks to health in the United States. For example, in a review of two unsuccessful U.S. government initiatives intended to streamline environmental regulatory processes, Hoffmann and others conclude that institutional inertia impedes attempts to improve the efficiency of U.S. environmental regulatory programs (Hoffman et al. 2002). Addressing environmental problems in new and more efficient ways, Hoffmann and others write, requires

> rethinking what has been ingrained within the government bureaucracy over the past 30 years. Some may resist this … process as contrary to their conception of the underlying purpose of the agency or as a threat to their own political interests, competencies, skills, or personal security (Hoffman et al. 2002).

Hoffman and others continue, "Believing that [the U.S.] is rapidly approaching the point of diminishing returns on … environmental regulation, many see the existing policy regime as possibly the greatest obstacle to continued environmental improve-

ment." In the UAE, unlike in the United States and other long-developed nations, it may be possible to develop highly efficient systems for protecting the environment and public health, without encountering seemingly intractable institutional inertia.

The UAE's Culture of Environmentalism

The UAE has a culture of concern for environmental stewardship, stemming both from its Islamic foundation and its Bedouin roots. "The Holy Qur'an makes frequent reference to animals and plants and instructs all Muslims to study and appreciate living and nonliving things around them," writes Aspinall in a history of environmental protection in the UAE (Aspinall 2001). Further, environmental conservation was essential for Bedouin survival in the desert. As a result, "Despite the irony of Abu Dhabi's being one of the largest hydrocarbon exporters, support for nature and improving the environment have historically been key legitimacy resources for the emirate's rulers," according to Davidson (2009).

One indicator of the cultural roots of environmentalism is the global recognition that H.H. Sheikh Zayed received for his conservation activities. He was the first sitting head of state (of any country) to receive the World Wildlife Foundation's Gold Panda Award. Posthumously, he received the Champion of the Earth Award from the United Nations Environment Programme. Commenting on the former award, Sheikh Zayed reflected a commonly held local view (Aspinall 2001):

> With God's will, … we shall continue to work to protect our environment and our wildlife, as did our forefathers before us. It is a duty—and, if we fail, our children, rightly, will reproach us for squandering an essential part of their inheritance and of our heritage.

Already, the UAE has demonstrated an ability to be creative in redressing environmental damages brought on by its rapid development. Perhaps no example better illustrates this creativity than the program to restore the endangered houbara bustard (Muller 2011). This migratory bird historically provided an important food source for Bedouins, who hunted with the assistance of pet falcons. While no longer essential for survival, hunting houbara remains popular in the UAE. In the 1980s, Sheikh Zayed noticed declining populations of houbara on his hunting expeditions, and he established the National Avian Research Center (NARC) to study the causes. Habitat fragmentation and increasing human populations, along with excessive hunting and illegal trapping, were among the key factors of the bird's disappearance, the new NARC found. Subsequently, under Sheikh Zayed's leadership, the NARC developed an innovative captive breeding program that now releases about 1,000 birds a year with a survival rate exceeding 50%. By contrast, other breeding programs have struggled to raise more than 20–100 at a time in captivity (Van Heezik and Seddon 2001). The NARC has not only replenished houbara populations in the UAE but also is working to regenerate the species across its habitat, which spans multiple continents (Launay et al. 1997).

The success of the houbara restoration program illustrates the UAE's propensity to innovate, rather than relying solely on conventional approaches for environmental problem solving. The environmental burden of disease assessment presented in this book is but another example of such an innovation. Rather than adopting a piecemeal approach to reducing environmental threats to human health, the UAE has sought to develop an evidence-based process that quantifies environmental pollution risks across all exposure media and that incorporates the multiple values of stakeholders in prioritizing those risks. This approach, as documented in the following chapters, offers the potential to achieve the kind of efficiency in environmental protection long sought but not yet achieved in other nations.

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