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Accumulation of environmental risks to human health: geographical differences in the Netherlands

M.J.M. Pruppers *, M.P.M. Janssen, B.J.M. Ale, R.M.J. Pennders, K.D. van den Hout [1], H.M.E. Miedema [1]

National Institute of Public Health and the Environment, PO Box 1, 3720 BA Bilthoven, Netherlands

Abstract

The project 'Accumulation of environmental risks' was aimed at developing methods to illustrate the geographical differences in risks to human health due to several types of environmental pollution. The following risks were considered: possible major accidents, radioactive substances and radiation, several carcinogenic substances in air and environmental noise, with the methods used based on the risk concept implemented in the Netherlands environmental policy. Starting with information on sources and emissions of several contaminants, their dispersion in air and human exposure to them were calculated, and the effects on human health estimated. The results were presented in a number of national maps. In spite of the complexity of discussions on risk-related subjects, applying the methods developed during the project has been shown to lead to insight into the geographical distribution and the comparison of different kinds of risk. The maps on possible major accidents and noise showed high risks on a local scale, whereas the risks due to radiation and substances were found to be more evenly distributed over large parts of the Netherlands. © 1998 Elsevier Science B.V. All rights reserved.

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1. Introduction

One of the main issues in environmental policy-making nowadays is establishing priority when it comes to the different environmental problems. It is beyond a doubt that policy-makers need a scale of reference for ranking environmental problems. The development of such a scale will demand answers to both scientific and policy-related

* Corresponding author. Tel.: +31 30 2742515; fax: +31 30 2744428; e-mail: mathieu.pruppers@rivm.nl
[1] Present address: Netherlands Organization for Applied Scientific Research (TNO), Netherlands.

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questions. The risk scale has been chosen as a reference scale for making environmental policy in the Netherlands [1].

Risk is defined as the unwanted consequences of a particular activity in relation to the likelihood that these consequences may occur [1]. Environmental risks are not equally distributed. It is well-known that risks in certain areas are higher than in others [2]. If the question on where environmental risks accumulate, or better, 'geographically coincide' is to be answered, the risks should be comparable, which means that the endpoints of different source–effect chains should be expressed in exactly the same unit.

The project 'Accumulation of environmental risks' made some types of human-health effects of several environmental threats comparable through calculation of these risks [3]. One of the goals of the project was to calculate the geographical differences on a national scale. In this paper a series of national maps of risks in the Netherlands is presented. The project, initiated by the Ministry of Housing, Spatial Planning and Environment of the Netherlands, was carried out in 1995 and 1996 by the National Institute of Public Health and the Environment (RIVM) and the Netherlands Organization for Applied Scientific Research (TNO).

2. Theory and experiment: creating risk maps

We calculated the *potential* individual risk according to the definition of risk in the environmental policy of the Netherlands. Because every area in the Netherlands should be suitable for any function, the risks were calculated on the assumption that a person could live and work in the grid element for which the risk is calculated. In the calculations our individual was not 'allowed' to leave the grid element, so that risk is seen rather as a characteristic of a place than an actual or an imaginary person.

2.1. Sources of environmental pollution

The following types of environmental pollution were considered in the project: possible major accidents, emission of radioactive substances and radiation, emissions of several carcinogenic substances in air and environmental noise. The risks, referring to additional effects due to activities in 1992, are expressed as the yearly probability that the effect will occur. The estimates are based on data for domestic sources. Only in the case of carcinogenic substances was transboundary air pollution taken into account.

Important sources and substances were identified. Sources for possible major accidents were industrial sites which have to make a so-called External Safety Report, several railway marshalling yards, the network of high pressure natural gas pipelines and a large airport. Several smaller sites and all other transport routes were omitted because of lack of approved information.

In 1992 the nuclear industry included two operational nuclear power plants, two sites with research reactors and one uranium enrichment facility. Other sources of radioactive substances are the so-called non-nuclear industries [4]. Some processing industries use large quantities of ores and other raw materials which contain small amounts of naturally occurring radioactive substances. These substances are emitted to air and water, posing a risk after inhalation or ingestion. The risks due to emissions from radionuclide laboratories and equipment emitting radiation were left out because of lack of sufficient and adequate data.

The selection of the carcinogenic substances was based on predictions of probable environmental concentrations divided by the maximum allowable concentration according to Dutch policy. Six carcinogenic substances were selected: benzo[*a*]pyrene, benzene, ethylene oxide, vinyl chloride, 1,2-dichloroethane and acrylonitrile. These substances are mostly emitted by industry, but some are also released by road traffic and households. Other toxic substances which are not carcinogenic, like ozone and nitrogen dioxide, were considered in the project, but are not discussed here. Industrial sites and roads, and rail and air traffic were considered as sources of noise pollution.

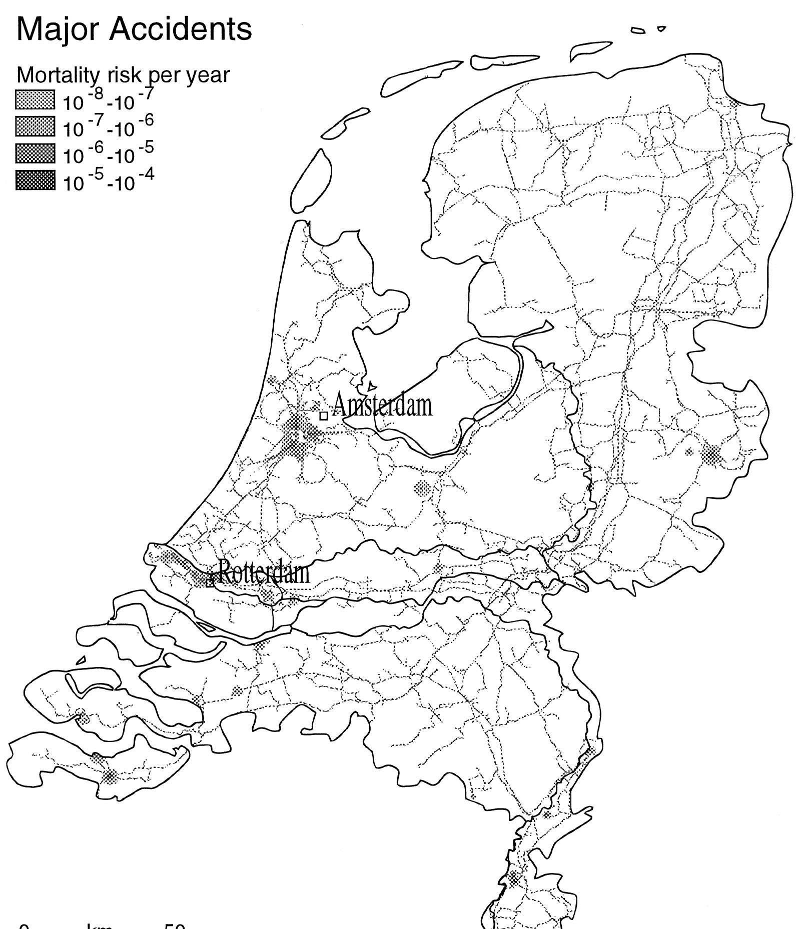

Fig. 1. Mortality risks due to possible major accidents.

The following types of environmental pollution were left off the maps because their risk is assumed to be uniformly distributed throughout the country: radon in dwellings, gamma radiation from building materials, ultraviolet radiation due to depletion of the ozone layer and discharges of radioactive substances to surface water.

2.2. From emissions to risks

The risks were calculated using a number of source–effect chain models. These models are based on knowledge of sources and receptors of the pollution, and of the processes by which the pollution reaches the receptor. The explicit or implicit differences in the dispersion and exposure models, which were developed in different fields, were studied. The methodological discussions during the project focused primarily on

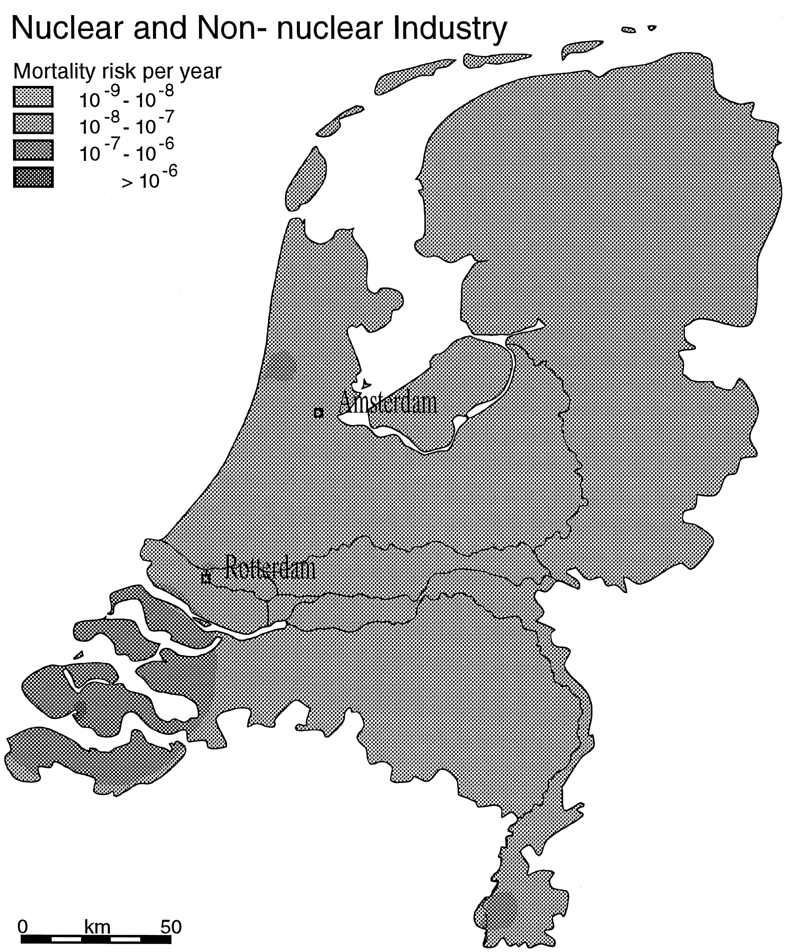

Fig. 2. Mortality risks due to emissions of radioactive substances by nuclear and non-nuclear industries to air.

the questions on how to define the properties of the receptor, and what pollution and sources have to be considered.

The estimated emissions of substances, and emissions from radiation and noise sources were based on data published elsewhere and often in Dutch-language documents (see Ref. [3] for a more complete list). This is also the case for the models and model parameters used to calculate, for instance, dispersion in air, deposition of substances and transfer of noise [5,6].

The risks were calculated for the type of human-health effect for which the policy maker has chosen to protect members of the general public or members of a defined group. In the cases of major accidents, and radioactive and carcinogenic emissions, mortality is the effect considered; for noise the effect is annoyance [1]. A linear relationship for radiation was assumed. Linear concentration–response/effect relation-

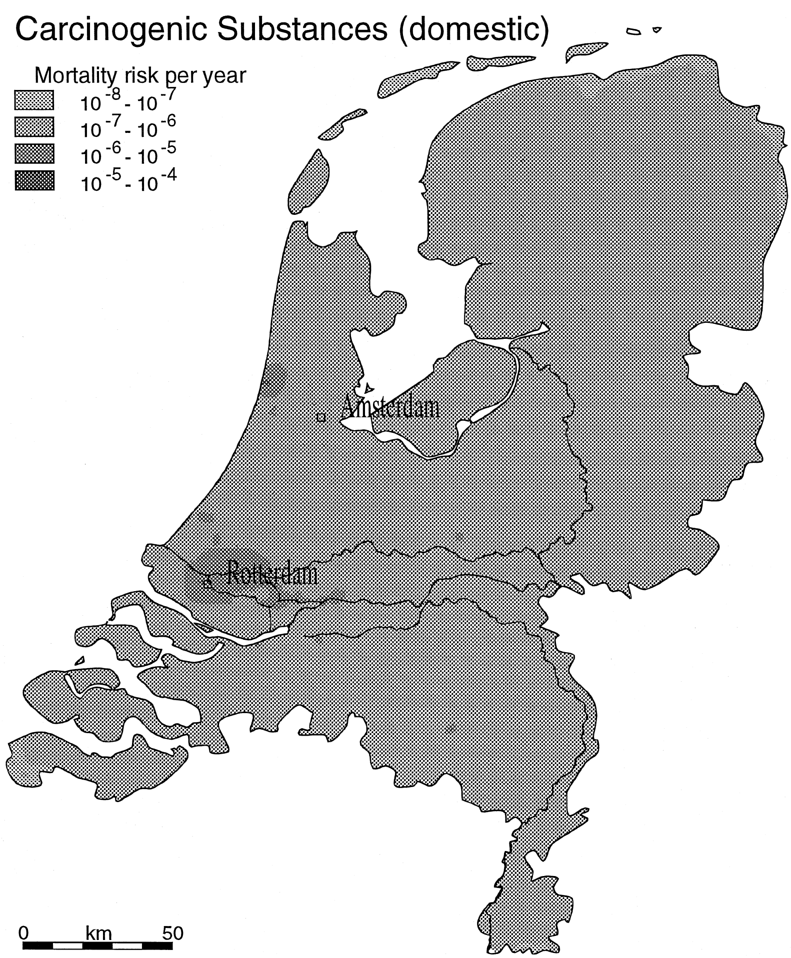

Fig. 3. Mortality risks due to emissions to air of carcinogenic substances from domestic sources.

ships from references on toxicology were used to calculate air concentrations of carcinogenic substances into risks. Empirical relationships were used for noise [6].

2.3. Using a geographic information system

The maps were finally combined using ArcInfo. Maps on a national scale were created for grid elements of 500 m × 500 m or 100 m × 100 m (major accidents and noise). Deformation problems related to projection can be neglected. The colours where chosen in such a way that one colour always represented the same range of risk. In the black and white versions in this paper, this cannot be optimally illustrated. The noise map was drawn to a scale different from the other maps.

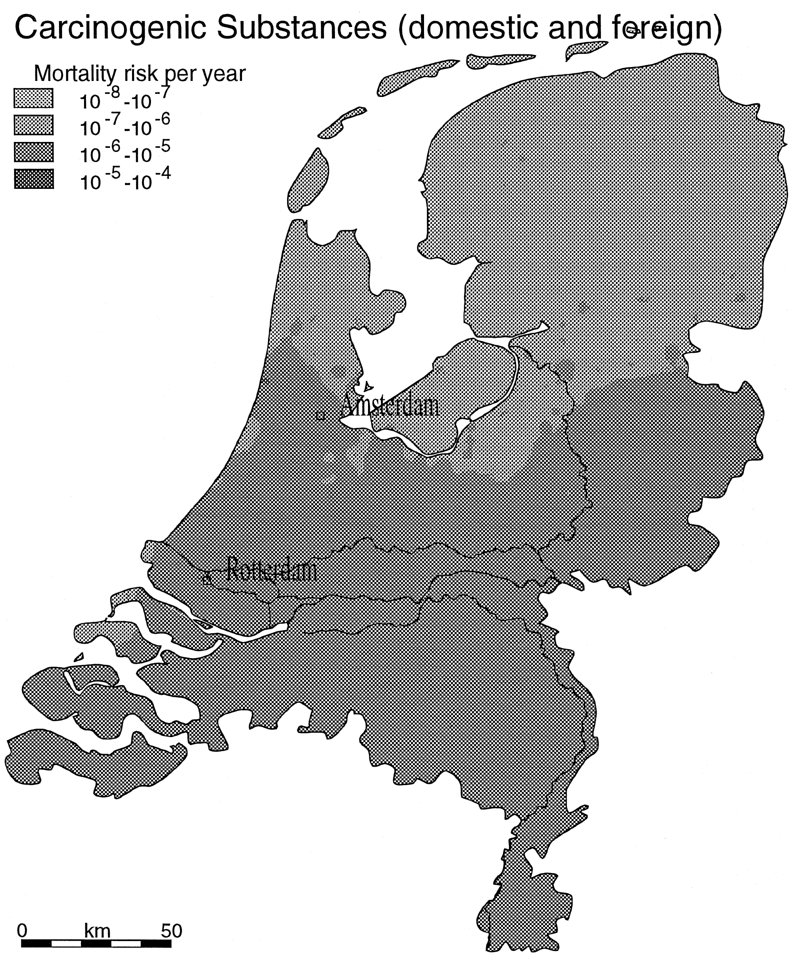

Fig. 4. Mortality risks due to emissions of carcinogenic substances to air by domestic and foreign sources.

Finally, the collective risk to the Dutch population is defined per type of environmental pollution as the national sum of the individual risk multiplied by the number of people exposed to this risk. For risks which are assumed to be uniformly distributed throughout the country, risk is simply multiplied by the total number of people (15×10^6). ArcInfo was used to calculate the collective risks by multiplying the map of the potential individual risk by the map of the population density. The assumption that a

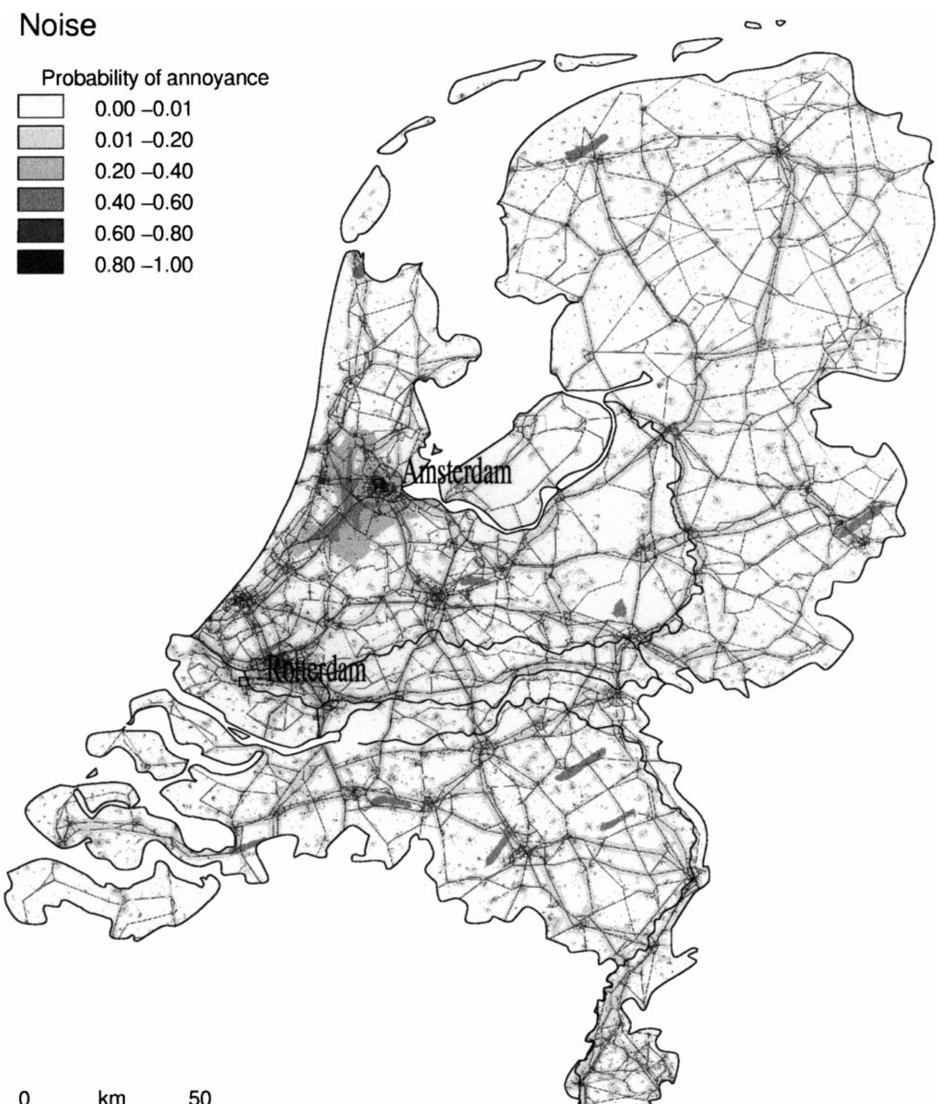

Fig. 5. Risk due to environmental noise.

person will remain in the grid cell is rigorous. However, for policy purposes, in which two sources should receive equal treatment, this is valid *by definition*. For scientific purposes, however, it is not valid. Most individuals in real life are not restricted to one grid cell and their activities can be very different.

3. Results and discussion

It is beyond the scope of this paper to discuss in detail all the differences in the assumptions between all the models used, although harmonisation of model parameters is essential to make risks comparable. Each specialisation also has its specific requirements and limitations, as well as specific reasons for simplifications. For instance, in dispersion models used in major accident analysis, gravity is important, while the inversion layer is not; however, in long-range dispersion models used for air pollution, gravity is not important and the inversion layer is essential.

The methodological discussions in the project resulted in the policy-maker deciding to add the risks related to different types of effects to human health only if the relative importance was clear. Therefore the map on annoyance due to noise has not been added to the maps on mortality risks.

An approach to integrating all the risk maps into one is at the moment being worked out. However, a weighting factor will have to be assigned to each type of effect on human health. This weighting factor will probably include the period of time the effect

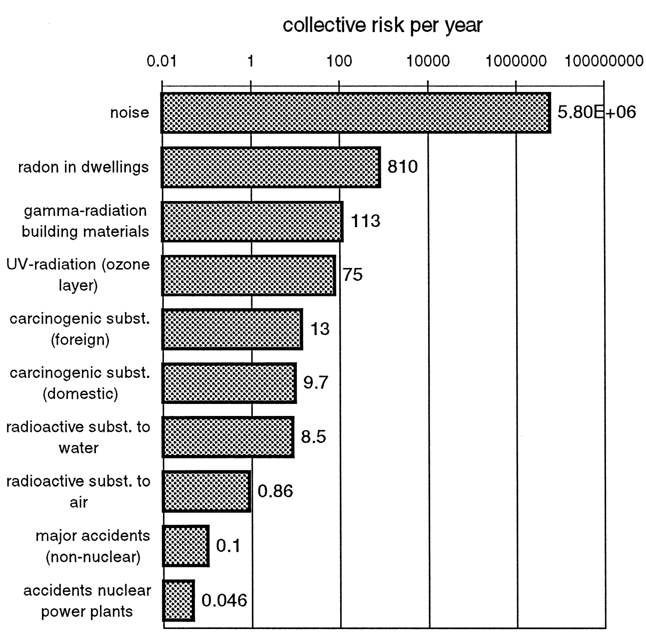

Fig. 6. Collective risks.

is detrimental to an individual and each type of effect will carry a severity factor, for instance, with death as reference. The severity factor is, of course, the difficult part. It is subjective and it needs broad support in society to be acceptable to policy-makers.

Figs. 1–4 show the maps on the mortality risks due to possible major accidents and to emissions of radioactive and carcinogenic substances to air. Fig. 5 shows the map on environmental noise. Characteristic for the major accident map is restriction of the risks to relatively small areas. On the contrary, risks due to radioactive and carcinogenic substances cover large parts of the Netherlands, with local increases near large industrial sources.

The risks due to emissions of radioactive substances to air are lower than 10^{-6} per year almost everywhere (Fig. 2). One source, an elemental phosphorus plant in the southwest of the Netherlands, dominates in the list of risks. Transboundary air pollution contributes more to the risks of carcinogenic substances than the indigenous sources, except in the vicinity of such sources. These substances raise the risks in the southern half of the country to more than 10^{-6} per year.

Fig. 6 shows the calculated collective risks. For noise, the collective risk represents the total number of people expected to be annoyed by noise: this is almost 40% of the people in the Netherlands. For all the other categories of environmental pollution in Fig. 6, the collective risks represent the expected number of deaths per year. There are very large differences between the collective risks for different sources.

4. Conclusions

Insight into the relative importance of the several types of environmental pollution in the Netherlands was obtained by studying both the individual and the collective risks, and the geographical distribution of the individual risks. The use of the geographical distribution of risks has turned out to be important for risk comparison and calculation of collective risks. Although collective risk is an indicator of the overall effects on health of the total population in the Netherlands, other aspects are important for ranking environmental problems.

Risk mapping proved to be a great stimulator in the discussions on the comparability of risks—a major goal of this project. To make risks comparable it is essential to harmonise model parameters. However, because each specialisation has its specific requirements and limitations, as well as its specific reasons for introducing simplifications, harmonisation between these specialisations is not always possible. Nevertheless, the risk mapping process leads to clear insights into the different responsibilities of those involved in risk calculations and policy-making.

Acknowledgements

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