

Public Health and Geological Processes: An Overview of a Fundamental Relationship

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Contents

2.1 Public Health Definitions and Approaches	15
2.2 Historical Background	16
2.3 Current and Future Trends and Priorities in Public Health	18
2.4 Measuring Health and Disease in Populations	20
2.5 Assessing Risk in the Community	21
2.6 Monitoring and Surveillance of Disease	24
2.7 Disease Prevention and Control	25
2.8 Research Methods in Public Health	27
2.9 Integration and Application	30
References	31

2.1 Public Health Definitions and Approaches

The health of human populations is highly dependent on a range of environmental determinants, including those relating to geologic materials and processes on our planet (Fig. 2.1). There is a clear continuum of geochemical cycles and pathways for uptake of elements into plants, animals and humans. Indeed, the optimal functioning of the human body itself is reliant upon the maintenance of an appropriate balance of elements and minerals. The discipline of medical geology can assist in the elucidation and management of many public health issues, ranging from the effects of exposure to or deficiencies of trace elements and minerals in the diet, to the transportation, modification and concentration of natural compounds in the soil, atmosphere and water sources.

The activity known as *public health* has been subject to a range of interpretations. In fundamental terms, however, its focus is to provide *population-based solutions to collectively-defined health problems*. The emphasis on the incidence, distribution, and control of diseases within a population is often contrasted with the focus of clinical medicine, which is directed towards how illness affects an individual patient.

One widely cited definition is from the *Acheson Report on Public Health* (1988), in which public health is described as:

The science and art of preventing disease, prolonging life, and promoting health through organised efforts of society.

(Great Britain. Dept. of Health and Social Security. Committee of Inquiry into the Future Development of the Public Health Function. and Great Britain. Dept. of Health and Social Security. 1988)

Another, more extensive definition, was provided by John Last in the *Dictionary of Epidemiology* (1995):

Public health is one of the efforts organised by society to protect, promote, and restore the people's health. It is the combination of sciences, skills, and beliefs that is directed to the maintenance

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Fig. 2.1 A community exposed to occupational and environmental geogenic material: an iron-ore mining town located in the arid Pilbara region, Western Australia (Picture courtesy of Fiona Maley)

and improvement of the health of all the people through collective or social actions. The programs, services, and institutions involved emphasize the prevention of disease and the health needs of the population as a whole. Public health activities change with changing technology and social values, but the goals remain the same: to reduce the amount of disease, premature death, and disease-produced discomfort and disability in the population. Public health is thus a social institution, a discipline, and a practice.

(Last and International Epidemiological Association 1995)

There are two core components needed for the operation of a successful public health system: an “*analysis/investigation*” function and an “*action/intervention*” function. The first set of activities includes monitoring and surveillance of communicable (infectious) and non-communicable – often more chronic – diseases. In response to the information gathered from these sources, an intervention – or group of interventions – is then implemented. These may range across a wide spectrum of activities, including health legislation (such as those relating to tobacco control or driving under the influence of alcohol or drugs), regulations to control

occupational or environmental hazards, the provision of specific public health services (such as screening programs), or the implementation of health promotion measures (such support of health lifestyles and behaviours) (World Health Organization 1998). The public health measures may be directed towards the entire population or they may, depending on the health issue of interest, target vulnerable and high-risk populations.

This chapter will explore a number of these public health approaches in greater detail, where possible using examples to illustrate how medical geology can and has contributed to the elucidation and mitigation of public health problems.

2.2 Historical Background

Although many of the features of modern public health systems arose in the nineteenth and twentieth centuries, there were a number of precedents in earlier periods. The Classical Romans constructed systems to supply clean water

to their cities – including impressive networks of aqueducts, cisterns and domestic pipes – although these were often lined with a malleable metal (*plumbum*, or lead) whose toxic effects were not fully appreciated. The public health implications of fuel use became apparent in the early 1300s, with the banning of coal burning in London because it led “to the annoyance of the magistrates, citizens, and others there dwelling and to the injury of their bodily health” (Nef 1966). In the expanding cities of late medieval Europe, there were attempts to regulate urban waste and to limit the movements of infected people (such as those with leprosy). The Italian city-states were notable in their achievements, with the foundation of civic hospitals (including specialised plague hospitals), establishment of public Boards of Health (such as the Milan *Sanità*, 1424), and the strict enforcement of quarantine regulations. In the 1600s, the field of medical demography and analysis of population data advanced with the publication of John Graunt’s *Natural and Political Observations ... upon the Bills of Mortality* (1662), in which it was noted that more boys were born than girls and that urban mortality exceeds that of rural areas (Porter 1998).

However, it was the Industrial Revolution and subsequent societal shifts in the nineteenth century that created a new series of health challenges. Increasing numbers of people migrated from the countryside to the cities, where many were forced to take on dangerous, arduous work for near-subsistence wages. The population was growing rapidly without a concurrent expansion in new housing, and overcrowding contributed to the relatively fast spread of disease in many urban centres.

One of the leading reformers of this period was Sir Edwin Chadwick (1800–1890), a lawyer from Manchester who took an active part in the modifications to the Poor Law and in factory legislation. Public health became a political issue in 1842 with the publication of Chadwick’s *Report on the Sanitary Condition of the Labouring Population of Great Britain* (Chadwick and Great Britain. Poor Law Commissioners. 1842). Chadwick had collated vast quantities of vital statistics, information from town maps, and descriptions of dwellings and problems with living conditions (such as inadequate drainage and foul odours). Chadwick viewed the problems of destitution, slums, smoke, water supply and sewerage as matters for *public action*, as opposed to simply being the responsibility of individuals or local authorities (Porter 1998). Chadwick’s advocacy and influence contributed to the first *Public Health Act* in 1848, which established a General Board of Health. This central authority was empowered to set up local boards with the task of ensuring that new homes had proper drainage and that local water supplies were dependable. Furthermore, the first Medical Officer of Health for Great Britain was appointed. By 1872, local boards of health were

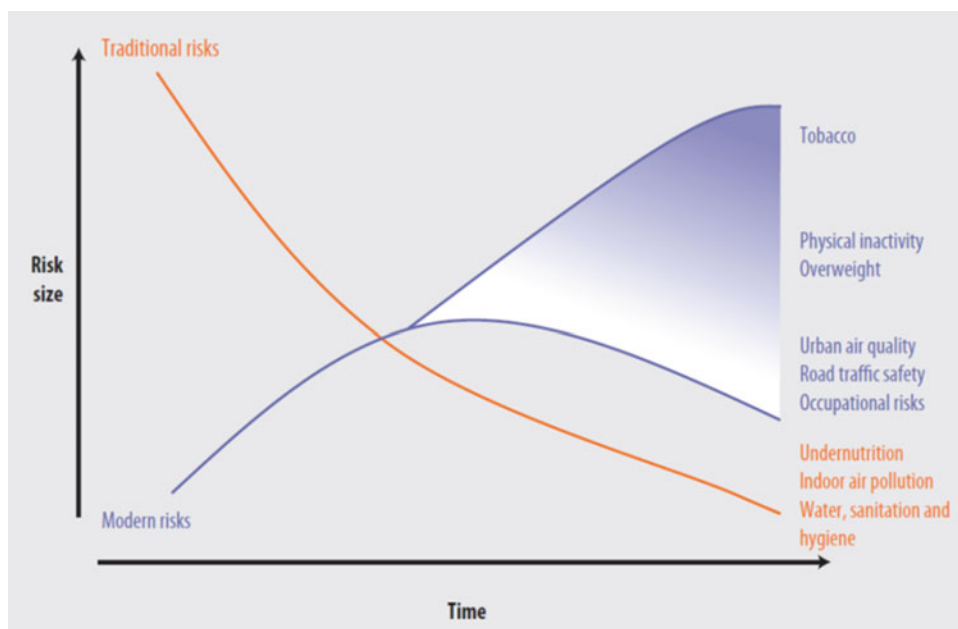
compelled to employ medical officers of health who were responsible for sanitary inspection and improvement, and isolation and tracing of persons with infections. Other public health legislation, covering factory management, child welfare, care of the elderly and those with physical or mental disabilities, and many other initiatives in social reform were introduced.

In the United States, boards of health were created in the eastern seaboard cities in the 1830s, but they were largely concerned with quarantine regulations. A national awareness of epidemic disease arose from the trauma of the Civil War (1861–1865), in which a large proportion of deaths arose from infections (especially dysentery). Louisiana formed the first state board of health in 1855 and most other states followed by the 1870s. Social conditions deteriorated in the large cities between 1860 and 1890 as a result of increased industrialisation and immigration, leading to a range of social reforms, including those relating to public health. In 1872, the American Public Health Association was formed as a multidisciplinary consortium of engineers, physicians and public-spirited citizens, especially members of the women’s movement who spoke of sanitary reform as ‘municipal housekeeping’ (Rosen 1993).

New discoveries in the field of microbiology also fired a series of new public initiatives and a greater degree of community awareness about infectious disease. Improved methods for water and food sanitation and safety emerged. Rodent and pest control grew in importance. Individual hygiene practices were encouraged. In 1920, Charles Winslow, an American authority on public health and professor at Yale University, emphasised the importance of “*organised community efforts for the sanitation of the environment*”, “*the control of community infections*” and, more broadly, “*the development of the social machinery which will ensure to every individual in the community a standard of living adequate for the maintenance of health*” (Winslow 1920).

Despite these improvements in public health in the early years of the twentieth century, there were a number of unwanted effects of increasing industrialisation, population growth and urbanisation. The environmental and health impacts of widespread mining, metallurgical activities (such as smelting and refining) and fuel extraction (such as coal) also became increasingly apparent (Krech et al. 2004). High levels of pollutants were released into the atmosphere, waterways and soils. The Industrial Revolution was also associated with a growing incidence of occupational diseases, such as lung disorders (examples include coal workers pneumoconiosis, silicosis, and asbestosis), occupational cancers, and poisoning from various toxic compounds (including lead, white phosphorous, mercury, cadmium, arsenic and radioactive agents).

Fig. 2.2 Risk transition in public health. The diagram indicates the magnitude of the shift from “traditional” risks (such as from inadequate nutrition and poor water supply) to “modern” risks over time. The scale of the time variable varies depending on the particular community (Source: World Health Organisation 2009: http://www.who.int/healthinfo/global_burden_disease/global_health_risks/en/index.html)



2.3 Current and Future Trends and Priorities in Public Health

In general terms, industrialised, high-income nations have undergone a significant shift in disease patterns in the past century (Mathers et al. 2009). The increasing average wealth of a nation broadly corresponds to improvements in hygiene and nutrition, substantial declines in the frequency of infectious diseases, and improved population health indicators (such as life expectancy). In many respects, high-income nations have many of the previous “external” or “environmental” causes of disease under control through prevention or management of infectious disease, removal of many water and food contaminants, and improved safety standards and regulations (Fig. 2.2). However, affluence has also been accompanied by increased levels of sedentary behaviour and overnutrition, contributing to such problems as obesity, metabolic disorders and cardiovascular disease. The causes of death in industrialised society primarily relate to chronic diseases – such as cancer, cardiovascular disease, some respiratory diseases – and to a lesser degree, injury and accidents (e.g. in workplaces or from motor vehicle accidents). Many of these current health problems relate – at least partly – to attitudes and behaviours relating to smoking, diet, exercise levels and alcohol intake. As leading researchers have noted with respect to one of the major “lifestyle” diseases, type II diabetes mellitus: “overall, a healthy diet, together with regular physical activity, maintenance of a healthy weight, moderate alcohol consumption, and avoidance of sedentary activities and smoking, could nearly eliminate [this disorder]” (Schulze and Hu 2005).

There remains a significant contrast in health status between those in lower- and higher-income countries. A comparison of causes of death (in millions) for low-, middle- and high-income countries (2004) is provided in Table 2.1. Traditionally, as we noted above, affluence has been linked to those diseases arising from tobacco use, consumption of alcohol and energy-rich foods, and a sedentary lifestyle. In contrast, those living in poverty have usually been perceived as being at risk of inadequate health infrastructure and limited access to care, with the prospect of famine, recurrent infections and a limited life span.

However, this overly simplified description does not capture the current and evolving profile of global health (Lopez and Disease Control Priorities Project 2006). In recent decades, there have been profound changes in many “developing” countries (especially across Asia and Latin America) with accelerating industrialisation and economic development, urbanisation of populations, and globalisation of food systems. Life expectancy is increasing in many parts of Latin America, North Africa, the Middle East and Central and East Asia, although there remain significant variations within and between communities. This rise in average life expectancy primarily relates to a decrease in infant/childhood deaths.

An additional shift has been the “nutrition transition”: that is, a shift away from traditional diets to “Westernised” diets (highly processed, high energy, low fibre) and towards lower levels of physical activity. This has led to the co-existence of under- and over-nutrition in many middle-income countries. Rates of cardiovascular disease and diabetes are now dramatically escalating (Yach et al. 2006).

At the same time, major health problems in lower-income countries continue to be associated with poor sanitation,

Table 2.1 Comparison of causes of death (in millions) between low-, middle- and high-income countries (2004)

Disease or injury	Deaths (millions)	Percent of total deaths	Disease or injury	Deaths (millions)	Percent of total deaths
World			Low-income countries		
1 Ischaemic heart disease	7.2	12.2	1 Lower respiratory infections	2.9	11.2
2 Cerebrovascular disease	5.7	9.7	2 Ischaemic heart disease	2.5	9.4
3 Lower respiratory infections	4.2	7.1	3 Diarrhoeal diseases	1.8	6.9
4 COPD	3.0	5.1	4 HIV/AIDS	1.5	5.7
5 Diarrhoeal diseases	2.2	3.7	5 Cerebrovascular disease	1.5	5.6
6 HIV/AIDS	2	3.5	6 COPD	0.9	3.6
7 Tuberculosis	1.5	2.5	7 Tuberculosis	0.9	3.5
8 Trachea, bronchus, lung cancers	1.3	2.3	8 Neonatal infections	0.9	3.4
9 Road traffic accidents	1.3	2.2	9 Malaria	0.9	3.3
10 Prematurity and low birth weight	1.2	2	10 Prematurity and low birth weight	0.8	3.2
Middle-income countries			High-income countries		
1 Cerebrovascular disease	3.5	14.2	1 Ischaemic heart disease	1.3	16.3
2 Ischaemic heart disease	3.4	13.9	2 Cerebrovascular disease	0.8	9.3
3 COPD	1.8	7.4	3 Trachea, bronchus, lung cancers	0.5	5.9
4 Lower respiratory infections	0.9	3.8	4 Lower respiratory infections	0.3	3.8
5 Trachea, bronchus, lung cancers	0.7	2.9	5 COPD	0.3	3.5
6 Road traffic accidents	0.7	2.8	6 Alzheimer and other dementias	0.3	3.4
7 Hypertensive heart disease	0.6	2.5	7 Colon and rectum cancers	0.3	3.3
8 Stomach cancer	0.5	2.2	8 Diabetes mellitus	0.2	2.8
9 Tuberculosis	0.5	2.2	9 Breast cancer	0.2	2
10 Diabetes mellitus	0.5	2.1	10 Stomach cancer	0.1	1.8

Source: http://www.who.int/healthinfo/global_burden_disease/2004_report_update/en/index.html

COPD chronic obstructive pulmonary disease

inadequate hygiene standards, low vaccination coverage, poor access to health services, and malnutrition. Most preventable deaths in these nations occur in children: globally, around 11 million per year die before the age of 5 years, and it is estimated that half of these could be averted through simple, low-cost solutions (Black et al. 2006). The main causes of premature mortality in lower income nations are infections i.e. respiratory tract infections (such as pneumonia), vaccine-preventable disease (including measles, whooping cough, poliomyelitis, tetanus) and diarrhoeal illnesses, many of which are superimposed on a background of poverty and malnutrition. Malaria and HIV/AIDS are also important contributors to mortality (World Health Organization 2003). These health concerns have prompted a range of responses at the local and international level, including the development of the United Nations Millennium Development Goals (MDGs), which seek to alleviate extreme poverty, hunger, illiteracy and disease (UN Millennium Project et al. 2005; World Health Organization 2005).

It is critical to consider the wider social, economic and political context when addressing public health issues. There is ample historical evidence that public health efforts have

been most successful when the socio-cultural context has been changed. For example, the separation of sewage from drinking water is arguably the greatest of all public health achievements, although it remains to be achieved in many societies.

Social deprivation and inequality are strong predictors of health status within and between populations, and of trends over time, and consequently much public health effort is directed towards the alleviation of these imbalances (e.g., the World Health Organisation's *Health for All by the Year 2000* (World Health Organization 1981)). Social inequalities lead to differentials across a range of health measures, including: (i) overall mortality rates and life expectancies; (ii) morbidity and disability from a range of specific conditions (e.g., infectious diseases, cardiovascular diseases, adverse perinatal outcomes, injury and poisoning); (iii) risk behaviours/factors (e.g., smoking, physical inactivity; lipid/cholesterol profiles; higher consumption of refined sugars and fats; less fruit and vegetable intake); (iv) physical environmental factors (e.g., residence in flood-prone regions; proximity to contaminated sites, such as those with elevated lead levels from old housing, leaded fuels, and industry);

(v) utilisation of health services (disadvantaged groups tend to have reduced utilisation of preventive services, such as screening). The patterns and underlying causes of such health disparities have been explored in detail in a number of reports and publications (Berkman and Kawachi 2000; Great Britain Working Group on Inequalities in Health and Great Britain Department of Health and Social Security 1980; Marmot and Feeney 1997; Marmot 2005). However the relationship today between health and average income in developing countries is not a simple correlation. Regions with significant improvements in health despite low per person wealth are Sri Lanka, Costa Rica, Kerala in India and parts of China. Mass education and political commitment to primary care are considered to have played an important part in such improvements (Black et al. 2006).

A related issue in public health is the nature and structure of the health system itself. This encompasses not only the specific health facilities (such as clinics and hospitals), but the entire set of related social structures and processes that impinge on the well-being of the community (Scutchfield and Keck 2009). Attributes of the health system that affect health status and the success of disease control include: (i) overall allocation of resources at the governmental level, such as how much of the national budget is to be spent on health as opposed to other areas (such as defence); (ii) the range and effectiveness of preventive, treatment, rehabilitative and continuing care programs available; (iii) access to services (e.g. universality of health care; systems of pricing health services); (iv) the provision of special services to disadvantaged groups.

In 1981, the World Health Assembly endorsed a resolution that health was to be one of the major social goals of government, thereby initiating the “*Health for All by the Year 2000*” (HFA2000) movement (World Health Organization 1981). In this period, health policy shifted progressively towards emphasising *community-based interventions* as the main vehicle for improving health. This has been accompanied by a general shift away from an overly “medicalised” model of health care. This transition was taken further by the *Ottawa Charter* (1986), which advanced the view that it is *people themselves* that hold power in health matters, not just institutions, officials, professionals or those who develop and control technology (Green and Kreuter 1990; Green and Tones 1999). The Charter stressed the importance of *health promotion*, defined as follows:

Health promotion is the process of enabling people to increase control over, and to improve, their health. . . Health is a positive concept emphasizing social and personal resources, as well as physical capacities. Therefore, health promotion is not just the responsibility of the health sector, but goes beyond healthy life-styles to well-being.

Ottawa Charter (1986) (World Health Organization. Division of Health Promotion. 1986)

A number of key areas of activity were identified to achieve the health promotion model. These include the *creation of supportive environments*, with provision of living and working conditions that are safe, stimulating, satisfying, enjoyable and conducive to health-enhancing behaviours. This emphasises the need to identify and manage environmental barriers that might prohibit or inhibit optimal health. Another element of promoting health is through *strengthening of community actions*, with an emphasis on using and supporting community resources to promote health. This approach encourages community “ownership” of health and empowerment, in which individuals act collectively to manage the determinants of their health and the quality of life in their community.

2.4 Measuring Health and Disease in Populations

Health and health status is a complex and abstract concept: there is no single satisfactory definition which encompasses all aspects of health. Traditionally, health has been viewed as the absence of disease. However, the World Health Organization defined health much more broadly as “*a state of physical, emotional and social well-being, and not merely the absence of disease or infirmity.*” Although there has been considerable debate about the merits of this definition, it has provided a focus for the measurement of a broad range of indicators of health beyond just the presence or absence of some clinical or pathological entity.

In attempting to capture a population’s overall “state of health,” there is a wide array of measures from which to choose. However, most of the commonly used measures have a shared goal: to meaningfully quantify and summarise some dimension of health or disease in a population. An example is the *mortality rate* (or *death rate*). These take different forms: the *crude* mortality rate is the number of deaths in an entire population over a set period (usually a year), expressed per unit of population at risk of dying, whereas *specific* mortality rates are the number of deaths occurring within a subgroup of the population, such as by gender or across particular age strata or ethnic groups. A common measure used for international comparisons is the *infant mortality rate* (IMR): the ratio of the number of deaths of children under 1 year of age (in a given year) divided by the number of live births (in that year).

A related population-based measure is *life expectancy*: the average number of years yet to be lived for individuals at a specified age (commonly taken from birth). It is based on a set of age-specific death rates, and usually draws on the mortality conditions prevailing at the time of the estimate. In low-income countries with high infant mortality, most

of the gains in life expectancy occur by improving the likelihood of survival of infants. In contrast, for high-income countries with low infant mortality, most of the gains in life expectancy occur in the oldest members of the population.

However, measures such as mortality rates and life expectancy only capture part of a community's experience of health and disease. For example, mental illness, visual loss and osteoarthritis are all major sources of ill-health in the population, but the extent of such conditions is not reliably captured by examining death rates. Examples from the field of medical geology include the iodine deficiency disorders (IDDs), which are estimated to affect hundreds of millions of people worldwide. A considerable community burden arises from serious neurological deficits (including cretinism and hearing impairments) arising from inadequate iodine during foetal and early childhood development (De Benoist et al. 2004; Mason et al. 2001). However, IDD in children and adults are not commonly a direct cause of death, and therefore will not usually be detected solely by examining mortality records.

Other measures are required to capture the frequency of a condition or disease in a population, also known as *morbidity*. One of the most important measures of disease frequency is the *incidence*. Incidence reflects the frequency of *new* health- or disease- related events (such as the first onset of a particular disease). These may be expressed as rates, such as new cases per person-year, per person-month, or per person-day. These values may be converted to a rate per 1,000 or 100,000 person-years (for example, cancers are often reported in terms of an incidence rate of *X* cases “per 100,000 person-years”.) *Prevalence* is another common measure of morbidity. This encompasses the frequency of *existing* (whether new or pre-existing) *health- or disease-related events*. In other words, prevalence focuses on *disease status*, or the *current “burden of disease”*, in a community, as opposed to the number of new events (which is captured using incidence). Common sources of morbidity data include: disease registries (e.g. for cancers); notification systems for infectious diseases, industrial diseases and accidents, discharge information from hospitals and registers in general practice (family medicine clinics).

In terms of assessing the frequency of events, morbidity differs from mortality in some crucial respects. Death is a well-documented and final state, and is relatively easily enumerated. When counting and summarising other (non-fatal) “disease states” across the community, however, there are a far wider range of measures available. At the biological level, morbidity may for example be assessed using *biochemical markers* (e.g. blood glucose), *physiological markers* (e.g. blood pressure), and *pathological markers* (e.g. tumour size; evidence of dental or skeletal fluorosis). Alternatively, functional measures of morbidity reflect how a disease or condition results in *impairment* (reduction in

physical or mental capacities at an organ or bodily system level), *disability* (restriction in a person's ability to perform a particular task or function, such as walking) and *handicap* (limitations in a person's ability to fulfil a normal social role, such as their usual job).

Morbidity may also be assessed using *self-reported measures*, which are used to assess factors associated with quality of life, such as “wellness,” psychological and emotional wellbeing, or social functioning. These aspects of poor health and disability are of great importance to patients but are often difficult to measure.

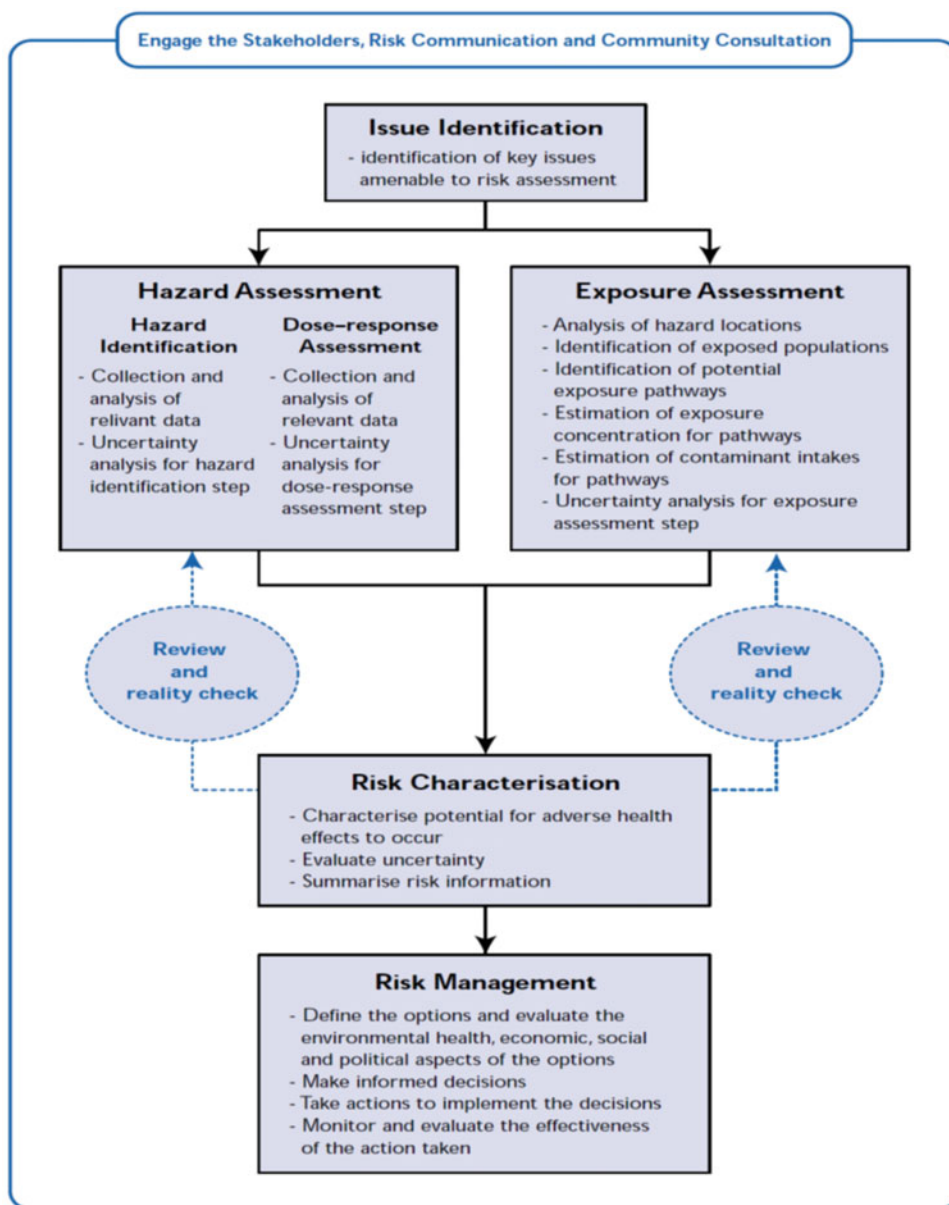
‘Composite’ measures of health status combine the aspects of those described above, such as life expectancy and morbidity indicators. One example is the *Disability Adjusted Life Year, or DALY*. This metric takes into account both the fatal and non-fatal outcomes of disease. One DALY can be thought of as one lost year of “healthy” life due to death, disease or disability. It quantifies the health burden in terms of years of life lost (due to premature death) and years “lost” to disability, with different “weights” assigned to medical conditions depending on their severity. One of the most important functions of DALYs is to assess the national (or global) burdens of disease and injury associated with certain diseases or groups of diseases. In higher-income countries, significant DALYs are associated with cardiovascular diseases, mental illness, dementia, cancers, diabetes and injury (e.g. road traffic accidents). In middle- and low-income countries, cardiovascular diseases, and mental illnesses are also important, but infectious diseases and perinatal conditions also account for a significant burden (Lopez and Disease Control Priorities Project 2006). The use of DALYs can be extended to assess the global burden of disease and injury associated with particular risk factors, such as DALYs “lost” from malnutrition (including iron and/or iodine deficiencies), unsafe water supplies (including those containing excess fluoride or arsenic), tobacco and alcohol use.

In general, the uses of these various sources of health data are diverse. Information on the frequency of diseases causing death and disability provide a general framework for health policy. Morbidity statistics are of particular relevance to health services planning. Statistics on utilisation patterns and the diseases and illnesses presenting to hospitals and other health care institutions are essential to a rational policy for the organisation of health care.

2.5 Assessing Risk in the Community

The term “risk” has multiple interpretations, and is used in different contexts in the field of public health. A *risk factor*, for example, denotes a factor or characteristic associated with (but not necessarily always the direct cause of) a

Fig. 2.3 Stages of risk assessment for environmental hazards (from Environmental health risk assessment: guidelines for assessing human health risks from environmental hazards, used by permission of the Australian Government) (Source: Department of Health and Ageing, Canberra, Australia/enHealth Council 2002; <http://www.nphp.gov.au/enhealth/council/pubs/pdf/envhazards.pdf>)



particular disease or outcome. A risk factor can be an aspect of behaviour or lifestyle, an environmental exposure, or an inborn or inherited characteristic, that is associated with an increased occurrence of disease or other health-related event or condition.

Another usage of the term “risk” is within the framework of a *risk assessment*. In general, this process involves estimating the potential impact of chemical, biological or physical agents on a specified human population over a given time. In a medical geology setting, such assessments can be considered in terms of: (i) *defining exposure pathways*: such as the nature of the geological hazard, including its physicochemical properties and bioavailability; whether there are multiple and/or interacting hazards (e.g. from various sources); the routes of exposure; and projected

patterns of exposure in at-risk populations; coupled with: (ii) *defining the progression to health end-points*: that is, the probability that the geological processes or agents are likely to produce any adverse health effects. This may involve defining the relationship between toxicant “dose” and occurrence of a particular disease, and calculation of the potential rates of disease in the given population.

This process of evaluation has been separated into a number of discrete stages (Brownson and Petitti 1998; National Research Council (U.S.). Committee on the Institutional Means for Assessment of Risks to Public Health 1983). These are summarised in Fig. 2.3 (enHealth Council and Australian Department of Health and Ageing 2002).

The first component of the risk assessment is **Issue identification**. This involves identifying and confirming a role of

the risk assessment approach for a particular issue: that is, Why is this issue of particular concern? Is the issue urgent? How do all the stakeholders (often including the community) perceive the issue? At this early stage, it is essential to consider whether the issue is amendable to the risk assessment approach and to determine the social context (for many environmental issues, there may be a high level of anger, anxiety, and impatience).

Evaluation of risk from complex industrial processes or contaminated sites is often a challenging task because of the diversity of compounds produced and multiplicity of potential exposure contexts and health impacts. In mine tailings, for example, a mixture of pollutants may be present, including: trace elements such as arsenic, mercury, lead, and cadmium; radioactive materials; acid-producing sulphide compounds; fine-grained minerals such as asbestos and quartz; hydrocarbons, often introduced by mining and processing equipment; as well as additives such as cyanide (including leaching agents, sodium cyanide and hydrogen cyanide) (Nriagu 2011).

The next stage is **Hazard assessment**, which – as applied to a medical geology context – often involves investigating a hazardous process or the inherent properties of hazardous agents. This process of assessment requires two major activities: (i) *Hazard identification: Are the agents of concern presumed or known to cause adverse health effects?* The disciplines of toxicology (including animal or *in vitro* studies) and epidemiology (studies of human populations) are used to help address this question. For hazardous chemicals, it is often necessary to collect and compare relevant data on physical state, volatility and mobility as well as potential for degradation, bioaccumulation and toxicity; (ii) *Dose-response assessment: What is the relationship between the dose and occurrence of the adverse health effects? At what dose does this health effect occur?* Estimations of human health risks from exposure to specific chemicals are generally based on extrapolations of the results of toxicological experiments on animals. These extrapolations provide standard human “dose-response” relationships for the chemicals. The validity of the data and the weight-of-evidence of various toxicity data must be assessed.

For example, the International Agency for Research on Cancer (IARC) grades hazards according to whether they are likely to be carcinogenic. One common contaminant, arsenic, is classed as a Group 1 carcinogen based on evidence of its association with a spectrum of cancers (including those of the skin and liver, lung, kidney, and bladder) arising in human populations exposed to this contaminant (such as smelter workers, arsenical pesticide workers, patients treated with arsenic-containing medicinals, and communities who have ingested arsenic in drinking water across many geographical regions (Tchounwou et al. 2003)). However,

arsenic is a widely distributed metalloid and occurs in different oxidation states and forms, including elemental arsenic, arsenides, sulphides, oxides, arsenates and arsenites (Centeno et al. 2006; Tchounwou et al. 2004). Therefore, *speciation* of arsenic (and many other compounds) is critical for accurate toxicological evaluation. The particular chemical form (i.e. oxidation/valency states) and physical attributes (morphological state) of the element often determine its toxicity, mobility of an element in the environment, and bioavailability (Refer to Chaps. 27 and 12)

The next component of the risk assessment process is **Exposure assessment**, which seeks to define the exposure pathways that are currently experienced or anticipated under different conditions: that is, *Under what circumstances or conditions could people be exposed to the hazard? What forms of assessment or estimation will be used to determine whether exposure had occurred?* This requires assessment of the following parameters: the frequency, extent, and duration of the exposure; the locations in which the exposure is likely to occur; the exposed populations; the pathways of exposure and actual or predicted intake of contaminants. Depending on the agent and exposure context, intake usually occurs through ingestion (such as incidental ingestion of contaminated soil or dust, or via contaminated food or drinking water), inhalation, or dermal absorption. It must be noted, however, that compounds (such as metals) detected in the environment are not necessarily biologically available to humans because of large particle size, low solubility, limited release from soil, or entrainment in surrounding rocks and soils. Exposure can be estimated *directly* (such as with biological testing or personal monitoring of each individual, including urine, blood, hair and nail samples) and/or *indirectly* through environmental monitoring, questionnaires and diaries.

Risk characterisation [also called **risk estimation**] integrates the preceding analyses of hazard and exposure measurements in order to decide: *What is the estimated probability that adverse outcomes will occur in this particular population at the specific level of exposure?* This assessment on the likelihood of harm is then used to guide the process of decision-making (Stern et al. 1996).

Throughout the risk assessment process, it is important to conduct ongoing **evaluation of limitations and uncertainties**. There are always likely to be elements of uncertainty in the analyses and these need to be explicitly acknowledged. These include: gaps in information about the profile of the hazards at a particular site; inadequate exposure information, including problems defining the population affected or the geographical area involved; limits in the availability and consistency of toxicology data, including extrapolations of findings (e.g. from animal studies) to human populations; limitations in the use of point estimates in the present day when trying to infer past exposures over a long duration. For many toxic agents, there may be

no specific models to define the relationship between contaminant levels or durations of exposure and the probability of disease outcomes.

The conclusions from the risk assessment process are then used to inform the final stage: **Risk management**. This involves evaluating possible actions and alternatives to minimise risk, taking into account all the relevant factors: the risk assessment, as well as the practicality (cost and technological constraints), social and political implications of the available options. A “zero risk” option is usually not achievable, given that almost any action potentially entails some degree of risk. The strategies are then implemented and monitored to ensure that they have been effective. Risk management also involves deciding upon the process and form of engagement and communication with relevant stakeholders, including the community. This process is often influenced by the degree of outrage experienced by public, the intensity of media attention, and attribution of blame (e.g. whether the problem was caused by a natural event or by human error) (Covello et al. 1989).

2.6 Monitoring and Surveillance of Disease

Many communities and countries have a formal set of arrangements to prevent, monitor and respond to communicable and non-communicable diseases. These “surveillance systems” aim to provide “*a continuous and systematic process of collection, analysis, interpretation, and dissemination of descriptive information for monitoring health problems*” (Rothman et al. 2008). Usually the surveillance systems are operated by public health officials to assist in disease prevention and to guide control.

In *active* surveillance, the health agency actively initiates information gathering, such as by regular calls or visits to doctors or hospitals. In contrast, for *passive* surveillance, the health agency does not actively contact reporters – it leaves the contact to others (such as treating doctors). Often both active and passive options exist in the same system. For example, the surveillance organisation may actively contact large representative hospitals while leaving smaller centres to passively participate.

In the process of *notifiable disease reporting*, health workers are (often legally) required to contact a central public health agency when a particular disease is identified. Examples include infectious diseases with serious health implications, such as whooping cough, cholera or rabies. The time requirements vary: some diseases require rapid notification; with others, there is less urgency. Other systems for obtaining health data include: *laboratory-based surveillance*, in which summaries (e.g. of microbiological samples) are provided by a laboratory; *registries*, which are designed

to capture all occurrences of a disease or group of diseases (such as cancers) in a specified area; and *surveys*, which involves direct contact with a community, or a sample population, to define an outcome of interest, such as the presence of disease, levels of risk behaviour, or use of health services (Silva and International Agency for Research on Cancer 1999). Diagnostic tests form an important basis for identifying those with the disease or outcome of interest. It is imperative to consider the accuracy and availability of the tests, how they are used, and whether they are being reliably interpreted.

The populations to which surveillance is applied may be defined in narrow terms (such as a hospital) or in broad terms (e.g. the global population, as conducted by the World Health Organisation in tracking the emergence of new influenza strains). Surveillance systems need to maximise confidentiality: it is an ethical requirement and is required to engender community trust in the system. Usually security measures are put in place to ensure that no violations of privacy can occur.

Surveillance systems have different objectives. They may be to provide rapid feedback (e.g. in infectious disease outbreaks) or may be used for longer term health care planning or monitoring of prevention programs. For example, surveillance data can be used to identify whether changes in disease incidence are occurring, such as by comparing them to historical records. Declining trends can follow the pattern of disease or the effectiveness of control measures (e.g. infection incidence after the introduction of an immunisation campaign).

Examples of surveillance systems with particular applications to medical geology include those designed to assess the health consequences of lead exposure. The presence of lead in the environment was, and in many locations remains, a major environmental hazard, with sources including leaded gasoline, lead-based paint, other household items containing lead (e.g. ceramics, toys), and contamination from mining, smelting and other industrial processes (e.g. battery manufacture). The presence of lead and its capacity for ingestion by children – such as in paint, dust or contaminated soils – has major implications for health, particularly in relation to neurodevelopmental effects. Elevated lead has been linked to behavioural disturbances, delayed learning, and diminished intellectual capacity in children. Other effects of lead exposure in children and adults include renal damage, anaemia and a range of other toxic effects on the reproductive, neurological and cardiovascular systems.

In the United States, population-based programs have been established to evaluate young children for signs of lead poisoning, primarily through blood tests and clinical evaluations (United States. Dept. of Health and Human Services. Committee to Coordinate Environmental Health

and Related Programs. Subcommittee on Risk Management and Centers for Disease Control (U.S.) 1991). This public health issue has been addressed through various forms of surveillance, including: (i) at the State level: reviews of blood lead level (BLL) analyses from laboratories, which may also incorporate information gathered directly by public health officials or clinicians (e.g. evidence of lead toxicity – such as developmental and behavioural disorders – and/or risk factors for lead exposure in screened children); (ii) at a national level: the Centers for Disease Control's National Center for Environmental Health is responsible for developing and maintaining the national surveillance system for childhood lead levels. In practical terms, this task involves centralising the data (mainly laboratory blood lead tests, with personal details removed to ensure confidentiality) from participating agencies across the United States. This aggregated information is then collated and analysed to identify those regions and communities at highest risk, to target interventions, and to track the progress of programs that aim to reduce lead exposure (Centers for Disease Control and Prevention CDC's National Surveillance Data (1997–2008)).

2.7 Disease Prevention and Control

Preventive health care is a term used to describe a range of both *technical* and *educative strategies* applied by doctors, nurses, allied health professionals and public health workers in community and clinical settings. These interventions are designed to prevent the onset of disease or to slow or stop the progress of illness, and may be applied at different stages in the natural history of disease.

These strategies are commonly categorised in terms of *primary*, *secondary* and *tertiary prevention*. *Primary prevention* seeks to prevent the occurrence of disease altogether (that is, it aims to reduce disease *incidence*). It often focuses on strategies to control hazards (e.g. infectious agents; chemicals) and to modify risk factors in the population through health promotion and health education (such as by reducing smoking or encouraging greater participation in aerobic exercise).

With respect to minimising exposure to hazardous chemicals, primary prevention usually involves a combination of education and legislation. For example, exposure to asbestos and natural asbestiform compounds has major implications for health, including asbestosis (diffuse fibrosis of the lung), pleural lesions and various cancers. Contact with asbestos and asbestiform compounds may be controlled through the following strategies (United States Environmental Protection Agency 2012):

- Government legislation to prevent extraction and use of asbestos in building or for other industrial purposes
- Public and worker education

- Establishment of exposure limits (e.g. maximum allowable concentrations)
- Strict controls on removal and replacement of existing asbestos materials (e.g. insulation)
- Use of protective equipment and warning signs

Many other geological materials are also monitored and regulated in order to limit the degree of public and occupational exposure. These include metals and metalloids (such as arsenic, lead, mercury, cadmium, chromium, and beryllium), silica dusts, and radionuclides.

Secondary prevention is designed to intervene early in the course of a disease to halt or slow its progress, and thereby stop or reduce its clinical manifestations. Secondary prevention of both communicable and non-communicable diseases is closely related to the concept of disease *screening*, which is the identification of preclinical disease (usually by a relatively simple test). Screening is the evaluation of people who are apparently healthy (that is, without clinically overt symptoms) “to detect unrecognized disease [or its early biological manifestations] in order that measures can be taken that will prevent or delay the development of disease or improve the prognosis” (Last and International Epidemiological Association 1995). In practice, secondary prevention involves the *interaction of community health measures* (mass screening campaigns, central registers e.g. for cytology, mammography) and *clinical medicine*, such as through family doctors who provide clinical screening services (such as cervical smears).

In general, the screening procedure is not *in itself* designed to simply diagnose the end-stage illness. It is assumed that screening will detect a disease at an earlier stage than would have occurred otherwise, and will thereby offer the potential for improved prognosis (a greater chance of survival). However, it is also important to emphasise that screening alone (that is, simply achieving early detection) is not enough to constitute prevention. It is the combination of screening and the subsequent application of an effective early intervention that comprises secondary prevention.

Tertiary prevention differs from the primary and secondary approaches in that it is applied after the diagnosis of the disease. It aims to intervene later in the course of disease so as to reduce the number and impact of complications which add to the patient's disability and suffering. Tertiary prevention may be difficult to distinguish from treatment because it forms an integral part of the clinical care plan for patients with established disease. The basis for the distinction is that a *preventive intervention* is one that is applied before a potential problem occurs, such as debilitating complications (e.g. eye or kidney damage from diabetes mellitus), whereas *treatment* is applied to alleviate a problem that has actually occurred. The different stages of prevention are summarised in Fig. 2.4a, with an example provided using exposure to asbestos-induced cancer (Fig. 2.4b) (Das et al. 2007; Tiitola et al. 2002; Wagner 1997).

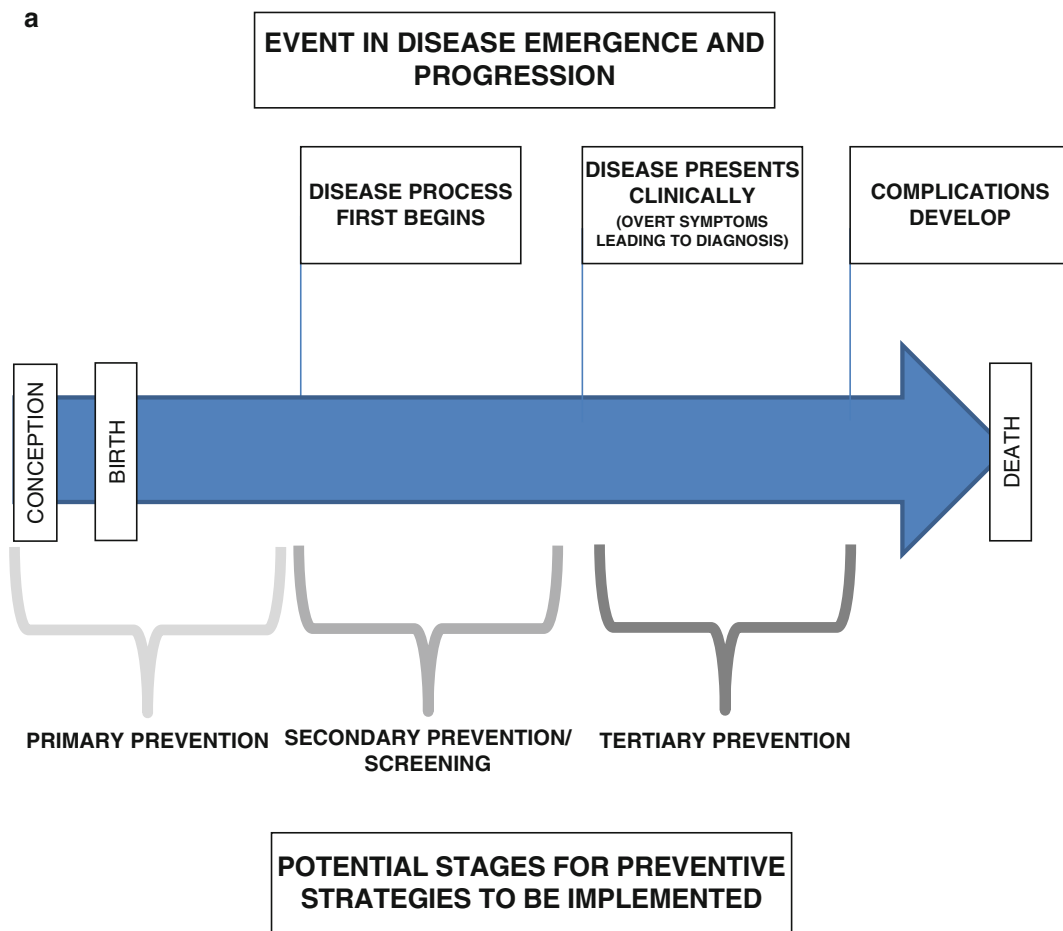


Fig. 2.4 (a) Overview of preventive strategies in relation to disease progression. (b) Illustration of preventive strategies as applied to an asbestos-induced cancer

In the field of preventive medicine, a distinction is often possible between two competing strategies for prevention: those oriented towards the *population* versus those oriented towards *high-risk groups or individuals*. In other words, there is debate over whether such initiatives should seek to address the needs of “sick individuals” or “sick populations” (Rose 1985)? In population strategies, efforts at prevention are directed *en masse* at an entire community (or significant portions of the community). Examples include the provision of general nutritional advice to consume more fruit and vegetables; screening of biochemical disorders at birth; health checks in women, men or older age groups. In contrast, a high risk strategy targets specific diseases or predisposing conditions in individuals known to be at higher risk of developing the condition. For example, lung function tests and imaging may be used to detect lung disease (such as pneumoconioses) in those who have worked in the industries with high levels of mineral dusts.

The distinction between population and high risk strategies is illustrated by considering possible public health

strategies for the control of elevated blood lipids (“high cholesterol”) (Rose 1993). A general population approach would tend to use regulatory, educative and structural strategies across the community (such as through advice on nutrition and exercise through the media) to reduce the overall levels of blood lipids in the entire population. In comparison, a “high-risk” approach might involve screening for high levels of blood lipids (such as through the individual’s family doctor) followed by specific dietary or medication regimes in those identified as being at high-risk. Depending upon the nature of the risk factor and the disease, a combination of both population-based and high-risk strategies may be implemented.

In practical terms, a large number of people exposed to a small degree of risk (e.g. moderately elevated cholesterol or moderately excessive bodyweight) may generate many more cases than a small number of people with high risk (Rose 1993). Therefore it may be necessary to focus on modifying behaviour in the large mass of people with slightly elevated risk in order to have a major impact on the overall rate of

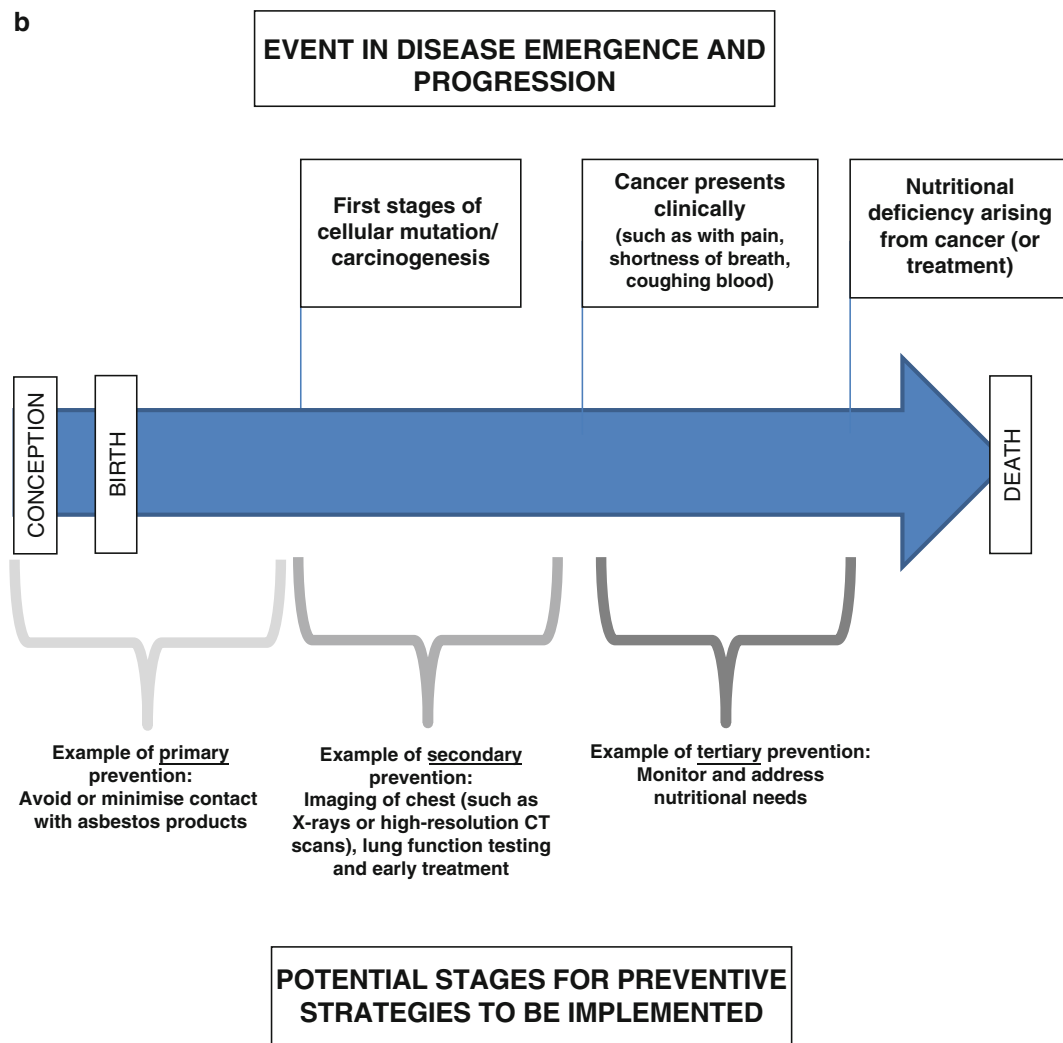


Fig. 2.4 (continued)

disease. In general, any preventive strategy should seek to provide the greatest benefit to the largest number of people, while also attempting to minimise the chance of causing inadvertent harm to the same population.

2.8 Research Methods in Public Health

Research into public health issues often employs the approaches and techniques of *epidemiology*. Epidemiology is broadly defined as the study of disease patterns in populations. Epidemiological analyses often seek to discover the causes, determinants or risk factors of a disease, usually in order to make prevention possible. The factors that may impact on disease include: hazardous agents such as micro-organisms or toxic chemicals, trace elements and minerals; lifestyle factors; and genetic influences. The term *environmental epidemiology* is often used to apply factors in

the environment that impact on disease, ranging from pollutants to infectious agents. Many of the principles of environmental epidemiology also have implications for studies used in the field of medical geology, and are described in Chap. 23.

There are three underlying questions common to all epidemiological studies. The first question is: *Who is to be sampled?* The study population must contain a proportion of people who either have the disease of interest or are potentially at risk of developing the disease, and should be representative of any broader populations to which the study results will be applied. The study population must be of sufficient size – and, by implication, a sufficient number of the participants must experience the exposure and disease events of interest – to achieve the required statistical power in the analysis. For example, an analysis of the relationship between inhalation of beryllium dust and lung cancer that drew all its participants from the general population would

be inefficient, because high levels of exposure to this compound in the community is relatively uncommon. Other practical issues that must be considered include the likely degree of cooperation from the study population, accessibility of the participants for enrolment, maintenance of confidentiality of the data, and the overall cost of recruitment, evaluation and follow-up of the participants.

The next question is: *How is data collection to proceed?* This involves considering the optimal approach to capturing information on the *risk factor or exposure of interest* and the *subsequent disease events*. Many methods may be used to estimate risk factors and exposure, including the use of interviews, questionnaires or diaries for each individual (Nieuwenhuijsen 2003; White et al. 2008). In some situations, physical or chemical measurements may be used at the point of contact, such as with personal monitoring (two well-known examples include dust monitors used by mining personnel and personal dosimeters used to record ionising radiation exposure). Bioindicators or biomarkers are measurements from body tissue, fluid or excretion products to obtain data on past exposure to chemicals or other agents. Exposure may also be inferred through use of physical, chemical and biological measurements of the environment, including soil, air, food, water and indicator organisms. For disease events, the process of ascertainment may include self-reports of illness, medical records, laboratory results, or the study itself may involve testing procedures in the protocol (Silva and International Agency for Research on Cancer 1999).

Lastly, *What sort of analysis and evaluation is planned?* This involves a thorough interrogation of the data: Were the sampling procedures conducted successfully? How strong is the evidence of an association between the exposure and the disease? How much of the relationship between exposure and disease might be influenced by random variation, bias (systematic distortion of results) or confounding (mixing of effects)? How generalisable are our data to other populations?

Epidemiological results are often presented in terms of *measures of effect*. In general, these provide an estimate of the magnitude of association between the *risk factor or exposure* and *the disease* (or outcome of interest). A commonly used measure of effect is the *relative risk (RR)*, which estimates how many times more likely it is for “exposed” persons to develop the disease relative to “non-exposed” persons. An example of how these relative measures are applied is provided by Baris and Grandjean (2006) in their prospective study of mesothelioma mortality in Turkish villages exposed to fibrous zeolite. (In certain villages on the Anatolian plateau in Turkey, inhabitants are exposed to erionite, a form of fibrous zeolite, which is present in the volcanic tuffs that are used as building stone. Mesothelioma is an aggressive form of cancer linked to exposure to certain fibrous minerals.) In this study, the residents from a selection

of villages in the area were followed up for the period 1979–2003, and the mortality rates from mesothelioma were calculated. For one of the analyses, adults from villages with high levels of erionite exposure were compared with a non-exposed “general population”: in this case, the population of another country (Denmark) was used as the referent. The authors reported that the mortality rate from pleural mesothelioma (which affect the membranous linings the lungs and chest cavity) of highest-risk villages *relative to* the general population was 485 (a measure called the *standardised mortality ratio* for pleural mesothelioma). In other words, the “exposed” population (that is, residents from the high-risk villages) were 485 times more likely to develop pleural mesotheliomas than a “non-exposed” (“general”) population.

Epidemiological studies are often classified into different groups, depending upon their purpose and design. These include *descriptive studies*, *analytic studies*, and *intervention/experimental studies*. A brief outline only is provided here, and readers seeking more detail are encouraged to refer to Chap. 23 or a general textbook on epidemiological principles (such as (Farmer and Lawrenson 2004; Gordis 2009; Rothman et al. 2008; Szklo and Nieto 2007)).

Descriptive studies often focus on the “time, place and person” component of epidemiology. In other words, such studies seek to determine: *Who* is at particular risk of this disease? *When* did they get the disease? *Where* are they located?

The “person” component of the analysis identifies the characteristics of the group at risk of the disease, such as their age, gender, ethnicity, occupation, personal habits and presence of co-existing disease. The “place” component determines the spatial dimension of the disease events. Diseases may vary with the biological environment (e.g. local ecology may influence the presence of disease vectors, such as mosquitoes carrying malaria), the physical environment (e.g. climate; geology) and the sociocultural environment (e.g. sanitation and hygiene practices; cultural practices; nature of social interactions). The importance of place and of mapping diseases has been part of epidemiology since the discipline formally began: John Snow famously mapped cholera cases around the Broad Street water pump in London in 1854, thereby helping to confirm that the disease was water-borne (and not spread by miasmatic vapours, as had been widely assumed). The spatial patterns of disease can often provide supporting evidence for the underlying disease process, such as relating cases of thyroid cancer to the Chernobyl nuclear accident or the increased risk of kidney damage in areas with cadmium contamination in Japan.

The “time” component of descriptive studies defines how the frequency of the disease varies over a defined interval (or may seek to determine whether the disease frequency is different now than in the past). *Time series*

studies refer to analyses that follow the rates of disease in a given community or region through time. Time patterns in disease may be: *short-term*: temporary aberrations in the incidence of disease, such as outbreaks of gastroenteritis; *periodic/cyclical*: diseases with a recurring temporal pattern, such as the seasonal fluctuations in respiratory diseases, which are often more common in the winter months, or; *long-term/secular*: changes in the incidence of disease over a number of years or decades, such as the rise in HIV/AIDS incidence since the 1980s.

Different terms are used to capture variations in the disease pattern. An *epidemic* refers to a general rise in case numbers above the background rate of the disease. An *outbreak* usually refers to a localised epidemic, and is often applied to infectious diseases. Although a *cluster* also refers to a close grouping of disease (or related events) in space and/or time, it is usually applied to uncommon or specific diseases, such as birth defects or cancer.

An example of how this descriptive approach may be applied is provided by the outbreak of coccidioidomycosis in California in 1994 (Pappagianis et al. 1994). This infectious disease usually results from inhalation of spores of the dimorphic fungus *Coccidioides immitis*, which grows in topsoil. In their report, the study authors define the “time, place, person” components as follows: “[f]rom January 24 through March 15, 1994, 170 persons with laboratory evidence of acute coccidioidomycosis were identified in Ventura County, California.” This number “substantially” exceeded the usual number of coccidioidomycosis cases seen in Ventura County. To account for this change in incidence, the authors noted that the “increase in cases follows the January 17 earthquake centered in Northridge (in adjacent Los Angeles County), which may have exposed Ventura County residents to increased levels of airborne dust” (Pappagianis et al. 1994). The temporal and geographical pattern were supported by subsequent environmental data indicating that significant volumes of dust been generated by landslides in the wake of the earthquake and aftershocks, and that this dust had been dispersed into nearby valleys by northeast winds (Schneider et al. 1997).

Another group of epidemiological studies are termed *analytic*. Traditionally, these address specific hypotheses using more formalised designs than the descriptive studies, and incorporate a well-defined comparison (“control”) group. For example, in *case-control studies*, the population is first defined with reference to the presence or absence of disease (such as lung cancer). The individuals with the disease, known as the “cases”, are compared to a non-diseased group (known as the “controls”) with respect to some exposure history (such as their past employment in the asbestos industry). In contrast, for *cohort studies*, a study population is first defined with reference to their degree of exposure or presence of the risk factor (such as the number of years they have been employed in the

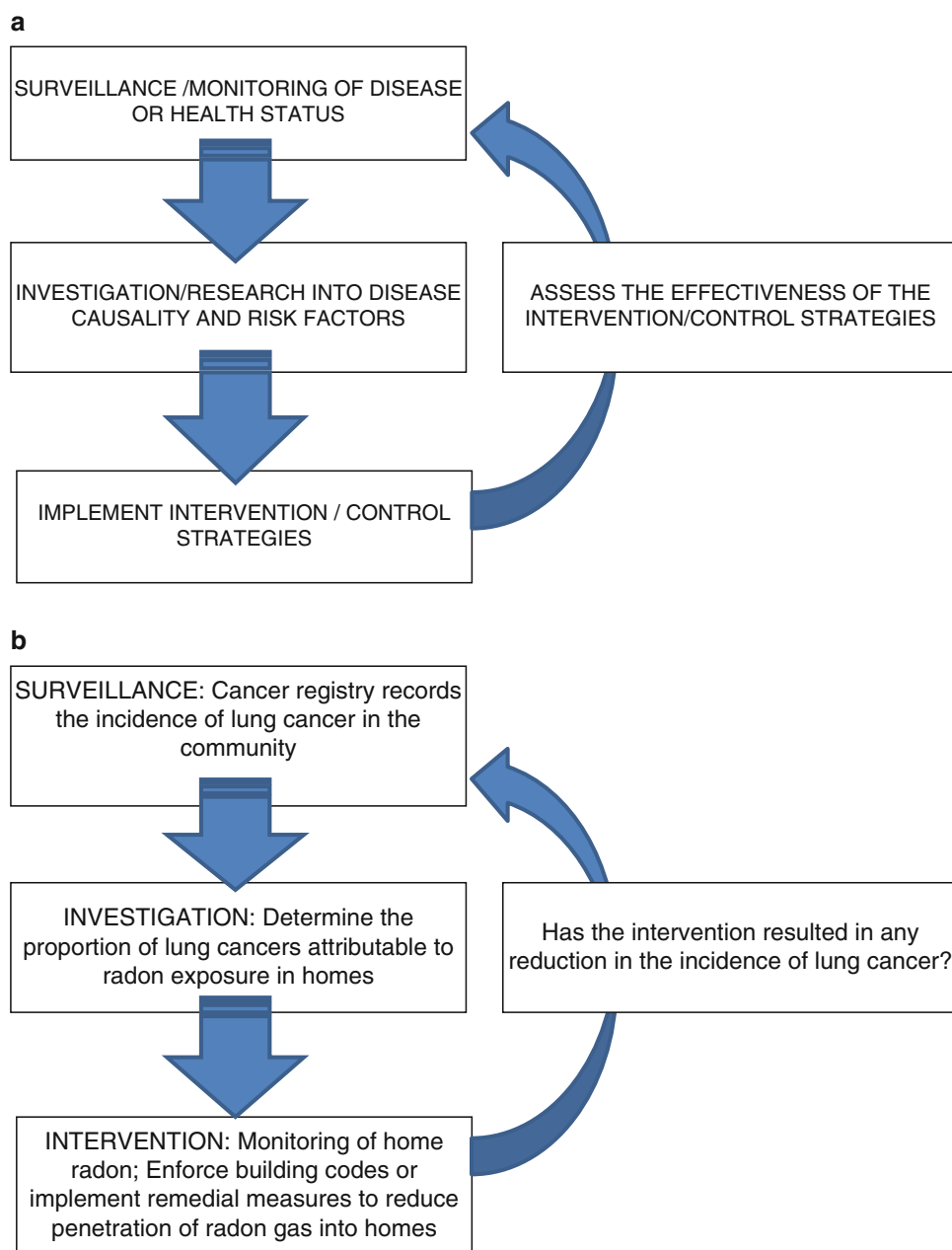
asbestos industry). This population is “disease-free” at the start of the study period. The participants (known collectively as a “cohort”) are then followed over time to determine who experiences the disease (such as lung cancer) and who does not.

This analytical approach is demonstrated in the prospective study of arsenic exposure from drinking water and skin lesions (skin thickening or changes in pigmentation) in Bangladesh by Argos et al. (2011). (The skin lesions are often precursors to later skin cancers.) This cohort study involved identifying a group of around 10,000 individuals who were free of skin lesions at the start of the study. The exposure variable was defined as differential use of wells in the study area as a source of drinking water. There were a total of 5,966 wells, encompassing a range of arsenic levels from the detection limit (0.1 µg/L) to >200 µg/L. The study participants were followed for the years 2000–2009 (inclusive) and assessed clinically to determine who developed skin lesions. The authors reported that for every quintile increase in the concentration of arsenic measured in the well water, there was a 31 % increase in the risk of developing skin lesions.

In environmental epidemiology, one of the main challenges in conducting analytic studies relates to the reliable estimation of exposure. Although a range of environmental sampling techniques are available, it may be difficult to infer personal exposure based on such measurements. In practical terms, samples are often collected over short periods of time that may not correspond with the – often prolonged – process of disease emergence in a population. The disease may only occur after a significant delay in time, often decades in the case of cancer. Often, little may be known about the concentrations of contaminants which produce epidemiological effects in human populations, or the time period between the exposure and an expected effect. Reliance on, or inferences based on, past measurements may also be problematic because of inaccuracies in the historical data.

The last group of epidemiological studies use *intervention-based (or experimental) designs*. Such studies compare a group of subjects who receive an intervention (the “treatment group”) versus a group who receive another (or no) intervention (the “control group”). Often there is a process of random assignment of participants into these two groups. For example, a new cholesterol-lowering tablet may be compared to an alternative form of medication to determine whether there is significant difference on the rates of a subsequent cardiovascular event (such as a heart attack). Environmental epidemiological studies often do not use experimental interventions because it is difficult to manipulate environmental variables on a large scale, and the interventions may be unethical if the safety or wellbeing of either the “treatment” or “control” group is jeopardised.

Fig. 2.5 (a) Schema of the main elements of a public health system. (b) Public health in a medical geology context: Radon exposure in the home and lung cancer



2.9 Integration and Application

In summary, geological and geochemical dynamics are integral to most of Earth's systems, and should be incorporated into existing descriptions and models of public health. The discipline of medical geology emphasises the fundamental degree to which geological processes are interconnected with the wellbeing of human communities. In many situations, patterns of disease emergence must directly or indirectly take account of geologically-driven determinants. Maintenance of wellbeing in human populations relies upon effective monitoring and management of the geosphere, especially given that anthropogenic interventions can accelerate

the nature and pace of change. An integrative framework is required to evaluate, investigate and manage potential risks to communities, and must incorporate knowledge from both earth sciences and health sciences.

The core elements of the public health system can be conceptualised in Fig. 2.5a.

As noted, there are many applications of medical geology that have direct relevance to the field of public health. An integrative example will be provided here, emphasising the major themes and inter-disciplinary links covered in this chapter.

A major risk to human populations is the radioactive gas, radon, which has been linked to lung cancer. Radon-222 is a naturally occurring decay product of uranium-238 which is

commonly found in soils and rocks. Radon-222 progeny, particularly polonium-218, lead-214, and bismuth-214, are of health importance because they can be inspired and retained in the lung. Public health agencies rank residential radon-222 exposure as one of the leading causes of lung cancer after tobacco smoking. An example of how the main components of a public health system relate to the issue of radon exposure in the home and lung cancer is provided in Fig. 2.5b.

See Also the Following Chapters. Chapter 3 (Natural Distribution and Abundance of Elements) • Chapter 12 (Arsenic in Groundwater and the Environment) • Chapter 19 (Natural Aerosolic Mineral Dusts and Human Health) • Chapter 24 (Environmental Medicine) • Chapter 25 (Environmental Pathology).

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