Environmental health: research for policy

Gezondheidsraad **President**
Health Council of the Netherlands

The State Secretary for Housing, Physical Planning
and the Environment

Subject : Advisory report on the Action Programme Environment and Health
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Mr. State Secretary,

In response to the request in your letter DGM/SAS/2002085338, I herewith present the advisory report *Environmental health: research for policy*. It was prepared after consultation of the Standing Committee on Health and Environment, members of other standing Health Council committees and a few other experts.

I also presented the report today to the Minister of Health, Welfare and Sport. Furthermore I provided the Minister of Housing, Physical Planning and the Environment, the State Secretary of Social Affairs and Employment, the Minister and State Secretary of Transport, Public Works and Water Management, the minister of Agriculture, Nature and Food Quality, the Minister and State Secretary of Economic Affairs, and the Minister of Education, Culture and Science with a copy.

Yours sincerely,

(signed)

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Environmental health: research for policy

to:

the State Secretary of Housing, Spatial Planning and the Environment

the Minister of Health, Welfare and Sport

No. 2003/20E, The Hague, 14 October 2003

The Health Council of the Netherlands, established in 1902, is an independent scientific advisory body. Its remit is "to advise the government and Parliament on the current level of knowledge with respect to public health issues..." (Section 21, Health Act).

The Health Council receives most requests for advice from the Ministers of Health, Welfare & Sport, Housing, Spatial Planning & the Environment, Social Affairs & Employment, and Agriculture, Nature and Food Quality. The Council can publish advisory reports on its own initiative. It usually does this in order to ask attention for developments or trends that are thought to be relevant to government policy.

Most Health Council reports are prepared by multidisciplinary committees of Dutch or, sometimes, foreign experts, appointed in a personal capacity. The reports are available to the public.

This report can be downloaded from www.healthcouncil.nl.

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Executive Summary

Issue addressed and approach

What knowledge are we missing about the way our surroundings influence our health? And what research is required to fill the holes in such knowledge? These questions were posed by the Netherlands' State Secretary for Housing, Spatial Planning and the Environment when asking the Health Council to produce this report. Behind the questions was a wish to obtain the research data necessary to more effectively protect public health against harmful environmental factors and to allay unfounded concerns about environmental factors. The State Secretary was chiefly interested in the effects of physical factors, such as substances in the air, the water and the soil, ionising radiation, electromagnetic radiation and fields, and noise. Every one of these factors was referred to in the Action Plan Environmental Health: Implementing more powerful policy, presented to the Lower House of the Dutch parliament in 2002. The Environmental Health Action Plan also highlighted the importance of research into risk perception and risk communication.

To formulate a response to the State Secretary, the President of the Health Council sought input from both Council members and external experts that were consulted individually and invited to air their views at a working conference. This report has been drawn up on the basis of the feedback received.

The State Secretary asked the Council to put forward and assess subjects regarding promising fields of research. However, scientific research tends to produce isolated puzzle pieces rather than an immediately coherent picture. If research is to offer practical

support in the formulation of policy, it is necessary to determine which puzzle pieces go where and to sketch in the gaps in the picture—a process known as knowledge synthesis. As well as identifying topics warranting further investigation, this report therefore also indicates the fields where synthesis is desirable with a view to aiding the development of environmental health policy in the relatively short term (e.g. through the preparation of a report by the Health Council or some other body).

Health and the environment

The report begins with a general examination of the relationship between health and the environment. Less than a century ago, environmental factors such as polluted air and water were major causes of illness and death. Since then, adverse environmental effects on public health have been greatly reduced by action in the fields of environmental management and health care. The problems we face today tend to involve the combination of environmental influences with socio-economic and lifestyle factors, aggravating existing medical conditions and impairing the quality of life. When confronted by such problems, it is difficult to determine where one can most effectively intervene in order to reduce the health risks associated with our surroundings. In this report the Health Council advises the State Secretary not to focus exclusively on research that offers the prospect of short-term benefit, but also to promote fundamental research that will be valuable in the longer term. In this way, sustainable solutions can more easily be achieved.

Government policies aimed at enhancing the quality of our surroundings require coordination between various policy domains; improved public health can be achieved only through inter-sector collaboration. Such collaboration should not be confined to the public health and environmental policy domains (as occurred during the realization of the Environmental Health Action Plan), but should also embrace fields such as nature management, transport and the economy.

Themes

The background to the Environmental Health Action Plan and hence to the State Secretary's request for advice was the consensus among Europe's environment and health ministers that public policy had tended to neglect the influence of the environment on public health. There was also a consensus that there was a lack of both knowledge and initiatives capable of effectively controlling the health risks associated with environmental factors. This has led to increases in research efforts across the EU.

This report does not provide a comprehensive overview of such ongoing research. The research and knowledge synthesis initiatives proposed are intended to complement the work already being done in the Netherlands and elsewhere.

The report considers proposals for research and advice linked to nine themes:

- The quality of the human environment
- Chemical substances
- Noise
- Non-ionizing electromagnetic radiation
- Air pollution
- The indoor environment
- Combined exposures
- Risk perception and risk communication
- Monitoring

For each theme, the report assesses the extent to which knowledge regarding the seriousness and extent of the health effects is lacking and the level of public concern regarding the possible health detriment. The potential for each proposed research or synthesis activity to contribute to greater understanding of the health risks is then discussed, along with the short-term feasibility of each proposal.

The quality of the human environment

The report treats 'The quality of the human environment' as a general heading for a number of related topics. The quality of the human environment is influenced by numerous factors, between which the interactions are manifold. Consequently, it is not currently possible to quantify the health implications of the quality of our immediate surroundings. Nevertheless, while warning that it will take time to secure results, the report stresses the importance of research into this complex of factors and into ways of measuring the influence of this complex.

Chemical substances

The heading 'Chemical substances' covers issues relevant to the licensing of new substances and to the assessment of risks associated with existing substances, particularly those that are found in our living environment. Much work remains to be done in this field, since little or nothing is known about the significance of many substances to public health. The report emphasizes the potential benefits of research into the application of molecular-epidemiological methods designed to yield information about exposure to, and the impact of, substances in our living environment. A combination with genome

research (genomics) offers the prospect of greater insight into the toxic effects of chemical substances.

Noise

A significant proportion of the Dutch population is annoyed or seriously annoyed by noise from neighbours, road, rail and air traffic, and industrial sources. The report focuses particularly on traffic noise and industrial noise. Gaps are identified in scientific knowledge regarding the relationship between cardiovascular disease and exposure to noise and regarding the general health implications of sleep disturbance associated with nocturnal noise. The report also suggests that more research is required into the way noise in domestic, school and recreational settings affects health and childrens' short-term and long-term performance. Research into this topic is currently in progress, some of it under the European umbrella.

In view of the number of people exposed to and affected by noise, research into the effectiveness and efficiency of exposure reduction methods is also considered important.

Non-ionizing electromagnetic radiation

The possibility that mobile telephones or high-voltage power transmission may have public health implications is regularly aired in the media. The principal alleged culprits are radio-frequency radiation and the electromagnetic fields associated with power lines.

As previously recommended by the Health Council, a European epidemiological research initiative is currently underway with a view to obtaining additional information. The report suggests that further action should be deferred pending publication of the results of this research. Nevertheless, the Council does recommend a survey of exposure to fields generated by high-voltage power lines and electric equipment, as well as epidemiological research into the prevalence of leukaemia associated with such exposure. The State Secretary is warned, however, that such research is difficult, should be considered only in the context of international cooperation and cannot be expected to provide conclusive results in the short term.

Another topic addressed by the report is the effect on the immune system of ultraviolet radiation in sunlight and from sun beds. The Council's view is that the time is ripe for a re-assessment of scientific knowledge in this field. Evaluation of extant research data on the protection against skin cancer offered by sun creams is also considered worthwhile.

Air pollution

One of the main causes of atmospheric pollution is the combustion of fossil fuels, particularly for transport purposes. Such pollution causes serious decrements in public health. Fine particulate matter, nitrogen oxides and ozone are of particular importance in this context. However, there is only partial knowledge concerning which pollutants or combinations of pollutants are detrimental to health and under what circumstances. The report therefore underlines the importance of research in this field and draws attention to the research already in progress, where Dutch researchers are also involved. It is expected that the results of such research will in due course enable the scientific community to advise the government with regard to its policies on air pollution.

Unpleasant odours are also a form of pollution of the outside air. While typically localized, odorous emissions can have a significant influence on the quality of the surroundings for those who live in affected areas. Although little additional evidence has come to light in recent decades regarding the relationship between odour, odour-related nuisance and health problems, the Council believes there to be scope for a synthesis of the published information.

The indoor environment

The theme ‘The indoor environment’ covers air quality within the home. The air we breathe in our own homes is generally more polluted than the immediate exterior atmosphere. The sources and causes of indoor pollution are well known: building materials, soft furnishings and furniture upholstery, cooking, and oxygen consumption and the production of carbon dioxide by the occupants. Yet, despite this knowledge, research indicates that little has been achieved in terms of reducing the negative influence that domestic pollution has on public health. The report therefore recommends the compilation in the short-term of a scientific basis to facilitate the development of a strategic vision for improvement of our indoor environments, particularly the home environment.

The report also suggests that the situation in school buildings should be considered. It is conceivable that poor air quality in the school environment, possibly in combination with other environmental factors such as noise, could have an adverse effect on academic performance. However, little research has been done in this field.

Combined exposures

In practice, people are not exposed to an isolated environmental factor, such as a particular insecticide or a particular form of radiation. Exposure always involves several factors simultaneously or subsequently—different forms of air pollution, for example, or

air pollution together with noise, or benzene both in the workplace and in the hobby room at home, etc. Despite this, we know much less about the significance of exposure to combinations of factors than about the effects of exposure to individual factors. The report accordingly highlights a number of topics that are felt to warrant further investigation: methods of risk assessment and, more fundamentally, the roles played by individual sensitivity and socio-economic circumstances in the occurrence of health effects. The State Secretary is advised that knowledge synthesis would be valuable for the assessment of ways of measuring health impairment, since measures of impairment are particularly relevant in the context of compound exposure.

Risk perception and risk communication

The public's view of the health risks associated with a particular environmental factor is often very different from that taken by experts or the government. Given the divergent perceptions of risk and risk assessment that exist in society, the report would like to see more done to promote proper risk communication. Risk communication is defined as a two-sided process involving interaction between the government and the public (or between different non-governmental stakeholders) where there is the exchange of information concerning risk and value judgements. Through such a process, it is hoped that a common context can be created, within which appropriate value can be attached to estimates of environmental risk factors. The report holds that research into the effectiveness of risk communication methods is urgently required and that there is a need for the synthesis of knowledge in this area.

Monitoring

The report does not address the theme of monitoring because the Health Council has very recently published a report entitled *Gezondheid en milieu: mogelijkheden van monitoring* (Health and the environment: monitoring options), in which detailed consideration is given to the development and the role of monitoring systems.

Taking action

The report does not provide a list of proposals that can simply be picked up in sequence. Rather, it makes proposals that are intended as a basis for a strategic research programme that should tie in with international activities, in particular at the EU-level, and to which researchers could lend their support. The report calls for the promotion of a durable knowledge structure where fundamental research is accorded proper importance. It is envisaged that such a structure would be formed by researchers within uni-

versities and research institutes, such as the Netherlands Organization for Applied Scientific Research (TNO) and the National Institute of Public Health and the Environment (RIVM). The Netherlands Organization for Scientific Research (NWO) is perceived as the obvious supervisory body for the proposed strategic programme, and the Netherlands Organisation for Health Research and Development (ZonMW) for the applied research programme. NWO has adequate and established procedures for assessing the quality of research proposals and testing them against a strategic programme. Given the breadth of the issues relevant to health and the environment, the report argues that the suggested programme should be supported by several government departments. Interdepartmental support would also be consistent with the desired intersector approach to the development and implementation of policies on health and the environment.

The report concludes that the existing structures are adequate for the purposes of knowledge synthesis.

Over the centuries, the adverse effects of our physical surroundings on public health have been reduced by environmental management. Nevertheless, much remains still to be done to protect public health against environmental hazards as new factors continue to emerge and old factors threaten to reassert themselves. The processes of globalisation are, at present, particularly important in this context. The Health Council therefore believes that there are compelling reasons for energetically implementing the measures announced in the fourth National Environmental Policy Plan, the Environmental Health Action Plan and the recently published European Strategy for the Environment and Health. The subjects identified in the report support that implementation.

Chapter 1

Request for advice

1.1 Background

In 1989 the environment and health Ministers of the countries in the 'European zone' of the World Health Organization (WHO)* issued a joint declaration in Frankfurt-am-Main emphasizing the association between environment and health.[1] In the 1989 *European Charter on Environment and Health*, the Ministers announced their intention to introduce a series of measures designed to protect the (physical) environment and thus to improve public health. Five years later, a similar ministerial meeting was held, this time in Helsinki. It was concluded at this meeting that the targets set in 1989 had largely been achieved, and it was agreed that *National Environmental Health Action Plans* (NEHAPs) should be drawn up, to be in place no later than 1997.[2] As used in this declaration, 'environment' means the physical environment,[3] although the deliberations leading to the declaration also included referred to the social environment.[2]

The Frankfurt and Helsinki declarations both stress the inter-sectoral nature of environmental health policy. In other words, such policy not only embraces public health and environmental management, but also depends upon measures in fields such as economics, spatial planning and transport in order to achieve environmental health gains. In the Netherlands, this integration of environmental and public health policy (or, indeed, the coordination of the public health and environmental management policy sectors) has

* WHO Europe includes the EU member states plus the republics of Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

not been easy to achieve.[4] A report by Cramer outlined how this situation might be improved.[5]

In November 2001 the Minister of Health, Welfare and Sport (VWS), acting also on behalf of the Minister of Housing, Spatial Planning and the Environment (VROM), presented The Second Chamber with a policy document entitled *Gezondheid en Milieu, opmaat voor een beleidsversterking* (Policy Document on Environment and Health: an overture to more powerful policy).[6] The Ministers in question regarded this document as the Netherlands' version of the NEHAP. As well as stating the need to reinforce policy in the field of environment and health, the document announced the Ministers' intention to establish an 'action programme' for this purpose. An extensive inventory of risks, aims, policy proposals, and initiatives (drawn up by TNO Prevention and Health) accompanied the document.[7]

One of the conclusions of the *Actieprogramma gezondheid en milieu, uitwerking van een beleidsversterking* (Environment Health Action Programme: Implementing more powerful policy)), which appeared in May 2002, was that research into the relationship between environment and health required fresh impetus in the Netherlands, as elsewhere.[8] The document identified and indicated the relative priority of a number of themes that were considered important in relation to the assessment of health risks, and concerning which more knowledge was required. The report indicated that the next step should be the development of a phased and prioritised environment and health research programme under the programme of 'Environment and Health'.[8] The Ministers in question consulted various bodies, including the Health Council, regarding the form that this programme should take.

The European Commission recently published a *European Environment and Health Strategy*.[9] This strategy seeks to harmonize policy and research on environment and health by focusing on five key areas: science, children, awareness, legal instruments and evaluation; referred to collectively by the acronym 'SCALE'. The Netherlands' Action Programme and associated research programme are in line with these European developments and *vice versa*.

1.2 Ministerial request and the scope of this report

On 9 December 2002 the State Secretary for the Environment (VROM) asked the Health Council to advise him regarding the following matters:

- The research themes proposed in the Action Programme (Annex C), in particular the extent to which research on such themes would cover existing gaps in knowledge
- The priorities for research in the Netherlands, taking account of:
  - existing research programmes and expertise in the Netherlands and elsewhere

- the extent to which the results of each proposed research activity can contribute to the understanding of health risks and potential health benefits
- the extent to which each proposed research activity can provide information that reduces public concern
- the extent to which each proposed research activity can provide information that can be of use within the Action Programme period
- the feasibility of further research
- the cost of further research.

The State Secretary also asked that the Council should, when addressing these questions, indicate the cost per additional quality-adjusted life year (QALY) secured. He also indicated that an assessment framework was being developed to provide a clear basis for decision-making regarding environment-related health effects and asked the Council to make a scientific appraisal of this assessment framework. The full text of the Minister's letter is reproduced in Annex A.

In his response to the Minister's letter, the President of the Health Council reported that an initial advisory report would be produced dealing with the present gaps in scientific knowledge (see Annex A). He did not feel that it was presently practicable to express the potential effectiveness of research initiatives in terms of QALYs or similar measurement units. In addition, he believed that the appraisal of the assessment framework was best deferred until after the National Institute for Public Health and the Environment (RIVM) had completed and published its report.*

The State Secretary's question concerning research into the influence that environmental factors have on public health is addressed in the present report by reference to the Action Programme themes. However, the State Secretary's request has been interpreted fairly widely. The reason for this is that a considerable amount of information is already available in certain fields, but this information is insufficiently structured to allow for proper risk assessment or to provide a proper basis for effective protection policies. What is primarily required in such fields is synthesis and detailed analysis of the information already available (referred to in Chapter 3 simply as 'advice). It was accordingly felt that recommendations should be provided regarding these fields as well.

Policy implementation becomes a relevant issue if sufficient knowledge is already available to provide a basis for protection policy. This can necessitate further research and further synthesis of research data, particularly where the effectiveness and effi-

* The said report was published in June 2003 and the Health Council assessment of it should be completed in the last quarter of 2003.[10]

ciency of protective measures are concerned. This advisory report therefore also highlights the areas where such research and synthesis are required.

1.3 Methodology

The first preparatory steps were taken towards formulation of a report in anticipation of the receipt of the formal ministerial request. In view of the breadth of the matters concerned, the President of the Health Council felt it appropriate to draw particularly upon the expertise within the Council's Standing Committee on Environment and Health. The Standing Committee met to discuss the Action Programme research themes on 26 November 2002. The President also invited the chairs of the Health Council's other Standing Committees and the President of the Advisory Council on Health Research to attend, along with individuals with particular expertise in the field of environment and health. The people present at this 'working conference' are listed in Annex B and the programme for the conference is set out in Annex D.

Subsequently, Ms T Fast (Fast Advies, Utrecht) and Professor WF Passchier from the Health Council staff drew up a draft report that was initially submitted to an 'editorial committee' (Annex B) and then to everyone who had participated in the meeting on 26 November 2002. The draft was modified in line with the feedback received, and a second draft distributed for comment in the same way, after which the President of the Health Council finalized the report. The report is written in the first person plural; 'we' should be interpreted as the President and Deputy Executive director of the Council (who acted as co-ordinating editor).

1.4 Structure of the report

In order to identify gaps in scientific knowledge regarding environmental influences on health, it must be decided what is meant by 'health' and how that concept is understood by the society at large. These issues are considered in Chapter 2. Since government policy on environment and health is directly linked to the way risks are addressed, Chapter 2 also examines the process of risk assessment and the role of knowledge and knowledge synthesis in this context. Chapter 3 is subsequently devoted to the gaps in knowledge regarding the influence that environmental factors have on health, as well as to the research and consultative activities necessary to cover such gaps. The Action Programme themes are also explored and there is a brief discussion of a number of other themes previously identified in the *Policy Document on Environment and Health: an overture to more powerful policy*. Finally, consideration is given in Chapter 4 to the relative importance of the various themes and to the relationship between short-term and long-term research.

Chapter 2

Points of departure

In this chapter, we discuss our views concerning the relationship between environment and health.

2.1 Environmental quality and health

The Health Council's views on the relationship between environment and health have already been set out in an earlier publication.[11] The views defined in that context formed the starting point for this report. They are summarized below and certain aspects are elaborated. For further information on this topic, the reader is referred to the earlier report (and to relevant publications produced by the RIVM[12,13] and others).

When considering the relationship between environmental quality and health, commentators frequently start from the WHO's definition of health, namely: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity".[14] The breadth of this definition has attracted criticism from some quarters. It has been suggested that the wording amounts to a definition of personal well-being, rather than of a state for which governments can reasonably be expected to share responsibility.[15] Calls have accordingly been made, particularly in the context of collective healthcare provision, to define health more narrowly in the interests of affordability and the realization of objectives concerning the reduction and cure of illness.[16] The German Advisory Council on the Environment does quote the WHO definition, but chooses to interpret the concept of health primarily in terms of the collective functionality of organs and organ systems.[17] Since psychological functionality cannot be divorced from

physical health (and *vice versa*), issues of well-being are also relevant. We support this interpretation of the concept of health.

An individual's health is influenced by a great variety of external factors that may be described as socio-cultural, economic and ecological.[18,19] The socio-cultural factors include relations with other people, population growth, social change and education; the economic factors involve work and income; and the ecological factors relate to nourishment, water, environmental pollution and climate. Thinking concerning the relative significance of these factors has been subject to change over the years.[4] Greater understanding of the significance of the physical environment and higher living standards (combined with progress in the fields of public hygiene, prevention and healthcare) have pushed average life expectancy in Western industrialized countries up from around thirty years to around eighty years. At the same time, there has been a decline in infectious diseases that are often caused by dirty water and food. Attention has therefore shifted to chronic illness and diseases of old age, while accidents have become the largest cause of death among younger people.[12,13,20] In terms of serious disease and premature death, the negative influence of environmental factors on health are not as great as they once were, although certain infectious diseases are re-establishing themselves.[21] In relatively prosperous countries, such as the Netherlands, environmental influences tend to affect health mainly by compromising welfare and aggravating existing conditions.[22] Where environmental quality is locally poor and there are concerns about the possibility of involvement in a serious or fatal accident, people feel unsafe and alienated. They consequently perceive themselves to be unhealthy or over-stressed.[23,24] Government policy already acknowledges that the physical environment and the socio-cultural setting (including individual and collective behaviour [lifestyle]) can have a major influence on health.[25,26]

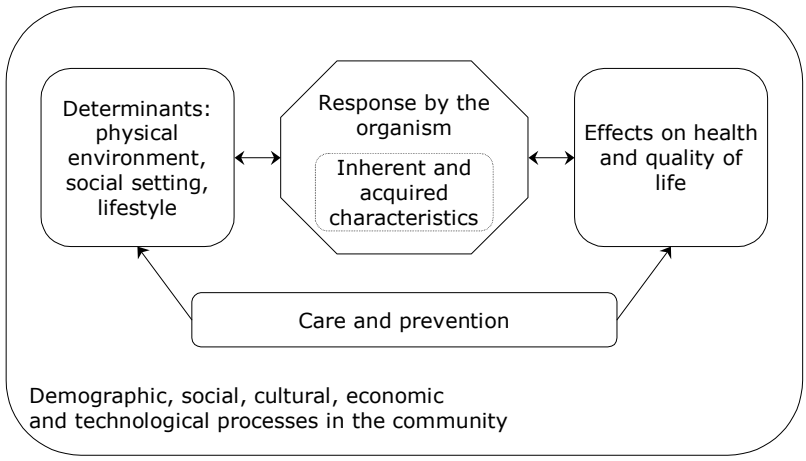

Figure 1 A model of the relationship between environment and health.

Figure 1 illustrates the way that environment influences health and draws upon the work of Canadian Minister of Health La Londe (1974)[4] and upon RIVM publications,[27] amongst other sources. In the illustrated model, environmental effects on health and quality of life depend on the way in which the individual responds to external determinants (*i.e.* characteristics of the individual's physical and social environment and lifestyle). An individual's response is shaped to a large extent by hereditary and acquired personal characteristics. Exposure to environmental factors and the associated responses take place within a community with the social, cultural, economic and technological characteristics referred to above. Because exposure and effect are linked by such a complex chain of factors, the consequences of exposure to a given environmental influence can vary considerably from one population group to another and from one individual to another.[28] The emergence of the genomics discipline has led to increased interest in hereditary factors and to greater understanding of differences in sensitivity to environmental factors.[29,30]

Figure 1 distinguishes between three types of external determinant: physical environment (the ecological factors referred to above), social environment and lifestyle (the socio-cultural factors referred to above). Physical environmental factors include energy, radiation, noise, vibration and temperature, oxygen supply and nutrients, hazardous chemicals in the interior and exterior environment (including the working environment), and bacteria and other micro-organisms. Any of these may have an influence which may be positive or negative upon health. These factors are central to this report, as they are to the Action Programme. Lifestyle includes influences such as dietary habits, smoking, use of drugs and alcohol, sexual behaviour and (lack of) exercise. A person's social environment is characterized by, for example, his or her pattern of social contacts and socio-economic status, and also by the day-to-day significance of the side-effects of major infrastructural development projects.[31]

As indicated earlier, health problems in Western society are frequently at least partially psychosomatic in nature. Symptoms attributed to environmental factors can also be psychosomatic (witness the disquiet concerning symptoms experienced after drinking odd-smelling Coca-Cola[32-34]). This phenomenon has been linked to the apparent guarantees of modern technology: quality assurance in the foodstuffs industry is such that food is expected to be safe but still is occasionally contaminated (as in the Coca-Cola case), and medical science does not ultimately have a solution for every ailment.[35,36] Such health problems are real, but their association with exposure is sometimes tenuous. Nevertheless, the health complaints should be taken seriously and treated where necessary and possible.[37]

It is worth making the point that concern regarding environmental risks is not inherently undesirable. It can focus attention on genuine threats to health that would other-

wise be underestimated, or on other difficulties in the interaction between the government and the public.[38]

2.2 Risk assessment and risk management

If an environmental factor can have an adverse effect on health, exposure to that factor constitutes a health risk. Effective and efficient management of such risks requires an understanding of the nature and extent of the risk, as well as of the effectiveness of associated risk-reduction measures.

In 1995 and 1996 the Health Council produced two advisory reports on the assessment and management of risks in the context of environmental policy.[39,40] The committee that produced these reports drew a distinction between risk assessment and risk management (see Figure 2). Risk assessment involves the analysis and characterization of possible environmental influences on health. The emphasis in the risk management phase is on defining and implementing protection policies. However, the model presented in Figure 2 suggests that risk assessment and risk management are inseparable and interact. The core of risk assessment (risk analysis) is principally an activity for people with scientific training, while problem definition and risk characterization are shaped by social and policy preferences.

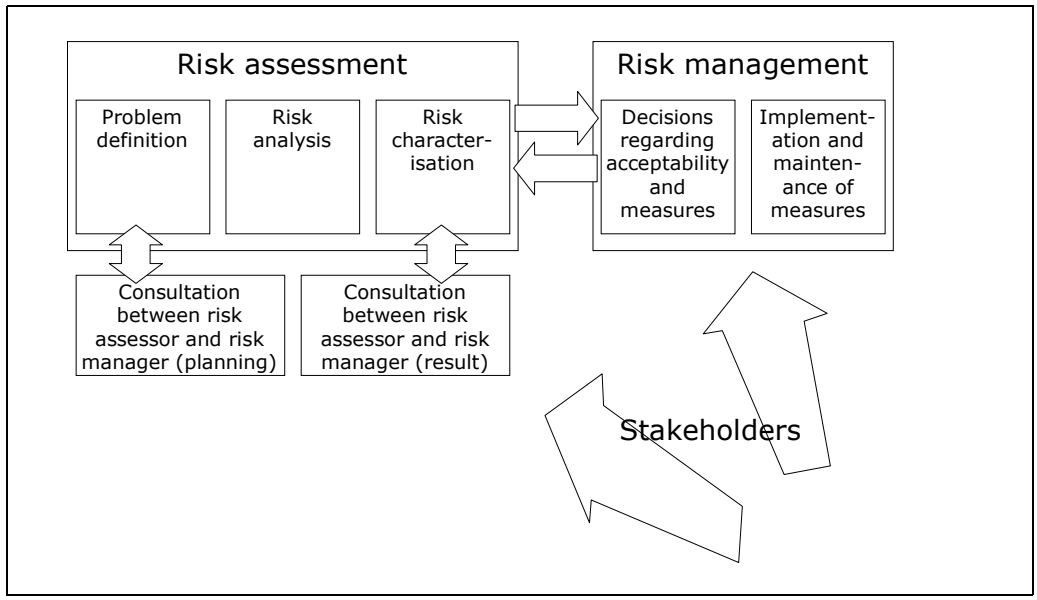

Figure 2 Relationship between risk assessment, risk management, and the positions of the actors involved in the risk assessment and risk management process. Taken from [39,40].

Risk analysis may be subdivided into identification of the relevant environmental factors or stressors, determination of the extent of the exposure to these stressors and estimation of the effect of such exposure on the basis of knowledge concerning the exposure-effect relationship.[39,40] Figure 3 additionally illustrates the position of research or knowledge acquisition. Knowledge synthesis is of great importance in this context. Research findings can serve as a trigger to focus attention on a particular risk. The research then yields information that leads to the definition of a problem, to the identification of the relevant stressors (e.g. one of the physical factors referred to above) and to greater insight into the extent of the exposure to the stressors in question. Synthesis of the available knowledge is necessary in order to estimate and characterize risks with any degree of reliability. Such synthesis is concerned primarily with data from fundamental research into the relationship between environment and health (the link between stressors and the consequences of exposure). However, the synthesis is also intended to identify lessons that can be learnt from specialized, typically time-specific and location-specific, research results. The object of synthesis is to piece together a coherent picture from sundry pieces of data.

Research also plays a role in the determination and evaluation of the effectiveness of risk-reduction measures. Where more complex problems are concerned, knowledge synthesis may again be necessary in order to arrive at reliable conclusions.

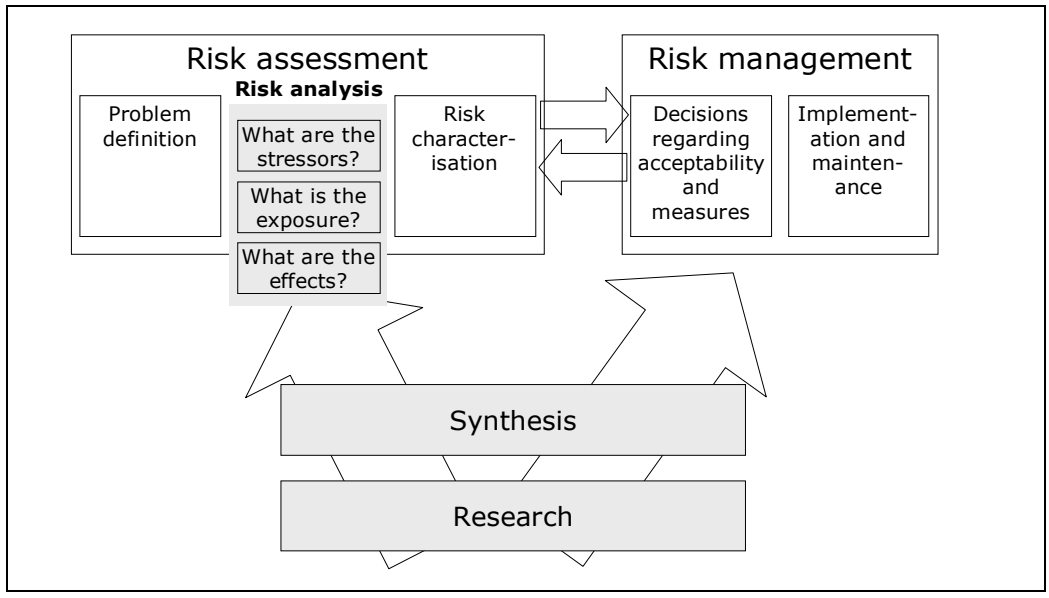

Figure 3 The role of research and of the synthesis of research-based knowledge in the process of risk assessment and risk management. In this figure, the risk analysis activity which forms part of the risk assessment phase identified in Figure 2 is worked out in more detail.

Figures 2 and 3 illustrate a theoretical model that underpins the recommendations given in this report. However, one key feature of the concept of risk is not illustrated: the principle that risk always involves uncertainty.[41,42] The point is that it is not possible to say exactly where, when and upon whom a stressor will make its effect felt. This uncertainty may derive from lack of information regarding exposure or regarding the effect mechanism (stressors and effects; Figure 3). However, it may also be of a more fundamental nature: there may be a lack of scientific knowledge (a few decades ago, for example, scientists were unaware of the greenhouse effect[43]) or complete ignorance regarding the risks associated with an activity (as with the inclusion of animal remains in livestock feed, which was not originally known to have a possible link with Creutzfeldt-Jacob's disease[41]). Some sociologists regard this type of risk characteristic as typifying modern industrialized societies and exercising an influence over health and well-being (see, among others, [45,46]).

2.3 Risk characterization

Risk characterization (see Figures 2 and 3) involves describing the seriousness and the extent of the risk in question. Risk characterization forms a distinct phase of the risk assessment and risk management process, because there are a number of different ways of expressing the findings of a risk analysis. The reason for this is that since the purpose of characterization is to make it possible to take risk-reduction measures, it has to be aligned with the values of the risk managers, the population groups affected by the risk and society at large. Such values can vary considerably from party to party and from situation to situation.[39,40]

A commonly used yardstick in the characterization of health risks is loss of quality-adjusted life years. These are known as QALYs and are a unit widely employed in healthcare for cost-effectiveness analysis.[47] When comparing the disease burdens of different countries or groups of countries, and when establishing the primary contributors to disease burden, use is often made of the disability-adjusted life year (DALY), a unit first introduced by the World Bank.[48] The RIVM has used the latter unit when quantifying the influence of environmental factors on health.[49] Such calculations by the Institute form the basis for the statement often reproduced in policy documents, that between 2 and 5 per cent of the Netherlands' disease burden is attributable to "pollution of the general atmosphere with particulate matter and ozone, serious noise pollution from traffic and pollution of interior environment with radon, particulates (tobacco smoke) and allergenic 'moisture-loving' biological agents such as dust mites and fungi".[6]

The Health Council is to produce a separate advisory report concerning the value of DALYs and QALYs in the context of public health and risk-management policy (see Annex A). At this point, it is sufficient to say that these measurement units reflect

important parameters, such as life expectancy, freedom from disease or disability, and the prevention of health damage early in life. However, they do not necessarily take account of other important parameters, such as quality of life diminution attributable to psychosocial conditions, the protection of the health of future generations and the scope for personal risk management (see also [47]). Another problem is the lack of critical data. We believe that calculations such as those made by the RIVM and others provide useful insight into albeit limited aspects of the role of environmental factors in the determination of health risks. However, it is important to recognize that the attribution of around 3 per cent of disease to environmental factors by no means gives the full picture of the risks associated with environmental factors.

2.4 Activities outside the Netherlands

Political interest in policies that redress the negative influence of environmental factors on health (see Section 1.1) has led to new research and research programmes. In the present context, we will confine ourselves to highlighting certain activities organized at the European level. Following the 1994 Helsinki Conference of Ministers, for example, the European Science Foundation (ESF) took the initiative to perform an exercise very similar to our own. With assistance from the WHO's European Office, the ESF compiled a list of research priorities for environment and health in 1998/1999.[50,51]

Overarching needs

Environment and health indicators

Health and environment geographical information systems.

Cross-cutting issues

Risk assessment

The environmental contribution to social variations in health

Cognitive functions as mediators of environmental effects on health

Specific research areas

Air quality

Water quality and drinking-water

Environmental effects on cognitive functions

Children and unintentional injuries

Climate change and stratospheric ozone depletion.

The ESF's list of proposed research topics is reproduced in Annex E and has been taken into account in our own survey of research requirements presented in Chapter 3.

In addition, certain elements of the EU's framework programmes are (partly) concerned with the relationship between environment and health. The Fifth Framework Programme (covering the period 1998 to 2002) started at the end of 1998.[52,53] This programme provided funding for research into the relationship between environment and health, particularly in connection with the theme 'Quality of Life and Management of Living Resources'. Furthermore, particular emphasis was placed upon the prevention and consequences of exposure to air pollution, heavy metals, toxic chemicals, noise, climate change and electromagnetic fields. Another EU programme (1999-2001) was specifically concerned with diseases associated with environment pollution, such as air pollution and noise.[54]

The Fifth Framework Programme has in the meantime been succeeded by the Sixth.[55] This programme contains three themes of particular relevance in the present context, namely 'Life sciences, genomics and biotechnology for health', 'Food quality and safety' and 'Sustainable development, global change and ecosystems'.

The research topics identified in the following chapter are in our view best addressed as much as possible in an international context. Coordination with the European programmes mentioned would seem the most obvious route forward with this.[9] However, this certainly does not mean that coordination with other programmes is not also possible. At the very least, we consider the alignment of Dutch research programmes with EU or WHO initiatives to be desirable.

Chapter 3

Gaps in knowledge on environment and health

This chapter lists (by reference to the Action Programme themes) the areas in which the experts consulted at the working conference held on 26 November 2002 (and subsequently via other channels) considered research and advice to be necessary. Each research and advice proposal is assessed against a number of criteria.

3.1 Themes

The authors of the policy document *Gezondheid en Milieu, opmaat voor een beleidsversterking* (Policy Document on Environment and Health: an overture to more powerful policy) considered the themes identified below to be of significance in relation to the impairment of health by environmental factors.[6]

- Pollution of the outdoor air
- Noise pollution from traffic
- External safety
- Quality of the living environment
- Accumulation of threats
- Electromagnetic fields
- Odour nuisance
- Perception of risk
- Pollution of the indoor environment
- Hazards and risks from substances
- Food safety
- Water
- Biotechnology
- Biological risks
- Soil pollution
- Local environmental health policy*

* The emphasis on environmental factors in local health policies

It is clear from the themes included that the authors were concerned primarily with the physical environment. However, the influence of the social environment is also acknowledged by the inclusion of the themes 'Quality of the living environment', 'Perception of risk' and 'Local health policy and the environment'. It is striking that the topics differ from one another considerably in their nature. 'Noise' is an agent, while the 'Outdoor air' is an environmental compartment, the 'Quality of the living environment' is a general health determinant, and 'Local environmental health policy' is a policy field.

The Action Programme addresses all these themes, plus a number of topics not referred to above (such as ionizing radiation). After consulting the various interested groups, the compilers of the programme identified twelve themes as warranting further study. The twelve themes did not include 'Water', 'Biotechnology', 'Odour nuisance' and 'Soil pollution', partly because these subjects were felt to already be receiving sufficient attention. We have used the selection of themes made for the Action Programme as our starting point, although we have included 'Odour nuisance' as a topic within the theme of 'Pollution of outdoor air'.

The Action Programme research themes are listed in Annex C, complete with an initial elaboration of each. We have chosen to redefine the themes somewhat, thus ending up with nine, rather than twelve, themes. The theme 'Hormone disruptors' has been included under 'Chemicals'. We also felt that all 'Policy support' activities had to relate to all other themes, and that a separate 'Policy support' theme was therefore unnecessary. The subject 'Food safety' is only briefly touched upon, since we feel it advisable to await the outcome of the ongoing developments involving the Food and Consumer Product Safety Authority (VWA). The VWA, in any case, regards the direction of research in the field of food safety to be its responsibility.[56] Certain research topics relating to food safety have in any case been included under the 'Chemicals' theme. The themes 'Ionizing radiation', 'Biotechnology', 'Water' and 'Soil', which are not included in the Action Programme, are considered in Section 3.12. The resulting nine themes are listed in Table 1.

Table 1 The Action Programme themes considered in this report.

Type	Theme
Umbrella theme	Quality of the human environment
Agents	Chemicals
	Noise
	Non-ionizing electromagnetic radiation
Compartments	Outdoor air
	Indoor climate
Determinants	Cumulative and combined exposures
	Risk perception and communication
Instruments	Monitoring

3.2 Approach

The assessment of the importance of a research project aimed at improving understanding of the influence that an environmental factor has on health or at identifying ways of limiting negative influences and promoting positive influences takes place on two levels. First, it is necessary to assess the importance of the theme to which the project relates, and then to assess the importance of the project in relation to that theme.

The importance of a theme may be assessed using the criteria of the *Beoordelingskader milieu en gezondheid* (Environment and Health Assessment Framework) contained in the Action Programme.[8] These criteria can be divided into the extent of the associated health impairment, the risk perceptions, the scope for intervention, and the associated costs and benefits. We have restricted ourselves in this report to a general of the extent of the associated health effects, as well as the level of concern (the risk perceptions) for each theme. It is worth noting that we do not believe it is possible to place the themes in order along a single dimension.

We begin below by describing the gaps in research and recommendations associated with each theme. The various topics are taken from the Action Programme or were proposed by the Council members and the other experts consulted in the preparation of this advisory report (Annex B). We have always indicated whether each proposal is relevant for risk assessment or risk management. Proposals that are relevant for risk assessment are further subdivided into those relating to exposure to an environmental factor and those relating to health effects. Similarly, research and recommendations that are relevant for risk management are split into two categories: those that relate to policy development and those that relate to intervention measures.

Various research projects have been set in motion since publication of the Action Programme in May 2002. We have not further assessed such research against the criteria listed by the State Secretary in his request for advice (Annex A). Research in the context

of other initiatives at home or abroad have also not been assessed against these criteria. Nevertheless, we have indicated whether each research or recommendation is sufficiently important to warrant looking into the need for follow-up research within the period covered by the Action Programme.

When considering the importance of the various research and recommendation proposals, our primary criterion has been the extent of the health problems and public concerns associated with the relevant environmental factor. The health effects are more significant here than public concern. Each proposal has subsequently been further assessed against the other criteria referred to in the State Secretary's letter. Because detailed information is not available concerning the short-term scope for realization of the proposals or concerning the feasibility of implementing the results, these criteria have been amalgamated to form a single criterion regarding the 'feasibility' of research or recommendations.

The various criteria do not cover all the parameters that are relevant to the assessment of research and recommendations. In particular, we draw attention to the importance of research of a fundamental and therefore often complex nature. Because such research generally yields results only in the long term, it does not score well in terms of 'feasibility' as defined in the context of this report, in spite of the fact that it may be crucial in terms of long-term protection or health promotion. We will return to this point in Chapter 4.

The approach that we have used may be summarized as follows. First, we have considered whether the research or advice topic in question is already being addressed in the context of an established or recently initiated programme in the Netherlands or elsewhere. If so, no further consideration is given to the topic in most cases. Those topics for research and advice that are not already being addressed are then qualitatively assessed against the following criteria:

- Theme:
  - The extent of the associated health effects
  - The level of public concern regarding the (possible) impact on health
- Research or advice proposal:
  - The extent to which the proposed research or advice would enhance understanding of the risk of health effects
  - The feasibility of the proposed research or advice in the short-term (whether it is likely to yield short-term results, but also the proposals position is in terms of complexity, scale and cost)

Each proposal has been scored as 'Low', 'Medium' or 'High' in relation to each criterion (except where it is indicated that meaningful assessment was not considered possi-

ble). The scores are based upon feedback from the consulted experts, but, of course, ultimately reflect our own views.

In each of the following theme-specific sections, our assessments are presented in two tables; one headed 'Gaps' and the other headed 'Priorities', following the format of Tables 2 and 3, respectively.

Example

The following example is given to illustrate the approach that has been taken. Within the 'Noise' theme, research into the relationship between, on the one hand, noise exposure, annoyance and sleep disturbance and, on the other, the construction of the home, can increase understanding of the factors that determine the effects of exposure to noise. This research proposal is included in the 'Gaps' table, under 'Risk assessment – Effects'; see Table 2. On the same theme, the Health Council is currently preparing an advisory report on the health significance of sleep disturbance resulting from exposure to noise. That report, which is scheduled for publication in the first half of 2004, may prompt additional research and is placed under 'Requiring evaluation during the course of the Action Programme' (Table 2).

Table 2 Specimen 'Gaps' table (based on Table 8).

	Research	Advice
Risk assessment		
Exposure		
Effects	Research into further differentiation of the relationships between noise exposure, annoyance and sleep disturbance and the extent of the isolation and the orientation of noise sensitive rooms	
Risk management		
Policy development		
Intervention		
Requiring evaluation during the course of the Action Programme		
		Advice on the significance of noise-induced sleep disturbance for health

Each proposal is then assessed against the criteria referred to above, unless, of course, the topic has been classified as 'Requiring evaluation during the course of the Action Programme'. The proposed research into the influence of housing construction techniques is scored '+' for 'Health effects', '(Enhancement of) understanding' and 'Feasibility' and '-/+' for 'Public concern' (Table 3). The criteria 'Health effects' and

'Public concern' relate to the 'noise' theme. Although the seriousness of effects such as sleep disturbance and annoyance is the subject of debate, these effects are sufficiently widespread to warrant grading them 'High' (+). Noise nuisance and noise-related sleep disruption, particularly in the vicinity of traffic bottlenecks, cause the required public concern in which perceived health effects certainly play a role. However, the exposed population tends to make a limited connection between such problems and long-term health impairment. Hence, this topic is scored 'Medium' (-/+) for 'Public concern'. The research proposal in question is capable of contributing to understanding of the factors that determine the effects of noise on health. In addition, we regard such research as feasible in the short-term and we anticipate that it is capable of yielding results within the relevant time frame that will be of practical value in the context of protection policy. Consequently, the proposal is scored 'High' (+) on both counts. The result is presented in Table 3.

Table 3 Specimen 'Priorities' table (based on Table 9).

	Appraisal[1]			
	Theme		Research, advice	
	Health effects[2]	Public concern[3]	Understanding[4]	Feasibility[5]
Risk assessment				
Research into further differentiation of the relationship between noise exposure, annoyance and sleep disturbance and the extent of the isolation and the orientation of noise sensitive rooms	+	-/+	+	+
Risk management				

1: Explanation of symbols: - Not or low, -/+ Medium, + High, ? unknown (as yet)
2: Nature and extent of health effects
3: Degree of public concern about (possible) health effects
4: Contribution of the research or advice topic to the enhancement of understanding of the health risks
5: Short term feasibility of research or advice (complexity, scale, costs)

3.3 Quality of the human environment

3.3.1 Description

We regard the quality of the human environment as the umbrella theme in the field of 'environment and health'. The term 'human environment' covers both physical and social environmental characteristics and is thus a critical determinant of health (Figure 1). These characteristics are influenced in turn by economic factors ('prosperity'). Dietary habits, housing quality, the quality of the domestic environment and educational level thus all depend to some extent on individual and collective prosperity. The quality of the human environment is therefore a complex concept involving numerous strongly interdependent factors.[13,57]

Factors relevant to the quality of the physical human environment include noise, odour, local air pollution, vibration, lighting, the presence of water and greenery, recreational and play facilities, and the visual appearance of the buildings and open spaces. Given our definition of the quality of the human environment (see 2.1), it follows that the characteristics of the human environment, even if limited to those listed in the previous sentence, can have a positive or negative influence on health. Vehicular emissions of nitrogen oxides and particulates increase the disease burden.[58] On the other hand, more greenery in the human environment (including the urban environment) promotes health.[59,60]

3.3.2 *Gaps in research and advice*

The RIVM and others are conducting research into the quality of the human environment, in particular the residential environment. Key questions in this context are: what is quality of the human environment, what are its main characteristics and how do these characteristics relate to welfare and health?[13] In its 1998 report *Leefomgevingsbalans* (The Human Environmental Balance), the RIVM sought to define a single metric for the quality of the human environment that took account of all the relevant characteristics.[61] In response to the report, the Council for Housing, Spatial Planning and Environmental Management (the *VROMRaad*) observed that there was still a long way to go before a useful policy tool could be formed from the obtained information.[62] There is a real need for theory development, especially in relation to the association between the physical and social characteristics of the human environment.[57] An advisory report regarding ways of measuring the quality of the human environment could serve as a catalyst in this regard.

Together with the Utrecht University, the RIVM is studying the relationship between the human environment, in particular local environmental quality, and the socio-economic status of the local population. The intention is to tie in with research projects supported by the EU, with a view to building up an international network of expertise regarding the quality of the human environment.[57] The health implications of socio-economic differences have been the subject of research in the Netherlands for some time, at Erasmus University Rotterdam, among other places.[63] In addition, TNO Inro is compiling a database of quality indicators for the human environment, known as the *Kennisbestand Leefomgevingskwaliteit* (Knowledge Base on the Quality of the Human Environment).[64] The researchers are not confining themselves with this to the physical characteristics of the human environment.

We have included research into the relationship between human environmental characteristics and health and welfare in Table 4, even though an important part of this concerned research that is already in progress. This was done because of the complexity of

the concept of the quality of the human environment and the amount of work that would be necessary to produce results that were of practical value in relation to government policy.

In 2002 the State Secretary for Agriculture, Nature Management and Fisheries (LNV) (partly in the name of the State Secretary for VROM, and the Minister of VWS) asked the Advisory Council for Research on Nature and the Environment (RMNO) to report on research into the relationship between the ecological environment and health, and to identify gaps in knowledge and advice. The RMNO has accordingly been working with the Health Council to produce a survey of what is currently known about this topic. The two councils' report is to form the basis for a research agenda, which we have included under the heading '*Evaluaren gedurende de looptijd van het Actieprogramma'* ('Evaluating during the course of the Action Programme').

The gaps in research and advice are listed in Table 4.

Table 4 Gaps in research and advice on the theme of 'The quality of the human environment'.

	Research	Advice
Risk assessment		
Exposure		
Effects	Research into the relationship between wellbeing and health and determinants of the quality of the human environment (visual quality, built environment and living space, water and nature)	
Risk management		
Policy development		Advice about measures for the quality of the human environment in relation to health
Intervention		
Requiring evaluation during the course of the Action Programme		
		Advice about a research programme on the relationship between nature and health

3.3.3 *Research and advice priorities*

Theme: extent of health effects and level of public concern

It is not presently easy to quantify the degree to which direct health benefits might be achieved by improving the physical environment. Lack of space is creating increasing pressures on the quality of the human environment. Health is an increasingly important issue in the context of spatial planning, even though there is uncertainty regarding the

precise relationships between human environmental characteristics and, therefore, regarding the potential value of a given form of intervention. We accordingly consider it very important that further research is conducted into such relationships. Public concern regarding the deteriorating quality of the human environment manifests itself particularly in the context of major infrastructural initiatives that frequently meet vigorous opposition, as with the Schiphol expansion* and the Betuwelijn**.

Topics: extent of enhanced understanding and short-term feasibility

As indicated above, numerous research projects are already in progress. We recommend waiting for the results of these studies and for the advisory report on the relationship nature and health, then quickly acting to determine the fields in which research should be encouraged.

The appraisals of the various topics are presented in Table 5.

Table 5 Research and advice priorities for the theme 'quality of the human environment'.

	Appraisal[1]			
	Theme		Research, advice	
	Health effects[2]	Public concern[3]	Understanding[4]	Feasibility[5]
Risk assessment				
Research into the relationship between wellbeing and health and determinants of the quality of the human environment (visual quality, built environment and living space, water and nature)	+	-/+	+	+[6]
Risk management				

1: Explanation of symbols: - Not or low, -/+ Medium, + High, ? unknown (as yet)
2: Nature and extent of health effects
3: Degree of public concern about (possible) health effects
4: Contribution of the research or advice topic to the enhancement of understanding of the health risks
5: Short term feasibility of research or advice (complexity, scale, costs)
6: Ongoing research, but implementation in the short term is doubtful

3.4 Chemicals

3.4.1 Description

In 1989 the Ministry of VROM compiled a list of fifty environmentally hazardous so-called priority chemicals.[65] The RIVM produced integrated criteria documents for many

* Construction and putting into operation of a fifth runway.
** A dedicated railway line for freight transport from the Port of Rotterdam to Germany.

of these chemicals. These documents were subsequently assessed by the Health Council.[66] By 2000, sixteen of these chemicals were still regarded as a national problem. The Minister of VROM regarded the problems associated with the other chemicals as manageable.[67]

Only limited knowledge is available about the health significance of most of the tens of thousands of other chemicals present in the environment. However, it is not practicable in the short-term to seek to establish how all these chemicals affect human health. The situation is further complicated by the fact that some chemicals occur naturally, with local or regional concentrations often increased by human activity. Examples include zinc[68], and radon and radon decay products.[69] In recent decades, particular attention has been focused on carcinogenic chemicals, and most recently on chemicals that can influence fertility and development or can be harmful to the nervous system. Hormone disruptors, thus directly interfering with development, have been attracting considerable scientific interest. Exposure to such chemicals can affect fertility, cause congenital abnormalities and trigger the development of hormone-related tumours. In some cases, such effects have been demonstrated in laboratory animals or humans, while in other cases effects are assumed on the basis of the observation of living wild animals.[17,70,71] For adults, the consumption of hormone disruptors in food general involves quantities that are insignificant in relation to normal hormone levels. However, such consumption during development may have a significant effect on hormone levels. There have been increasing questions in recent years about whether such chemicals may harm the immune system, particularly if exposure occurs while that system is being formed.[72]

A 'quick scan' procedure was developed in connection with the Minister of VROM's *Strategienota Omgaan met Stoffen* (Policy Document on Strategy on Management of Substances, known as the SOMS).[73] This is a screening procedure that uses toxicity data to generate profiles for individual chemicals. A chemical can then be placed in one of five categories defined by the government on the basis of its profile, ranging from 'No concern' to 'Very high concern'. The risk posed by chemicals that give cause for concern are then to be carefully assessed. It is important that a chemical's profile indicates not only the toxicity of the chemical in question, but also the degree of exposure. Classification of chemicals on both these axes makes it possible to identify those that are most significant in terms of public health and should therefore be the focus of research. The quick scan will be used for a series of trial assessments of chemicals used in industry. The first of these trials are already underway in various trades. Nevertheless, the trial programme has been running into delays, aside from the objective of SOMS.[74] However, we do not believe that the process could be expedited or, where necessary, set in motion by initiating further scientific research or knowledge synthesis projects.

Various categories of substance and product are covered by regulations that prevent them being marketed until their safety has been assessed. These categories include pesticides,[75] medicines,[76] new chemicals[77] and 'novel' foods.[78] Other categories of substance (for example, radioactive substances) can be used only under licence[79]

3.4.2 Gaps in research and advice

A committee of the Health Council produced an advisory report entitled *Onderzoek gezondheidsrisico's stoffen: een gerichte benadering* (Toxicity testing: a more efficient approach), in which recommendations were made regarding ways of making toxicity research more efficient.[80] The committee presented a decision tree, showing how the results of research into effect mechanisms, such as structure-activity relationships, and exposure profiles can be used to support decision-making regarding further toxicity research. The value of such a strategic approach needs to be tried out with chemicals for which an extensive toxicity dossier is already available. Following refinement as necessary on the basis of feedback from the trials, such an approach could be useful for the assessment of chemicals that quick scans have indicated as giving cause for concern.

The report referred to in the previous paragraph was concerned primarily with the efficiency of the assessment techniques. However, American researchers believe that material progress must wait for new technologies. We are now beginning to see just what may be possible in the future on the strength of advances made in the field of toxicogenomics.[81,82] It seems probable that, in the medium term, the products of this youthful discipline will make it possible to quickly screen chemicals to identify toxic properties, to gain insight into toxic effect mechanisms and to identify individuals and groups who are particularly sensitive to the effects of exposure to particular toxic chemicals.[83] One of the challenges that scientists are currently working to overcome is how to organize, sift and interpret the large volume of basic data generated by research into the properties of chemicals.[84]

Information gained through toxicogenomics could also play a role in the identification of hormone disruptors. Concern regarding the effects of these chemicals and the prevalence of certain of these compounds has led to the development of screening programmes aimed at identifying the hazards.[85] For example, a screening method is being developed with a view to detecting any effect on foetal development caused by the interaction of hormone disrupting chemicals with transcription factors.[86] Fundamental research is required to further develop and validate this screening method. It is thought that dairy products may contain high levels of hormone disruptors.[87] Research into this possibility, and in particular into the relationship between hormone-dependent tumours and the consumption of dairy produce, should be considered.

One of the ways in which a government can protect the public from hazardous levels of exposure to chemicals is by setting exposure limits. Insight into effect mechanisms can enhance the validity of the limits set. It is also advisable to make the best possible use of the available toxicity data. Against this background, the Health Council has recently published an advisory report on use of the so-called benchmark-dose method.[88] In addition, the Council is currently working on a report concerning ways of addressing uncertainty in the derivation of health-based exposure limits.

As understanding of the effects that chemicals have on the human body (especially during development) increases, many scientists have started to ask whether the present procedures for deriving exposure limits provide sufficient protection for children. A committee of the Health Council is currently examining this issue and hopes to present its conclusions towards the end of 2003.

Research into the toxicity of chemicals (and thus the recommendations regarding the streamlining of this research) mainly entails laboratory experiments and the collection of exposure data. The focus on experimental work and exposure data collection is understandable, certainly when concerning new chemicals where the emphasis is always on preventing health effects. However, the health risks associated with chemicals are typically revealed by epidemiological research (as happened with vinyl chloride).[89] At this point, we feel it is appropriate to draw attention to two trends in epidemiological research that deserve support. The first is the use of biomarkers in the emerging discipline of molecular epidemiology,[30] in which epidemiology and toxicology come together. In addition, the scope for research involving large cohorts continues to increase. For example, a cohort of Dutch people formed in 1986 for a study into diet and cancer[90] is now to act as the subject population for research into the consequences of exposure to air pollution and possibly noise (see Sections 3.5, 3.7 and 3.9). Although this research does not relate specifically to chemicals, we felt it should be mentioned in the present context in order to emphasize the importance of molecular epidemiology.

This brings us to the gaps listed in Table 6.

Table 6 Gaps in research and advice on the theme of 'Chemicals'.

	Research	Advice
Risk assessment		
Exposure	Research into the concentration of hormone disruptors in dairy produce	
Effects	Validation of the toxicity testing approach recommended by the Health Council of the Netherlands	
	Research into the interaction mechanisms of hormone disruptors and transcription factors	
	Research into the relationship between hormone-dependent tumours and consumption of dairy produce	
	Stimulating toxicogenomics	
	Explorative study to intensify longitudinal and molecular-epidemiological research	
Risk management		
Policy development		
Intervention		
Requiring evaluation during the course of the Action Programme		
		Advice about the appropriateness of the present standards for chemicals regarding the protection of children

3.4.3 Research and advice priorities

Theme: extent of health effects and level of public concern

For many chemicals, not enough—if anything—is known about the extent of exposure, the levels of exposure that are significant in relation to health, and any associated health effects. Therefore, the amount of health impairment associated with exposure to such chemicals cannot be confidently quantified. Nevertheless, the information that we have to date makes it seem likely that air pollutants contribute significantly to respiratory disease, but only marginally to the incidence of cancer (see also Section 3.7).[11,49].

In an advisory report published in 1997, a committee of the Health Council indicated that there was no evidence that hormone-disrupting chemicals constituted a direct or acute health hazard.[70] However, the committee considered it plausible that such chemicals could affect reproduction and development. The government was accordingly advised to closely monitor the situation. Significant levels of public concern have arisen

because of the nature of the health effects involved and because the chemicals in question are commonplace in the environment.

The need for research and advice in this field is not so much directed towards the assessment of the risks associated with individual chemicals as it is directed at finding improved means for determining and managing risks. This applies in relation to both experimental and 'field' research.

Topics: extent of understanding and short-term feasibility

The promotion of toxicogenomics will deliver no short-term benefit to public health. In the longer term, however, research data generated has the potential to improve understanding and thus support effective intervention. In view of the expertise in this field that already exists within the Netherlands' universities and at TNO, we consider it possible to place the promotion of toxicogenomics at the heart of the present funding programmes.[91,92]

At the same time, and to some extent in association with developments in the field of toxicogenomics, it is important to intensify epidemiological research. Again, such research can initially be expected to provide insight. Much can be achieved in the short-term by tying in with research that is already in progress.

The testing of a strategic approach to toxicity research, as recommended by the Health Council, would not be directly beneficial to public health. However, such testing could provide a basis for organizing toxicity research on efficient lines. One benefit of this would be that fewer laboratory animals were needed. The study is realizable within the short-term.

The proposed research into the interaction of hormone disruptors with transcription factors should make it possible to more effectively screen chemicals for hormone-disturbing effects. The nature of any such research would be largely fundamental and the work would have to be supported through the genomic funding programmes. It is not clear whether the proposed research would yield results that would benefit public health in the short-term.

The relationship between hormone-dependent tumours and dairy product consumption is also a complex research field, so short-term gains are again improbable. It is for these reasons that the research is given a low priority. The research into the concentrations of hormone-disturbing chemicals in dairy products may be regarded as a first step and may also serve to allay public fears. This research is less complex and can be undertaken in the short-term. Both types of study would readily tie in with the European programme of research into hormone disruptors.[93]

Our judgement is reported in Table 7.

Table 7 Research and advice priorities for the theme 'Chemicals'.

	Appraisal[1]			
	Theme		Research, advice	
	Health effects[2]	Public concern[3]	Understanding[4]	Feasibility[5]
Risk assessment				
Research into the concentration of hormone disruptors in dairy produce	-/+	+	-/+	+
Validation of the toxicity testing approach recommended by the Health Council of the Netherlands	-/+	+	-/+	+
Research into the interaction mechanisms of hormone disruptors and transcription factors	-/+	+	+	-/+
Research into the relationship between hormone-dependent tumours and consumption of dairy produce	-/+	+	+	-
Stimulating toxicogenomics	-/+	+	+	+
Explorative study to intensify longitudinal and molecular-epidemiological research	-/+	+	+	+
Risk management				

1: Explanation of symbols: - Not or low, -/+ Medium, + High, ? unknown (as yet)
2: Nature and extent of health effects
3: Degree of public concern about (possible) health effects
4: Contribution of the research or advice topic to the enhancement of understanding of the health risks
5: Short term feasibility of research or advice (complexity, scale, costs)

3.5 Noise

3.5.1 Description

The consequences of exposure to noise in the residential, recreational and working environments have been under investigation for many years in the Netherlands. The Health Council has, with a certain regularity, reviewed the scientific knowledge in this field and reported on the public health implications of exposure to noise in the Netherlands.[11,94] The main focus in the working environment is on noise-induced hearing damage. By contrast, the problems associated with noise in the residential environment are annoyance and sleep disturbance. There is also evidence that exposure to environmental noise contributes to hypertension and thus to cardiovascular disease, as well as having a negative influence on learning performance. The particular influence of noise on children has in recent years been identified as a largely unexplored research field.[95,96]

3.5.2 Gaps in research and advice

An adequate picture of exposure to noise from air, road and rail traffic can be mapped by a combination of measurement and modelling.[12] However, exposure to industrial and neighbours' noise cannot be similarly assessed. The problem with industrial noise is obtaining a complete national picture from the local noise emissions that are subject to very strong local fluctuations. The diversity of neighbours' noise makes modelling impossible. The position is further complicated by the fact that the annoyance associated with neighbours' noise is not directly related to the noise level.

Adequate data is available regarding traffic noise to determine what relationships exist between exposure and annoyance.[97,98] Nevertheless, there will be situations in the field where the actual annoyance is not as the theory would suggest. This is because noise-related annoyance depends not only on the level of exposure, but also on various other factors. These particularly include social and psychosocial factors, such as anxiety and the (lack of) control of an individual over his or her personal environment.[99-101]

There are gaps in scientific knowledge regarding the links between exposure and effect, particularly in relation to sleep disturbance and cardiovascular disease.[11,94] Where sleep disturbance is concerned, adequate data is available regarding the impact of noise from air traffic, but less is known about the role of noise from road and rail traffic. The implications of noise-related sleep disturbance for health and, more generally, for quality of life are not entirely clear. Nor can science really say whether children are more or less sensitive to the consequences of disturbed sleep than adults. There are indications that nocturnal exposure to noise can influence children's cognitive and possibly emotional development.[96] At the end of 2002, the Ministry of VROM asked the RIVM and TNO Inro to look into sleep disturbance in adults caused by noise from road and rail traffic.* In addition, the State Secretary for VROM has recently asked the Health Council for advice regarding the influence of nocturnal noise on sleep, the significance of sleep disturbance for health and the effectiveness of preventive measures.[102] We therefore believe it is wise to await this report and the results of the RIVM and TNO research before identifying topics for further research.

It has already been scientifically demonstrated that high levels of exposure to noise can contribute to the development of cardiovascular disease.[94] However, knowledge is sketchy regarding the height of the effect threshold and the proportion of people experiencing problems. Such knowledge is important for policy purposes, since the highest noise burdens in the domestic environment are around the estimated effect thresholds. Research has recently been initiated both in the Netherlands and other countries to fill in

* DJM Houthuijs, RIVM, Bilthoven, W Passchier-Vermeer, TNO Inro, Delft: personal communication.

some of the identified gaps in knowledge. As part of a project entitled *Road traffic and Aircraft Noise exposure and Children's cognition and Health* (RANCH), funded partly by the EU, field studies are underway in Sweden, the Netherlands, England and Spain to obtain information regarding the relationship between childhood exposure to noise from road and air traffic in the domestic and school environments, and levels of cognitive performance, blood pressure, general health, annoyance and sleep disturbance.[103] RIVM and TNO Nutrition and Food Research are participating in RANCH. The findings are expected to be made available in the middle of 2004. A study of noise-related cardiovascular disease among adults was also started under the auspices of the EU at the end of 2002. The four-year HYENA project (*Hypertension and Exposure to Noise near Airports*) is looking at the effects of noise from road and air traffic on blood pressure in six European countries, including the Netherlands (see also 3.9). RIVM is involved in this project.*

We refer readers to the section devoted to cumulative and combined exposures (Section 3.9) for information about gaps in knowledge regarding the relationship between cardiovascular disease and simultaneous exposure to noise and air pollution.

There is an absence of knowledge about the health implications of compound noise burdens involving exposure to noise from various sources under various circumstances. It is estimated that 8 per cent of the Dutch population is exposed to a considerable level of noise from more than one source.[104] In 1997 a committee of the Health Council outlined a method for determining the degree of annoyance and sleep disturbance experienced as a result of the combination of noise from road, air or rail traffic.[97] This method has been partly adopted by the MIG Programme (MIG is a Dutch acronym that stands for Modernization of Noise Policy Tools)**. However, the proposed approach still needs to be validated by a questionnaire-based survey.

Noise-attenuation measures, such as acoustic insulation in the home and noise screens, are in widespread use today. However, there is evidence to suggest that such measures may not be as effective in reducing noise burden as had been anticipated. Furthermore, it is not clear how effective domestic insulation is in reducing noise-related annoyance. The relationships between annoyance and noise burden are based on noise levels measured where the burden is greatest. Information regarding these relationships is therefore a valid basis for calculation only in the context of the annoyance generally experienced by large groups of residents, within which there will inevitably be significant inter-individual differences in terms of home insulation, bedroom orientation and habits. General relationship information sheds little light on the annoyance experienced by people living in well-insulated homes or with their bedrooms on the least noisy side

* DJM Houthuijs, RIVM, Bilthoven: personal communication.

** The plans for introduction of the MIG have since been considerably changed.[105]

of the building. Particularly at the local level, for town planning purposes, it is important to be able to quantify the effect that noise-attenuation measures have on levels of noise-related nuisance, taking account of particular forms of exposure to noise.

All of these considerations lead to the gaps in knowledge and need for advice listed in Table 8.

Table 8 Gaps in research and advice on the theme of 'Noise'.

	Research	Advice
Risk assessment		
Exposure		
Effects	Research in to the health effects of compound noise exposure in the residential, work and recreational environment	
	Research into further differentiation of the relationships between noise exposure, annoyance and sleep disturbance and the extent of the isolation and the orientation of noise sensitive rooms	
Risk management		
Policy development		Advice about instruments for the assessment of the effectiveness of local noise policies
Intervention	Research into the effectiveness of insulation measures with respect to noise exposure, annoyance and sleep disturbance	
Requiring evaluation during the course of the Action Programme		
	Research into the relationship between road traffic noise exposure and sleep disturbance	
	Research into the relationship between aircraft and road traffic noise exposure and the cognitive performance and health of children	
	Research into the relationship between aircraft and road traffic noise exposure and cardiovascular disease	
		Advice on the significance of noise-induced sleep disturbance for health

3.5.3 *Research and advice priorities*

Theme: extent of health effects and level of public concern

Many people in the Netherlands are exposed to noise levels sufficient to cause annoyance, disrupt sleep and impair health (by, for example, inducing cardiovascular disease). It was estimated in 1998 that 27 per cent of the Dutch population experienced serious annoyance associated with noise from road traffic and 13 per cent were similarly affected by aircraft noise.[12] Some 11 per cent suffered serious sleep disturbance as a result.[7] It is also estimated that between a thousand and ten thousand people in the Netherlands are affected by hypertension attributable partly to exposure to excessive noise burdens, and that between a hundred and a thousand of these people require hospitalisation for ischemic heart disease.[94*] In view of the high levels of health impairment, we regard research and recommendation in this field as a high priority.

Both night and daytime noise-related annoyance are very commonplace. However, people only associate such problems to a limited degree with deteriorating health. We have therefore scored the level of 'Public concern' regarding noise as 'Medium' (-/+).

Numerous questions concerning the exact relationship between noise exposure and health remain unanswered. Various studies have recently been started that should shed light on the most important of these questions. Nevertheless, there is a gap in knowledge regarding risk assessment and, in particular, risk management.

Topics: extent of enhanced understanding and short-term feasibility

A special calculation method has been devised for determining the degree of annoyance associated with a combination of noise sources.[97] This method still needs to be validated by a questionnaire-based survey. Such a survey will be labour-intensive and complex, so it is uncertain whether it will yield results that can be utilized in the short-term.

Research into the effectiveness of noise-attenuating measures has the potential to bring quite significant health benefits. Noise-attenuating measures are expensive, so it is very important to be able to quantify the effects achieved from such an investment. Appropriate research can be organized at the local level and is feasible in the short-term.

The result of our assessment is reported Table 9.

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* The corresponding figures in [7] are one order of magnitude too high (W Passchier-Vermeer, TNO Inro: personal communication).

Table 9 Research and advice priorities for the theme 'Noise'.

	Appraisal[1]			
	Theme		Research, advice	
	Health effects[2]	Public concern[3]	Understanding[4]	Feasibility[5]
Risk assessment				
Research in to the health effects of compound noise exposure in the residential, work and recreational environment	+	-/+	-/+	-/+
Research into further differentiation of the relationships between noise exposure, annoyance and sleep disturbance and the extent of the isolation and the orientation of noise sensitive rooms	+	-/+	+	+
Risk management				
Advice about instruments for the assessment of the effectiveness of local noise policies	+	-/+	+	+
Research into the effectiveness of insulation measures with respect to noise exposure, annoyance and sleep disturbance	+	-/+	+	+

1: Explanation of symbols: - Not or low, -/+ Medium, + High, ? unknown (as yet)
2: Nature and extent of health effects
3: Degree of public concern about (possible) health effects
4: Contribution of the research or advice topic to the enhancement of understanding of the health risks
5: Short term feasibility of research or advice (complexity, scale, costs)

3.6 Non-ionizing electromagnetic radiation

3.6.1 Description

Non-ionizing electromagnetic radiation includes ultraviolet radiation, optical radiation, radio-frequency radiation and extremely low-frequency electromagnetic fields. In recent years, the Health Council has reported on what is known of the health consequences of exposure to all these forms of radiation.[66] Where ultraviolet radiation is concerned, the most pertinent gaps in scientific knowledge involve the influence that such radiation may have on the immune system.[106,107] By contrast, enough is already known about optical radiation to support a protection policy.

The Action Programme places the greatest emphasis on increasing insight into the health effects of radio-frequency (RF) and extremely low-frequency (ELF) electromagnetic radiation and fields. For the general population, exposure to radio-frequency electromagnetic radiation is associated mainly with mobile phones and with radio, television and mobile telephony transmitters. RF technology is being used for an increasing number of applications. Exposure to ELF electromagnetic fields in the domestic environment is associated with the use of electricity (electric appliances and high-voltage lines).[108-112]

3.6.2 Gaps in research and advice

The Health Council has suggested in previous reports that further research should be conducted to establish what implications exposure to ultraviolet radiation has for resistance to infectious disease.[106] In the meantime, there has been publication of the findings of various relevant studies carried out in the Netherlands and elsewhere.[113,114] An evaluation of the available scientific information on this subject is now called for. This likewise applies to the assessment of the results of research into the protection that UV-blocking sun creams afford against cancer and immune system damage.[115,116]

No evidence has been found to suggest that exposure to radio-frequency electromagnetic radiation is linked to genotoxic or carcinogenic effects, or to other syndromes.[109] Nevertheless and in view of the burgeoning of mobile telephony, the Health Council's Electromagnetic Fields Committee feels it is advisable to undertake epidemiological research into the long-term effects of exposure. The Committee recommends alignment with research being carried out in other countries.[117] Numerous international patient-control studies are in progress to determine the relationship between the use of cellular phones and the incidence of brain tumours and other tumours in the head and neck area (INTERPHONE).[118] There are also European programmes investigating the effect of radio-frequency radiation on tissue (*in vitro*) and in laboratory animals (*in vivo*). The Health Council report referred to at the start of this section includes an overview of these studies.[117]

Various studies have found a link between living in the vicinity of high-voltage lines and an increased incidence of childhood leukaemia. This cannot be ascribed to coincidence.[119-121] However, no effect mechanism has yet been detected that might explain this link and the influence of other factors cannot be excluded. Clarification of this phenomenon is necessary, particularly in view of the key role that electricity plays in our society. It will be necessary for this study to build up a better picture of exposure to ELF electromagnetic fields, including those associated with household and workplace electric appliances.

Some people claim to be extra-sensitive to exposure to electromagnetic fields. However, no proper overview is available of symptoms that may be linked to such exposure.[117] TNO FEL has started a study designed to shed light on this matter.*

* Professor APM Zwamborn, TNO FEL, The Hague: personal communication. The initial findings of this study are due to be published at about the same time as this report (Zwamborn APM, Vossen SHJA, van Leersum BJAM, Ouwens MA, Mäkel WN. Effects of Global Communication system radio-frequency fields on Well Being and Coignitive Functions of human beings with and without subjective complaints. Den Haag: TNO Physics and Electronics Laboratory; 9-2003; TNO-report FEL-03-C148).

There is concern in the community at large about the possible health implications of exposure to electromagnetic fields associated with high-voltage lines. We therefore feel that good communication regarding the risks is very important. Research into and advice about the field of risk-related communication are discussed in Section 3.10.

We indicate the gaps in research and advice in Table 10.

Table 10 Gaps in research and advice on the theme of 'Non-ionizing electromagnetic radiation'.

	Research	Advice
Risk assessment		
Exposure	Compilation of data on exposure to ELF electromagnetic fields	
Effects	Research into the long term effects (cancer) of ELF electromagnetic fields	
		Advice about the possible impairment of the immune system and decreased resistance against infections by UV exposure
Risk management		
Policy development		Advice about the labelling of UV-blocking sun creams with respect to protection against skin cancer and immune system impairment
		Advice about risk communication on electromagnetic fields of power lines (see 3.10)
Intervention		
Requiring evaluation during the course of the Action Programme		
	Research into the relationship between the incidence of brain tumours and other tumours in the head and neck region and the use of GSM telephony	
	Research into health complaints that are associated with electromagnetic field exposure	

3.6.3 *Research and recommendation priorities*

Theme: extent of health effects and level of public concern

The research and advice within the theme of non-ionizing electromagnetic radiation relate to ultraviolet (UV) radiation, radio-frequency (RF) radiation and extremely low-frequency (ELF) electromagnetic fields.

It is estimated that exposure to UV radiation in sunlight leads to several hundred skin cancer deaths a year.[106] In view of the popularity of sunny holiday destinations and the use of solariums, we believe that the level of public concern regarding these effects is limited.

The evidence currently available does not suggest that exposure to radio-frequency radiation from mobile phones, and from radio and television and cellular telephony transmitters, has any direct adverse effect on health. However, if it is assumed that the increased incidence of leukaemia in children living near to high-voltage lines is caused by exposure to ELF electromagnetic fields, we estimate that up to one case of childhood leukaemia per year in the Netherlands is attributable to exposure to such fields.[122] There is concern within the community about the possible health effects of living or attending school in the vicinity of high-voltage lines.

Because of this public concern, it is important to investigate the possibility that 'extra-sensitive' individuals may be suffering health problems as a result of exposure to electromagnetic fields. In addition, coordinated communication regarding the risks would be helpful. We address this matter in Section 3.10.

Topics: enhanced understanding and short-term feasibility

The causes of the increased incidence of childhood leukaemia in the vicinity of high-voltage lines need long-term investigation in an international context because the background incidence of the disease is quite low. Hence, the work required to clarify the findings obtained to date is relatively complex and not likely to yield results in the short-term.

Information about patterns of exposure to ELF electromagnetic fields associated with sources inside and outside the home can increase understanding of the health implications of exposure, thus helping to allay public concern. Such research can be conducted on a local scale and should provide results in the relatively short-term.

Table 11 shows the research and recommendation priorities of the identified gaps.

Table 11 Research and advice priorities for the theme 'Non-ionizing radiation'.

	Appraisal[1]			
	Theme		Research, advice	
	Health effects[2]	Public concern[3]	Understanding[4]	Feasibility[5]
Risk assessment				
Compilation of data on exposure to ELF electromagnetic fields	-/+	+	+	-/+
Research into the long term effects (cancer) of ELF electromagnetic fields	-/+	+	+	-
Advice about the possible impairment of the immune system and decreased resistance against infections by UV exposure	+	-	+	+
Risk management				
Advice about the labelling of UV-blocking sun creams with respect to protection against skin cancer and immune system impairment	+	-	+	+

1: Explanation of symbols: - Not or low, -/+ Medium, + High, ? unknown (as yet)
2: Nature and extent of health effects
3: Degree of public concern about (possible) health effects
4: Contribution of the research or advice topic to the enhancement of understanding of the health risks
5: Short term feasibility of research or advice (complexity, scale, costs)

3.7 Outdoor air

3.7.1 Description

The Health Council has repeatedly reported on the health implications of outdoor air pollution (including odour), most recently in 1999.[11] The Council has concluded in this context that there is sufficient evidence that both air pollution episodes and chronic exposure to atmospheric pollutants (including ozone, nitrogen oxides and fine particulates) can cause premature death and the aggravation of respiratory conditions. It is less clear, however, whether respiratory illness in children is to any significant extent attributable to outdoor air pollution.[123,124] One of the main sources of air pollution, and therefore of pollution-related health problems, is vehicular traffic.[58,124-127] Along with this, other important sources include power plants, industrial processes and agriculture. It is possible to obtain a good picture of the outdoor air quality by means of field measurements and modelling.[128]

Air pollution is the subject of much epidemiological, experimental and technological research around the world.[129] The main focuses are the sources of air pollution and the nature and extent of the exposure. In addition, researchers are looking into the factors that determine levels of exposure and therefore the implications for health, including the relationship between outdoor air pollution and air pollution indoors.

Odour is a characteristic of chemicals that are inhaled. Some odours are perceived to be unpleasant and therefore a nuisance. In the Netherlands, 10 to 20 per cent of the population suffers serious odour-related annoyance. The main odour sources are road and air traffic, industrial processes, incinerators and the sewer system.[11,130]

3.7.2 *Gaps in research and advice*

We consider it important to more precisely quantify the levels of premature mortality, particularly as associated with chronic exposure to air pollution.

Traffic-related air pollution is a complex mixture of substances. It is not yet clear which of these substances are responsible for the observed health effects. More information on this subject is important for the selection of appropriate risk-reduction measures. However, scientific knowledge is also lacking regarding the scope for risk reduction and, in particular, regarding the relative effectiveness of national, regional and local action. Examples of possible risk-reduction measures include traffic management, speed limits and infrastructural measures. Knowledge synthesis, including a review of the findings of earlier studies, will be required once more research has been conducted in this field,

Although standardized methods for determining odour concentrations[131] and odour-related annoyance[132] are now available or under development, it is difficult to directly link odour levels with annoyance, and even more so with other health effects[133]. We consider it desirable that an advisory report be prepared as a basis for targeted research.*

The gaps in knowledge are listed in Table 12.

3.7.3 *Research and recommendation priorities for the theme of 'Exterior atmosphere'*

Theme: extent of health effects and level of public concern

Almost the entire population is exposed to concentrations of air pollution that epidemiological research suggests may be capable of influencing health. However, it cannot be said that there is serious public concern regarding this issue in the population at large, except where exceptional smog episodes are concerned. Nevertheless, local communities can become animated on subjects such as the placement of schools close to busy motorways. Calculations indicate that traffic-related air pollution is responsible for quite a lot of health damage. It is possible that there are several thousand deaths per year that can be ascribed to traffic-related air pollution.

* The Health Council has proposed including this topic in its work programme for 2004.

Table 12 Gaps in research and advice on the theme of 'Outdoor air'.

	Research	Advice
Risk assessment		
Exposure		
Effects	Research into substances generated by traffic emissions that are primarily responsible for health effects	
	Research into the quantitative assessment of premature mortality	
		Advice about substances generated by traffic emissions that are primarily responsible for health effects (review and appraisal of recent research data and earlier assessments)
		Advice about the quantitative assessment of premature mortality (review and appraisal of recent research data and earlier assessments)
		Advice about the scientific basis for an odour policy
Risk management		
Policy development		
Intervention	Research into the effectiveness of interventions	
		Advice about the effectiveness of interventions (review and appraisal of recent research data and earlier assessments)

Odour is often a trigger for public disquiet regarding health problems associated with environmental factors.[134] In view of the extent of odour-related annoyance in the Netherlands, it is therefore reasonable to suggest that a relevant problem exists. The relationship between odour and other health problems is unclear.

Topics: enhanced understanding and short-term feasibility

A more precise quantification of premature mortality would increase insight into the extent of the adverse impact on health, but would not provide any direct health benefit. Such quantification would require large-scale research. Further research to identify the substances responsible for the observed health effects would provide a basis for more effective intervention. Both epidemiological and experimental research would be required for this, and it is not easy to predict how long it would be before useful findings

were made. It is worth noting that research is already in progress, both in the Netherlands and abroad, with which any new initiative could easily tie in.[129,135-138] Utrecht University is particularly active in these fields in the Netherlands.[58,124,137] On behalf of the Ministry of VROM, RIVM is investigating whether the analysis of the composition of daily air samples makes is possible to determine the contributions made by different sources (e.g. traffic and industrial processes) to the overall level of pollution. The next step will be to investigate the relationship between the various source contributions and daily mortality. The initial results of this research are expected in 2003.

The need for an advisory report on these topics depends on the results of the research presently in progress and therefore cannot yet be arranged.

The effectiveness of assessment measures could be adequately studied in the context of smaller-scale projects. Such research could be undertaken in the short-term and could, in principle, yield considerable health benefits.

The problem of odour-related nuisance is mainly one that concerns local authorities.[139] An advisory report on the social problem of odour would be feasible in the short-term and could serve to promote a sustainable strategy for addressing this problem.

Our conclusions are presented in Table 13.

Table 13 Research and advice priorities for the theme 'Outdoor air'.

	Appraisal[1]			
	Theme		Research, advice	
	Health effects[2]	Public concern[3]	Understanding[4]	Feasibility[5]
Risk assessment				
Research into substances generated by traffic emissions that are primarily responsible for health effects	+	-/+	+	-/+
Research into the quantitative assessment of premature mortality	+	-/+	-/+	-/+
Advice about the quantitative assessment of premature mortality (review and appraisal of recent research data and earlier assessments)	+	-/+	?	?
Advice about the scientific basis for an odour policy	-/+	-	?	?
Risk management				
Research into the effectiveness of interventions	+	-/+	+	+
Advice about the effectiveness of interventions (review and appraisal of recent research data and earlier assessments)	+	-/+	?	?

1: Explanation of symbols: - Not or low, -/+ Medium, + High, ? unknown (as yet)
2: Nature and extent of health effects
3: Degree of public concern about (possible) health effects
4: Contribution of the research or advice topic to the enhancement of understanding of the health risks
5: Short term feasibility of research or advice (complexity, scale, costs)

3.8 Indoor climate

3.8.1 Description

The quality of the environment inside homes and office buildings has previously been described in considerable detail.[140] Generally speaking, the quality of the air in the home is lower than that of the exterior atmosphere. This is because of limited ventilation combined with the presence of numerous pollution sources in the average home.[124] Domestic sources of pollution include building materials, soft furnishings and furniture, cooking, and oxygen use and carbon dioxide production by the occupants. It is by no means unusual for homes to contain very high concentrations of nitrogen oxides, carbon monoxide, volatile organic compounds, fine particulates, and biological agents or radon, especially in poorly ventilated areas. It is not known which factors, or mainly combinations of factors, lead to increased levels of exposure. Associations have been demonstrated at the population level between a poor indoor climate and effects such as odour-related annoyance, headaches, respiratory problems, impaired lung function and aggravation of asthma and COPD (chronic bronchitis and pulmonary emphysema), lung cancer and mortality (see, among others, [141]).

The health implications of electromagnetic radiation and fields within the home are dealt with in Section 3.6.

3.8.2 Gaps in research and advice

The exposure situation is reasonably well understood and the problem areas are sufficiently well known. Furthermore, there is adequate knowledge regarding the health effects of most agents found in the indoor environment.[140] Nevertheless, a poor indoor climate remains an important cause of environment-related health impairment.[49] It is therefore desirable to take stock, to establish what else is required in order to bring the risks under control and to develop a strategic vision of the action to be taken. This may include the following.

It is desirable to have a set of health-based reference exposure limits for the indoor environment with a view to determining which interior environmental problems should be tackled first and how new policy-related developments, such as increasingly airtight homes, should be assessed. At present, no such reference set is available. Nor can exposure limits be easily calculated from the data that is available, since there is no definitive framework for health-based assessment of the indoor environment. It will only be possible to identify groups of ‘problem homes’ or ‘problem buildings’, or to establish what additional knowledge is required in order to adequately manage indoor environmental

problems, once field data has been assessed on the basis of such reference concentrations.

One issue that is likely to be of relevance in this context include how the exposure to combinations of volatile organic compounds[142] or to compounds from different sources should be assessed. Another issue is whether research and policy should focus on high levels of exposure occurring in small numbers of homes, on levels of exposure just below the recommended limits occurring in larger numbers of homes, or on (modest) deviations from average concentrations. How can such average concentrations be determined in a statistically valid way? Furthermore, it is pertinent to ask whether the quality of the immediate surroundings of the home (amount of greenery, spatial quality) should be included in any health-based assessment of the indoor environment. A good problem definition is therefore vital. The prevention or management of indoor environmental problems also raises questions regarding the role and capabilities of the various tiers of government, other agencies and residents.

Once these questions have been answered, a strategic vision (incorporating the assessment framework referred to above) can be developed as a basis for determining health-based reference exposure limits for the indoor environment. This vision should also cover the roles of the various agencies and parties in the prevention or management of indoor environment problems. Finally, it is possible to identify the fields in which gaps in knowledge still exist.

The quality of the indoor climate in schools often leaves something to be desired. It is known that impaired cognitive function can be associated with noise exposure and with the combination of crowded classrooms and poor ventilation. As part of the RANCH project (see above, Section 3.5.2), field studies are underway in the Netherlands and elsewhere to shed light on the relationship between noise exposure at school and cognitive function in children.[103] Because of its ongoing status, this research is not included in the list of priorities presented below.

Another study is in progress in the province of Limburg, with the aim of clarifying how pupils' learning performance is affected by carbon dioxide level, relative humidity and temperature in the classroom. The study is to involve validation for year 6 and the use of specially adapted IQ tests that test working memory.[143] We favour waiting for the definitive results of the two studies referred to above before indicating whether further research is required and, if so, what direction that research should take.

The identified gaps are listed in Table 14.

Table 14 Gaps in research and advice on the theme of 'Indoor climate'.

	Research	Advice
Risk assessment		
Exposure		
Effects		
Risk management		
Policy development		Advice about a strategy for the assessment and management of problems with indoor climate
Intervention		
Requiring evaluation during the course of the Action Programme		
	Research into the relationship between the indoor environmental quality of schools and cognitive performance of children	

3.8.3 *Research and advice priorities for the theme 'Indoor climate'*

Theme: extent of health effects and level of public concern

The average Dutch person spends around 70 to 80 per cent of his or her time at home.[144] The extent of the health impairment associated with poor interior environmental conditions is quite high. For example, the respiratory problems of hundreds of thousands of people who are susceptible to asthma are aggravated by living in damp homes.[145] In addition, it is estimated that between 100 and 1,200 people a year die as a result of exposure to radon.[146] It is not believed that the present levels of exposure to volatile organic compounds have generally detrimental effects on health.[140] We estimate the level of public concern to be slight.

Topics: enhanced understanding and short-term feasibility

Indoor environment problems are not confined to older damp homes, but also occur in new and very airtight buildings. In order to obtain health benefits, it is important to direct research of the indoor environment to the types of homes or buildings in which the greatest problems occur. It is vital to develop a strategic vision for this that includes a good definition of the problem categories of homes. This strategic vision can be developed in the short-term.

This brings us to the review in Table 15.

Table 15 Research and advice priorities for the theme 'Indoor climate'.

	Appraisal[1]			
	Theme		Research, advice	
	Health effects[2]	Public concern[3]	Understanding[4]	Feasibility[5]
Risk assessment				
Risk management				
Advice about a strategy for the assessment and management of problems with indoor climate	+	-	+	+

1: Explanation of symbols: - Not or low, -/+ Medium, + High, ? unknown (as yet)
2: Nature and extent of health effects
3: Degree of public concern about (possible) health effects
4: Contribution of the research or advice topic to the enhancement of understanding of the health risks
5: Short term feasibility of research or advice (complexity, scale, costs)

3.9 Cumulative and combined exposures

3.9.1 Description

Concurrent exposure to various environmental factors is the norm, rather than an exception. For example, traffic-related air pollution involves a complex of atmospheric pollutants and exposure to high levels of traffic noise will typically also be accompanied by exposure to traffic-related air pollution.[147] 'Cumulative and combined exposures' may entail simultaneous or consecutive exposure to several factors (as can happen if someone is exposed to solvents both at work and in the hobby room at home). The indoor environment almost always involves exposure to airborne pollutants, ionizing and non-ionizing radiation and biological agents.

We have confined ourselves in our consideration of this theme to concurrent exposure to agents. We refer to Section 3.3 for information regarding the interaction between physical and social environmental factors.

3.9.2 Gaps in research and advice

In most cases, it is not known whether and, if so, how the health effects of compound exposure differ from the sum of the effects of exposure to the individual factors. A recent Health Council report outlined a methodological framework for assessing the toxicity of a given combination of chemicals.[148,149] This method still requires further development and testing in real-life exposure situations. There is a particularly pressing need for greater toxicological insight into the effects of the cocktail of air pollutants associ-

ated with traffic emissions.[150] It appears to us that it would be useful to first test the method on this cocktail.

Researchers at the *Agency for Toxic Substances and Disease Registry* (ATSDR) and TNO Nutrition and Food Research have developed the *Weight of Evidence Method* for the detailed assessment of combination exposure to chemicals.[151] This method has been incorporated into the US Environmental Protection Agency's guidelines for the assessment of chemicals.[152] The approach quantifies the extent to which the effects of a mixture of agents differ from the accumulated effects of the individual agents. We believe that experience with this method should also be acquired in the Netherlands. For example, it could be used to assess the 'top ten' chemicals found in the indoor and outdoor atmosphere. In addition, it would be useful to conduct trials to establish whether the method can also be employed for the assessment of exposure to different environmental factors. This would be done in order to shed light on the significance of combined effects.

Both raised concentrations of traffic-related air pollution and high traffic noise burdens are known to lead to cardiovascular disease. However, it is not known what effect each factor has on its own and to what extent interactions between the two factors play a role. Air pollution is also recorded in the HYENA project, which is primarily concerned with the effects of noise (see Section 3.5).[153] The object of this project is to study the effect of noise on blood pressure and thus on cardiovascular disease, and to establish how this relationship is influenced by simultaneous exposure to air pollution.

The results of a pilot cohort study into the relationship between traffic-related air pollution and mortality as a consequence of cardiovascular disease, among other causes, have recently been published.[58] The Ministry of VROM has asked TNO Inro to examine the feasibility of including noise exposure in this research.*

There are people that are particularly sensitive to individual components of air pollutants, noises or odours. However, the connection to personal characteristics is not yet clear. It is also not clear whether there is such a thing as 'group sensitivity'. This would involve people who show, for example, heightened sensitivity to both noise and odour.[99,154]

The assessment of the concurrence of different forms of environmental influence is very important in the context of planning of the urban residential environment. In this context, collective metrics of the seriousness and extent of the health effects associated with several concurrent environmental factors would be very useful.[155] The availability of such metrics would make it possible to compare different planning options or to place various environmental problems in order of priority. There is a need for this at the national, regional and local level. It is worth noting that an assessment method would be

* Dr HME Miedema, TNO Inro, personal communication.

even more valuable if it were able to take account of the interaction between physical environmental factors and socio-economic factors (see Section 3.3). It should be noted that it is often the case that deprived areas are not only affected by high levels of exposure to individual environmental factors, but also by the concurrence of factors.[156,157] Issues of environmental equity and environmental justice have been particularly interesting to researchers and administrators in the USA. However, little is known in the Netherlands about the relationship between cumulative and combined exposures to environmental and socio-economic influences. We therefore feel that exploratory research is in order.

Various aggregated metrics of health effect have been developed that seek, for example, to calculate overall health impairment or express it in monetary terms. One unit of measurement used at the national level is the disability-adjusted life year (DALY; see also Section 2.3).[49] However, little use has been made of this measure at the local or regional levels. As indicated earlier (see Sections 1.2 and 2.3), the Health Council is to report on the use of this approach in the near future. The report in question should be available to support the development of policy and further research proposals within the period covered by the Action Programme.

The gaps that we have identified are indicated in Table 16.

3.9.3 Research and advice priorities for the theme of 'Cumulative and combined exposures'.

Theme: extent of health effects and level of public concern

As indicated above, cumulative and combined exposure is the norm, not the exception. Yet the extent to which such exposure equates to greater health impairment is unclear. The universal nature of the exposure makes clarification highly desirable. The aggregation of perceived or real environmental health problems is liable to lead to public anxiety. We have accordingly graded the 'Health effects' of cumulative and combined exposures as 'Uncertain' (?) and the level of public concern regarding this topic as 'Medium' (-/+).

Topics: enhanced understanding and short-term feasibility

The testing of a methodological framework for determining the toxicity of any given combination of chemicals would contribute to understanding of the health effects of this type of compound exposure. If it were possible to test the framework by looking at the cocktail of pollutants in traffic-related emissions, this would then support efforts to learn more about the chemicals primarily responsible for the health effects of such emissions, as referred to in Section 3.7 on the 'Outdoor air' theme.

Table 16 Gaps in research and advice on the theme of 'Cumulative and combined exposures'.

	Research	Advice
Risk assessment		
Exposure		
Effects	Validation of the methodological framework for the risk assessment of mixtures that was recommended by the Health Council	
	Research into the individual susceptibility for various substances and other environmental factors	
	Research into cardiovascular disease caused by cumulative and combined exposure to traffic related air pollution and noise	
	Exploratory research into the phenomenon of 'group sensitivity' for cumulative and combined environmental exposures	
	Exploratory research into the relationship between cumulative and combined exposures and social-economic conditions	
Risk management		
Policy development	Research in the further development of metrics for health impairment and applying such metrics for setting policy priorities on a local and regional scale	
		Advice about the further development of the *Weight of Evidence*-method for setting priorities for combinations of substances
Intervention		
Requiring evaluation during the course of the Action Programme		
		Advice about the usefulness, applications and limitations of DALYs and similar metrics for policy evaluation

Greater insight into the occurrence of 'group sensitivity' to different environmental factors can support more effective and efficient protection policy. However, any research conducted in this field would necessarily be exploratory and it is therefore hard to predict what its outcome might be. A preliminary re-analysis of the published data would provide pointers as to how research might be progressed in this area.

Research into the link between concurrent exposure to a variety of environmental factors and socio-economic status would certainly provide points of attention for policy initiatives. Such research would be feasible in the short-term, partly due to the advanced geographic information systems now readily available. However, interpretation of the

data would not be easy, considering the expectation that the interrelationships will be complex (see Section 2.1).

This brings us to the priorities provided in Table 17.

Table 17 Research and advice priorities for the theme 'Cumulative and combined exposures'.

	Appraisal[1]			
	Theme		Research, advice	
	Health effects[2]	Public concern[3]	Understanding[4]	Feasibility[5]
Risk assessment				
Validation of the methodological framework for the risk assessment of mixtures that was recommended by the Health Council	?	-/+	+	+
Research into the individual susceptibility for various substances and other environmental factors	?	-/+	+	-/+
Research into cardiovascular disease caused by cumulative and combined exposure to traffic related air pollution and noise	?	-/+	+	+
Exploratory research into the phenomenon of 'group sensitivity' for cumulative and combined environmental exposures	?	-/+	+	+
Exploratory research into the relationship between cumulative and combined exposures and social-economic conditions	?	-/+	+	-/+
Risk management				
Research in the further development of metrics for health impairment and applying such metrics for setting policy priorities on a local and regional scale	?	-/+	+	+
Advice about the further development of the *Weight of Evidence*-method for setting priorities for combinations of substances	?	-/+	+	+

1: Explanation of symbols: - Not or low, -/+ Medium, + High, ? unknown (as yet)
2: Nature and extent of health effects
3: Degree of public concern about (possible) health effects
4: Contribution of the research or advice topic to the enhancement of understanding of the health risks
5: Short term feasibility of research or advice (complexity, scale, costs)

3.10 Risk perception and communication

3.10.1 Description

Experts tend to focus primarily on quantitative data when assessing risks. By comparison, the general public is much more likely to be swayed by qualitative considerations, such as the uncontrollable nature of pollution, uncertainty as to whether a health effect will actually occur and the degree of trust in the agencies responsible for health protection.[17,158] In addition, personal and collective perceptions of (emotional responses to) the risk-generating activities and the parties undertaking those activities also play a role.[159] The Health Council has previously pointed out that the government cannot concern itself exclusively with quantitative-scientifically determined risk, but that account must also be taken of risk perceptions and assessments of the stakeholders.[24] Early communication regarding the risks is very important in the context of local environment problems. Good risk communication can increase the likelihood of stakeholders reaching rational and informed conclusions.[160]

The risk communication referred to in the previous paragraph concerns that between the government and the individual citizen. Of course, many of the issues are also relevant in the context of communication between private parties. We would also emphasize that communication is a two-way process and does not therefore equate to the provision of information. Problems mainly arise due to the provision of risk information under the disguise of communication.[160,161]

3.10.2 Gaps in research and advice.

The importance of good risk communication is widely recognized, but the governments tend to have relatively little expertise in this field, often due to capacity problems. Furthermore, knowledge about the factors that determine the risk perceptions of different stakeholder groups is mostly missing. Another problem is that not enough use is made of methods developed in the field (suggesting the existence of dissemination problems). In addition, the effectiveness of most risk communication methods has not been properly evaluated.[162] In order to fill these gaps, we are thinking of studies conducted in the field and in more controlled situations (e.g. a behavioural laboratory), where risk communication strategies can be varied and the effects on variables such as public concern and risk perception can be assessed. Such studies would increase scientific understanding of risk perception and would contribute to good risk communication. A number of guidelines for communication regarding particular problem situations have recently been published, but the practical value of such documents has yet to be demonstrated.[24]

We consider the preparation of a report on the application of knowledge regarding the process and content of risk communication to be desirable.

The identified gaps are listed in Table 18.

Table 18 Gaps in research and advice on the theme of 'Risk perception and communication'.

	Research	Advice
Risk assessment		
Exposure		
Effects		
Risk management		
Policy development		Advice about the effectiveness of risk communication methods
		Advice about the implementation of risk communication knowledge
Intervention	Research into the effectiveness of risk communication methods	

3.10.3 Research and advice priorities on the theme of 'Risk perception and communication'

Theme: extent of health effects and level of public concern

Appropriately bilateral interactive risk communication could help to establish risk perceptions that are shared by the government and the general public, and thus help to diminish health problems and public anxiety regarding them.[24,160] As indicated above (subsection 2.1), public concern regarding environmental risks is not inherently undesirable. It can focus attention on genuine threats to health that would otherwise be underestimated or focus attention on other difficulties in the interaction between the government and the public.[38]

Topics: enhanced understanding and short-term feasibility

The main priorities are to increase understanding of risk perceptions and the effectiveness of risk communication methods, and to widely disseminate the obtained knowledge. A report dealing with the application of such knowledge and with the expansion of expertise within government is also regarded as a priority.

This led to the priorities in Table 19.

Table 19 Research and advice priorities for the theme 'Risk perception and communication'.

	Appraisal[1]			
	Theme		Research, advice	
	Health effects[2]	Public concern[3]	Understanding[4]	Feasibility[5]
Risk assessment				
Risk management				
Research into the effectiveness of risk communication methods	-/+	+	+	+
Advice about the effectiveness of risk communication methods	-/+	+	-/+	+
Advice about the implementation of risk communication knowledge	-/+	+	-/+	+

1: Explanation of symbols: - Not or low, -/+ Medium, + High, ? unknown (as yet)
2: Nature and extent of health effects
3: Degree of public concern about (possible) health effects
4: Contribution of the research or advice topic to the enhancement of understanding of the health risks
5: Short term feasibility of research or advice (complexity, scale, costs)

3.11 Monitoring

We refer to the recent Health Council report on the subject for advice regarding further research and advice on monitoring.[163] The report sets out the Council's views on the aims, applications, and conditions for monitoring. It also contains a comprehensive survey of indicators and monitoring programmes. Recommendations are made regarding the modification of existing health registration systems, the linking of such systems to exposure data and the establishment of new monitoring programmes. Adoption of the report's recommendations could lead to the initiation of further research (Table 20).

Table 20 Gaps in research and advice on the theme of 'Monitoring'.

Research	Advice
Risk assessment	
Exposure	
Effects	
Risk management	
Policy development	
Intervention	
Requiring evaluation during the course of the Action Programme	
	Health Council advisory report 'Health and the environment: monitoring

3.12 A few remaining themes

No mention has yet been made of various themes that are likewise important to a coherent policy on environment and health. The reason for this is that the main body of this chapter is devoted to the themes identified in the Action Programme. A few of these additional themes are briefly considered below. However, we have not attempted to indicate the relative importance of each topic.

3.12.1 External safety

The management of accidents involving chemical processing plants or the use of LPG as a fuel has always been an integral element of the Netherlands' policy on environmental risks. Technological analyses of business processes can provide insight into the nature and extent of the accident potential, as well as the likelihood of accidents. Important milestones in this field have included Rasmussen's study of safety at nuclear reactors[164] in the USA, the British Canvey Island research[165] and the Dutch COVO study[166] of safety at chemical processing plants in the Rijnmond area. Taken together, these studies provided the basis on which government has defined the requirements that regulate the external safety risks associated with 'fixed installations'.[167,168] The studies also showed that the perceptions of people exposed to risks of the kind in question are not necessarily consistent with the actual likelihood of accidents and their potential extent.[169,170] The situation is complicated by the fact that perceptions of external safety risks can influence health and can aggravate health problems by means of poorly understood mechanisms (see 2.1 and, for example, [99]).

It is particularly important in the area of external safety to obtain greater insight into mechanisms so that risks can be managed over the longer term and the necessary knowledge can be acquired to arrive at decisions that can command general support with regard to the regulation of activities associated with very low risks of extremely serious accidents.[11,39,40,169,171-174] Accidents such as the explosion at the Enschede firework factory[175] and the debate concerning the transportation of chlorine from Delfzijl to the Rijnmond area by rail[176] have pushed external safety back towards the top of the political agenda. RIVM has now set up a special centre for external and firework safety, with the purpose of acquiring knowledge and translating it into policy recommendations.[177]

3.12.2 Biotechnology

The flow of developments in biotechnology has been extremely rapid in recent years. New applications that are being developed in fields such as medicines, diagnostic meth-

ods and food production are seen as bringing important social benefits. Recent developments affecting the Netherlands and the government's role in these developments are described in the *Beleidsnota Biotechnologie* (Biotechnology Policy Document), the report on the *Eten en Genen* (Food and Genes) debate, and the government's response to that debate.[178-180] Discussions regarding the relationship between environment and health centre mainly on the interference with ecosystems and the loss of biodiversity (with the consequences for humans in their wake), and on the side-effects of foodstuffs produced by modern biotechnological methods or containing genetically modified material. The publications referred to above consider these issues and highlight the need for both fundamental research and research into further reinforcement of the safety assessment system by, for example, the introduction of post-marketing monitoring.[181]

For the rest, there is in this context, as in connection with various other themes, a need to address questions regarding the openness of the decision-making processes. This is particularly so regarding the way that the interests of different stakeholders are weighed up and the way that stakeholders, including ordinary citizens in their capacity as consumers and patients, can participate in decision-making. Risk communication (see Section 3.10) has a prominent role to play in relation to these processes.

3.12.3 Nuclear, biological and chemical terrorism

The vulnerability of our society to terrorism has become all too clear in recent years. Extremely violent terrorist attacks can occur anywhere; the trend towards globalisation is evident. The 11 September 2001 attack on the Twin Towers of the World Trade Centre in New York using civil aircraft carrying passengers and fuel has triggered a particularly strong international reaction. As part of its response, the Dutch government presented an action plan designed to counter the 'new' terrorist threat.[182,183] Environmental factors could be used by terrorists to threaten public health in three ways:

- By the dispersal of microbial pathogens (such as anthrax or smallpox virus)
- By the dispersal of toxic chemicals (such as the nerve gas sarin)
- By the dispersal of radioactive materials (the use of a 'dirty nuclear bomb').

Generally speaking, the effects and effect mechanisms associated with the materials that terrorists might use are well known. What is therefore required is to use existing contingency plans (such as the municipal emergency plans, the *Nationaal Plan Kernongevallenbestrijding* [National Nuclear Accident Response Plan] and the infectious disease response guidelines) as a basis for the definition of appropriate risk management measures. This point was emphasized by the Health Council in its recent reports on measures against the bioterrorist threat.[184,185] Modification of the relevant plans is nearly complete.[183]

However, none of this implies that no further research is required. More research is needed in the area of exposure modalities and in areas involving detection and control methods. Furthermore, the need for research in these fields is ongoing, since it must be assumed that the methods potentially open to terrorists, including the environmental dispersal of hazardous agents, are constantly liable to change.

3.12.4 *Water and soil*

Water and soil can contain 'foreign' chemicals capable of adversely affecting health. Alternatively, the concentrations of naturally occurring chemicals can sometimes be raised to undesirable levels in these environmental compartments. Drinking and bathing water can additionally be contaminated with micro-organisms. The main risks to health involve the consumption of contaminated water or produce grown on contaminated soil. Other more incidental exposure routes include the ingestion of soil (usually by children), the inhalation of volatile soil pollutants, the consumption of food that has been in contact with contaminated drinking water, and washing in contaminated mains water. An indirect health hazard may be said to exist where ecological interference results in the compromised functionality of water or soil for human applications. This can occur if the fertility of the soil is diminished, or if surface or ground water is rendered less suitable for drinking water production. An overview of the situation in the Netherlands is given in documents published by TNO Prevention & Health and RIVM.[7,12] These reports also contain information about government policy in this field.

The gaps in knowledge chiefly relate to the extent of the adverse health effects and the identity of the main population groups affected. Where soil pollution is concerned, there is a particular need to look at the reliability of the models used to calculate exposure and at the intervention standards linked to exposure levels.[186] The Technical Committee on Soil Protection (TCB) has now completed its report on the RIVM's recent proposals.[187] Meanwhile, the Health Council is preparing an advisory report that is scheduled for publication later this year (2003). Apart from that, other countries are also working on the acquisition and assessment of knowledge regarding the consequences of soil pollution. It will suffice to refer to the *Agency for Toxic Substances and Disease Registry* (ATSDR) in the USA (an organization linked to the *Centre for Disease Control*). This agency is active in the study of soil-pollution related risks and the supervision of intervention measures. Another topic currently receiving attention is the psychosocial aspects of living in a polluted area and the associated health problems that this can cause.[188-190]

Issues concerning the nature and extent of the associated health risks are also pertinent in the regulatory context of water pollution. The Health Council recently evaluated

knowledge regarding the microbial risks associated with swimming in surface waters.[191] A report on Legionella was also published a short while ago.[192]

3.12.5 *Ionizing radiation*

The phenomenon of ionizing radiation was discovered around 1900. A wide variety of applications were soon found for both X-rays and radioactive substances, particularly in the medical profession. However, it did not take people very long to realize that ionizing radiation was also a potential health hazard. The first radiological protection guidelines were published in the Netherlands and elsewhere in about 1920. A brief outline of the way the regulation of this field developed is given in a report published in 1991 by the Health Council.[193] The development of the atomic bomb in the Second World War subsequently led to a substantial increase in the number of applications of radiation sources. The most important new application to emerge was the use of nuclear energy for electricity generation. Medical applications also grew sharply in number, and continue to do so today. Radiation sources are also used in a wide variety of measurement instruments and various forms of research.

In 2000 a committee of the United Nations issued the most recent of its periodic reports on what is known about exposure to radiation and its effects.[194] The situation in the Netherlands was described in a report compiled in 2001 by TNO Prevention & Health to support development of the environment and health policy document.[7]

There is continued interest in research into the effects of radiation and the improvement of protection measures, partly because of public attitudes to the possibility of exposure to radiation. In the Netherlands, however, the amount of research conducted into the effects of ionizing radiation has declined sharply over the last couple of decades, perhaps because plans for the expansion of the country's nuclear generating capacity have been abandoned or at least put on the back burner for the time being.

The Health Council is currently preparing a new survey of the health risks associated with exposure to ionizing radiation. This is likely to appear in 2004.

3.12.6 *Climate change*

The large-scale consumption of raw materials is leading to discernible degradation of the biosphere on a global scale. This has serious implications for the planet that sustains human society. Scientific research suggests that irreversible climate changes are taking place.[195] In view of the repercussions of climate change for the three main aspects of the society (the ecology, the economy and society), such change inevitably has consequences for health. The direct consequences include increased mortality resulting from

higher temperatures and heightened risk of diseases communicated by insects or water organisms.[196] The findings also apply to the Netherlands.[197,198]

It is generally accepted within the scientific community that global change is one of the greatest threats to, and challenges facing, humanity. Enormous communal effort is required merely to mitigate such change.[195] Effective and efficient action therefore depends upon political will and cooperation on an international scale, as well as on the performance of appropriate research. Both the physical systems themselves and their interactions with social and economic systems are, for that matter, so complex that it is only the most general predictions, cursed with greater uncertainties, that can be made. In the Netherlands, KNMI, RIVM and Utrecht University's *Institute for Marine and Atmospheric Research Utrecht* (IMAU) have together established the *Centrum voor Klimaatonderzoek* (Centre for Climate Research), which coordinates Dutch research into climate change.

3.12.7 *Food safety*

The consumption of nutritional substances is a basic precondition for good health. However, there are numerous points at which pollutants may enter the chain linking basic foodstuffs to fully prepared food products. Examples include the use of pesticides in agriculture and fruit-growing, the use of additives in animal feed, the use of additives during the processing of raw materials to final products, the escape of chemicals from packaging materials and bacterial infection at any point in the chain. Adequate safety can be achieved only by the cooperation of government, the business community and the consumer.[199] One development that has caused concern in this regard is that food production has become largely industrialized.[200] As a result of this, there has been a change in the character of the management of risk.

Gaps in knowledge are continually re-occurring, partly because of the ceaseless nature of technological development (see Section 3.4). One example is the relationship between BSE and Creutzfeldt-Jakob's disease. Lack of knowledge regarding the nature and cause of the disease, and shortcomings in the field of risk communication, worked together to lead to a breakdown of public trust in government and to a crisis within the European Union.[201,202] We refer to Section 3.4 for more information on xenobiotic chemicals such as pesticides, environmental pollutants and additives. The use of modern biotechnology in food production is covered in Section 3.12.2.

Microbial contamination is very significant in terms of disease burden.[203] Since such contamination cannot be tackled by action taken at only one point in the chain, exclusion of the associated risks is very difficult. Furthermore, the prevention of contamination is expensive. The government has indicated that an assessment framework is required to

weigh up the costs and benefits of different policy options.[204] The RIVM has accordingly started work on such a framework.[205]

Chapter 4

Action

The gaps in knowledge concerning environment and health were grouped into eight themes in the previous section and reference was made to a recent Health Council report in connection with a ninth theme, 'Monitoring'. The proposals were assessed against the criteria 'Health effects', 'Public concern', 'Enhancement of understanding' and 'Feasibility' (see Section 3.2). In this concluding section, we address the question, 'What should happen next?' We also consider the prioritisation of themes and proposals, and the direction of research and advice.

Quality of the human environment: policy harmonization

The challenge facing Dutch society as far as the protection of public health is concerned is how to exercise more control over the interaction between the economy, ecology and the social environment. This issue is particularly pressing in the Netherlands because of the relatively large number of people living, working and pursuing recreational interests in a relatively small area. The high population density increases environmental pressures and thus the health risks associated with the human environment.[7,67] However, no comprehensive overview is available of the ways in which the quality of the human environment influences health, thus making it difficult to determine the most effective and efficient forms of potential government intervention.[57] The coordination of the research proposals set out in Section 3 within the context of a research programme should therefore be directed towards a complete picture.

If government policies are to make any real impact on the quality of the human environment, various policy fields need to be aligned with one another. The best route to significant health benefits is, in particular, inter-sectoral collaboration. The *Gezondheid en Milieu* (Environment and Health) policy document[6] and the associated Action Programme[8] may have the support of the Ministers responsible for public health and environmental management, but the involvement of those in charge of other areas of policy (such as working conditions, nature management, transport and the economy) is also required.

The themes: integration required, not ranking

Can themes be placed in order of their importance for the protection and promotion of health? In due course, the results of research carried out on the theme of 'The quality of the human environment' can provide a framework for the assessment of specific intervention options. The issues associated with the theme of 'Cumulative and combined exposure' may ultimately have to be merged with those relating to the theme of 'The quality of the human environment'. After all, concurrences involve not only cocktails of chemicals, but also factors of a divergent nature acting together, such as chemicals and noise or work-related factors and domestic factors. Furthermore, both exposure and effects are influenced by behavioural and social relations, as well as by economics and by spatial factors.

In terms of the amounts of health impairment involved, we regard the themes 'Outdoor air', 'Noise' and 'Indoor climate' as being of particular significance. This view is supported by the figures published by RIVM.[49] We believe that RIVM's estimates provide reasonable insight into the contributions to ill health made by various environmental factors in the Netherlands (see Section 2.3). The three themes referred to are not the ones about which the public is most concerned in this context.[206] The public is more worried about electromagnetic fields (high-voltage lines and transmitters) and about carcinogenic and hormone-disturbing chemicals. This implies that effective risk communication is very important, both with a view to establishing what people are concerned about and why, and in order to enable people to take scientific research findings and the associated uncertainties into account when making personal judgements about risk. However, effective risk communication is itself dependent upon further research and advice in the field of risk perception and communication (see Section 3.10). Any government that wishes to address public concerns therefore needs to prioritise these research and recommendation activities.

It is worth noting that public concern often leads to additional attention and resources being devoted to research into effects and exposure, even where much is already known. The interest in ionizing radiation in the 1970s serves as a good example

in this regard. Particular questions concern sensitive groups: are children, pregnant women, women of childbearing age or older people at particular risk?

Monitoring is important in order to enable the government to remain abreast of what is happening: Is progress being made in terms of environmental influences on health? How effective are the intervention measures taken? Where is intervention required? And so forth. As indicated in Section 3.11, the Health Council has prepared a separate advisory report on this subject in response to a request from a former Minister of VROM.[163]

To sum up, it is not possible to place the themes in an absolute order of importance, from very important to unimportant. Nevertheless, we regard the quality of the human environment as the linking or umbrella theme in the field of environment and health. This theme can serve as the basis for the integration of knowledge acquisition activities in the various fields.

The proposals: quality of researchers and plans are critical

Is it then possible to place the recommendation proposals and, more particularly, the research proposals in order of importance? We think that this is similarly unlikely. Although the scores we have assigned to the proposals in the tables of 'priorities' do amount to a ranking system of sorts, the scores only reflect the considerations that the State Secretary asked the Council to address and (as indicated earlier) ignore various respects relevant to a proposal's 'importance'. As explained at the start of Section 3, we believe that long-term research is very important, yet this has not been included in the consideration. Another reason is that we have not assessed research currently in progress. Research always raises new questions and the studies now ongoing may lead to the proposal of promising initiatives that warrant prioritisation (partly dependent upon the measurement used). Finally, a separate Dutch ranking of proposals is of limited value. Much of the research into the relationship between environment and health is conducted under an international umbrella (indeed, in Section 2.4 we called for Dutch research to be positioned within this international context). Thus, the Dutch contribution to the international research effort inevitably depends partly on priorities defined elsewhere. The time available to us made it impossible to provide a meaningful picture of the priorities in other countries.

We therefore see the findings presented in Chapter 3 primarily as a reference framework that the Dutch government can use in the assessment and promotion of Dutch research proposals and research programmes. Decision-making regarding support for individual research proposals needs to take account of the considerations we have outlined, plus other matters, including in particular the quality of the researchers and the thoroughness of the research plans.

Research in the Netherlands: retain and promote diversity

People reading Chapter 3 might easily get the impression that research into the relationship between environment and health carried out in the Netherlands is only conducted by RIVM, with TNO undertaking a little, and the universities and other bodies involving themselves only incidentally. This is not in fact the case, as literature searches indicate.* While the RIVM is undoubtedly a major player in this research field, other institutes and universities likewise play very significant roles. The contributions made by the universities are often under other headings, such as health education, spatial planning, transport and traffic planning, respiratory disease, etc.

We recommend that the Action Programme be used to maintain and strengthen the Netherlands' present research capacity. This recommendation is based on two considerations. The first consideration is our belief in the importance of long-term research. Not all problems can be resolved in the period covered by the Action Programme, even as focus not only tends to shift from one field to another over time, but new issues also arise (examples of such new research questions nowadays include mobile telephony and the shift from traditional to industrial processes of food production). The second consideration is that the Netherlands can only play a significant role in international research programmes if it has a close-knit, yet appropriately diverse, research infrastructure. As indicated earlier, such an infrastructure is in our opinion the most appropriate basis for research.

Organization: use of NWO frameworks

We regard the *Netherlands Organization for Scientific Research* (NWO) as the appropriate organizing body, particularly when it concerns research of a fundamental nature and therefore of a longer duration. Indeed, the NWO has considerable experience with research programmes and its procedures for the assessment and funding of research proposals are respected within the research community. The NWO can also act as a springboard for research activities in an international context by promoting contact between the funding recipients and potential recipients. A strategic research programme using

* A literature search carried out using the *PubMed* database (http://www.ncbi.nlm.nih.gov/PubMed/) using the parameters 'all fields:environment', 'all fields:health' and 'affiliation:Netherlands' produced more than four hundred hits. Roughly half of the academic publications in question were relevant to this report. Of these, roughly 20 per cent concerned RIVM studies, just under 10 per cent related to work by other research institutes, and the rest to studies in university departments. These figures provide only a general impression. Not all important publications were identified by the search, while some relevant research has been published only in report form and is not included in *PubMed*.

our proposals as the starting point should be defined in order to provide a framework for the assessment of funding applications.

We believe consideration should be given to the establishment of an independent programme committee for the supervision of research of a more applied nature. ZonMW (*Netherlands Organisation for Health Research and Development*) might provide the institutional framework for this committee.

With regard to funding we recommend that, given the intersector nature of environmental health problems, research projects are supported by several government departments.

Synthesis: use of existing consultative structures

In many instances, we regard the analysis and synthesis of the knowledge already available to be important. We refer to proposals to this effect (in Chapter 3) as 'advice' topics. We do not believe that this necessitates the creation of new structures.

The adverse effects of our physical surroundings on public health have been reduced over the centuries by environmental management. Nevertheless, much can still be done to protect public health against environmental hazards as new factors continue to emerge and old factors threaten to reassert themselves. The processes of globalisation are, at present, particularly important in this context. The Health Council therefore believes that there are compelling reasons for energetically implementing the measures announced in the fourth *National Environmental Policy Plan*,[67] the Action Programme[8] and the initiatives announced by the European Commission.[9]

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A Ministerial request for advice and response

B Persons involved

C Research themes listed in the Environment and Health Action Programme

D Programme of the 26 November 2003 working conference

E *European Science Foundation* research topics

Annexes

Annex **A**

Ministerial request for advice and response

On 9 December 2002, the State Secretary for Housing, Spatial Planning and the Environment wrote the following missive requesting advice from the President of Health Council under reference number DGM/SAS/2002085338.

Environment and Health Action Programme

The fourth National Environmental Policy Plan (NMP4, June 2001) made it clear that, without a change in policy, the Netherlands was in due course liable to be confronted with various health problems that are not yet presently apparent to any significant extent. It was also indicated that public safety and the quality of the human environment threaten to deteriorate. The National Advisory Council for Public Health (RVZ) produced the August 2001 advisory report entitled *Gezondheidsrisico's voorzien, voorkomen en verzekeren* (Predicting, Preventing and Insuring Against Health Risks), which contained an analysis of the public health threats likely to face Dutch society over the coming decades and the ways in which that would result in more appropriate responses to these threats.

On the basis of the environment-related health risks identified in the NMP4 and the RVZ report, together with the recommendations contained in the Health Council's advisory report *Ongerustheid over lokale milieufactoren* (Local Environmental Health Concerns, April 2001), the then Minister of VWS drew up a policy document entitled *Gezondheid en Milieu, opmaat voor een beleidsversterking* (Policy Document on Environment and Health: an overture to more powerful policy). This was presented to the Lower House of Parliament in November of last year. In this document, environmental factors are ranked on the basis of the extent to which their adverse effects on health can be quantified and how they are perceived by the public. This approach was elaborated in the *Actieprogramma gezondheid en milieu, uitwerking van een beleids-*

versterking (Environmental Health Action Plan: Implementing more powerful policy) that the last Minister of VROM submitted to the Lower House on 25 April this year. I have included a copy of this document for your information.

The Action Programme identifies thirty-six points requiring action over the next five years. The first action point is consultation with your Council regarding certain elements of the Action Programme. I am therefore writing to ask the Health Council to accordingly advise me and my colleague, the State Secretary for Health, Welfare and Sport. The Council for Research on Nature and the Environment (RMNO) will also be asked to give recommendations about appropriate elements of the Action Programme.

Among other things, the Action Programme indicates that research into the relationship between environment and health requires fresh impetus. It also identifies a number of themes that are regarded as important in relation to the assessment of health risks and in the context of which gaps in knowledge exist. These themes are arranged in order of significance (Appendix II, 2.3.2). The themes were selected primarily on the basis of the TNO report *Milieu en Gezondheid 2001* (Environment and Health 2001), subject to the omission of themes that are adequately covered by projects and programmes already in progress. An Environment and Health Research Programme that sets out a phased timetable and priorities for environmental health research should have been formulated before the end of 2002. Against this background, I ask the Health Council to provide recommendations regarding the following matters:

- Do the proposed themes adequately cover the existing gaps in knowledge regarding environment and health?
- The identification of priorities for research in the Netherlands, given the knowledge that is available in this country and elsewhere and taking account of existing research programmes and expertise here and abroad. In this context, I suggest that you consider the involvement of experts from RGO circles.

When formulating your advice, I would like you to consider the extent to which the results of the research would contribute to insight into the risks of adverse health effects and the health benefits potentially attainable, the easing of public anxiety, and the cost and feasibility of further research. I would specifically also like you to take account of the cost per additional quality-adjusted life year in order to perform an initial priority ranking.

Your analysis should also take into account the extent to which the research is likely to yield results that are of practical value within the period covered by the Action Programme.

The Action Programme also addresses the question of monitoring. I assume that this matter is to be dealt with in the advisory report you are currently preparing on the identification and monitoring of health risks associated with environmental factors.

In the interests of transparent decision-making regarding environment-related health effects, an assessment framework is being developed that is to include criteria pertinent to the assessment process. A draft checklist has been produced in which these criteria are grouped in five general categories. The checklist is not intended as a scientific decision-support instrument, but as an aid that facilitates the illumination and discussion of matters that are pertinent to assessment of the nature and necessity of intervention options for

which views amongst stakeholders differ. It is not only scientific, but also policy-related and social, criteria that play a role here

- I ask the Health Council to make a scientific appraisal of the draft checklist, to highlight anything regarded as an omission and to make such proposals as the Council sees fit regarding the improvement and/or further development of the checklist. Both technical and behavioural-scientific matters are of relevance in this regard.

I would be grateful if the Health Council could provide me with an advisory report on the closure of gaps in knowledge and the prioritisation of research topics by the end of this year. I appreciate that the formulation of recommendations regarding the other matters referred to in my questions will require more time and I will therefore be grateful to receive a report on such other matters by the summer of 2003. In view of the importance of this topic, I hope that the Health Council is able to make allowance for the preparation of such a report in its work programme for 2003.

Yours sincerely,
[signed]

B.A. van Geel
State Secretary for Housing, Spatial Planning and the Environment

On 3 February 2003 and under reference no. U221/WP/mk/720, the President of the Health Council replied to the State Secretary as follows:

In your 9 December 2003 letter, cited above, you posed a number of questions to the Health Council in connection with the development of your policy (and that of the Minister of VWS) concerning Environment and Health. I am please to inform you that, following discussions with your staff and in anticipation of your request, the Council has already begun deliberation of the matters referred to. I anticipate being able to respond in the short-term (i.e. by April 2003) to your questions regarding the themes set out in the Environment and Health Action Programme. However, I fear it will not be possible (within that time-scale) to use the gain or loss of terms such as quality-adjusted life years (QALYs) or other such units to measure the likely impact of options within (or possibly outside) the said themes. Various expert members of the Council have stressed to me that the use of such units requires further consideration. I will arrange for an advisory report on this topic to be prepared in the short-term. I expect that the preparation of that report could make good use of the findings of a study commissioned by the Health Council in connection with the very recently published advisory report on the shape of the basic healthcare service package. A copy of the latter report is enclosed.

The last question you posed related to the assessment framework. I am aware that the RIVM is currently in the process of refining that framework. I will therefore ask the RIVM to indicate when the framework is likely to be ready for appraisal by the Health Council, since I do not feel it would be efficient to prepare an advisory report on the framework while it is still under development. You may rest assured that I will make preparations to ensure that a report can be quickly prepared.

Yours sincerely,
[signed]

Professor JA Knottnerus

Annex **B**

Persons involved

The following individuals attended the working conference held on 26 November 2002 (G&O is the Dutch acronym for the Health Council's Standing Committee Environment and Health):

- dr JA Knottnerus – *president* and chairman of G&O
  President of the Health Council of the Netherlands, The Hague and professor of general practice, Universiteit Maastricht
- dr CJM van den Bogaard – advisor G&O
  inspector of environmental health, VROM Inspectorate, The Hague
- dr JSM Boleij – member G&O
  directeur Board for the Authorisation of Pesticides, Wageningen
- dr ir B Brunekreef – member G&O
  professor of environmental and occupational health, Utrecht University
- dr HR Büller – vice-chairman Standing Committee on Medicine of the Health Council
  professor of internal medicine, Academic Medical Centre, Amsterdam
- drs JEF van Dongen
  senior scientist, Department Environment and Health, TNO Inro, Delft
- ir ND van Egmond – member G&O
  professor of systems-based approaches to environmental policy, Utrecht University
- dr VJ Feron – member G&O
  emeritus professor of biological toxicology, Utrecht University

- dr JKM Gevers – vice-chairman Standing Committee on Medical Ethics and Health Law of the Health Council
  professor of health law, Academic Medical Centre, Amsterdam
- drs AEM de Hollander
  scientist/project director, National Institute for Public Health and the Environment, Bilthoven
- dr JCS Kleinjans
  professor of environmental health sciences, Universiteit Maastricht
- dr NJ Leschot – vice-chairman Standing Committee on Genetics of the Health Council (not present on 26 November 2002)
  professor of clinical genetics, Academic Medical Centre, Amsterdam
- dr JWM van der Meer – vice-chairman Standing Committee on Infectious Diseases and Immunity of the Health Council
  professor of internal medicine,St Radboud University Medical Centre, Nijmegen
- ms dr RM Meertens – member G&O
  associate professor of health promotion and health education, Universiteit Maastricht
- dr HME Miedema – member G&O
  director, Department Environment and Health, TNO Inro, Delft
- drs AAJP Mulder
  directorate Occupational Safety and Health, Ministry of Social Affairs and Employment, The Hague
- dr WRF Notten – member G&O
  director of TNO Prevention & Health, Leiden
- dr D van Norren – vice-chairman Standing Committee on Radiological Protection of the Health Council
  professor of ophthalmic physics, Utrecht University and director of TNO Human Factors, Soesterberg
- dr WF Passchier – advisor G&O
  Dep. Executive director of the Health Council, The Hague and special professor of risk analysis, Universiteit Maastricht
- ms drs W Passchier-Vermeer
  senior scientist, Department Environment and Health, TNO Inro, Delft
- dr HGM Rooijmans
  President of the Advisory Council on Health Research, The Hague and emeritus professor of general psychiatry, Leiden University
- ir PJA Rombout
  Netherlands Environmental Assessment Agency, National Institute for Public Health and the Environment, Bilthoven

- dr EW Roubos – chairman Committee on Electromagnetic fields of the Health Council
  professor of veterinary medicine, neurophysiologist, University of Nijmegen
- dr W Seinen – member G&O
  professor of toxicology, Utrecht University
- ms drs BAM Staatsen
  director Sector Monitoring, Centre for Environmental Health Research, National Institute for Public Health and the Environment, Bilthoven
- ms ir WMAH Thien (not present on 26 November 2002)
  Prevention and Public Health Directorate, Ministry of Health, Welfare and Sport, The Hague
- dr MM Verberk – member G&O
  associate professor health and environmental factors, Academic Medical Centre, Amsterdam
- ms dr M de Visser – member G&O
  Vice-President Health Council, The Hague and professor of neuromuscular diseases, Academic Medical Centre, Amsterdam
- ms ir PW van Vliet – *scientific secretary*
  scientist Health Council, The Hague
- ms A Wijbenga – vice-chairman G&O
  head of Department of Strategy, Environment and Safety, Province of South Holland, The Hague,
- dr JH van Wijnen – member G&O
  head Environmental Medicine, Municipal Health Service, Amsterdam
- dr FA de Wolff – member G&O
  professor of clinical and forensic toxicology, Leiden Unversity
- dr F Woudenberg
  head Sector General Health Care, Municipal Health Service, Rotterdam
- prof. dr ir AA van Zeeland
  professor of molecular radiation dosimetry and radiation mutagenesis, Leiden University Medical Centre
- dr JA van Zorge – advisor G&O
  Directorate of Substances, Waste and Radiation, Minister of Housing, Spatial Planning and the Environment, The Hague

The ‘editorial working group’ that reviewed drafts of the present report consisted of:
- ms ir T Fast (Fast Advies, Utrecht)
- drs AEM de Hollander
- dr JCS Kleinjans

- dr WF Passchier – *secretary-chairman*
- ms drs W Passchier-Vermeer
- ms ir A Wijbenga
- dr F Woudenberg

Administrative support: ms WY Lee and ms MFC van Kan.
Lay-out: ms AMC van Kan.

Annex **C**

Research themes listed in the *Environment and Health Action Programme*

Table 21 [Table 2.2 from the Action Programme]

Type of research	Description	Innovative/ already commences
Quality of living environment		
Impact research and development of method	• Develop conceptual framework and instruments in interdisciplinary context • Link data about perception and experience of health (from existing databases) for each living environment to physical, social and environmental data • Additional research into relationship between determinants • Spatial modelling • A supplement to current cohort study at VINEX location Leidse Rijn focusing on the relationship between chronic stress and daily hassles arising from the perception of the quality of the environment and 'control' over the housing environment. Multidisciplinary. Possibly supplement with research into noise and household water (see Health Council of the Netherlands, November 2001) • Bottom-up approach: identify individual perception of living environment and expand to larger scale • Influence of (known) environmental factors on individuals who are confronted with other risk factors. For instance, socio-economic risk factors in deprived neighbourhoods or other risk groups such as children	1-4 already in RIVM and TNO projects. PhD research into environmental inequity underway (University of Utrecht-RIVM)
	• International (EU) research into the quality of the living environment and well-being in which a combination of methods could be used: focus groups, survey, GIS method, cumulative environmental problems, etc.	Coordinate with section on communication

Risk perception / communication		
Development of method	• Research into the effectiveness of existing guidelines for communicating about risk through evaluation studies (recommendation of Health Council of the Netherlands) • Research into the effects of communication of information about risk on the perception of risk in real-life settings • On-line centre of expertise to assemble good practices • Social science research into the causes of and solutions for the gap between perception of risk and information about risk from the government • Research with questionnaire into the influence of perception of risk on experience and reporting of health complaints • Periodic collection of information about perception of risk through focus group discussions (national barometer of concerns) • Research into the need for information about risky situations	
Monitoring		
Modelling and development of method	• Options to supplement existing registers: expansion of family doctors' records, more extensive inspections of drinking water quality, monitoring of specific products (in the context of food safety), development of methodology, see also section 4.5 on monitoring	See also the Environment and Health Monitoring project of RIVM and the Health Council of the Netherlands
Outdoor air		
Impact and exposure research, modelling	• Epidemiological research into chronic exposure and long-term impact on mortality • Analysis of contribution to exposure and impact of specific categories of sources: what is the role of particulate air pollution and the role of traffic, air pollution to the incidence of asthma? • Epidemiological research into the long-term impact on early indicators of allergies, respiratory and cardiovascular complaints among children • Continuation of toxicological research with realistic mixtures; issue of mixed toxicity; development of new biomarkers (innovative). • Hypotheses that apply focus on interaction of particulates with lung macrophages, vascular wall and immune system • Traffic-related research with emphasis on interactions with allergies/allergens an toxicological evaluation of new technology • Availability test: leachability as indicator for impact (analogous to soil problem), directed at total content of components	On the basis of report to appear this year: RIVMIRAS-ECN-TNO-F11. Number of actions already commenced
Combined exposure		
Modelling and development of method	• Experimental research, application of genomics (gene expression profiling) • Development of models • Epidemiological research in combination with good description of air quality and noise nuisance • Comparison of experimental research and epidemiological research • Study of how people spend their time	New technology

Indoor environment		
Impact and exposure research	• Research into the contribution of the quality of the indoor environment to health risks. For example, through pilot projects at large new building locations by means of epidemiological (cohort) studies, supported by measurements of chemical and biological factors in the indoor environment. Enquire about aspects of health perception in national questionnaire. Determine exposure by developing methodology and strategy for measurement and models • Research into effects of measures • Research into ventilation systems for residents	
Hormone disrupting substances		
Impact and exposure research	• Establish whether hormone-disrupting substances appear in the drinking water chain (make available measuring methods) and determine the disposal yield of treatment • Also study combined effect of these substances • Toxicological research into effects • Monitoring of routes along which the consumer can be burdened by them • Epidemiological research into effects of PCBs and dioxins • Screening for PCBs and dioxins in mothers (breast milk) (ongoing) • Pre-conception research among women for PCB and T4 levels • Predict risks on the basis of structure of substance (QSAR)	Epidemiological research into effects on infants is ongoing, as is research into contaminants in breast milk
Food safety		
Exposure research	• Hormone-disrupting substances in food: see above • Human exposure study into organochlorine compounds and organobromide compounds • Research into effects of genetically modified food components: experimental and monitoring. Look at more than just allergies • Use monitoring, impact research, surveillance and a rapid-alert system for contaminants in food • Reprioritise choices on contaminants in current surveillance programmes	Wait for development of Dutch Food Authority (NVA)
Noise		
Particularly impact research	• Epidemiological (cohort) research into the role of ambient noise on health and performance in the general population • Epidemiological research (possibly supplemented with experimental research with sleeping volunteers) into the impact of noise from road traffic on sleep and psychosomatic reactions • Research into living in a noisy environment and the effects of sound-proofing measures • Research focusing on the overall noise quality in various environments (objective, subjective), with attention also for pleasant noise environments • Evaluation of the method of integrating the burden from various sources (acoustic models, methods for measuring combinations of exposure)	Incorporate in planned field study by the Ministry of Housing, Spatial Planning and the Environment; Follow-up to RANCH;

	• Release and testing of instruments that can be used on different scales to pursue an integrated policy which highlights the impact of measures and enables the local authority to assess the overall noise situation.	
Substances		
Exposure and impact research	• Experimental research, supported by toxic-kinetic and dynamic models to evaluate the quality of the new substances policy (Strategy on Management of Substances). Experimental research into effects of combined exposure	Cooperation with EU member states
Non-ionizing agents		
Impact and exposure research	• An inventory of sources of and exposure to electromagnetic fields • An inventory of the possible effects of exposure to electromagnetic fields • An inventory of complaints (register) • Demonstration projects for ALARA ('as low as reasonably achievable') principle in light of ignorance	Join with international research
Research to assist policy		
Development of method	• Further development of instruments for quantifying, weighing and prioritising current or future health impacts of environmental pollution, such as Disability Adjusted Life Years (DALYs) • Testing and evaluation of recently developed instruments (for instance, City & Environment health effects screening) • Research into the effect of policy measures on the quality of the environment and health with demonstration projects. Examples include reducing particulates in industry, radon in the building industry, energy-efficient adapted ventilation in existing buildings, dioxin/PCB reduction in animal production chains, elimination of phthalates, elimination of hormone toxic pesticides • Local research into (a) current bottlenecks in policy on environment and health and (b) possibilities for improving evaluation of new local policy	To be combined with monitoring programmes

Annex **D**

Programme of the 26 November 2002 working conference

09.30-10.00	opening	
10.00-10.30	general introduction, assessment framework	
10.30-11.30	cluster Agents	
	substances	Prof. dr VJ Feron
	noise	Drs W Passchier-Vermeer
	non-ionizing radiation	Prof. dr EW Roubos
	hormone disruptors	Prof. dr W Seinen
11.45-12.45	cluster Risk	
	risk perception and communication	Dr RM Meertens
	monitoring	Drs BAM Staatsen
	food safety	Prof. dr JCS Kleinjans
	policy support	Drs AEM de Hollander
14.00-15.00	cluster Environment	
	human environment	Prof. ir ND van Egmond
	indoor climate	Drs JEF van Dongen
	outdoor air	Prof. dr ir B Brunekreef
	combined and cumulative exposures	Dr HME Miedema
15.45-16.45	results and discussion	
16.45-17.00	closure	

Annex **E**

European Science Foundation research topics

The *European Science Foundation* compiled a list of research priorities for the conference of European health and environment Ministers. This list is reproduced in Table 22.

Table 22 Research priorities identified by the European Science Foundation.[147]

Overarching needs		
	Environment and health indicators	Develop a meaningful set of environment and health indicators to be used to monitor, compare and prioritise environment and health benefits;
	Health and environment geographical information systems.	Improve the comparability of environment and health data, develop better indicators and improve methods of data analysis(through, for example, Health and Environment Geographical Information Systems – HEGIS).
Cross-cutting issues		
	Risk assessment	Improve methodologies for exposure and effect assessment
		Further develop quantitative chemical risk characterisation based on experimental and human data
		Develop methods to assess the oral and respiratory allergenicity of agents.
		Develop methods for the identification of genetic or nongenetic susceptibility
	The environmental contribution to social variations in health	Investigate to what extent the link between socio-economic status and health is mediated by environmental factors.
	Cognitive functions as mediators of environmental effects on health	Identify psychological and psychobiological mechanisms of symptom formation and determine the prevalence, impact and outcomes of health beliefs concerning unexplained symptoms and environmental syndromes
		Evaluate existing and identify best strategies of risk management for environmental incidents, to limit their psychosocial impact

Specific research areas	
Air quality	Identify mechanisms of effects related to short-term and long-term exposure to particles and air pollution mix, considering their physical and chemical characterisation and source apportionment
	Improve understanding of the effects of long-term exposure to particulate matter and air pollution mix.
Water quality and drinking-water	Identify the sources of waterborne pathogens and determine their impact on health, paying particular attention to the role of recently recognised pathogens, including protozoa and viruses
	Develop quantitative methods for risk characterisation for infectious agents
Environmental effects on cognitive functions	Evaluate to what extent chemical and physical agents contribute to impaired mental and cognitive functions
Children and unintentional injuries	Evaluate interventions to identify the most effective strategies for preventing unintentional injuries to children
Climate change and stratospheric ozone depletion.	Improve the epidemiological and mechanistic science base and develop predictive methods for assessing the future health risks of human-induced climate change and increased exposure to UV radiation.