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FACTORS IN THE PHYSICAL ENVIRONMENT AND THE HEALTH OF THE DUTCH POPULATION

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PREFACE

In November 1993 the National Institute of Public Health and Environmental Protection (RIVM) published a document which describes the current health status of the Dutch population and which contains past trends and, where possible, expected future developments over the period 1950-2010: *the Public Health Status and Forecasts (PHSF) document.* The document is a rearrangement of existing information by the RIVM along the lines of a conceptual model in close cooperation with many other research institutions. The PHSF document is to be used in policy development or policy evaluation by the Dutch Ministry of Health, Welfare and Sport. It is the first in a series and has to appear every fourth year.

The Dutch edition of the PHSF document is made up of three parts. *Part I* gives the broad 'story line'. Starting with the formulation of the concept, it goes on to give a summary of the most important data on the current health status and that of the recent past, and on the determinants of this health status, ending with a look at possible future developments and the usefulness of the assembled material for policy development. *Part II* contains various contributions on the health status and its indicators, and *part III* those on the determinants of health status.

Part I of the PHSF is already translated into English. From the *parts II and III* only several contributions are translated into English, 'Factors in the physical enviroment and health' is one of them and the subject of this RIVM report. In international literature a lot of attention is payed to this subject. So translation into English seems justified. The report gives a summary and analysis of the available information on factors in the physical environment and health in the Netherlands. This is a translation of *part III 2.2* of the Dutch version. The English edition of 'Public Health Status and Forecasts: The health status of the Dutch population over the period 1950-2010' is published by the Sdu Uitgeverij Plantijnstraat, The Hague 1994, under ISBN 90 339 0697 1. This publication can be ordered from Sdu servicecentrum Uitgeverijen, PO box 20014, 2500 EA The Hague, The Netherlands. Telephone: 031 70378 98 80. Or by fax: 031 70378 97 83. The price of Public Health Status and Forecasts is DFL 44.50 (the forwarding not included).

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ABSTRACT

The number of factors in the physical environment possibly having an adverse effect on human health is very substantial. There are, for example, all kinds of pathogenic micro-organisms, countless substances which have been shown to be carcinogenic in laboratory animals, as well as various forms of radiation. In addition, many hazardous activities, such as motoring, skiing or diving, may pose a threat to our health.

In this document, which was previously published in Dutch as part of the Public Health Status and Forecasts document, a structured overview is given of factors in the physical environment which may adversely affect human health. In addition the chain of events from exposure to health effect is described in terms of different types of environmental health risk indicators. Methodologies for health risk identification and quantitative assessment will be discussed briefly, as well as the possible health gain of risk reducing policy measures.

After this general introduction examples of chemical (indoor and outdoor air pollution), physical (noise, radiation) and biotic (microorganisms in drinking water) factors will be elaborated in successive contributions (chapter 2 to 4). In all contributions topics of the relationship with other determinants of health, intervention and policy (possible health gain), data and information requirements are addressed.

1 PHYSICAL ENVIRONMENT

1.1 Introduction

The number of factors in the physical environment possibly having an adverse effect on public health is very substantial. There are, for example, all kinds of pathogenic microorganisms, countless substances which have been shown to be carcinogenic in laboratory animals, and various forms of radiation. In addition, there are many hazardous activities, such as motoring. It is not possible to deal in depth here with all the risk factors which have been identified. After a general introduction (factors in the physical environment and health), examples of physical, chemical and biotic factors will be elaborated in successive contributions (*2 to 4*), specifically: radiation, noise, some forms of air pollution, and microorganisms in drinking water. The examples do not give a representative picture; this is not possible, given the state of knowledge. The availability of scientific views, the interest of policy-makers and the public, and the likelihood of effects occurring all played a part in the selection.

1.2 Factors in the physical environmental and health

A.E.M. de Hollander [1 2]

1.2.1 Physical, chemical and biotic factors

"Physical environment" is used to mean everything that can be described in chemical, physical or biological terms, such as soil, water, air, climate and the organisms surrounding us. In common parlance the term *the environment* is used to mean the physical environment.

Human beings are adapted to the physical conditions occurring on earth. These conditions, such as temperature, air pressure, the ratio of gases in the atmosphere, the amount of sunlight and the availability of water, can vary within certain limits. Plants, animals and microorganisms, in combination with the physical and chemical conditions, form *ecosystems* which fulfil functions that are essential to human health. Such functions include the permanent production of food and natural resources, the degradation of waste products and the stabilisation of climatological and geological conditions.

It cannot be taken for granted that the physical environment is benign, however. Every biological species finds in its environment both basic conditions for health and threats to health. Thus edible plants, besides containing essential components such as vitamins and antioxidants, also contain toxic substances (for example, natural pesticides which enable plants to defend themselves against insect damage or against being ousted by other plants). Our own ecosystem includes not only the organisms which provide us with food, and the microorganisms making up our intestinal flora, with which we live in useful symbiosis, but also predators, vermin, parasites, germs and viruses which threaten our health.

Generally speaking, the more that factors in the physical environment depart from the conditions to which man is adapted, the greater the threat to health. This is the case, for example, with exceptional cold or heat. In striving to overcome natural threats and improve the quality of his existence, man has in the course of time increasingly managed his environment. This "stewardship" has led to new threats, such as contamination of the environment with substances and radiation. Large-scale phenomena such as the rapid decline in the integrity and diversity of natural ecosystems, climatic changes due to greenhouse gases, and acidification, eutrophication and desertification pose an indirect threat to public health (WHO, 1990).

Factors in the physical environment are often classified according to their nature into three groups: chemical, physical and biotic factors. *Physical factors* like sunshine, rainfall and soil conditions largely determine the livelihood of human populations and thus also their health. Physical factors also include noise, radiation, vibrations, light, physical loading and causes of accidents associated with the transfer of energy, such as earthquakes, floods, fires, explosions in industrial plants, and road accidents.

The number of *chemical factors* is almost infinite. Tobacco smoke alone contains around 3,800 different substances (NRC, 1986). In 1990 the ten millionth unique chemical compound was added to the American Chemical Society's "Chemical Abstract Service" (ACS, 1992). Roughly 100,000 chemical substances are produced for the market, including (veterinary) medicines, pesticides, food additives and solvents (CEC, 1990). Other substances, such as radon or heavy metals, occur naturally. These can pose a threat to health where exposure to them or their biological availability increases as a result of human activity. Some substances are an absolute prerequisite for life, others are harmful even in small quantities. The harmfulness is determined above all by the dose. Substances we cannot do without, such as oxygen or vitamin A, are already toxic when there is a relatively small increase in exposure. Only for a limited number of chemical substances is there any quantitative data on properties which are detrimental to health.

Biotic factors include living organisms occurring in or on the human body and in man's immediate environment, or products and their remains (pollen, endotoxins, allergens). The organisms involved here are: viruses, bacteria, protozoa, worms, moulds and yeasts; vermin such as mites, lice, mosquitoes, cockroaches and ticks which can transmit pathogens (vectors); and hazardous substances of biological origin. The human body is in any case permanently colonised by a large variety of microorganisms which often perform an important function in metabolism and in protecting against invading foreign organisms. In healthy people this "commensal microflora" is in equilibrium with the body's immune system. When this equilibrium is upset, a "harmless" microorganism can cause a disease (or even death). Examples of such commensal infections are boils (*staphylococci*), *candida, legionella, herpes simplex* and *tuberculosis*.

With infectious diseases, *infection cycles* play an important part. Where the microorganism that caused the infection is still viable when excreted, the infection cycle is complete. Some cycles of this kind are simple, as with the polio virus (from person to person), but with other pathogens (e.g. Salmonella) the cycle includes people, animals, food and various environmental compartments. A distinction is made between *reservoirs* (places where the microorganism actively multiplies), *vectors* (live or other factors which spread the organism) and *hosts* (in which effects can also occur following infection). A host is by definition also a reservoir and often the most important or even the only reservoir. In the case of parasites a distinction is made between the *definitive host* (the organism in which the adult parasite lives and reproduces) and the *intermediate host* in which the infectious stage develops for a subsequent host (usually via asexual reproduction). An intermediate host is often also a vector. A well-known complex infection cycle is that of *malaria*.

1.2.2 Threats to health which are associated with factors in the physical environment

Environmental factors can pose a threat to every conceivable aspect of health. Some threats are so obvious that they often don't occur to us: for example accidents (drowning, burns, frostbite or road accidents). Others become apparent to us only after complicated scientific models have been used - for example, the breakdown of the ozone layer by CFCs in the atmosphere and the consequences of this, or the theoretical increase in the risk of cancer through exposure to a few molecules of certain carcinogenic substances. From time immemorial, man has learnt to live with poisonous substances of animal or vegetable origin. Sometimes he has even turned these to his advantage, for example by making use of the therapeutic or narcotic effect of plant constituents. However, the nature and pattern of exposure to chemical factors has changed drastically as a result of recent industrial and agricultural developments. A great number of substances produced or processed by man (persistent chlorinated hydrocarbons, heavy metals, pesticides, herbicides, radioactive substances) are dispersed throughout the environment, though the concentrations are generally relatively low.

As long ago as 1775, Sir Percival Pott established that cancer of the scrotum in young chimney sweeps was attributable to the tar which they accumulated in the folds of their skin in the course of their work. This early finding with respect to industrial hygiene was followed by a long series of observed associations between working conditions and the poor state of health of employees: pneumoconiosis among miners, asbestosis and mesotheliomas among asbestos workers, leukaemia among workers in the petrochemical industry or at nuclear power stations, neurological functional disorders among workers in the chemical industry, and lung cancer among coke-oven workers.

The outdoor environment has also constituted a threat to health. British researchers have made a reasonable case to show that a serious episode of London *smog* in 1952 led to the premature death of around 4,000 people (Logan, 1953; Thurston *et al.*, 1989). Similar observations have been made during episodes of smog in the valley of the river Meuse (1930) and in the town of Donora in Pennsylvania (1948). Many environmental incidents followed, such as itai-itai disease in Japan (a painful bone disease caused by cadmium poisoning - the Japanese name means "ouch-ouch"), skin and liver diseases and neurological disorders in Japan and Taiwan caused by rice oil being contaminated with polychlorinated biphenyls (PCBs), deaths on a massive scale in Iraq caused by grain contaminated with methyl mercury, and a seriously disordered immune response in a large number of people in Spain after using olive oil contaminated with PCBs (Van den Doel *et al.*, 1989; WHO, 1991).

The 1953 flood disaster in the Netherlands which affected the islands of the provinces of Zeeland and South Holland is an example of an "environmental incident" of a physical kind; air and rail disasters, explosions of industrial plants, and the epidemic of road accidents (like during the holiday exodus) can also be regarded as environmental incidents. Other examples of physical factors which may be detrimental to health are the worldwide spread of radioactive substances as a result of nuclear weapons testing carried out above ground, the steadily growing use of radioactivity and nuclear power (UNSCEAR, 1988), and noise and vibrations in the working environment (SoZaWe, 1991).

It has long been realised that there is a link between the occurrence of infectious diseases and the "environment", even if the causal factor was often not known. The Ancient Greeks, and later the people of the Middle Ages, attributed epidemics to *miasma*, a mythical contagium in the (humid) environment. In 1854 John Snow, without knowing of the existence of pathogenic microorganisms, correctly ascribed a cholera epidemic to the use of water from the Thames as drinking water. Infectious diseases remain topical in view of the annual recurrence of influenza, outbreaks of tuberculosis and polio, or the AIDS epidemic. Food poisoning (ranging from mild to very severe) is still a very common occurrence in the Netherlands (*see Part IIB, 1.2* of the Dutch edition).

From the foregoing, the picture which emerges is of a world full of danger. However, many evident causes of morbidity or mortality have in the course of time been tackled wherever possible, for example by means of infrastructure provisions (ranging from traffic lights to the Delta Works [the series of dams built to prevent any repeat of the disastrous 1953 floods in the Netherlands]) and preventive measures, and through health protection legislation (*see Part III, 3.2.3* of the Dutch edition). Technological developments too have sometimes played a part. Thus the quality of our diet has improved considerably since the refrigerator found a place in almost every home.

Unravelling the relationships between environment and health

It is difficult to answer the question as to how far the physical environment currently affects the health of the population. This is firstly because the various determinants of morbidity and mortality are often closely interwoven. The pattern of predominant causes of death (cardiovascular disease, cancer, chronic respiratory disorders), for example, may be attributed above all to determinants such as lifestyle, social environment and the health-care system, as well as to the substantial increase in life expectancy and the elimination of other causes of death. In the morbidity and mortality statistics available one would search in vain for any new cancer epidemic or inherited disorders caused by recent industrial and agricultural developments (Doll and Peto, 1981; Rose, 1987; RIVM, 1991a; Doll, 1992). This is not to say that factors in the physical environment play no part at all in the development of these diseases. The complex interplay of causes has generally not been unravelled enough to allow the contribution of less dominant factors to be clearly distinguished, however. It is possible that the favourable effects on public health of increased welfare and technological developments are for the time being still hiding the unfavourable effects of the downside of all this: the adverse effect on the quality of the environment (RIVM, 1991; Schaapveld *et al.*, 1992). There are of course exceptions where the effect is quite clear, such as infectious diseases which may be put down to exposure to specific pathogens, or mesotheliomas, which are almost always associated with earlier exposure to high concentrations of asbestos fibres.

Secondly, the methods involving animal experiments and the epidemiological methods available are often not sufficiently sensitive to be able to determine the effect of factors in the physical environment. As long as a population's exposure to a risk factor is more or less the same, as is often the case, epidemiological studies are unlikely to reveal any effects on health. The significance for health of observations in (toxicological) animal models is often not sufficiently clear; conversely, for many diseases suitable animal models are lacking. For many disorders which produce a considerable burden of disease the role of environmental factors is still unclear - degenerative disorders of the nervous system (dementia, Parkinson's disease, Alzheimer's disease, multiple sclerosis) or of the locomotor system (rheumatoid arthritis), and disorders of the reproductive and immune system spring to mind here.

The chain from exposure to effects on health

The effect on health of factors in the physical environment starts with *exposure*. This can lead to a certain *body burden* (or, in the case of microorganisms, to infection). This body burden can then cause biochemical, physiological or mental changes which may or may not fall within the normal range of variation. Whether these changes are of significance to health depends above all on the degree to which the function of organ systems (or social functioning) is affected, on the duration of the changes and the possibilities for recovery or compensation, and on the possible loss of resilience (Netherlands Health Council (*Gezondheidsraad*), 1990). Hereditary or acquired (endogenous) factors, on the one hand, and interactions with other exogenous determinants, on the other, also play an important part. This is because endogenous factors determine an individual's vulnerability to the effects of exposure. The excess mortality seen in recent American research during episodes of air pollution can thus be regarded as the tip of the iceberg. Less pronounced effects, such as respiratory complaints and a slight reduction in lung function, occur in a much larger proportion of the population. In some people this leads, for instance, to absence from work, a visit to the doctor, or admission to hospital; for the very weakest with serious respiratory and cardiovascular disorders, the extra stimulus sometimes proves fatal (*see 2 and Figures 1.1 and 1.2*). Another example is microbial food poisoning, which is also a fairly common occurrence in the Netherlands. Serious complications and death due to food poisoning are rare, however, and affect mainly elderly people in the least robust health (*see Part IIB, 1.2* of the Dutch edition). The relationships between environmental factors and health can be brought into the picture using a number of "indicators" (*Figure 1.1*).

Exposure to chemical, physical or biotic factors can be determined, for example, as concentrations in air, food and drinking water, or the noise level outside people's homes. In most cases it is difficult to obtain an accurate picture of the exposure of the (Dutch) population. Exposure often takes place via various routes (ingestion, inhalation, sometimes via the skin) and in various environments (at home, at work, in the car). The levels of pollution may vary considerably from one environment to the next and from one minute to the next. Indoors they are sometimes structurally lower (ozone) but often also structurally higher (radon in dwellings, traffic emissions in cars, noise or chemical substances in the working environment) than out-of-door. The levels are also heavily dependent on behaviour (smoking, ventilation). There are structural differences in air pollution levels between urban and rural environments. Exposure is thus strongly associated with one's living environment and with determinants like diet and work.

Figure 1: Schematic representation of the distribution of the effects of air pollution among the population.
Source: American Thorax Society, 1985.

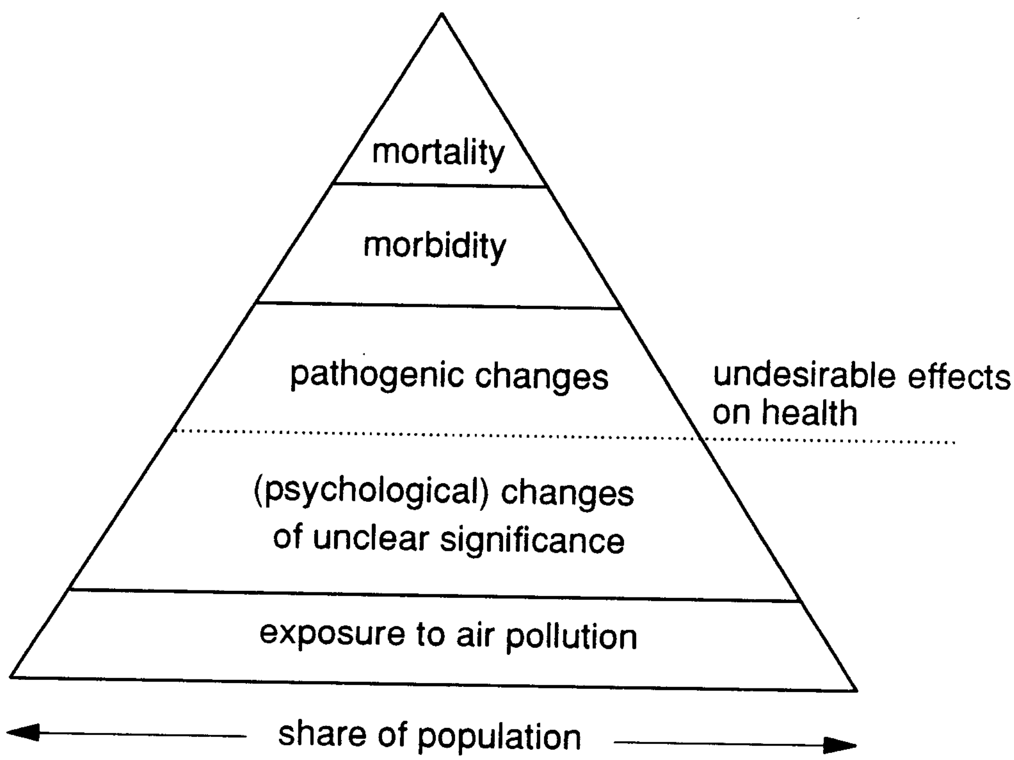
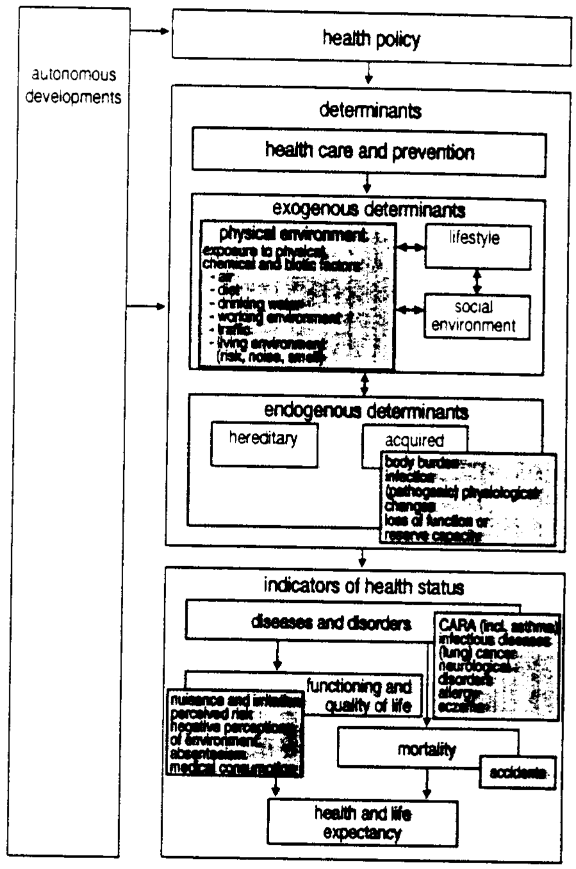


Figure 1.2: Schematic representation of the effect of the determinant 'physical environment' on public health in relation to other determinants.



Body burden as a result of exposure can be measured by determining concentrations of harmful substances or their metabolites in tissues or body fluids (biomonitoring: cadmium in urine, lead or carboxyhaemoglobin in blood, organochlorine compounds in breast milk, strontium in bone). For pathogens too, there is a series of tests for demonstrating infection.

Physiological changes as a result of body burden can lie within the normal biological variation or be of unclear health significance, such as a slight, reversible decrease in lung function and inflammatory reactions in the lungs during episodes of smog; enzyme induction upon exposure to solvents; or slight impairment of cellular DNA or protein as a result of exposure to substances or radiation.

Pathogenic physiological changes or reduced (organ) functions can also lead to disease or affect social functioning (sometimes measurable as absenteeism or medical consumption) and quality of life. Examples are: disturbed intellectual development in children as a result of chronic lead poisoning, sleep and concentration disturbance from aircraft noise, or sensitisation through exposure to pollen or (house-dust-mite) allergen.

For some *diseases and disorders*, there are known to be risk factors in the physical environment. Thus various forms of air pollution increase the risk of COPD and lung cancer. As already stated, however, only rarely is it possible to make a reliable quantitative estimate of the extent to which the environmental factor contributes to the development of a disease. Infectious diseases, of course, form an important exception.

Mortality. Since everyone dies sooner or later, here it is above all *potential years of life lost* (PYLL) which are of importance. Mention has already been made of the excess mortality in the United States during periods of air pollution (see also *2*). Statistics on major and minor accidents (traffic, industry) and infectious diseases also exist.

Besides the objective measures of health, e.g. by using questionnaires, one may measure subjective feelings with respect to health and wellbeing.

Thus *nuisance and irritation* as a result of smell or noise, or due to air-polluting substances which act on the mucous membranes, can affect social functioning and the quality of life, besides possibly leading to the development of disease or disorders.

Self-rated health and *perception* of the living environment reflect a person's social functioning and quality of life. The proximity of industrial complexes with smoking chimneys and processing plants, busy trunk roads and impaired natural scenery can lead to a negative perception of the quality of the environment. Experts' opinions on health risks often play a subordinate role here (Vlek, 1990; Provincie Zuid-Holland, 1991).

Possible effects on health in the long-term

Apart from the current public health effects, there is cause for concern about the consequences for public health of global changes in the biosphere which are being predicted for the next century. The *greenhouse effect* and the *breakdown of ozone in the stratosphere* have already been mentioned. The possible effects on health mentioned most (WHO, 1990) are:

* more skin cancer and cataracts as a result of increased exposure to UV radiation;

* more and different infectious diseases as a result of changes in the patterns of distribution of vector organisms such as mosquitoes and ticks;
* epidemics of diseases which are transmitted via drinking water, for example cholera and dysentery, associated with the reduced availability of drinking water and the higher temperatures which are to be expected;
* more famine and malnutrition through the loss of farmland;
* accelerated mortality among the elderly due to cold spells and heatwaves;
* more respiratory disorders (COPD, including asthma) due to air pollution.

At the same time, account will have to be taken of indirect effects like large influxes of environmental refugees and increasing international tension. To what extent such effects will actually occur, however, is still open to question.

Assessing health risks caused by environmental factors

The (toxicological) assessment of health risks has traditionally been geared above all to the nature and extent of the effect of separate factors at the level of the individual. After all, in most cases it was a matter of determining safe levels of exposure for the purpose of health protection. From the point of view of public health, it is also important to know how the exposure and the associated risk are distributed among the population, what the nature and extent of the exposure is, how the susceptibility of the "most susceptible" compares with that of the "least susceptible", and the extent to which there is accumulation of factors which may be detrimental to health. *Predicting* the effects on health of environmental factors at the level of populations, however, is still in its infancy.

The fact that a harmful effect of environmental factors frequently does not show up in health statistics or does not emerge from specific research does not, however, release the authorities from their obligation to pursue a preventive policy. Estimates of health risks can in that case serve as substitutes for observed effects. To this end, it is necessary to both identify and quantify the risks. In the case of exposure to hazardous substances or radiation, the quantitative risk can be assessed by extrapolating the relationships between exposure and response seen in animal experiments or epidemiological research (workers in the chemical industry, miners, patients who have been irradiated, or the Japanese survivors of both atom bombs) to the general population (or subpopulations). This will mean having to deal with various *uncertainties* such as:

* differences in susceptibility to the harmful effect of substances or radiation between laboratory animals and man, but equally between individual human beings (e.g. healthy as opposed to sick employees, infants, children, the elderly and pregnant women);
* differences between the research conditions and reality, for example in the level or pattern of exposure. Research involving animal experiments mostly relates to just one or a few substances, whereas in reality it is possible to be exposed to a large number of substances at the same time. All kinds of interactions are left out of consideration;
* limited information value of response variables in the research; a lot of research involves measurements of (biochemical) response variables whose significance for health is unclear; conversely, it is possible that the epidemiological and toxicological methods available (animal models) are "blind" to just those effects which are of great significance for public health;
* lack of experience (empiricism) with the quantitative analysis (estimates of the odds) of risks associated with large installations (chemical industry, nuclear power stations). There is also always the possibility of fundamental malfunctions or (human) errors being overlooked in accident scenarios.

The (quantitative) assessment of risk has always been geared above all to establishing levels considered to be safe by using "early" effects in laboratory animals and, in so doing, taking account of safety margins or making use of models which probably overestimated the risk. The aim was, after all, to prevent the effects as far as possible. Most estimates of this kind are consequently less suitable for predicting the actual occurrence of effects in terms of public health.

In order to be able to assess the risk of exposure to pathogenic microorganisms, it is necessary to have some insight into the nature and extent of *infection cycles*. Enhanced insight of this kind at the same time offers points of departure for combating and preventing infectious diseases. To date, this has been done mainly qualitatively, with the emphasis being on running (production) processes hygienically and breaking through infection cycles. There is a growing need for more quantitative risk analyses.

1.2.3 The quality of the physical environment in the Netherlands

The quality of the physical environment in the Netherlands is measured by a large number of (government) agencies. Physical factors like the weather and earth tremors are recorded by the Royal Dutch Meteorological Institute (KNMI), while the safety (or otherwise) of processing plants and traffic is recorded by the competent departments (the Ministry of Housing, Spatial Planning and the Environment (VROM) and the Ministry of Transport, Public Works and Water Management (V & W), respectively), and also at the provincial and municipal level (Nuisance Act, municipal traffic policy).

The spread of various chemical and radioactive substances in the environment is monitored with the help of national monitoring networks for air, surface water and ground water (e.g. by the RIVM (National Institute of Public Health and Environmental Protection), the KIWA (Waterworks Undertakings Testing and Research Institute of the Netherlands), DBW/RIZA (Government Institute for Integral Freshwater Management and Waste-Water Treatment), District Water Control Boards and waterworks undertakings). Cases of soil pollution are listed by the provinces and collected in the "Soil Pollution Information System" at the Ministry of Housing, Spatial Planning and the Environment (VROM). The larger municipalities (ones with more than 40,000 inhabitants) collect information on concentrations of traffic emissions at street level and on the noise load outside people's homes in so-called "environmental traffic maps".

Levels of a number of chemical and radioactive substances in food and drinking water are monitored by various institutes (RIKILT (National Quality Control Institute for Agricultural and Horticultural Products), the Health Protection Inspectorate/Food Inspection Department, RIVM, various TNO institutes and waterworks undertakings). At the Chief Medical Inspectorate's request, RIVM is carrying out a monitoring programme entitled *Man and Nutrition* in which the exposure of the general population is monitored by means of periodic analyses of foodstuffs or tissue specimens, body fluids and excretion products. The substances involved are PCBs, dibenzodioxins and dibenzofurans, heavy metals such as lead and cadmium, polycyclic aromatic hydrocarbons (PAHs) and some pesticides. The Coordinating Committee on the Monitoring of Radioactivity and Xenobiotic Substances (CCRX) has been collecting the results of the various monitoring programmes since 1974 and issuing reports on them each year (CCRX, 1993).

Fewer but more systematic inspections of the microbiological quality of foodstuffs, meat products, drinking water, surface water and swimming water are also carried out with the help of indicator organisms (*see Part III, 3.2.3* of the Dutch edition). At the same time, a reporting requirement applies with respect to certain infectious diseases (*see Part III, 3.2.1.1*).

The National Environmental Outlook documents which RIVM periodically issues in collaboration with other scientific institutions evaluate the current and future quality of the environment in order to provide a basis for national environmental policy. Aspects of environmental quality (emissions, depositions or concentrations of pollutants in environmental compartments) are integrated in these documents at different scale levels. Trends are predicted with the help of prospective scenarios, and gaps in present knowledge are also indicated (RIVM, 1991a).

TNO Prevention and Health is just one of the organisations commissioned by the Ministry of Social Affairs and Employment (SoZaWe) to collect data on factors in the physical environment, such as the ones occurring as a result of working conditions in various sectors of employment. The factors involved are physical loading, noise, vibrations, climate, chemical and biotic factors, and ionising and non-ionising radiation (SoZaWe, 1991).

1.2.4 Relationship with other determinants

Risk groups

Different individuals may react very differently to the same exposure to a particular factor in the physical environment. After all, this individual response depends on the interaction between endogenous (genetic factors and acquired) characteristics and other *exogenous* factors which affect health, such as social environment and lifestyle (*see Figure 1.2*). The more unfavourable factors there are, the more severe an individual's response to exposure to a particular factor will be. Examples of this are:

* high genetic susceptibility; for example unfavourable detoxification metabolism (*see Part III, 1.1* of the Dutch edition) or a defective DNA repair mechanism;
* reduced resilience as a result of (earlier) disease, youth or old age (*see Part III, 1.2.6* of the Dutch edition);

* (simultaneous) exposure to other environmental factors (for example smoking, alcohol, medicines, microorganisms);
* factors which disorder the body's immune system (*see Part III, 1.2.5* of the Dutch edition), such as infectious diseases, certain forms of (pharmaco)therapy, and possible exposure to chemical substances or UV radiation (Goettsch *et al.*, 1992; Gezondheidsraad, 1991).

For some groups, certain factors thus constitute a higher-than-average risk (Zielhuis and Wibowo, 1989). People with serious cardiovascular and respiratory disorders are thus more sensitive to air pollution (WHO, 1991). Where soil pollution is concerned, children constitute a risk group, firstly because they explore the world with their hands and mouths, and secondly because many organ systems are still in the course of development (Barltrop, 1966; Brunekreef, 1985). In connection with ageing of the population, it is important to remember that the elderly are sometimes at greater risk because of the declining function with age of organs and organ systems such as the kidneys, liver, the immune system or the lungs. A longer life span also means that toxic substances can act longer on biological systems or accumulate in tissues (NRC, 1986; Cooper *et al.*, 1990).

Other determinants

Behaviour (lifestyle) can have an important effect on both exposure to environmental factors and a person's susceptibility (endogenous determinant) to them. Examples are: excessive sunbathing, smoking, excessive consumption of alcohol, reckless behaviour or a rather limited diet.

Socioeconomic status is also often associated with both exposure and susceptibility to health-threatening environmental factors. In the older quarters of towns a lower socioeconomic status goes hand in hand with a generally less healthy lifestyle, lower consumption of health-care facilities, unhealthier work and higher unemployment, frequently also associated with a living environment characterised by poorer-quality housing, heavy traffic, industrial emissions and nuisance from smells and noise (OLR, 1976; Provincie Zuid-Holland, 1991; Van Oers *et al.*, 1991).

1.2.5 Interventions and policy

In the West, public health has seen favourable developments, particularly in the last 150 years. The installation of drains and sewers and drinking-water supplies, good housing, and the availability of a varied, high-quality diet (partly thanks to the use of pesticides, biotechnology, modern cold-storage techniques and preservatives) have had a positive influence on a number of indicators for public health, such as infant survival rates and average life expectancy (McKeown, 1978; Cohen, 1987; RIVM, 1991). A substantial part of the gain may be attributed to the successful combating of child mortality from infectious diseases, as is also apparent from comparisons with mortality figures from the Third World (Doll, 1992). In addition, *health protection* (food safety, working conditions, drinking-water supply; *see Part III, 3.2.3* of the Dutch edition) is expected to have had a favourable effect, albeit one which is not easy to quantify.

Health gain

A distinction can be made between *measurable* effects on health of environmental factors, and effects which are based purely and solely on the *application* of insights gained from animal experiments, but which have not been observed in epidemiological research. The first group includes infectious diseases, effects on the respiratory system of air pollution (NO_2, tobacco smoke and allergens indoors; smog and vehicle emissions outdoors), nuisance from noise and smells in population centres with high levels of industry and traffic, (road) accidents, and skin cancer caused by UV in sunlight. There are also various disorders associated with the loading found in certain occupations: back trouble and arthrosis caused by physical loading and vibrations, hearing loss caused by noise, and neurological and respiratory disorders caused by chemical substances. Tackling factors such as these should result in further measurable health gains (RIVM, 1991; SoZaWe, 1991).

The *second National Environmental Outlook document* (RIVM, 1991a) lists a number of chemical or physical factors which, on the basis of quantitative analyses, may be expected to have effects on health (radon, polychlorobiphenyls, polycyclic aromatic hydrocarbons, benzene). Further reductions in exposure could mean gains from the point of view of prevention. Given the limited resources available, it would be necessary to look at the cost and benefits of measures. Here one might ask whether the exceeding of a theoretical risk level is enough or whether an assessment should be made of the gains to be obtained in terms of public health. The questions to be asked would then include the following:

* how big is the population which is at risk?
* can risk groups be identified?
* how many (healthy) potential years of life lost are involved?
* what is the contribution to the occurrence of disease, nuisance, absenteeism and medical consumption?
* what importance does the population attach to the problem defined by experts (Vlek, 1990; Midden, 1993)?

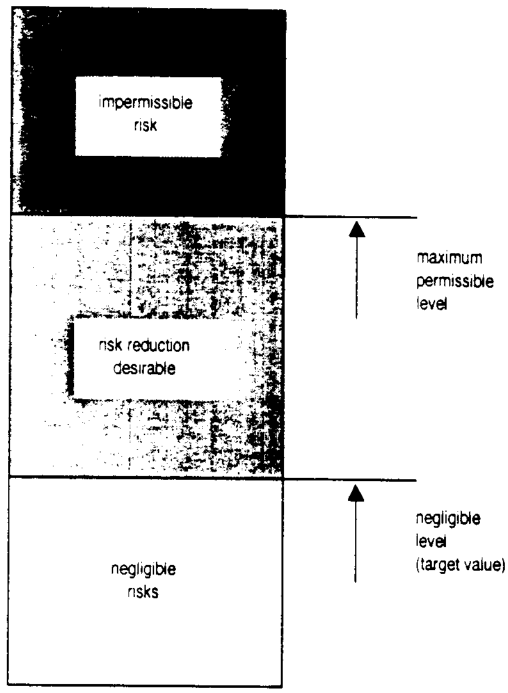
Controlling processes which lead to global changes to the biosphere will eventually result in major health gains, albeit that these will be enjoyed above all by future generations (WHO, 1990).

Policy

An important principle of industrial hygiene and environmental protection is that the prevention of adverse effects on health due to factors in the physical environment is better than cure. At the same time, in principle each individual deserves protection. Policy is determined from the estimated health risks for the individual, and preferably not on the basis of observed effects on health.

The most obvious way of curbing the health risks arising from (industrial) developments is to have the processes run as cleanly, safely and economically as possible. Secondly, one can try to limit an individual's exposure to health-threatening factors by setting standards. Standards exist for the quality of ambient air and indoor air at the workplace, for additives and residues of pesticides and veterinary medicines in foodstuffs, for the chemical and microbiological quality of drinking water, for the surface water and soil, and for external safety. Sometimes these are based on quantitative risk assessments, but often also on qualitative considerations (for example, not detectable, or below an arbitrary limit). Considerations of (socioeconomic) attainability also apply.

Figure 1.3: The systematics of risk standardisation.
Source: Policy document "Premises for Risk Management" (Tweede Kamer, 1990).



For environmental policy, the approach which has been elaborated the most is one which involves setting standards on the basis of risks. According to the approach described in the policy document *Premises for Risk Management* (Tweede Kamer, 1990), the severity of environmental problems (radiation, substances and external safety) is "measured" using quantitative estimates of the risk to human health and the environment. The quantitative measure which has been worked out most is the *individual risk*, i.e. "the risk per year that an individual will die as a result of exposure to a particular risk factor". A system of risk standards is central to this approach, these being taken as the "measure" of different environmental problems. Once the (individual) risk exceeds a certain level, the activity or situation is impermissible. Below a certain risk level, an activity may be ignored as far as the authorities are concerned. In the area in between, the rate at which risk-reducing measures are introduced is determined by weighing up the costs and benefits (*see Figure 1.3*). It is up to politicians to decide the level at which risks are deemed to be impermissible or at which they are considered negligible.

In some areas of policy this approach leads to standardisation of environmental risks which is acceptable to most parties, for example where problems of external safety are concerned. In other cases, the approach fails because the measure used, mostly the mortality risk, does not sufficiently characterise the risk. There are all kinds of activities which do not cause death directly, but do cause nuisance or non-lethal impairment of health. Moreover, the population's acceptance of risky activities is often heavily dependent on sociopsychological aspects such as their (general) usefulness, confidence in the authorities and management, familiarity with or dependence on risky activities, the presumed (un)controllability of activities and their negative consequences, the social distribution of the pros and cons, and the voluntariness of exposure. Expert risk assessments are only of limited significance in all this. Establishing risk standards is therefore not invariably the most suitable way of protecting health (Vlek, 1990; Midden, 1993).

1.2.6 Data lacking and recommendations

A review of the physical environment as a determinant of health gives rise to many minor and major research questions. A number of lines of research are important for the further development of insight into this determinant and for policy in this area, from the point of view of both public health and environmental management:

* the development and validation of animal models in order to study risk factors for disorders which mean a substantial burden of disease (both quantitatively and qualitatively), such as (degenerative) disorders with a neurological, hormonal and/or (auto)immunological origin;
* the development and validation of biological markers (*biomarkers*) of exposure or early effects on health, for the purpose of epidemiological research into and monitoring of environmental factors detrimental to health;
* research into the effects on public health of global changes in the biosphere, such as the greenhouse effect (model studies);
* the development of methods for the qualitative, integral risk analysis of exposure to pathogens (infection cycles) by analogy with risk analysis for chemical substances;
* the characterisation of population exposure to environmental factors (substances, radiation, noise, smell, external safety risks, biotic factors) with the help of integral

models (combining data on nutritional and time/activity patterns with concentration distributions in relevant environmental compartments and environments), geographical information systems and monitoring programmes (diet, drinking water, outdoor and indoor air);

* the characterisation of the population response on the basis of toxicological and epidemiological data, paying particular attention to the variation in susceptibility (meta-analysis of studies of environmental epidemiology and toxicology, exposure-response modelling);
* the development of "universal" measures of mortality and morbidity which allow various types of health effects to be brought together in a single denominator, for example (healthy) potential years of life lost, attributive morbidity or mortality risk, absenteeism, medical consumption;
* the development of measures for expressing the accumulation of various environmental factors (e.g. noise, smell, external danger) in a way which is relevant to health;
* the development of measures of risk in which non-lethal health effects, perceived risk and endurance can be expressed as a measure and number.

1 RIVM, Bilthoven.

2 With thanks to A.H. Havelaar (RIVM, Bilthoven) for contributions as regards content.

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LIST OF ABBREVIATIONS

ACS	American Chemical Society
CEC	Commission of the European Communities
CCRX	*Coördinatie Commissie voor de metingen van Radioactiviteit en Xenobiotische stoffen* (Coordinating Committee on the Monitoring of Radioactivity and Xenobiotic Substances)
CFCs	chlorofluorocarbons
DBW	Dienst Binnenwater (Inland Waterways Service) [now part of RIZA]
DNA	deoxyribonucleic acid
IBA	*Integraal Beleidsplan Arbeidomstandigheden* (Integral Policy Plan on Working Conditions)
KIWA	*Keuringsinstituut voor Waterleidingsartikelen* (Waterworks Undertakings Testing and Research Institute of the Netherlands)
KNMI	*Koninklijk Nederlands Meteorologisch Instituut* (Royal Dutch Meteorological Institute)
NRC	National Research Council
OLR	*Openbaar Lichaam Rijnmond* (Rijnmond Public Corporation)
PCBs	polychlorinated biphenyls
RIKILT	*Rijks Kwaliteitsinstituut voor Land- en Tuinbouwprodukten* (National Quality Control Institute for Agricultural and Horticultural Products)
RIVM	*Rijksinstituut voor Volksgezondheid en Milieuhygiëne* (National Institute of Public Health and Environmental Protection)
RIZA	*Rijksinstituut voor de Zuivering van Afvalwater* (Government Institute for Sewage and Waste-Water Treatment)
SCMO-TNO	Studiecentrum Milieuonderzoek [van TNO] (TNO Study Centre for Environmental Research
SDU	*Staatsdrukkerij en -uitgeverij* (= government printing office and publishing house)
SoZaWe	*[Ministerie van] Sociale Zaken en Werkgelegenheid* (Ministry of Social Affairs and Employment)
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

UV	ultraviolet
VROM	*[Ministerie van] Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer* (Ministry of Housing, Spatial Planning and the Environment)
V & W	*[Ministerie van] Verkeer en Waterstaat* (Ministry of Transport, Public Works and Water Management)
WHO	World Health Organization

2 CHEMICAL FACTORS

"Ambient air pollution " and "indoor air pollution" will be discussed below as examples of the effect of chemical factors on health. A combined bibliography follows the two contributions.

2.1 Ambient air pollution

A.E.M. de Hollander [1]

2.1.1 Regional air pollution

If during the summer there is a longish spell of fine weather, with light easterly to southerly winds and a stable area of high pressure, the action of sunlight on the ambiant (outdoor) air leads the nitrogen oxides and volatile hydrocarbons present in the air to form a "cauldron" of reactive compounds. Such episodes of photochemical air pollution are better known as *summer smog* (Rombout *et al.*, 1989).

In winter, episodes of air pollution occur when there is prolonged freezing weather and light easterly winds - in other words the sort of conditions under which Friesland's *elfstedentocht* or 'eleven towns' skating race could be staged. Partly due to the severe cold, large quantities of (high-sulphur) fuels are burnt in urbanised and industrialised source areas in Germany and Eastern Europe. Temperature inversion (cold lower layer/warmer upper layer) traps pollutants in a relatively small volume, causing the concentrations of sulphur dioxide and airborne (fine) dust to rise substantially. As the episode continues, so the proportion of local emissions from traffic and industry grows (Rombout *et al.*, 1990). During such episodes, recommended values for the quality of the ambiant air which are of significance for health may be exceeded. This means that there is an increased risk of health effects occurring in people susceptible to them.

In the summer, the pollution level is determined from concentrations of ozone, in the winter from concentrations of suspended particulate matter and sulphur dioxide. However, these so-called "guide substances" give only a limited picture of the composition of the complex mixture making up the ambiant air (*Gezondheidsraad* [Netherlands Health Council], 1990).

The average summer concentrations of ozone at dwelling level have gradually doubled over the last hundred years. During an ordinary summer, hourly average ozone concentrations of more than 240 µg/m3 are regularly reached in and around the lee side of urban areas. In the "beautiful" summers of 1989 and 1990 there were a few dozen days of smog on which the hourly average ozone concentrations exceeded 180 µg/m3 (*moderate smog*; Rombout *et* *al.*, 1990; RIVM, 1991). Not only the concentration but also the duration of peaks in the afternoon and early evening have gradually increased in recent decades (RIVM, 1991). In Los Angeles photochemical smog was described as long ago as 1948, but this phenomenon has now become a nuisance in large cities all over the world. Mexico City takes the cake in this respect; in 1990 the recommended limit value for ozone given by the WHO (hourly average of 200 µg/m3) was exceeded there on 310 days of the year. In Europe the highest concentrations are measured in the central part of the continent (RIVM, 1991).

Structural reductions in sulphur dioxide emissions in neighbouring countries and Eastern Europe have caused large-scale episodes of winter smog to occur less and less frequently in the Netherlands. The most recent episodes of serious smog in north-west Europe were in 1985 and 1987. The levels of fine dust in urban areas, however, are permanently high (annual average concentrations of 40-80 µg/m3). The influence of local sources, namely traffic emissions, has become increasingly more important. Concentrations of fine dust and nitrogen dioxide are relatively high, whereas concentrations of sulphur dioxide have fallen sharply. In Eastern Europe the situation is considerably more unfavourable where sulphur dioxide is concerned. There, annual average background concentrations of sulphur dioxide are estimated to be five times higher than in the Netherlands (RIVM, 1991).

2.1.2 Urban air pollution

Chiefly due to the substantial growth in road traffic (and the introduction of "cleaner" natural gas in the home), air pollution in Dutch cities has since the end of the 1960s increasingly been dominated by traffic emissions. The most important substances are carbon monoxide, nitrogen dioxide, lead, benzene, polycyclic aromatic hydrocarbons (PAHs) and fine particulate matter/black smoke (soot). In the third *National Environmental Outlook* document (RIVM, 1993) it was calculated that in 1990 at least one limit value was exceeded along 3,000 kilometres of roads, despite the fact that the introduction of the automatically-regulated three-way catalytic converter has made cars considerably "cleaner". In most of the cases it was the limit value for fine particulate matter which was exceeded (RIVM, 1993).

Emissions of odorous substances (odour nuisance) can also be counted as urban (local) air pollution. On the basis of model calculations, the number of dwellings in the Netherlands affected by odour nuisance is estimated at more than one million (RIVM, 1991).

2.1.3 Health effects of ambiant air pollution

The most important *acute* health effect seen in association with summer smog is a temporary decrease in lung function. This may be accompanied by inflammatory reactions, changes in the clearing of particles from the bronchi, and airway complaints such as coughing, weezing or shortness of breath. People may also be bothered by unpleasant odours and irritation of the eyes and the mucous membranes of the oral cavity, the nasal cavity and the pharynx. With increasing levels of pollution, the effects gradually become more serious and the number of people affected by them also increases. On days on which the hourly average concentration of ozone exceeds 400 µg/m3, the health effects must (in the view of a WHO working party) be regarded as *serious*. More than half of the people are then bothered by eye, nose and throat irritation; in the most sensitive individuals some parameters of lung function may show a 50% reduction, and a substantial number of people are obliged to put off strenuous outdoor activities (WHO, 1992).

Winter smog too causes a slight reduction in lung function. Where levels of pollutants rise during "classic" smog episodes, it has been found that people whose physical resilience has been reduced by serious cardiovascular or respiratory disorders (particularly chronic bronchitis) are more often forced to take time off work and make use of medical services. Among elderly people with seriously impaired health, it is also likely that the mortality risk is slightly higher during such episodes (WHO, 1992).

Recent epidemiological studies have shown that there is a link between elevated concentrations of fine particulate matter, on the one hand, and reduced lung function, increased respiratory problems, absenteeism, medical consumption (taking of medication, visits to the doctor's or hospital admision) and daily mortality rates, on the other (Hoek, 1992; Annema *et al.*, 1993; Brunekreef, 1993). Such links have been established in different circumstances, using different research methods. The increase in the daily mortality rate under the influence of elevated concentrations of fine particulate matter has not (yet) been confirmed though from Dutch research.

There are indications that the natural ageing of the lungs may be accelerated by the repeated action of air-polluting components on the lining of the bronchial tubes during episodes of smog (or conditions almost amounting to smog). For people with a predisposition to (obstructive) respiratory disorders or for those whose lung capacity has been reduced by disease, this can mean that they have to contend (earlier) with functional impairments. In this respect the permanently high level of air pollution is at least as worrying as incidental exposure to peaks (Gezondheidsraad, 1990).

In the annual Health Interview Survey conducted by the CBS, more than one fifth of those interviewed in 1989 said that they regularly experienced nuisance from unpleasant smells. A quarter of them felt they were seriously bothered by such smells, the most important sources of which were industry (petrochemicals, foodstuffs/natural stimulants and metals, mentioned by 45%), traffic (30%), the agricultural sector (15%) and other sources such as households, sewage treatment and composting firms (CBS, 1989). Around 70% of registered complaints about the quality of the environment relate to nuisance from odour (RIVM, 1991). Experiments with test subjects have shown that odour can cause a series of physiological and psychological effects, including dizziness, nausea, headache, tendencies to vomit and loss of appetite. At the same time, effects on heartbeat, respiratory rate, blood pressure and peristalsis have been found. Psychological tests have shown that unpleasant smells can affect performance and arouse feelings of aggression. Regular nuisance from unpleasant smells reduces the quality of life. It can exceed people's ability to cope, which may be manifested in the aggravation of symptoms of existing disorders, feelings of insecurity, dissatisfaction with one's housing situation, and social isolation (Cavalini, 1992).

It has emerged from various epidemiological studies that cancer occurs more frequently in urban environments than in less urbanised environments. This is particularly true of lung cancer. The increased risk of cancer found by researchers seldom exceeds 50%, however. Urban air pollution is often cited as the causal factor. Model calculations indicate that concentrations of various "proven" carcinogens such as (nitro) PAHs, benzene, certain chlorinated hydrocarbons and diesel emissions along busy highways may be two to ten times higher than in rural areas. According to most researchers, however, the contribution of urban air pollution to this extra risk is only slight, if existing at all. The differences between urban and rural areas can for the most part be explained by differences in other determinants of health, such as lifestyle (smoking, diet), occupation and (access to and use of) health-care facilities. The epidemiological methods available are for the time being not sufficiently sensitive to be able to determine the contribution of air pollution to the occurrence of cancer, let alone express it in precise figures (Doll and Peto, 1981; Pershagen, 1990; Jöckel *et al.*, 1992).

2.1.4 Relationship with other determinants

Risk groups

As regards the possible effects of pollutants in the ambiant air, a number of risk groups may be distinguished:

* people with respiratory disorders (COPD, including asthma), cardiovascular disorders (CHD), and elderly people in frail health; these are generally more vulnerable to air pollution. This has been observed above all with winter smog;
* people who, because of their occupation or sports activities, exert themselves for lengthy periods in the ambiant air; above all during episodes of smog, pollution levels outdoors are substantially higher than indoors. During physical exertion the amount of polluted air inhaled increases considerably, and breathing is also deeper. Exposure to air pollution is therefore relatively high among this group of people;
* children; air pollution can disturb the development of the respiratory tract.

Health gain attainable

Air pollution aggravates respiratory complaints, especially in people with CARA (including asthma), and causes an increase in absenteeism, medical consumption and (possibly) mortality . There are indications that air pollution is one of the factors contributing to the development of CARA (and the increase in prevalence), for example through chronic action on the respiratory tract and through interactions with the immune system. The current state of knowledge does not, however, allow any precise estimate of that contribution, or of the health gain possible.

In 1981 Doll and Peto estimated that the contribution of environmental pollution to the occurrence of cancer was only a few percent at the most (Doll and Peto, 1981). There are as yet no signs that this estimate was far off the mark. Given the state of knowledge, it is not possible to quantify the contribution of air pollution.

2.1.5 Interventions and policy

Radical structural measures on a European scale are needed to reduce emissions of nitrogen oxides and volatile organic substances and so combat the frequent occurrence of summer smog. Ad hoc measures for (voluntarily) limiting emissions *during* episodes of summer smog are inadequate, because an ample supply of the precursors of photochemical reactions is by then already available. There are even indications that stopping traffic in cities could result in higher ozone levels (ozone reacts with substances emitted by traffic). Account also has to be taken of the possibility that, if traffic were to be stopped, people might adapt their patterns of activity in an unfavourable direction. People can cover fairly long distances on foot or by bicycle and might spend more recreational time outdoors, leading to higher exposures to air pollution. In the short term, education with regard to activities in the ambiant air appears to be the most suitable way of reducing exposure to smog as much as possible (Gezondheidsraad, 1990).

By setting standards for the quality of the ambiant air on health grounds, the authorities have committed themselves to reducing air pollution, for example at places with large volumes of traffic. Traffic policy is geared to curbing the number of kilometres travelled by car, spreading traffic flows, reducing emissions by means of technical measures, and limiting speed (Van Wee *et al.*, 1992).

In the National Environmental Policy Plan (NMP) the authorities have set themselves the goal of reducing the number of dwellings affected by odour nuisance to less than 12% by the year 2000. The Policy Document on Odour Nuisance issued in 1992 describes measures for achieving that goal. Policy relating to emissions of ammonia and volatile organic compounds and to vehicle emissions may also lead to a reduction in odour nuisance (VROM, 1992d; RIVM, 1993).

2.2 Indoor air pollution

2.2.1 Indoor air in the home

On average, the Dutch spend around 70% of their time in their own homes. However, the concentrations of important air-polluting substances are often higher indoor than outdoor. This is true, for example, of carbon monoxide, nitrogen oxide, fine particulate matter, radon, polycyclic aromatic hydrocarbons, a number of volatile hydrocarbons and some pesticides. Smokers constitute a major source of such pollutants; other sources are unvented gasfired waterheaters, fireplaces and cookers. Volatile hydrocarbons can be given off by a variety of building materials and household products (paint, adhesive, joint-filling compounds, cleaning agents, air fresheners). House-dust mites, moulds in damp places and pets are the best-known sources of allergens in indoor air (in this document, however, these are classed as biotic factors). Although nowadays alternatives are generally used, asbestos fibres can still be released from insulating material or products such as floor coverings (Slooff, 1990). Because the harmful effects of asbestos are probably due to its "physical" characteristics (fibres which split lengthwise and are hardly broken off), asbestos is strictly speaking a "physical" rather than a "chemical" environmental factor.

2.2.2 Indoor air at work

For many (especially "blue-collar") workers, work involves exposure to (mixtures of) chemical compounds. The concentrations of such substances can be considerably higher at the workplace than outdoors. It is estimated that 600,000 employees working in industry or agriculture are exposed to chemical substances which have the potential to impair health: pesticides, (heavy) metals, smoke from welding, medicines, oil and products containing oil, fibres, silicates, enzymes, and dust from timber, cotton and grain (SoZaWe, 1991).

2.2.3 Effects of indoor air pollution on health

Pollution of indoor air in the home (above all with tobacco smoke, nitrogen dioxide, dust and allergens) is associated with the more frequent and more serious prevalence of bronchial infections, asthma and other respiratory disorders. Some studies indicate a doubling of the number of hospital admissions for bronchial infections among young children whose parents smoke. Dutch researchers found that respiratory complaints occurred 20% to 30% more often among children whose parents smoked. Parents' smoking can also disturb children's lung-function development slightly. Similar effects have also been observed in households where flueless geysers result in high concentrations of nitrogen dioxide (Samet *et al.*, 1987/1988; Samet and Utell, 1990; Dijkstra *et al.*, 1990).

There are indications that people who frequently suffered from bronchial infections and respiratory symptoms in their youth have to contend with chronic obstructive pulmonary disorders more often in later life. The effects mentioned are therefore significant from the point of view of public health, but cannot be quantified on the basis of the data available (Gezondheidsraad, 1990).

Studies of non-smokers living under the same roof as smokers have provided only indirect proof that passive smoking can lead to a (slight) increase in the risk of lung cancer. Analyses of published results suggest that the risk of lung cancer among non-smokers subject to prolonged exposure is increased by between 10% and 60%. This means a relative risk of 1.1 to 1.6; the relative risk from smoking oneself, however, can rise to 20 (*see Part III, 2.1.2* of the Dutch edition). The Environmental Protection Agency in the USA recently placed environmental tobacco smoke on the list of proven human carcinogens (Reynolds, 1993). Because of the major methodological objections associated with this type of research, the results are nevertheless still disputed (Gezondheidsraad, 1990).

Workers who had been exposed to high concentrations of asbestos were found to be at greater risk of developing a particular form of lung cancer and cancers of the peritoneum and pleura. These types of cancer, known as "mesotheliomas" may be attributed almost entirely to (heavy) exposure to asbestos fibres in the workplace. It is not clear, however, to what extent exposure in the living environment may lead to an increased risk of developing these kinds of cancer. This is because the concentrations in the home are very much lower, in addition to which the fibres to which people may be exposed in the home are of a less dangerous dimension size (Slooff, 1990).

Various epidemiological studies have indicated that exposure to chemical compounds at work can be a risk factor for a variety of disorders. The most important are: increased risk of cancer (lung cancer, mesotheliomas, leukaemia, lymphomas, bladder cancer), COPD (including asthma), skin diseases (eczema, seborrhoeic acne), neurological disorders (concentration and sleep disorders), depression, headache and forgetfulness, effects on reproduction (infertility, hormonal disorders, spontaneous abortion, premature birth, pre- and postnatal development disorders, congenital anomalies) and cardiovascular disorders (Cullen *et al.*, 1990; Zielhuis and Wibowo, 1990; Landrigan, 1991; *see Part III, 2.3.4 and 3.2.3* of the Dutch edition).

The best-documented estimates assume that work makes a contribution of 4% to 10% to the occurrence of cancer (Doll and Peto, 1981; Landrigan, 1991); the estimates for COPD (including asthma) are 10% to 30% (Heederik, 1990, amongst others). It is then not exclusively chemical factors which are involved; the data which is available often also reflects above all the less hygienic working conditions which existed in the past.

2.2.4 The quality of the indoor air in the Netherlands

In the Netherlands the most important sources of indoor air pollution are the unvented gasfired water heaters (a typical Dutch problem in an estimated 10% of households) and smoking (about 60% of households). In kitchens with unvented gasfired water heaters, maximum hourly average values of nitrogen dioxide can occur which exceed the recommended limit value of 300 $\mu g/m^3$ several times over (Lebret, 1985). Smoking causes a tenfold increase in dust concentrations by 10 to 100 µg/m3 (Gezondheidsraad, 1990).

2.2.5 Relationship with other determinants

Important determinants associated with exposure to polluted indoor air are:

* smoking and ventilation habits in the home;
* occupation; "blue-collar" workers in particular may be subject to increased exposure to chemical compounds in the workplace;
* socioeconomic status; as a determinant for occupation, lifestyle factors and housing.

2.2.6 Interventions and policy

Because very many people are exposed to indoor air pollution, there are considerable health gains to be made in the area of "respiratory" health. Possible effective measures would be to replace unvented gasfired water heaters, limit the emission of gas appliances, continue with the anti-smoking policy and provide information and facilities as regards the ventilation of dwellings.

The Ministry of Housing, Spatial Planning and the Environment (VROM) gears its policy above all to the ambiant air. There is not as yet any government policy specifically aimed at the chemical pollution of the indoor environment at home. Smoking in public buildings is prohibited under the Tobacco Act.

Various safety provisions in the Working Conditions Act require employers to have an explicit and "effective" strategy for protecting employees against the detrimental effects of exposure to substances in the workplace. Measures need to start at the source; solutions may also be sought in ventilation and air-conditioning, or in the organisation of the work. Only in the last resort may protective measures be adopted. There is also a requirement for hazardous substances to be registered. Even where substances are permitted under the terms of the Pesticides Act and the Chemical Substances Act, exposure in the workplace is taken into account. The so-called "MAC" values (maximum allowable concentration at the place of work) play an important part in these arrangements (*see also Part III, 3.2.3* of the Dutch edition). These are essentially based on health views with respect to toxicity. MAC values now exist for about 700 substances. The scientific basis for these, however, often leaves much to be desired.

[1] RIVM, Bilthoven.

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LIST OF ABBREVIATIONS

CBS	*Centraal Bureau voor de Statistiek* (Netherlands Central Bureau of Statistics)
CHD	coronary heart disease
COPD	chronic obstructive pulmonary disease
EPA	Environmental Protection Agency (USA)
IARC	International Agency for Research on Cancer (Lyon)
IBA	*Integraal Beleidsplan Arbeidomstandigheden* (Integral Policy Plan on Working Conditions)
MAC	maximum allowable concentration [at place of work]
NMP	*Nationaal Milieubeleidsplan* (National Environmental Policy Plan)
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
RIVM	*Rijksinstituut voor Volksgezondheid en Milieuhygiëne* (National Institute of Public Health and Environmental Protection)
SoZaWe	*[Ministerie van] Sociale Zaken en Werkgelegenheid* (Ministry of Social Affairs and Employment)
VROM	*[Ministerie van] Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer* (Ministry of Housing, Spatial Planning and the Environment)
WHO	World Health Organization

3 PHYSICAL FACTORS

First "noise" and then various forms of "radiation" are discussed separately below as examples of the possible effects of physical factors on health.

3.1 Noise

A.E.M. de Hollander [1]

3.1.1 Noise in the living environment

Everyone in the Netherlands is exposed to noise in their living environment. A large number of people regularly experience nuisance or even serious nuisance from noise pollution (72% and 30%, respectively). The noise involved in these cases comes above all from neighbours (66% and 26%, respectively), road traffic (60% and 20%), the immediate living environment (48% and 12%), aircraft (40% and 15%), industrial activity (17% and 4%), recreation (16% and 5%), and rail traffic (7% and 2%) (De Jong *et al.*, 1989).

Besides causing nuisance, (constant) noise load as a result of the sources mentioned also causes stress and feelings of anxiety and discomfort. Everyday activities, like holding a conversation or reading, may be disturbed by it. At higher (peak) levels - more than 40 to 45 dB(A) (= decibels) - *sleep disturbance* or *awakening reactions* (at 50 to 55 dB(A)) may occur. Reduced performance and powers of concentration have also been observed at these levels. These effects may indirectly have an unfavourable influence on the onset or course of disorders or recovery from them. One thing to emerge from different studies is that sensitivity to noise load may vary considerably from one person to the next, depending on an individual's personal characteristics and experience (De Jong *et al.*, 1986; *Gezondheidsraad* (Netherlands Health Council), 1991). There are, however, no indications that this more generally distributed noise load from the environment causes damage to hearing (Passchier-Vermeer, 1993).

3.1.2 Noise during special activities or in the working environment

For a number of activities, noise levels may be so high that damage to hearing is very likely to occur. The activities in question are above all visits to pop concerts or discotheques, the use of headphones, playing in pop groups, motorcycling, playing with some types of toys, and setting off fireworks. It is estimated that each year 16,500 more young people in the Netherlands suffer reduced hearing capacity; 5,600 young people become hard of hearing to some extent and 400 hard of hearing. This estimate does not include the consequences of motorcycling. These young people are thus in a worse starting position for hearing and understanding language in everyday life than those with good hearing, which becomes particularly noticeable when senile deafness starts to occur in later life (*see Part IIB, 6.5* of the Dutch edition) (Passchier-Vermeer, 1989).

In the Netherlands around 900,000 workers are exposed to high noise levels (> 70 to 80 dB(A)) at work (in industry, construction, agriculture and transport) (SoZaWe, 1992). There are no good estimates available of the number of employees whose hearing is damaged at work each year.

3.1.3 Interventions and policy

In the Noise Abatement Act and the Aviation Act (*see Part III, 3.2.3* of the Dutch edition), standard values are stated for the noise load outside dwellings and other buildings. The size of these standard values is dependent on the source and the situation (existing versus new). There are *preferred values, maximum acceptable load values* and *intervention values* for remedial action. These values are not, however, based on so-called "no-effect levels"; it is permitted for a certain percentage of people to be bothered by noise. There are not yet any standard values in respect of the cumulative noise coming from various sources.

Traffic policy is geared to further tightening-up of the requirements laid down (for type approval) with respect to the noise produced by vehicles, and to the use of low-noise asphalt. Noise pollution from road traffic will probably decrease slightly in the future, despite the growth in volume. New aircraft can scarcely be made any quieter, however; in this area the only favourable effect to be expected is from the replacement of old types which make more noise. In view of the large growth in the volume of aviation, the noise pollution caused by air traffic is likely to increase (the expansion of Schiphol Airport springs to mind). The expansion of rail traffic may also lead to an increase in noise pollution (RIVM, 1993).

As far as noises in the immediate living environment are concerned (audio equipment indoors, parking, the hotel and catering industry, car doors slamming, motor vehicles starting and warming up, and the noise from people on the street), there are no regulations which are actually enforceable (RIVM, 1991).

No specific policy has been developed with regard to exposure to noise encountered when visiting (pop) concerts or discotheques, playing in pop groups or listening to loud hi-fi equipment. Requirements do exist with regard to the maximum permitted noise from motor bikes and mopeds, but the question is whether they are very effective (old motor bikes, "souping up"). The Fireworks Order of 1982 sets a limit to the noise level when fireworks are set off. Standards have also been set for the noise load in the work situation, and these form an aid to policy with respect to working conditions (*see Part III, 3.2.3* of the Dutch edition).

[1] RIVM, Bilthoven.

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LIST OF ABBREVIATIONS

IBA	*Integraal Beleidsplan Arbeidsomstandigheden* (Integral Policy Plan on Working Conditions)
INRETS	*Institut National de recherche sur les transports et leur securité* (National Research Institute for Transport and Transport Safety)
RIVM	*Rijksinstituut voor Volksgezondheid en Milieuhygiëne* (National Institute of Public Health and Environmental Protection)
SoZaWe	*[Ministerie van] Sociale Zaken en Werkgelegenheid* (Ministry of Social Affairs and Employment)
VROM	*[Ministerie van] Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer* (Ministry of Housing, Spatial Planning and the Environment)

3.2 Radiation

M.J.M. Pruppers, G.J. Eggink, H. Slaper, L.H. Vaas, H.P. Leenhouts [1]

3.2.1 Introduction

Depending on its action, radiation is said to be either *ionising* or *non-ionising*. Ionising radiation comes from radioactive substances or from devices which emit this radiation. Ionising radiation is either electromagnetic in nature (X-rays, gamma rays; wavelength 10^{-10} to 10^{-15} m) or consists of high-energy particles (neutrons, alpha and beta rays; energy 20 keV to 10 MeV).

The most important effect of ionising radiation is damage to genetic material (DNA), either through direct interaction with the DNA molecule or through interaction with the DNA of free radicals formed by radiation, resulting in cancer or genetic effects.

Non-ionising radiation is the collective name given to all kinds of electromagnetic radiation, which is subdivided on the basis of wavelength into: ultraviolet (UV) radiation, visible light, infrared (IR), radio frequency and microwaves, and extremely low-frequency electromagnetic fields (ELF, *see Table 3.1*). Attention has recently focused on the possible carcinogenic effects of ELF fields. These arise when electrical equipment and high-voltage transmission lines are used. Epidemiological research has not so far been able to provide any clarification in this respect. Nor is the biological mode of action known. In a recent recommendation, a Netherlands Health Council committee concluded that there was not currently any scientific evidence to suggest that exposure to ELF in the living and working environment caused cancer, the premature termination of pregnancies, or damage to the unborn child (*Gezondheidsraad* (Netherlands Health Council), 1992).

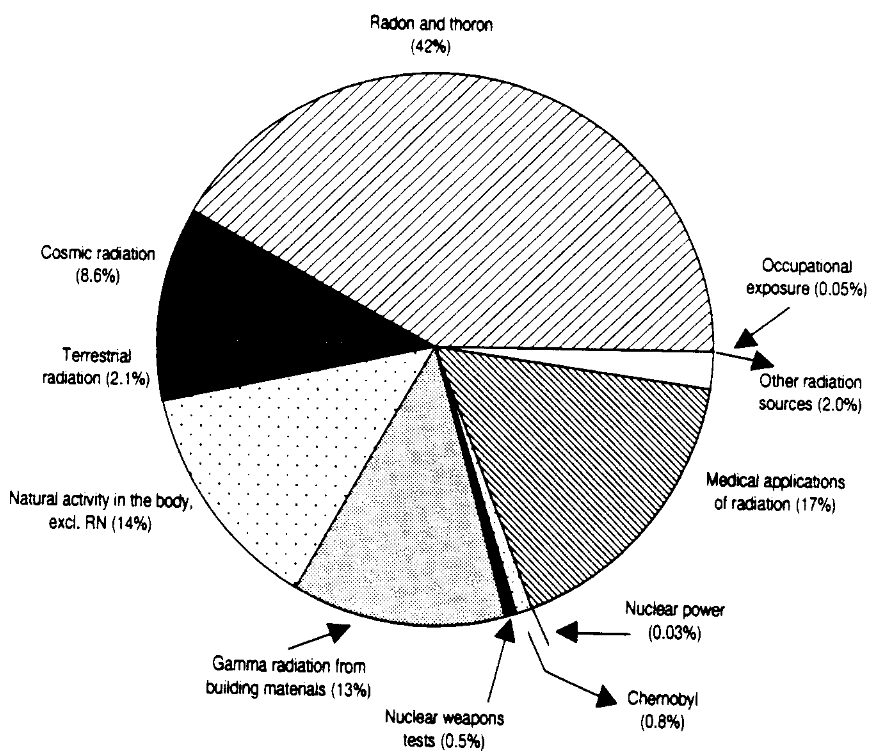
Table 3.1: Characteristics of various types of radiation.

wavelength	energy (from - to)	type of radiation	unit of dose	sources	effects
n/a (= not applicable)	20 keV-10 MeV	alpha radiation	Sv	various radioactive substances	genetic effects, cancer, radiation sickness
n/a		beta radiation	Sv	various radioactive substances, including building materials	(nausea, diarrhea, skin burns, alopecia)
10^{-15}-10^{-7}m	1.24 GeV-1.24 eV	gamma radiation and X-rays	Sv	radioactive substances X-ray equipment cosmic radiation	
100-280 nm	1.24 eV-0.44 eV	UV-C	MED	sun gas discharge lamps	sunburn ageing of skin
280-315 nm	0.44 eV-0.39 eV	UV-B	MED	tanning equipment halogen lamps	thickening of the skin skin cancer
315-400 nm	0.39 eV-0.31 eV	UV-A	MED	welding equipment medical lasers UV therapy	tanning, vitamin D production actinic conjunctivitis/snow blindness inflammation, cataracts, retinal burns immunosuppression
400-780 nm	0.31 eV-0.60 eV	visible light	lumen	sun, fire, lamps, welding equipment, lasers	retinal burns photopathy, cataracts
780 nm-1 mm	0.60 eV-1.24 meV	IR	J/m²	sun, fire, lamps, heating equipment, welding equipment, (medical) lasers	overheating burns cataracts
1 mm-100 km	1.24 meV-12.4 peV	RF	SAR	microwave ovens radio/TV transmitters, radar, inductive heating, (medical) diathermy equipment, MRI equipment	burns cataracts
100 km-∞	12.4 peV-0 eV	ELF	V/mT	storms, electrical equipment, high-voltage transmission lines	cancer?

The natural background of ionising radiation is of cosmic and terrestrial origin (soil, building materials) (*see Figure 3.1*). As a result of human activities, artificial radioactive substances get into the environment (nuclear industry, nuclide laboratories) or naturally-occurring radioactive substances are concentrated (non-nuclear industries, building materials, radon in the indoor environment). In addition, various kinds of radiation are used in medicine. The most important source of UV radiation is the sun.

A person may be exposed to ionising radiation externally, or internally, following inhalation or ingestion of radioactive substances. The amount of a particular radioactive substance is called the *activity*, the unit of measurement being the becquerel (Bq). Exposure to ionising radiation, the *radiation dose*, is expressed as the *effective dose equivalent*, for which the unit is the sievert (Sv). This measure takes account of the absorption of energy and the effectiveness (i.e. the capacity to cause damage) of the various kinds of ionising radiation and the sensitivity to radiation of various organs.

Figure 3.1: Contribution of the various sources of (ionising) radiation to the collective effective dose equivalent of the Dutch population in 1988.
Source: Blaauboer et al., 1991.



The minimal erythema dose (MED) is used to indicate the effective irradiation dose of UV radiation. This dose is dependent on the wavelength: 1 MED is, by definition, a dose of 200 J/m^2 for irradiation with UV radiation having a wavelength of 297 nm (Slaper and Eggink, 1991). In a Dutch summer, sunbathing for 15 minutes around midday gives a person a dose of about 1 MED.

3.2.2 Effects of radiation on health

The effects of ionising radiation may be divided into "early" effects, which occur as soon as a certain *threshold dose* is exceeded, and "late" effects. Examples of early effects are erythema of the skin, alopecia and gastrointestinal syndrome. Late effects are increased incidence of cancer and inherited disorders in subsequent generations. Both effects are associated with damage to DNA, as the carrier of genetic characteristics. The risks of cancer and inherited disorders are assumed to increase proportionally with dose. Some organs are extra sensitive because they receive the highest doses, or because a relatively high level of cell division takes place. Examples of late effects are: leukaemia, tumours of the breast, the lungs (radon), the thyroid gland (iodine) and bone (bone-seeking radionuclides).

The number of deaths from ionising radiation in the Dutch population as a whole may be estimated at around 2,000 per year. This figure is based on an average effective dose equivalent of 2.4 mSv per year and a mortality factor of about 5% (estimated uncertainty interval 3-8%) per Sv (ICRP, 1990). The number of non-fatal cases of cancer is estimated at 350 per year (20% of fatal cases; ICRP, 1990). By extrapolating the risk from high doses of radiation, the number of fatal lung tumours as a result of radon is estimated at 900 (with an uncertainty interval of 420-2,000) per year (Vaas *et al.*, 1991). The Netherlands Health Council (*Gezondheidsraad*, 1993), in its assessment of the integrated criteria document on radon, concluded that there was nothing to suggest that the order of magnitude of these estimates was incorrect. The total number of deaths from cancer and lung cancer in the Netherlands stands at around 35,000 and 8,300 per year, respectively (CBS, 1992).

The most important harmful effects of UV radiation in man are sunburn, ageing of the skin, skin cancer, actinic conjunctivitis or snow blindness, retinal burns and cataracts. There are also indications that UV radiation has an adverse effect on the immune system (Goettsch *et al.*, 1992).

The most common forms of skin cancer (basal cell and squamous cell carcinomas) are assumed to be the result of exposure of the skin to UV radiation. This relationship is less clear for melanomas, which often appear, for example, on skin which is not regularly exposed to sunlight. One theory which is often cited but has not been proved assumes that above all short, heavy exposures, such as those occurring during holiday periods, increase the risk of getting melanomas (De Gruijl, 1989; EPA, 1987). The number of people in the Netherlands who die each year as a result of melanomas is increasing; in 1990 there were about 300 deaths. For the group of skin carcinomas (around 15,000 cases per year in the Netherlands) the annual death rate (80-90 per year) is actually falling. This last form of skin cancer is only rarely fatal and, in addition, the possibilities for treatment have improved.

Radiation also has health-promoting applications, a few examples of which are:

* medical diagnostics with the help of X-rays, radioactive substances or forms of electromagnetic radiation (MRI);
* medical therapy, such as the irradiation of tumours, operating with lasers, and treating skin disorders with UV;
* sterilisation of food and medical aids by irradiating with gamma radiation;
* production of vitamin D in the skin and improvement of wellbeing by means of a sunbath.

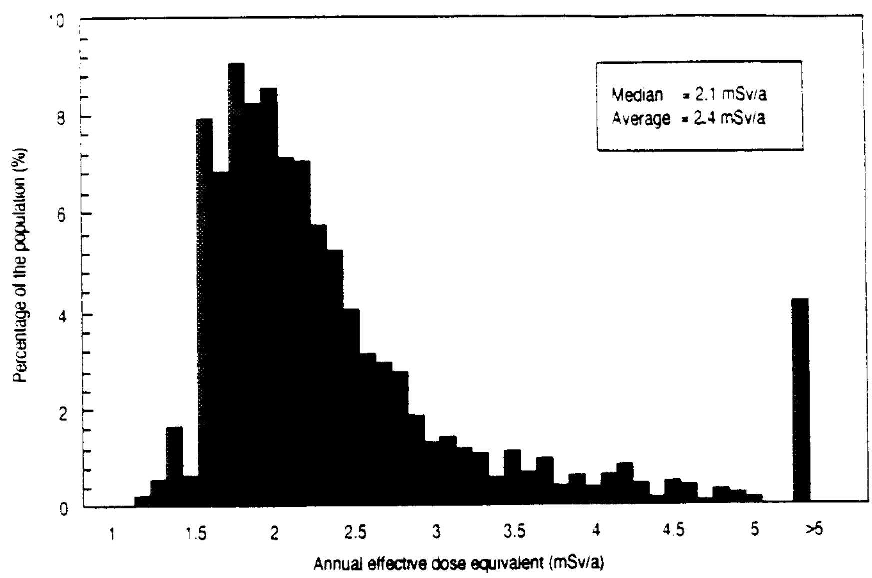
3.2.3 Exposure to radiation in the Netherlands

Figure 3.1 shows the contribution of a number of sources of ionising radiation to the so-called collective effective dose equivalent for the entire Dutch population. The total dose, averaged over the year, is 2.4 mSv per head of the population (Blaauboer *et al.*, 1991). This value is based on a combination of measurements and (model) calculations. The biggest contribution (42%) is provided by the inhalation of radon and thoron coming from the soil and building materials. About 40% is natural radiation, that is to say: unavoidable. A further 40% is natural radiation which has been increased as a result of human activity. This fraction consists mainly of the extra exposure to radon in the indoor environment. The remaining 20% is the result of medical applications.

The entire population is exposed to at least four of the five most important sources of radiation: radon and thoron, cosmic radiation, gamma radiation from building materials, and natural activity in the body. The dose can vary considerably from one person to the next (for example, radon: 0.2-4.4 mSv per year). Only part of the population is exposed to the other sources - for example, users of certain consumer products and people undergoing medical examination.

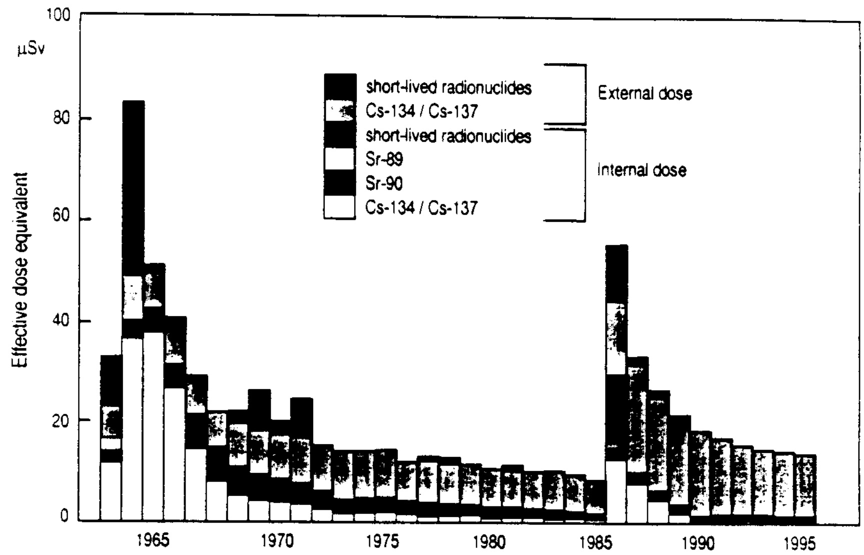
Figure 3.2 shows the distribution of the individual radiation dose from all sources of ionising radiation over the Dutch population (Blaauboer *et al.*, 1991). This was based on the assumption that people spend 80% of their time indoors and 20% out-of-doors. The annual dose of 3.5-10 mSv (10% of the population) is determined above all by exposure to radon in the indoor environment and to X-ray diagnostics. In some people the annual dose can rise to more than 50 mSv, for example certain patients and radiological workers.

Figure 3.2: Distribution of the total radiation dose over the Dutch population in 1988 [a]. Source: Blaauboer et al., 1991.



a It is assumed that there are no correlations between the various exposures to sources of ionising radiation.

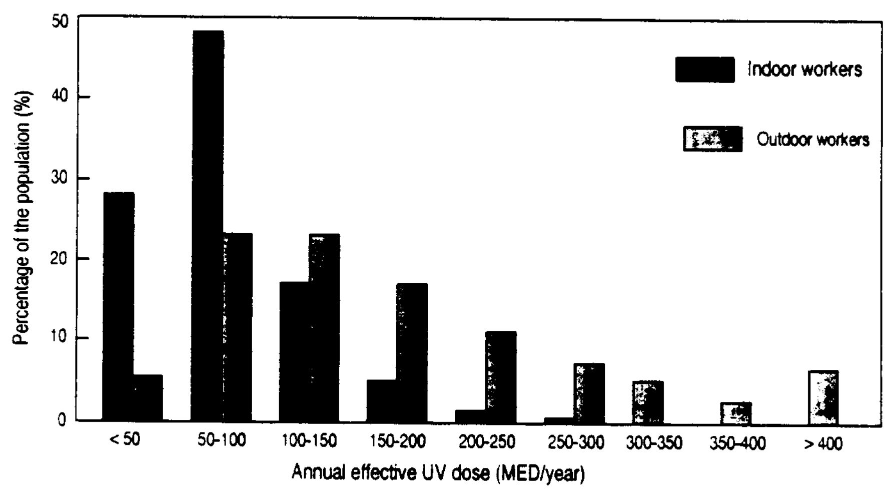
Figure 3.3: Annual average effective dose equivalent in the Netherlands since 1962, due to the presence of artificial radioactive substances in the environment.
Source: CCRX, 1991.



The total dose from ionising radiation changes only slowly with time. In 1950 it would probably have been lower than today, since radon concentrations were lower due to more ventilation of dwellings. Given current methods of construction, exposure to radon will slowly increase; in 2020 it is expected to be around 15% higher than today (Blaauboer *et al.*, 1993). Some trends have been determined accurately, such as the presence of artificial radioactive substances in the environment originating from surface nuclear weapons tests and the reactor accident in Chernobyl. The effects of these events on the annual dose are clear from *Figure 3.3* (CCRX, 1991). Note that these account for only about 1% of the total annual effective dose equivalent.

The estimated annual exposure to UV radiation is shown in *Figure 3.4*. Contributions from holidays in the sun and artificial sources of UV have not been taken into account here. A contribution of 30-100 MED for a three-week holiday in the Mediterranean region and of 20-50 MED for the same period in the Netherlands are realistic estimates. People who use tanning equipment get on average around 25 MED extra per year, while patients undergoing UV-B therapy get 250 MED extra per year. For people who make intensive use of halogen lighting, the estimated extra dose on the parts of the skin irradiated most may amount to 100 MED per year (Slaper and Eggink, 1991).

Figure 3.4: Annual effective dose of UV radiation for indoor and outdoor workers in the Netherlands, excluding holiday exposure [a].
Source: Slaper and Eggink, 1991.



[a] For indoor workers on average 70 MED per year, for outdoor workers on average 15 MED per year.

3.2.4 International comparison

Table 3.2 shows the average annual doses of ionising radiation for four different populations, specified according to the most important sources. The dose in the Netherlands is about the same as that in the United Kingdom, but is around 50% lower than that in the United States. Exposure to radon in the US is twice as high in the Netherlands. The total dose in the Netherlands is also relatively low compared with the UNSCEAR data for the world population (UNSCEAR, 1988).

Table 3.2: Comparison of the average doses caused by ionising radiation in four different populations, specified according to the most important sources.

Source category	Average individual annual dose (mSv)			
	Netherlands	United Kingdom	United States	World population
Radon and thoron	1.0	1.3	2.0	1.3
Gamma radiation from soil and building materials	0.35	0.35	0.28	0.41
Natural activity in the body[a]	0.33	0.30	0.39	0.36
Cosmic radiation	0.20	0.25	0.27	0.36
Medical applications of radiation	0.40	0.30	0.53	0.4-1.0
Other sources	0.08	0.03	0.13	0.01
Total	2.4	2.5	3.6	2.8-3.4

[a] Excluding radon and thoron

Estimates of the exposure to UV radiation for various countries are generally based on models, with no account being taken of possible differences in behaviour. The harmful UV dose in the Netherlands may be expected to be comparable to that in the United Kingdom, while that in Southern Europe (latitude 40° North) is about 50% higher (Slaper *et al.*, 1992). This difference is caused by the position of the sun being (on average) higher, with less UV radiation being filtered out by the atmosphere (ozone) as a result.

3.2.5 Relationship with other determinants

Exposure to (ionising) radiation and its effects on health are associated with endogenous factors such as age, sex, pregnancy and inherited characteristics, and with exogenous factors such as lifestyle (behaviour), working environment and system of health care (UNSCEAR, 1988: BEIR, 1988). (Pregnant) women and children are more sensitive; for them, stricter weighing factors exist for arriving at the mortality risk (UNSCEAR, 1988). People who live at high altitudes or who regularly spend time at a great altitude in the course of their work, such as aircraft personnel, receive higher doses of cosmic radiation.

Exposure to UV radiation is strongly dependent on lifestyle and behaviour: sun-worshippers or others who spend a lot of time out-of-doors when the sun is high in the sky, and the extent to which protective measures are used. Inherited characteristics are also of importance. Thus people with fair skin which is susceptible to sunburn run a risk which is 10 to 100 times higher than people with dark, pigmented skin. Emissions of substances which damage the ozone layer (CFCs, for example) mean that in the foreseeable future less UV from the sun will be absorbed and diffused. The risk of harmful UV effects like skin cancer and cataracts may possibly increase as a result.

In the health-care sector, the use of radiation can promote health on the one hand. On the other hand, however, patients may also receive an additional radiation dose. Weighing the advantages of a better diagnosis or therapy against the disadvantages of increased radiation doses is an integral part of deciding on the treatment indicated. At the moment, this is usually done by the specialist who makes the diagnosis. There is, however, a need for internationally accepted protocols in order to make this weighing-up procedure, and also the quality of implementation, more objective.

Food irradiation, despite its negative image with the population and scientific uncertainty about possible negative effects, has positive effects on the quality of food: bacterial contamination is reduced and with it the risk of food poisoning.

3.2.6 Interventions and policy

The following principles are used in radiation hygiene:

* *justification*: use of radiation only if there is no reasonable alternative or if the advantages of radiation are evident;
* *ALARA* (as low as reasonably achievable): measures must be taken to make the dose as low as possible. The "reasonable" level is determined by weighing up the pros and cons of the measures;
* *limitation* of the individual radiation dose, for example for radiological workers, to prevent the risk from being transferred to the individual.

As regards UV radiation, a similar general approach does not yet explicitly exist.

The Ministry of Housing, Spatial Planning and the Environment (VROM) also uses the risk approach for exposure to radiation via the environment. For certain sources, such as those in the "functional applications of radiation" and "non-nuclear industries" categories, risk limits have been drawn up (*Tweede Kamer* (Lower House), 1990). The annual individual risk per source due to external irradiation and due to emissions in the environment must not be more than 10^{-6}, and that due to exposure to all sources of radiation combined not more than 10^{-5}. These standards do not apply to the work situation. People who consume large quantities of shrimps and mussels from fishing grounds polluted due to emissions of waste gypsum from phosphate-ore processing plants, and users of welding rods and gas mantles containing thorium probably exceed the first standard (Blaauboer *et al.*, 1991). For radiological workers an annual dose limit of 20 mSv applies.

Besides the risks from ordinary circumstances, limits have also been set for the risk of fatalities due to the "early" effects of ionising radiation in the event of accidents involving nuclear installations. These limits are comparable to the risk limits for other (non-nuclear) accidents.

Health gain

As already mentioned, a substantial portion of the radiation dose in the Netherlands may be attributed to radon in the indoor environment. By installing ventilation provisions in crawl spaces, providing better sealing of ground floors and paying attention to the radiation aspect when choosing building materials, exposure to radon can be reduced somewhat. Depending on the scale on which measures are implemented (new buildings only, existing buildings too), exposure can be reduced by a few dozen percent (Blaauboer *et al.*, 1993).

The radiation dose due to medical applications can be reduced by optimising the number of operations involved and by replacing outdated equipment sooner.

A worldwide discontinuation - preferably as soon as possible - of emissions of substances which harm the ozone layer (such as CFCs) is important in order to halt the undesirable increase in UV radiation. However, the effects of substances already emitted will probably be felt also in the next century (Slaper *et al.*, 1992). Other possibilities for curbing exposure to UV are information on the dangers of sunbathing, on the importance of personal protection, and on the use of consumer products which emit UV radiation (such as tanning equipment and halogen lamps).

3.2.7 Data lacking and recommendations

The most important (policy) developments in the foreseeable future will be in the area of radon in the living and working environment ("STRATEGO" project on radiation with respect to the built environment) and in the area of exposure to UV radiation. Research is therefore needed into the effectiveness of measures to reduce exposure to radon in the indoor environment, and into exposure to UV radiation and the effects of this in man, plants, animals and in ecosystems.

In order to be able to make a better assessment of the relative importance of the various determinants (including radiation) of public health, it is desirable to further elaborate and harmonise measures for quantifying risks.

Finally, better monitoring of the current situation as regards the medical applications of radiation will be needed, partly also with an eye to EC directives.

[1] RIVM, Bilthoven.

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LIST OF ABBREVIATIONS

ALARA	as low as reasonably achievable
BEIR	Committee on the Biological Effects of Ionizing Radiation
CBS	*Centraal Bureau voor de Statistiek* (Netherlands Central Bureau of Statistics)
CCRX	*Coördinatie Commissie voor de metingen van Radioactiviteit en Xenobiotische stoffen* (Coordinating Committee on the Monitoring of Radioactivity and Xenobiotic Substances)
CFCs	chlorofluorocarbons
ELF	extremely low-frequency
EPA	Environmental Protection Agency (USA)
IBA	*Integraal Beleidsplan Arbeidsomstandigheden* (Integral Policy Plan on Working Conditions)
ICRP	International Commission on Radiological Protection
INRETS	*Institut National de recherche sur les transports et leur securité* (National Research Institute for Transport and Transport Safety)
IR	infrared
MED	minimal erythema dose
MRI	magnetic resonance imaging
n/a	not applicable
RF	radio frequency
RIVM	*Rijksinstituut voor Volksgezondheid en Milieuhygiëne* (National Institute of Public Health and Environmental Protection)
SAR	specific absorption rate
SDU	*Staatsdrukkerij en -uitgeverij* (= government printing office and publishing house)
SoZaWe	*[Ministerie van] Sociale Zaken en Werkgelegenheid* (Ministry of Social Affairs and Employment)
STRATEGO	*Straling ten aanzien van de gebouwde omgeving* (Radiation with respect to the built environment)
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UV	ultraviolet

VROM	*[Ministerie van] Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer* (Ministry of Housing, Spatial Planning and the Environment)

4 BIOTIC FACTORS

As an example of the possible effects of biotic factors on health, "microorganisms in drinking water" are discussed in more detail here. Biotic factors are also dealt with in the discussions of various (infectious) diseases (*Part IIB, 1.1 to 1.6* of the Dutch edition) and determinants of infectious diseases (*Part III, 1.2.5; 2.1.4; 2.1.7; 3.1.2.1; 3.1.2.3; 3.2.1.1 and 3.2.1.2* of the Dutch edition).

4.1 Microorganisms in drinking water

A.H. Havelaar [1]

4.1.1 Introduction

Contaminated drinking water plays an important part worldwide in the spread of infectious diseases (WHO, 1984). Recent cholera epidemics in South America are a graphic example of this. Besides the *quality* of drinking water, its *quantity* (and availability) also has a strong influence on the occurrence of infectious diseases. General hygiene and the level of sanitation (disposal of faecal and waste matter) plays an important part (Esrey *et al.*, 1985; Esrey and Habicht, 1986).

Over the years, various microorganisms occurring in drinking water have been shown to have pathogenic properties (*see Table 4.1*). Thanks to good drinking water supplies, some of these microorganisms are no longer of importance in the Netherlands (cholera and typhoid pathogens), whereas the risk of infection posed by others has only become apparent more recently (e.g. *Legionella* and *Cryptosporidium*, to which above all people with a weakened immune system fall victim).

Depending on the route of infection, two types of microorganism may be distinguished: microorganisms excreted in faeces, and bacteria which (may) naturally multiply in drinking water (see *Table 4.1*). Faecal bacteria specific to man, such as *Vibrio* and *Salmonella*, may be combated effectively by filtering and disinfecting with chlorine. Viruses and protozoa, on the other hand, often survive better outside man and are also much less sensitive to disinfectants. The legally prescribed bacteriological standards for drinking water therefore do not provide a cast-iron guarantee against infection. Thus, for most of the outbreaks of giardiasis and cryptosporidiosis seen, the drinking water did in fact satisfy the legal standards laid down for a number of bacterial organisms.

Drinking water is not sterile. Large numbers of living organisms occur in the distribution network, in the water or in biofilms on, for example, pipe walls and in debris (precipitation). For healthy individuals, most of these organisms constitute a slight risk. Where the immune system is (temporarily) weak, however, infections may indeed arise, sometimes even proving fatal. Species of *Legionella* and *Aeromonas* - so-called "atypical" mycobacteria which occur naturally in the mains system - then constitute a substantial health risk (Havelaar, 1992).

Table 4.1: Pathogenic microorganisms in drinking water.

year[a]	microorganism	type[b]	portal of entry	disease (most characteristic)	reservoir	survival in (drinking) water[c]	sensitivity to chlorine[d]
1849	*Vibrio cholerae*	B	oral	cholera	man (faeces), environment	days	0.1-1
1890	*Salmonella typhi*	B	oral	typhoid fever	man (faeces)	days	0.1-1
1945	*Poliovirus*	V	oral	poliomyelitis	man (faeces)	weeks	1.0-10
1955	*Hepatitis A virus*	V	oral	infectious hepatitis	man (faeces)	weeks	0.1-10
1955	*Giardia lamblia*	P	oral	gastroenteritis	man, wild animals (faeces)	months	100-1,000
1955	*Mycobacterium kansasii*	B	respiratory	tuberculosis	environment (drinking water)	grows	high
1978	*Norwalk virus*	V	oral	gastroenteritis	man (faeces)	?	?
1978	*Campylobacter jejuni*	B	oral	gastroenteritis	man, wild and domestic animals (faeces)	days	0.1-1
1980	*Legionella pneumophila*	B	respiratory	pneumonia	environment (drinking water)	grows	0.5-2
1984	*Aeromonas hydrophila*	B	oral	gastroenteritis	environment (drinking water)	grows	0.1-1
1986	*Cryptosporidium parvum*	P	oral	gastroenteritis	man, domestic animals	months	1,000-10,000

[a] First report of association between infection and drinking water
[b] B = bacteria; V = viruses; P = protozoa
[c] Decimal reduction time at 15-25°C
[d] Product of concentration (mg/l) and contact time (min) for 99% inactivation in drinking water at 5°C and neutral pH

4.1.2 Health effects of microorganisms in drinking water

Thanks to an extensive, well-organised supply of drinking water, epidemics of infectious diseases which spread via drinking water are hardly ever seen any more in the Netherlands. The last outbreak recognised as such happened in 1981 in the Scheepvaart district of Rotterdam and was caused by waste water discharged from a French naval vessel (Huisman and Nobel, 1981).

This is not to say that infections no longer occur via drinking water; in most cases it will not be possible to establish a link between the occurrence of infections and the quality of the drinking water, not least because monitoring of the microbiological quality of drinking water is limited.

Table 4.2: Infectivity of oral pathogens.
Source: Rose and Gerba, 1991 (extrapolation of studies carried out with volunteers).

Microorganism	Risk of infection upon exposure to a single "unit"
Rotavirus	0.31
Entamoeba histolytica	0.28
Poliovirus 3	0.031
Giardia lamblia	0.020
Echovirus 12	0.017
Campylobacter	0.007
Shigella	0.001
Salmonella typhi	0.000038
Vibrio cholerae	0.000007

The risk of infection varies considerably for various microorganisms. In *Table 4.2* the results of experiments carried out with volunteers are translated into risks of infection associated with exposure to a specific concentration of microorganisms (Haas, 1983). It is in principle possible to quantify the risks to public health of oral exposure to certain doses of microorganisms.

Figure 4.1: Dose-response relationships for various microorganisms, extrapolated from experiments carried out with volunteers.
Source: Regli et al., 1991.

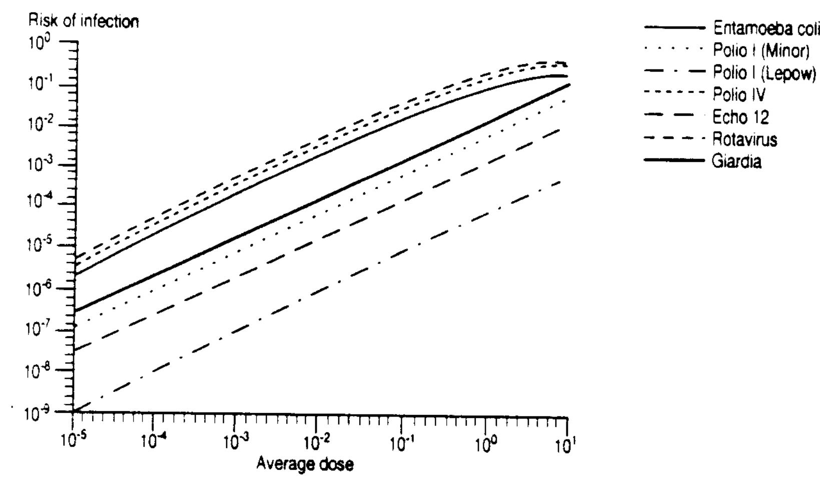
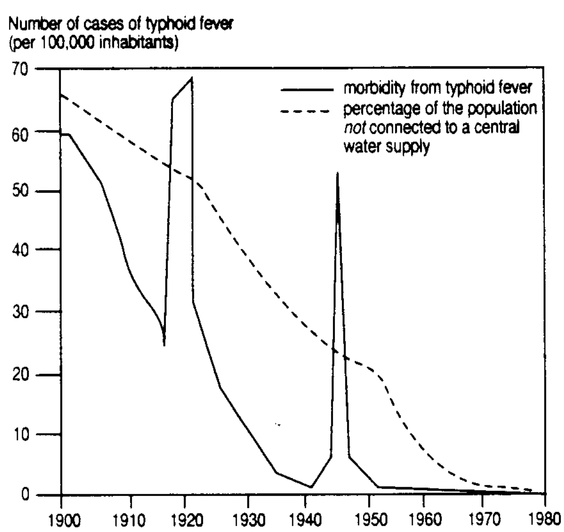


Figure 4.1 shows the relationship between exposure and response for a number of protozoa and viruses. From this it should be possible to derive standards for the quality of drinking water which have a sounder basis than those currently applying (Regli *et al.*, 1991).

4.1.3 Relationship with other determinants

In the Netherlands more than 99.9% of households are now connected to the central supply of drinking water - the highest percentage of connections in Western Europe. For comparison, the percentages in a number of other countries are as follows: Denmark 92%, Belgium 98%, Germany 98%, France and the UK 99% (IWSA, 1988). The disappearance of a typical waterborne disease like typhoid fever in the Netherlands (*see Figure 4.2*) is closely associated with the increase in the percentage of connections. The improvement in public hygiene has also undoubtedly played an important part. Two sharp peaks in the incidence of typhoid fever during the First and Second World Wars (Kool and Schaeffer, 1976) show just how fragile the situation is.

Figure 4.2: Drinking water connections and the incidence of typhoid fever in the Netherlands. Source: Kool and Schaeffer, 1976.



Whether exposure to naturally-occurring microorganisms in drinking water actually leads to infection depends not only on the dose and the virulence of the microorganism but also to a considerable extent on the immune system of the person drinking the water. In patients whose immune system has been weakened or suppressed, for example as a side-effect of medication, it may be necessary to advise against drinking tap water. Even slight disturbances of the immune system, for instance as a result of a holiday trip to the Mediterranean, may lead to increased sensitivity to, for example, legionellosis.

As again became apparent from the cholera epidemic in South America mentioned earlier, disinfection with chlorine is an effective means of preventing infection via drinking water (Salazar-Lindo *et al.*, 1992). One disadvantage of using disinfectants in the treatment of drinking water is the formation of compounds from residual substances, such as trihalomethanes and haloacetonitriles with possibly carcinogenic properties. In situations in which epidemics actually occur though, it is not difficult to make a choice between, for example, the risk of cholera and a theoretically slightly increased risk of cancer (Neutra and Ostro, 1993). In the relatively favourable situation existing in the Netherlands, efforts can be made to produce and distribute drinking water using as little disinfection as possible (Versteegh *et al.*, 1989).

4.1.4 Interventions and policy

Under the Dutch *Waterleidingbesluit* (Water Supply Decree), the microbiological quality of drinking water has to be tested against a number of bacteriological standards. Examples are the standards applying to coliform bacteria, faecal streptococci and germs culturable at 22°C and 37°C. As already mentioned, however, standards of this kind offer only limited guarantees. In assessing the safety of drinking water it would therefore be helpful to adopt a more process-oriented approach, with data on the incidence of pathogens in "raw" water being combined with data on the effectiveness of purification techniques. This approach would inevitably lead to more structured design and management of the drinking-water treatment process, by analogy with the HACCP (Hazard Analysis Critical Control Points) principle used in the foodstuffs industry. The data needed for this is available only to a limited extent, however.

Whereas in the past attention was focused above all on removing viruses in the course of treating surface water (because of the high level of contamination), now the emphasis is increasingly on treating and protecting ground water as the source. The removal of very resistant protozoa from surface water is also of importance.

The quantity of naturally-occurring bacteria in the drinking water network can be controlled by removing nutrients as far as possible, reducing the time spent in reservoirs, a sensible choice of materials, and by means of technical intervention, for example discharge schedules (Van der Kooij, 1990).

In the situation prevailing in the Netherlands, gains can be made above all by further reducing the risk of infection. In the absence of any direct insight into the risks from (opportunistic) pathogens in drinking water, efforts must be made to ensure the optimum use of the technical means available, for example in accordance with the principle of optimisation used in radiation hygiene (ALARA).

4.1.5 Information lacking and recommentdations

Controlling risks emanating from biotic environmental factors is often a complex matter which increasingly calls for a specific approach based on detailed insight into infection cycles, the risks for public health, and the technical and economic feasibility of measures. Sufficient attention must be paid to collecting the data required for this. Only on the basis of such data can the quality of policy decisions be further improved. Evaluation of the effectiveness of these decisions and the identification of new problem areas needs to be based on effective monitoring of infectious diseases (*see Part III, 3.2.1.1* of the Dutch edition).

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LIST OF ABBREVIATIONS

ALARA	as low as reasonably achievable
HACCP	Hazard Analysis Critical Control Points
IWSA	International Water Supply Association
KIWA	*Keuringsinstituut voor Waterleidingsartikelen* (Waterworks Undertakings Testing and Research Institute of the Netherlands)
RIVM	*Rijksinstituut voor Volksgezondheid en Milieuhygiëne* (National Institute of Public Health and Environmental Protection)
SVGW	*Schweizerischer Verein des Gas- und Wasserfaches* (Swiss Gas and Water Industry Association)
WHO	World Health Organization