Assessment of an integrated environmental exposure index

To the Minister of Health, Welfare and Sports
Sir Winston Churchilllaan 370
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Subject : Presentation of report
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Our ref. : 604/1993/JvdW/mr/392-N1
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In his letter dated February 3 1993 (ref. MBG 07D92011) the State Secretary of Welfare, Health and Cultural Affairs, on behalf of the Minister of Housing, Spatial Planning and the Environment, requested the Health Council to produce an advisory report on an environmental exposure index. A report on this subject has been issued by the Standing Committee on Environmental Factors and Health (an advisory committee within the meaning of clause 31 of the Health Act). I hereby present you the report. I would like to draw your attention to the following points.

The government's environmental risk management policy focuses on the risk of accidents in industrial installations, and on exposure to substances, radiation, noise, odour and genetically modified organisms. This policy is based on the view that any damage to health and to the environment can be evaluated in quantitative and qualitative terms. Such estimates can be used to establish risk limits. The combined risk to health posed by various forms of exposure could be considered as a single 'integral' risk to health. What is needed is a yardstick, in the form of a composite measure of the possible damage to human health caused by all of the environmental factors present at a single location. The Environmental Exposure Index proposed by the Institute of Environmental Research (IER-EEI) is meant to be such a yardstick - albeit in prototype form.

In the committee's view it would be quite possible to establish an index for odour and noise, based on their common denominator - annoyance. This approach, which was proposed by TNO Prevention & Health (TNO-P&H), constitutes the first step of the IER-EEI. The committee dismisses the notion of an index based on aggregated, empirical data for carcinogenic effects and for accident probability (external safety), even though both factors may lead to death. Nor does the committee consider it possible to construct a single index for substances causing toxic (but non-carcinogenic) effects, in view of the highly

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varied nature of the effects involved. It is only possible to construct a combined toxicity index of substances with similar effects.
The committee concludes that there is no scientific or medical basis to support the construction of a single measure for health damage or risk that would encompass annoyance, illness and death. Techniques developed in the social sciences, relating to value judgment and decision models, could be helpful in administrative decision-making.

(signed)
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President

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Report of a Committee of the Health Council of the Netherlands

to

the Minister of Health, Welfare and Sports

the Minister of Housing, Spatial Planning and the Environment

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Contents

Executive summary

An integrated environmental exposure index (in Dutch: MBI; in English EEI) is intended to serve as a tool for spatial planners in areas where activities like housing and industry compete for space. The idea behind an EEI is to take an assessment of various aspects of environmental quality and to express this as a single numerical measure. This report examines the feasibility of such an EEI in general, and the accuracy of a proposed procedure for deriving EEI values in particular. The EEI concerned (IER-EEI) was developed by the Institute for Environmental Research of the Free University of Amsterdam. The IER-EEI is intended to represent the health risk to the population of a given area affected by the air pollutants, noise and possibility of accidents associated with surrounding installations. Calculation of the IER-EEI involves applying a number of combination rules to measured or estimated data obtained for the area. It is important for the assessment that the IER-EEI should contain steps that can be verified more or less empirically, as well as steps that are based on a value judgement.

The committee considered to what extent, in general, an EEI can represent the integrated human health risk at a given site, posed by detrimental factors in the local environment. The individual components of an EEI procedure can be verified by empirical research or by establishing whether certain decision rules are consistent with current knowledge. However, the EEI number calculated for a given site *cannot* be verified by the study of adverse health effects in the population concerned. Such verification would require the prolonged and in-depth study of an extremely large and homogeneous population. All results obtained would then have to be compared to those derived

from a suitable control group. Moreover, the adverse effects on health caused by most environmental factors are difficult to measure. This is because such effects are minor compared to the effects of other determinants, such as lifestyle, profession, housing or genetic predisposition.

The IER-EEI is based on the implicit assumption that each member of the population at the site in question experiences a uniform degree of relatively constant exposure. Even when a population has lived at a site for an extended period, its exposure to environmental factors will vary from minute to minute and from year to year. The composition of the population will also change over time, and the fact that exposure to environmental factors may play a part in this serves to complicate matters still further. These considerations mean that it is difficult or even impossible to make reliable estimates of exposure and of the concomitant effects on health.

Some types of exposure to environmental factors are not included in the IER-EEI, even though they are detrimental to health. Air pollution from supra-regional *sources* is neglected, e.g. finely particulate substances and nitrogen dioxide. With regard to *routes of exposure* (to substances), the IER-EEI confines itself to the inhalation of outdoor air thereby ignoring uptake via soil or food for example. Furthermore, the IER-EEI ignores the following *polluting agents*: radiation, vibrations, and biological agents. A number of health effects are not taken into account from the IER-EEI, e.g. *illness* caused by exposure to carcinogens, *non-lethal injuries* resulting from accidents and *feelings of insecurity* in industrial environments.

If they are to be aggregated, the adverse factors in question (e.g. air pollutants, noise and accident risk) must have a common denominator. Given that the IER-EEI's intended purpose is to provide a yardstick for the risk to health, this common denominator must be a health related effect.

The committee feels that it would be feasible to establish an index for odour and noise using empirical data on their common denominator, annoyance. This coincides with the proposal made by Prevention & Health, which also constitutes the first step of the IER-EEI. Conversely, the committee believes that to construct an index based on aggregated, empirical data for carcinogenic effects and on accident probability (external safety) is not possible, even though both factors can result in death. An aggregated subindex for death would only be conceivable in the case of a postulated 'model population' that remains on a given site long enough for every single health effect resulting from environmental influences to be expressed. While carcinogens and accidents can result in death, they can also cause illness. But neither the natural sciences nor medicine can provide a common denominator for illness and death. Similarly, the committee considers the construction of a single index for substances causing toxic but non-carcinogenic effects to be impractical, given the highly disparate nature of such

effects. In principle it would be possible to construct a combined toxicity index, but only for clusters of substances with similar effects.

The committee concludes that neither the natural sciences nor medicine can provide a single yardstick for damage to health that encompasses annoyance, illness and death. Techniques developed in the social sciences, relating to value judgment and decision models, could be helpful in administrative decision making.

Chapter 1

Introduction

1.1 Background to the request for this report

Integral environmental zoning (Dutch abbreviation: IMZ; in English: IEZ) aims to achieve the geographical separation of environmentally sensitive functions (in particular, the residential function) from activities that are potentially damaging to the environment (in particular, industrial activities). IEZ also should lead to agreements to coordinate the future development of industrial areas and residential areas. Rational environmental zoning should be based on indications of the total and, if possible, integrated environmental exposure due to actual or planned activities. Within the context of IEZ, various methods have been developed for representing integral environmental exposure.

Environmental zoning has already been applied in practice to establish a system of zonation (e.g. between a factory and a residential area) for each individual environmental component. Such zones are based on the standards (e.g. the Noise Abatement Act) applicable to the environmental component in question.* Another option is to integrate all factors imposing a burden on the environment and to establish a zonation system on the basis of the resultant data. Individual zones could then be tested against general environmental quality standards. This approach to IEZ was adopted by the Ministry of Housing, Spatial Planning and the Environment (IMZ90a) in the development of 'Preliminary Systematics' (in Dutch: VS, in English: PS). PS has since been

* The establishment of a standard per component (i.e. per environmental factor) is viewed as sectoral norm establishment and should not be confused with the establishment of a standard per compartment.

used in 12 pilot projects. With both approaches, the establishment of a zonation system hinges around the values laid down in current standards. Standards which were drawn up following due political consideration of the balance of interests involved (particularly those relating to health, the environment and the economy).

The third option is based on the potential effects on human health of the environmental exposure in question. Here, measurements and calculations could be used to estimate the degree of exposure to environmental factors experienced by anyone living in the surrounding area. Such estimates could then be used as a basis for imposing restrictions on land use in that locality. Any subsequent zonation system would then hinge around the degree of impairment to human health, whether actual or predicted. This is the basis of the EEI developed by the Institute of Environmental Research (IER) of the Free University of Amsterdam, at the request of the Ministry of Housing, Spatial Planning and the Environment (IMZ90b and IMZ92). The IER-EEI is the subject of this report.

1.2 The request for a report

On 3 February 1993, the Minister of Housing, Spatial Planning and the Environment requested a report from the President of the Health Council. The subject of this report was an Environmental Exposure Index to be used for the further development of integral environmental zoning.

The Minister submitted a number of questions to the Health Council relating to the scientific basis of a study carried out by the TNO Institute of Prevention and Health (TNO-P&H), part of the Netherlands Organisation for Applied Research. The study in question concerned the cumulative action of noise and odour, based on actual perception of annoyance and on two IER studies into an EEI. The Minister also posed several specific questions about the approaches and methods used in deriving the IER-EEI. In addition, the Minister requested suggestions from the Health Council with regard to follow-up research. The complete text of the request for a report is presented in Annex A.

The President of the Health Council referred the request for a report to the Standing Committee on Environmental Factors and Health, to be referred to hereafter as 'the Committee'. Details of the Committee's composition are set out in Annex B.

1.3 Committee procedure

The Committee formed a working party to assist with the preparation of its report. This working party consisted of several Committee members and a number of external

experts (see Annex C). The Committee based its report on a draft document produced by the working party.

1.4 Design of the report

In Chapter 2 the Committee describes the role of the EEI concept in policy planning, while in Chapter 3 it provides details of the EEI developed by the IER. Chapter 4 sets out the standard EEI assessment criteria adopted by the Committee, together with the actual assessment of the IER-EEI based on these criteria. The TNO Prevention & Health (TNO-P&H) study is also discussed in Chapter 4. The Committee presents its conclusions in section 4.5 and its answers to the Minister's questions in Chapter 5.

Chapter 2

The environmental exposure index in policy planning

Protecting the health of the present human population, as well as that of future generations, is one of the goals underpinning attempts to achieve sustainable environmental quality. The current concept of health* is not restricted to the absence of illness and other ailments, it also incorporates physical, social and mental well-being (GR94a, WHO81, WVC88). The Health Council has previously defined health as being an essentially dynamic condition of the individual, whereby physical and mental functioning is optimal (in the opinion of the person concerned and that of their physician, and taking the person's own physical and mental capacities into consideration), allowing for their age, sex, and the general state of health of the population to which they belong, judged according to current scientific knowledge and the corresponding state of health care, the current era, as well as prevailing cultural patterns and social opinions (GR77). The quality of the physical environment is defined as a collection of chemical, physical and biotic conditions that can affect people. It influences the state of health of individuals as well as that of the population as a whole. Other factors that have a major influence on health, such as genetic predisposition, lifestyle, socioeconomic status and the quality and accessibility of health care (VTV93, ZvM88), are not considered in this report.

The government has developed general policies for the establishment of standards and priorities, as part of the effort to alleviate the negative effects of environmental

* The concept of health has been elaborated upon in several reports of the Health Council. This was often done in connection with the subject of the reports (e.g., GR77 and GR94a). The Committee explicitly presents its interpretation and use of the concept of health in relation to an EEI in section 4.1.

factors on people's health and on their surroundings. The Integrated Management Plan for the Environment (1986-1990) was the first step in this direction. This framework was further elaborated in the first National Environmental Policy Plan (NMP), especially in the attached policy memorandum entitled 'Premises for Risk Management' (PRM, see TK89). As a result of recent letters to Parliament (TK93a,b) and the ensuing exchange of views between Government and Parliament, the concept of a negligible risk level as the ultimate goal of progressive standards has now been discarded (with the single exception of substance policy). This implies that the ALARA (as low as reasonably achievable) principle from the PRM memorandum has been restored to its usual meaning of optimization without a fixed endpoint. The maximum tolerable risk level assumes the role of a precondition, which means that any situation in which this level is exceeded becomes unacceptable.

Government risk policy focuses on the risk* of accidents in industrial installations and of exposure to substances, radiation, noise, odour and genetically modified organisms. The approach to risk is based on the premise that any potential damage to people's health, or to that of their environment, can be estimated in quantitative and qualitative terms. Such estimates underpin the measures taken to limit risks.

The combined risk to health due to various forms of exposure could be considered as a single, 'integrated' risk to health. What is needed is a comprehensive perception of the potential damage to human health based on all the environmental factors present at a given site. This comprehensive perception of the situation is termed an Environmental Exposure Index (EEI).

A step by step plan has been devised (IMZ89) for the development of a system of integral environmental zoning. The Ministry of Housing, Spatial Planning and the Environment initiated research into the cumulative health effects of exposure and the prospects of quantifying them. While awaiting the results of this study the Ministry itself developed an IEZ method. Its purpose was to find prompt solutions for prevailing bottlenecks caused by combining the consequences of multiple exposures. This method, referred to as Preliminary Systematics (PS), was used in a limited number of projects (IMZ90a). Subsequent evaluation revealed dissatisfaction among the local authorities carrying out these projects. They lacked an understanding of the basic principles that had shaped the development of the PS. Clearly, an important criterion for the procedures followed when assessing the integral effect of environmental factors on health is that they should be as comprehensible as possible (Gun94).

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* The quantitative and qualitative aspects connected with the concept of risk vary from user to user. Risk is strongly associated with the possibility of damage being sustained by people and their environment, as well as with the nature and magnitude of such damage. More detailed discussions of the concept of risk are to be found in previous Health Council reports, such as 'Principles of radiological protection' (GR94b) and 'Not all risks are equal' (GR95).

Chapter 3

Description of the IER Environmental Exposure Index

3.1 The concept underlying the IER-EEI

In this chapter the Committee describes the EEI that was submitted for assessment. The IER-EEI derives its name from the Institute for Environmental Research of the Free University in Amsterdam, where it was developed.

IER research staff first carried out a feasibility study of an EEI. The ensuing report (IMZ90b) cited issues of a conceptual, policy-related and scientific nature that these workers consider of relevance to the process of calculating an EEI. Their approach is based on effects on health (IMZ90b).

"The EEI to be developed should indicate the exposure that people (might) experience at a given site as a result of given contaminating components (section 1.4 IMZ90b).
In this study, as is usually the case, 'exposure' is taken to mean the dose of an agent affecting a target organ or the whole body. This approach enables exposure to be related to deleterious health effects (section 1.4, IMZ90b).

Dose-effect relationships form the background and cornerstone of a complete framework that might serve as a basis for a possible yardstick of environmental exposure. Specifically, this is the relationship between people's exposure to an agent and the latter's effect on their health (section 4.1, IMZ90b).

A health based approach to the cumulative effects experienced by people following environmental exposure is preferable from the scientific point of view. Accordingly, it makes more sense to develop a

method that is directly based on health related data (methods A and B) than one that is based on standards (method C) (section 7.5, IMZ90b)."

The comments made by IER research workers with regard to the integration of various types of environmental exposure included the following:

"Integration in an EEI is based on the possibility that various forms of environmental exposure are associated with systemic stress. In this context, it is important to realize that agents acting at different sites can produce a combined effect on the human body (page 12, IMZ90b)."

They go on to state that:

"systemic stress is a complex phenomenon that cannot be measured readily (page 12, IMZ90b)".

People's exposure to noise, odour, local air pollution (by toxic or carcinogenic substances) and the risk of their health being damaged by industrial accidents is assumed to produce a common effect (systemic stress). It is this which allows these disparate elements to be conceptually combined and expressed as a single figure, the EEI.

In terms of the policy guidelines, the research workers summarize the critical characteristics of an EEI as follows (section 2.4, IMZ90b):

- "The use of the EEI must be compatible with zonation policy (noise, odour); the sources of the exposure should be easily traceable.
- The use of the EEI must be compatible with the relevant sectoral standards; when limit values are exceeded, the results obtained from the index should make this immediately apparent.
- The results obtained from the index should also indicate the societal valuation of various forms of environmental exposure.
- The index must be easily applicable; its suitability for use must be reflected in calculation methods with a high degree of accessibility, applicability and efficiency, in addition to compatibility with currently available measurement data.
- The index must have advantages over currently available instruments designed to achieve the same purpose.
- The index must have advantages over currently available instruments if it is to achieve the same purpose.
- It must have a potential for expansion to allow for the inclusion, in due course, of additional contaminating components and of effects other than those in people.
- If it is to be acceptable to the general public, the index must have genuine appeal, it should not be just another obscure number."

Finally, the authors of the feasibility study also formulate the scientific requirements for an EEI, as follows (section 2.4, IMZ90b):

- "The index must be a good representation of the environmental exposure that is considered relevant (validity).
- The results yielded by the method must have a sufficiently precise level of reproducibility (reliability).
- All steps taken when developing the EEI and all assumptions made must be clear and easy to follow (verifiability)."

3.2 Variants of the IER-EEI

Reports produced by the IER describe several variants of an EEI, designated EEI/A, EEI/B and EEI/C. Despite their differences, there is a common thread running through each of these variants. They all combine the degree of damage to the health of the population caused by exposure to noise, odour, or polluting substances as well as from (the risk of) an industrial accident, and express it as a single measurement of the quality of the environment (IMZ92).

In method A, environmental exposure is approached from the viewpoint of (health) effects that are seen as deleterious. To this end, the research workers adopt a classification system based on the categories of annoyance, toxic effects and mortality. They combine exposure to various sources by effect category, which generates a sub-index for each individual effect category. Subsequent aggregation of these sub-indices then yields an EEI number (see Table 1a).

Table 1a Construction of the IER-Environmental Exposure Index. Variant A.

input data	combination to sub-index	sub-index after rating	aggregation
noise L_1 to L_3	I_a	W_a	
odour L_4			$EEI = (W_a^p + W_t^p + W_m^p)^{1/p}$
toxic effects	I_t	W_t	
mortality	I_m	W_m	

a: annoyance, t: toxic effects, m: mortality.
L_1: noise of highway traffic and civil aviation. Industrial noise without impulse character.
L_2: noise of other road and rail traffic.
L_3: industrial noise with impulse character.
L_4: odour.

Table 1b Construction of the IER-Environmental Exposure Index. Variant B.

input data	combination to sub-index	sub-index after rating	aggregation
noise L_1 to L_3	I_n	W_n	
odour	I_o	W_o	$EEI = (W_n^p + W_o^p + W_t^p + W_c^p + W_e^p)^{1/p}$
toxic substances	I_t	W_t	
carcinogenic substances	I_c	W_c	
external safety	I_e	W_e	

n: noise, o: odour, t: toxic substances, c: carcinogenic substances, e: external safety
L_1: noise of highway traffic and civil aviation. Industrial noise without impulse character.
L_2: noise of other road and rail traffic.
L_3: industrial noise with impulse character.

Approach B also involves construction of the EEI on the basis of (health) effects that are seen as deleterious. Additionally, method B retains the sector classification used in environmental policy making. Analogous effects are combined into separate sub-indices for each of the exposure categories (noise, odour, toxic air pollution, carcinogenic air pollution and external safety). These sub-indices are then aggregated to yield an EEI number (see Table 1b).

Method C utilizes sectoral exposure standards rather than focusing directly on (health) effects that are seen as deleterious. The research workers express exposure to environmental factors as fractions of sectoral standards. These fractions are subsequently aggregated to produce a sub-index for each exposure category, after which the sub-indices are aggregated to yield an EEI number (see Table 1c).

Table 1c Construction of the IER-Enviromental Exposure Index. Variant C.

input data	indexing + rating	aggregation
noise	I_n	
odour	I_o	$MBI = (I_n^p + I_o^p + I_a^p + I_e^p)^{1/p}$
air pollution	I_a	
external safety	I_e	

n: noise, o: odour, a: air pollution, e: external safety.

3.3 Combination and rating in the IER-EEI

In the A and B variants of IER-EEI the impact on the environment per category is rated in two steps. First, the domain of the exposure to the environmental factor to be tested is established. The lower limit of this domain is the exposure that corresponds to the negligible risk level (NR), while the upper limit is the exposure corresponding to the maximum tolerable risk level (MTR).* This is followed by the introduction of a valuation function. To this end the IER research workers propose a linear increase in impact of exposure between NR and MTR. Finally (in variant A) the rated sub-indices for the various exposure categories are combined into an EEI number, according to the following formula:

$$(W_a^p + W_t^p + W_m^p)^{1/p}$$

The process of estimating the value of 'p' is also a rating step. The value of 'p' proposed in the IER reports is 2 (IMZ90b, page 81).

The IER research workers have also imposed the following limitation on the use of the proposed EEIs. These variants will be invalidated if exposure to an arbitrary agent exceeds the sectoral standard established by the Dutch Government for that agent.

The IER research workers appended the following comment to their proposals (IMZ90b, pages 97 etc.):

"From a purely scientific point of view, method A is to be preferred. This method is based, as far as possible, on empirical data and the rating is determined on the basis of environmental hygiene. From a broader perspective with respect to health, method A is better at handling instances of multiple exposure to the same substances via several different exposure routes. Method B involves classification of the effect categories into sectors. This entails additional value judgments, which hampers the process of verification. In method C, the approach used to establish a standard is not easily comprehensible and does not restrict itself to ratings based purely on environmental hygiene. Accordingly, there is a lack of certainty about whether the calculated EEI is indeed a faithful representation of the residential environment. Moreover, from a scientific standpoint, verifiability also leaves something to be desired.

From the point of view of policy, method C is the one that best satisfies several requisite characteristics. The method can be easily extended to cover additional agents within the same sector or to include extra sectors. Furthermore, method C has been shown to offer the best compatibility with zoning policy.

* The terms NR and MTR are used for the risk limits as well as for the exposure norms derived from these limits. The Committee points out that the derivation of an exposure norm from an exposure limit can occasionally be ambiguous.

With regard to the relative appeal of the various methods, no verdict has yet been reached. This depends on the actual application of the method, in which the true relevance of the EEI's domain will be established."

Chapter 4

Assessment of the IER Environmental Exposure Index

4.1 The concept

The Committee observes that in the IER-EEI concept the impact of environmental factors is related to damage to human health. Available reports (IMZ89, IMZ90a, IMZ90b) fail to make clear whether this decision resulted from an explicitly formulated government position to the effect that all EEIs should be based on risks to health. The aims of zoning, however, reveal that this is indeed the case. Obviously, one can conceive of alternative EEIs in which additional negative effects of environmental exposure are taken into account, such as damage to ecosystems. In this context, the Committee limits itself to negative effects on human health. The Committee believes that the concept of damage to health is covered reasonably well by:

- mortality
- deleterious effects, including disease and trauma
- annoyance
- negative experience of the residential environment, including fear of damage to health, mental burden.

According to the Committee, in addition to reflecting the empirical data, any measure of health risk should also have a comprehensible structure. Unless an EEI meets the first criterion, its health related significance will remain unclear, while failure to meet the second will impede its social acceptance.

The IER-EEI is based on the implicit assumption that human exposure at a particular site is relatively constant and that all members of the resident population experience it to the same degree. This assumption involves a major simplification of reality. Even when a population has lived at a site for an extended period, its exposure to environmental factors will vary from minute to minute and from year to year. The composition of the population will also change over time, and the fact that exposure to environmental factors may play a part in this serves to complicate matters still further. These considerations mean that it is difficult or even impossible to make reliable estimates of exposure and of the concomitant effects on health.

Not all types of exposure to environmental factors have been included in the IER-EEI. Furthermore, the effect on health due to most environmental factors is slight in comparison with the effects of other factors such as lifestyle, profession, housing and genetic predisposition, which makes it difficult to measure. The practical implication of this is that epidemiological studies of the population concerned cannot be used to test the (predictive) value of the EEI. Usually, a health risk can only be estimated by means of exposure data and exposure-response relationships. This does not mean, however, that these are grounds for rejecting an EEI out of hand. It is conceivable that the separate elements making up an EEI could be tested individually.

4.2 The procedure

The Committee has identified the following individual parts of the EEI procedure:

- collection of data about the site (exposure data)
- establishing exposure-response relationships for the agents to be assessed
- drafting rules for combining the anticipated health damage inflicted by the agents concerned.

The Committee feels that, in general, the actual degree of exposure to each individual stressor should be indicated when deciding upon the specific EEI procedure to be used. This is because the same environmental factor can inflict different types of damage, dependent on the degree of exposure involved. Take noise, for example. Low exposure results in annoyance, whereas higher exposure can cause damage to hearing. When considering exposure-response relationships, it is essential to select effects which give a true picture of the actual health risks involved at the level of exposure in question. Both the exposure data and the health damage data from which the exposure-response relationship was derived must meet the usual quality criteria (validity, reliability and verifiability). All measurements of exposure at a given site should be performed reliably and reproducibly. Furthermore, the original data on which model calculations of

exposure are based must be correct and complete in every detail.* The exposure-response relationships established for the agents to be assessed should be based on empirical data.

Concerning attempts to combine different effects, the Committee stipulates that these be restricted to effects that can be expressed in the same unit of quantity ('given the same common denominator'). A second requirement is the availability of exposure-response relationships showing the effects of varying degrees of exposure to combinations of the factors involved. If the effects are strictly additive, it might be sufficient to use exposure-response relationships in which the same effect has been measured using each of these factors.

The IER imposed several restrictions on the derivation of the EEI.** The Committee feels that the most important of these are:

- with respect to *sectors*: limiting consideration to air pollutants, odour, noise and external safety (thereby excluding factors such as ionizing radiation, vibration and biological agents)
- with respect to *sources:* limiting consideration to local sources (thereby excluding contamination by other sources which - together - constitute the background level of exposure at a given site)
- with respect to *routes:* (routes followed by substances): the IER-EEI limits itself to outdoor air (thereby excluding intake via soil or food, for example)
- certain health effects were excluded when deriving the IER-EEI, such as the annoyance caused by feelings of insecurity among the population of a site with questionable external safety; with respect to exposure to carcinogens, the effects on subsequent generations were excluded, as were those relating to disease; with respect to the health effects associated with external safety, both disease and invalidity were excluded
- there is no discussion of whether sensitive groups could or should serve as benchmarks within the EEI procedure.

According to its developers, the EEI can only be applied in cases where exposure has not exceeded sectoral standards. However, the Committee feels that an EEI based on health effects need not necessarily be subject to this restriction.

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* The IER study makes no specific mention of this. The Committee therefore assumes, by implication, that the research workers involved observed the current rules governing measurements and calculations.

** The Committee's comments are equally applicable to all IER-EEI variants (A, B and C).

4.3 Environmental factors

4.3.1 Noise

Exposure-response relationships have been derived for annoyance and exposure to noise (see Annex D). The relationship between annoyance scores and exposure to noise (expressed as an L_{etm} value) are based on empirical data. In view of this, the Committee considers these relationships to be sufficiently valid (certainly for the 50-70 dB(A) range that is relevant to zoning policies) to warrant their use in predicting noise annoyance (based on the L_{etm}*) for any given site in the Netherlands. This involves the prediction of an average annoyance score associated with a given L_{etm} value.

The Committee believes that the existence of a common health effect (annoyance) provides a good basis for combining noise from different sources. The measure of environmental quality (MKM(noise) - see Annex D) offers an indication. This yardstick is valid provided that the L_{etm} values for individual sources do not exceed 70 to 75 dB(A), dependent to some extent on the source. The reason for this restriction is that the measure is partly dependent on exposure-response relationships, and these have yet to be determined for values in excess of those cited above. Moreover, noise levels above 70 dB(A) increase the risk of conditions such as hypertension or ischaemic heart diseases (GR94a). However, the measure in question is purely an indicator of annoyance, and attaches no weight to such somatic effects.

4.3.2 Odour

The Committee feels that the empirical data provide a suitable basis for predicting annoyance due to odour at any given site in the Netherlands. This would be based on $C_{99.5}$, the concentration in odour units per cubic meter that is exceeded 0.5% of the time (see Annex D). The predicted value would be the average annoyance score associated with a given $C_{99.5}$ value. Given the heterogeneous nature of odours, there is a clear requirement for additional data on different sources of odour. The emission from an industrial plant may be the sum of individual emissions from various co-sources. These emissions occur at different sites and times, involving a different odour in each case. Here, $C_{99.5}$ is actually a measure of the cumulative annoyance caused by odours from various co-sources. The approach presented in Mie93, also uses $C_{99.5}$ to make a

* The 24-hour (in Dutch: etm) value is the highest value of the following three levels:
a the equivalent noise level during the day, i.e. between 07.00 and 19.00
b the equivalent noise level during the evening, i.e. between 19.00 and 23.00, increased by 5 dB(A)
c the equivalent noise level during the night, i.e. between 23.00 and 07.00, increased by 10 dB(A).

combined assessment of odour emissions from different sources (industries). The relationship between $C_{99.5}$ and annoyance has been established for $C_{99.5}$ values up to approximately 100 odour units per cubic meter. A separate assessment should be carried out to determine whether any of the substances in the mixture have effects above and beyond odour annoyance.

4.3.3 *Substances*

When assessing the consequences of exposure to substances, it is usually assumed (GR85) that substances can be differentiated on the basis of a threshold value. A distinction is made between substances whose effects are known to have a threshold value* (i.e. substances that will not cause harmful effects, even after chronic exposure, provided their concentration remains below a certain value) and those whose effects have no such value**. The latter category includes genotoxic carcinogens and mutagens, substances that are generally assumed to pose a health risk whatever the level of exposure.

Different rules hold for the two categories of substances regarding the extrapolation of experimentally established exposure-response relationships. Toxicity data is only available for a few of the substances whose effects exhibit a threshold value, and even then it is usually only derived from animal experiments. These figures are based on findings that are very heterogeneous in terms of the species of experimental animal involved, the numbers of such animals used, the number and type of human volunteers, as well as the type and intensity of the effect involved. Turning to substances whose effects have no threshold value, where genotoxic carcinogens are involved the additional risk of cancer (GR78, GR88) is taken into account. Reliable data are only available in a few dozen cases. Moreover, depending on their nature and quantity, substances can cause both odour annoyance and cancer or other toxic effects.

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* One cannot simply assume that a substance has a universal threshold value. The Committee notes that, in the case of substances with threshold values, this value can vary from person to person, particularly where certain individuals are hypersensitive to a given substance as a result of sensitisation (allergens).

** In the light of recent developments in research on the origin and development of cancer, it remains to be seen whether the classification of substances into those that have a threshold value for a given effect and those that do not is still viable. The Health Council will consider this matter in its forthcoming report on the bases for establishing standard values.

On the basis of current knowledge, exposure to a substance at levels below the NOAELa* or below the threshold value would not be expected to produce any deleterious effects on health. No data is available regarding the possible effects which substances at exposure levels below the NOAELa might have on the kinetics of other substances. This leads to additional problems when dealing with combinations of substances. Multiple exposure to a range of substances, each with different effects, has been examined in a handful of animal experiments. The results obtained indicate that the effects are not additive below the NOAELa (Fer93).

Take the case of exposure to a mix of toxic substances that is typically encountered in the practical situation. If these exceed the threshold values for their effects, each substance will generally exert its strongest (potential) effect on a different target organ. This means that this mix has (potentially) a diversity of effects. Where multiple effects occur in an individual (or a population), the Committee feels that the resultant health damage cannot be adequately expressed by a single number. For the time being there is no common denominator. In the Committee's view, a combined toxicity index for substances with heterogeneous effects has no biological significance whatsoever. However, it would be feasible to produce a combined toxicity index for substances with similar effects. The example cited in IER reports on the EEI relates to a group of substances from a single category. It unjustly conveys the impression that this approach can be made generally applicable.

In the case of substances with effects that have no threshold values, the Committee feels that the risks (increased incidences) pertaining to mortality can be added up. However, this is conditional upon there being only a very slight increase in the incidence of cancers caused by exposure to substances in the environment. The epidemiological and experimental animal data used to determine a health based recommended value usually focus on cancer incidence. However, given the success rates of current therapy, mortality due to cancer is significantly lower than the actual incidence of the disease. Since cancer involves a range of disorders with widely differing pathologies and prognoses, the EEI concept could have been expanded to include the resultant additional disease burden. In the Committee's view, the IER-EEI procedure is flawed by the failure to include such a proposal.

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* NOAELa: threshold value for the occurrence of an effect divided by an uncertainty or safety factor. This is a variant used by the IER of the general concept NOAEL (threshold value for an effect). The Committee does not offer any opinion about the use of the term NOAELa (comparable to health-based recommended value and TDI, accepted daily exposure). The Committee does comment that a better estimate of the magnitude of the threshold value for an effect in man can often be obtained by not applying some of the uncertainty or safety factors. This matter, however, is not relevant for the conclusion of the Committee with respect to substances.

4.3.4 *External safety*

*External safety** involves calculating the magnitude of the additional risk of mortality due to an accident at a given industrial installation per year of operation. In this connection, the Committee sees the failure to take account of illness and permanent invalidity as effect categories to be a weakness. Disasters can involve the generation of substances, ionizing radiation, heat radiation and overpressure. Known exposure-response relationships for various substances are used when calculating the risk. However, the domain of exposure associated with disasters greatly exceeds the permissible level of daily chronic exposure to these substances. It is seldom possible to establish complete exposure-response relationships for these levels of exposure (Wou92), given the limitations of available data. However, there is a better understanding of the exposure-response relationships for heat radiation and overpressure. The worst case scenarios used to calculate mortality risk due to an industrial accident are extremely inaccurate. Calculations of the disaster risk can involve an uncertainty factor of 10 - 100. Exposure can be calculated to a factor of 1.1 to 2, while similar calculations regarding the consequences for health are accurate to a factor of 10 (Bio90). The Committee feels that, within the external safety category, the risks of mortality due to different types of disasters can be added up, even though the causes can vary enormously.

In recent years, a considerable amount of research has been carried out in this area, both at national and international level. These studies relate primarily to the *perception* of local risks and to the *feelings of insecurity* associated with industrial environments. Both in terms of theory and methodology, there have been substantial improvements in scientists' understanding of the experience of insecurity. However, research has yet to produce a truly standardized, large-scale approach that can be applied to the development of environmental and safety policies. A method for the measurement of the mental load experienced by a population as a result of environmental exposure, 'Environmental Powerlessness' (Cla93a), is described in Annex E.

4.4 Combination and valuation of effects of different categories of exposure

Noise and odour have a common quantifiable health effect: annoyance. This satisfies an important condition formulated by the Committee for the combination of different

* The Committee uses the term 'external safety' purely because it is conventional to do so. However, it is of the opinion that 'external insecurity' better conveys the meaning of the concept (risk of mortality or other forms of severe damage to health as a result of industrial accidents).

environmental factors. Another condition is the availability of empirical data concerning the magnitude of the effect of combinations. Here it is important to establish whether corresponding categories of noise and odour (at least some annoyance, annoyance, major annoyance) express a corresponding degree of aversion. Comparative research carried out by Miedema (Mie93) showed that sources of noise and odour from identical categories of annoyance do indeed produce an identical degree of aversion.

Even though carcinogenic effects and accident risk ('external safety') can both lead to mortality, the Committee considers the development of a combined sub-index based on empirical data to be impractical. Carcinogens and accidents, however, can also lead to illness. Neither the natural sciences nor medicine can provide a common denominator for illness and death. If mortality alone were to be used as a common denominator for these two factors then an argument could be made in favour of a combined sub-index. However, this would only apply in the case of a postulated 'model population' that remains on the site in question long enough for every single health effect resulting from environmental influences to be expressed.

The 'valuation' procedures proposed by the IER utilize a linear exposure-response relationship extending from 'negligible risk' to 'maximum acceptable risk'. They also assign a value of 2 to exponent 'p' in the combination formula for the various exposure categories ($W^p_a + W^p_t + W^p_m$). The Committee points out that no empirical basis has been provided for these procedures, nor do the selected functions have sufficient scientific support.

The Committee believes that health effects in the form of annoyance, illness and death cannot be aggregated into a single unit. Long-range forecasts of public health in the Netherlands make mention of a composite yardstick for health, incorporating both the duration and quality of life. This yardstick could "probably lead, in the future, to the integrated quantification of the state of health of a population in a single number" (VTV93). In the context of the EEI, this would be analogous to a annoyance-free expectation of life. The problem here, however, is that it must be possible to equate the number of annoyance-free days lost as a result of noise annoyance or toxic substances to a given number of annoyance-free days lost due to premature death caused by environmental factors. The Committee feels that this problem will remain unsolved unless empirically based criteria can be identified for the conversion of these effects into a common unit. No such criteria are presently available, nor can they be established on scientific or medical principles alone.

4.5 Conclusions

The Committee concludes that the lack of any empirical scientific or medical basis prevents the construction of a single scale for health damage or risk associated with

annoyance, illness and death. Techniques developed in the social sciences, relating to value judgment and decision models, could be helpful in administrative decision making.

Chapter 5

Answers to the questions from the Minister of Housing, Spatial Planning and the Environment

5.1 Question A1:

The TNO Prevention & Health (TNO-P&H) study suggests a yardstick of environmental quality for use with noise and odour. Can the Health Council offer an opinion regarding the scientific basis of this environmental quality yardstick?

The yardstick in question is a measure of annoyance. In this connection, TNO Prevention & Health (TNO-P&H) has established two exposure-response relationships (Mie93). The first compares exposure to noise (experienced by the general population in residential areas) with annoyance, while the second compares exposure to odour with annoyance. The Committee considers these relationships to be adequately supported by empirical data (see 4.4 and Annex D). Annoyance, whether caused by odour or noise, is a health effect that occurs at low exposure values. The proposed yardstick is capable of *verification (can be empirically supported)*. This can be done by asking people exposed to combinations of certain types of noise and odour for their opinion regarding the actual annoyance caused. With regard to *quantification*, it has been shown that an increase in the numerical value (annoyance score) of the yardstick for environmental quality does correspond to an increase in actual perceived annoyance. The Committee considers that the *rules for combination* have sufficient empirical support. This also holds for the values of the parameters of the rules for combination of various types of noise. The combination rule proposed by Miedema (Mie93) for odour

and noise (linear addition based on equivalent annoyance score) has the Committee's support.

Given the present state of the art, the proposed annoyance score is a useful representation of the degree of annoyance experienced by the general population as a result of combinations of odour and noise.

5.2 Question A2:

Three aggregation methods were developed during the EEI feasibility study and the follow-up study. The factors to be combined by these methods were noise, odour and local air pollution by toxic and carcinogenic substances and the risk of death due to disasters in industrial complexes. Can the Health Council offer an opinion regarding the scientific basis of these studies as a whole and of each individual method?

The EEI attempts to express the health risk at a given site, caused by local sources of odour, noise, toxic substances, carcinogens and external safety. The Committee notes that the IER-EEI contains several flaws, primarily concerning the environmental factors and the effects on health selected for investigation. However, the Committee considers that the IER-EEI is correct in combining odour and noise using empirical data for annoyance. This facilitates the construction of a single, reliable sub-index that is related to health damage. A annoyance index for combinations of odour and noise. The Committee rejects the idea of combining the other effects with each other, or with annoyance, on the grounds that this would lack sufficient scientific or medical credibility. In principle, the construction of an EEI requires that annoyance, illness and death be expressed in common terms. This is not a scientific or medical issue, it is a question of valuation.

5.3 Question A3:

Can the Health Council indicate the primary points that it would like to see addressed in the follow-up study?

Clearly, no amount of additional scientific or medical knowledge will lead to the intended type of EEI. The only way in which effects on health such as annoyance, illness and death can be given a common denominator is by the use of value judgments. Techniques developed in the social sciences, relating to value judgment and decision models, could be helpful in the relevant administrative decision making.

5.4 Question S1:

Is the Health Council able to express a scientifically based preference for one of the three IER methods?

In the quest for an EEI, the preferred procedure would employ an appropriate common denominator for combining exposures to a number of different agents. This would be a health effect that is, as far as possible, measurable, predictable and comprehensible. The first step of variant A conforms with this view, to some extent, by generating sub-indices for annoyance, toxic effects and mortality. However, the Committee feels that subsequent steps lack any empirical scientific or medical basis.

5.5 Question S2:

The IER introduces a sub-index for toxic substances into the toxic substances category. The value of this sub-index is determined by first calculating the quotient of concentration and NOAEL for each substance, and then simply adding together the various fractions. In the Health Council's view, how practical is the IER's proposed method for aggregating the effects of various toxic substances, given the limitations of this method indicated by the IER itself?

The Committee believes that it would be feasible to construct a combined toxicity index based on a single given effect produced by substances with the same point of action. Indeed, the example cited in the IER-EEI reports belongs to this group. However, this should not be taken to mean that the approach adopted in these reports can be generalized. The greater the difference between substances' points of action, the less plausible such an index becomes. This is particularly true in the case of substances with differing primary health effects. The Committee feels that a combined toxicity index for substances with dissimilar health effects would lack any biological significance.

The limitation indicated by the IER itself concerns the specific collection of substances with comparable actions that was considered by that institute. The IER is fully aware that this type of addition cannot be applied to just any collection of substances. While agreeing with this in principle, the Committee feels that the true importance of this limitation has been understated. The index actually lacks any real significance for the most frequently occurring combinations of substances.

5.6 Question S3:

Does the Health Council consider the use of the proposed valuation methods for determining integral environmental quality to be scientifically justified?

In the IER reports, the concept of integral environmental quality has been made operational through the creation of an 'Environmental Exposure Index' (EEI) based on anticipated health damage. The process of defining such a measure always requires the use of various steps to combine the effects of diverse factors. This applies to the establishment either of exposure-response relationships and of rules for combinations. The IER has proposed the following valuation procedures: 1) a linear exposure-response relationship for each exposure category, extending from 'negligible risk' to 'maximum acceptable risk' and 2) a value of 2 for the exponent 'p' in the formula for combining the different exposure categories ($W^p_a + W^p_t + W^p_m$). However, the Committee notes that no empirical support, nor indeed any type of scientific basis, was offered in either case.

5.7 Question S4:

The shape of the valuation function between the relevant limit and target values for the various categories of environmental exposure plays an important part in the first aggregation step. Can the Health Council comment on the selected functions and, in particular, on the two distinct approaches to the accident risk (mortality risk) category mentioned in the IER follow-up study report?

This question, like its predecessor, springs from a conceptual framework that is quite different from the one used by the Committee. The Committee has restricted itself to exposure-response relationships and rules for combination that are based, as far as possible, on empirical data. 'Valuation functions' do not fall within the scope of empirical scientific inquiry.

5.8 Question S5:

The factor 'p' plays an important part in the second aggregation step. Can the Committee indicate an appropriate value for this factor?

The Committee feels that the question regarding the exact value of 'p' is of little relevance, since this occupies a domain that is beyond the scope of empirical scientific or medical assessment.

The Hague, April 27 1995,
on behalf of the Committee
(signed)

JAG van de Wiel,	L Ginjaar,
Secretary	Chairman

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Annexes

Annex **A**

Request for a report

The Secretary of State for Welfare, Health and Cultural Affairs received the following letter (code MBG 07D92011, dated 3 February 1993) from the Minister of Housing, Spatial Planning and the Environment:

Dear Mr Simons,

I am writing to ask your assistance with a request to the Health Council for a report on an aspect of integral environmental zoning. More specifically, this concerns the methods to be used in the aggregation of different types of environmental exposure. The request for a report has been structured as follows: there is a brief introduction, in which the Integral Environmental Zoning instrumentation is discussed, followed by a description of the results of some relevant studies. Next comes the actual request. This is subdivided into various questions, some of which are of a general nature while others are more specific.

Integral Environmental Zoning

In 1988, the Ministry of Housing, Spatial Planning and the Environment initiated the 'Aggregation of Sources and Integral Environmental Zoning' project. This project was intended to supplement sectoral policies. Its purpose was to arrive at a set of rules for tackling specific conflicts relating to planning and environmental management. These occur (or threaten to occur) in areas with complex industrial installations, as a consequence of the aggregation of various environmental exposures. More than four years have elapsed since then and the project is now approaching completion. The work included studies into the cumulative effects of the following disturbance components: noise, odour, substances and external safety.

With respect to external safety, only the individual risk (projected in spatial terms) has been considered and not the group risk.

The current state of affairs is that industrial areas associated with an accumulation of environmental exposures have been identified with reasonable accuracy. The magnitude of environmental exposures is also well understood. There is an equal level of awareness concerning the possible planological consequences of zoning and of the costs of measures for tackling pollution at source. Considerable experience has been gained in the application of the Integral Environmental Zoning instrumentation, which has now been used in twelve pilot projects. In the course of these projects, the Preliminary Systematics for Integral Environmental Zoning was used to chart environmental exposures around the relevant industrial areas. The environmental exposures were aggregated using a combination method based on policy considerations. In the majority of projects, preparations for decontamination are currently under way. Furthermore, within the framework of this project, research has been carried out into the scientific aspects of combining environmental exposures (the components of the disturbances). The objective is to develop a zoning arrangement and a definitive, systematic approach to zonation. This research forms a basis for the development of an environmental exposure index (EEI).

The development of an Environmental Exposure Index

TNO Prevention & Health (TNO-P&H) (TNO Institute of Preventive Health Care) is currently in the final stages of a research programme based on studies of the perception of annoyance. The aim is to develop a method for combining the effects of noise and odour. A recently published draft version of the final report contained summaries of each of the component reports. A copy of the draft report has been included with this letter, as an annex. A copy of the definitive final report relating to this study will be forwarded immediately upon completion.

In parallel to the NIPG studies, the Institute for Environmental Research of the Free University of Amsterdam (IER) has carried out two studies into the feasibility of an EEI for integral environmental zoning. The first report, entitled 'EEI feasibility study', was published as part of the IMZ series (no. 8), in October 1990. As a result of the feasibility study, three methods were drawn up that could potentially be used for the combination of noise, odour, external safety risks and air pollution. To this end, the feasibility study drew on various sources, including the TNO Prevention & Health (TNO-P&H) findings concerning the combination of noise and odour. The IER later published another study in the same series (no. 24), entitled 'EEI follow-up study'. This contained proposals, based on discussions with experts and on the results of a workshop, for resolving the remaining questions.

Request for a report

Pursuant to the above study, I should like to invite the Health Council to offer recommendations for the development of integral environmental zoning. Particular attention should be given to the following questions:

Question A1:

The TNO Prevention & Health (TNO-P&H) (TNO Institute of Preventive Health Care) study produced a yardstick for environmental quality in relation to noise and odour. Could the Health Council provide an assessment of the scientific basis for this yardstick?

Question A2:

Three aggregation methods were developed during the EEI feasibility study and the follow-up study. The factors to be combined by these methods were noise, odour and local air pollution by toxic and carcinogenic substances and the risk of death due to disasters in industrial complexes. Can the Health Council offer an opinion regarding the scientific basis of these studies as a whole and of each individual method?

Question A3:

Can the Health Council indicate the primary points that it would like to see addressed in the follow-up study?

In addition to these general questions, I would also ask that you address yourself to a number of more specific questions about the IER study:

Question S1:

Is the Health Council able to express a scientifically based preference for one of the three IER methods?

Question S2:

The IER introduces a sub-index for toxic substances into the toxic substances category. The value of this sub-index is determined by first calculating the quotient of concentration and NOAEL for each substance, and then simply adding together the various fractions. In the Health Council's view, how practical is the IER's proposed method for aggregating the effects of various toxic substances, given the limitations of this method indicated by the IER itself?

The IER proposes to develop an integrated EEI by the use of rating methods for the aggregation of various effect indices (method A) or exposure category indices (method B). This approach requires two steps. First, the value(s) of the effect and/or exposure category indices must be translated into rating scores. These scores indicate the extent to which the effects or exposures in question are considered undesirable. Second, the rating scores are combined into a total score, based on weighting of the various ratings.

Question S3:

Does the Health Council consider the use of the proposed valuation methods for determining integral environmental quality to be scientifically justified?

Question S4:

The shape of the valuation function between the relevant limit and target values for the various categories of environmental exposure plays an important part in the first aggregation step. Can the Health Council comment on the selected functions and, in particular, on the two distinct approaches to the accident risk (mortality risk) category mentioned in the IER follow-up study report?

Question S5:

The factor 'p' plays an important part in the second aggregation step. Can the Committee indicate an appropriate value for this factor? During 1993, I intend to take further steps toward the development of policies for integral environmental zoning. Your recommendations could be of pivotal importance with regard to the decisions that will have to be taken in the Autumn of 1993. Please bear this in mind, if possible, when planning your work schedule.

Yours faithfully,
Signed,
JGM Alders
Minister of Housing, Spatial Planning and the Environment

Annex **B**

The Committee

- L Ginjaar, *Chairman*
  professor of environmental science; Health Council of the Netherlands, The Hague
- A Wijbenga, *Vice-chairman*
  Province of South Holland; Service for water and environment, The Hague
- CJM van den Bogaard, *consultant*
  Ministry of Housing, Spatial Planning and the Environment, The Hague
- JSM Boleij
  Committee for the Registration of Herbicides/Pesticides, Wageningen Agricultural University
- B Brunekreef
  professor of health sciences; Wageningen Agricultural University
- LA Clarenburg
  emeritus professor of environmental science, University of Utrecht
- WF de Gids
  TNO Building and Construction Research, Delft
- HME Miedema
  TNO Prevention and Health, Leiden
- WRF Notten
  professor of occupational toxicology, TNO Prevention and Health, Leiden
- JJL Pieters, *consultant*
  Medical Inspectorate of Health, Ministry of Health, Welfare and Sports, Rijswijk

- HJA Schaap
  former advisor, Ministry of Housing, Spatial Planning and the Environment, The Hague
- HAJ Struyker Boudier
  professor of pharmacology and pharmacotherapy, University of Limburg, Maastricht
- MM Verkerk
  University of Amsterdam
- JH van Wijnen
  Municipal Health Service, Amsterdam
- JAG van de Wiel, *Secretary*
  Health Council of the Netherlands, The Hague

Editorial contributions: AB Leussink.
Administrative support: MI Roskam.
Lay-out: J van Kan.

Annex **C**

The Working Party

The Environmental Exposure Index (EEI) working party included the following members of the Committee:

- JH van Wijnen, *Chairman*
  Municipal Health Service, Amsterdam
- LA Clarenburg
  emeritus professor of environmental science, University of Utrecht
- HME Miedema
  TNO Prevention and Health, Leiden
- MM Verkerk
  University of Amsterdam

in addition to

- VE van der Gun, *consultant*
  Noise Abatement, Ministry of Housing, Spatial Planning and the Environment, The Hague
- CJH Midden
  professor of philosophy and social sciences; Eindhoven University of Technology
- GMH Swaen
  University of Limburg, Maastricht
- CAJ Vlek, consultant
  professor of social and organizational psychology; University of Groningen

- JAG van de Wiel, *Secretary*
  Health Council of the Netherlands, The Hague

Annex **D**

Exposure-response relationships for noise and odour

Noise

The unit L_{etm}* has been used as a measure of dosage. In the Noise Abatement Act, L_{etm} is used as a measure of exposure to sources of noise. The relationship between the annoyance score and the L_{etm} varies from source to source. At L_{etm} values below 40 dB(A), annoyance due to traffic is taken to be zero. Above this value, the annoyance score increases with the decibel level. However, the score due to air traffic and motorway traffic rises more steeply than the score associated with non-motorway traffic, trains or trams. Impulse noise is a special case. It is more intolerable than any other form of traffic noise, particularly at low levels. Any impulse noise loud enough to be heard is sufficient to cause annoyance.

At most sites in the study, the annoyance score for non-impulse industrial noise lay above the curve of the annoyance score for motorway traffic. Thus, where both have the same L_{etm} value, industrial noise causes more annoyance than does noise from motorway traffic. For industrial noise (a category that is very diverse in nature), the relationship with motorway noise is used as a 'conservative' approach to the relationship

* The 24-hour (in Dutch: etm) value is the highest of the following three levels:
a the equivalent noise level during the day, i.e. between 07.00 and 19.00
b the equivalent noise level during the evening, i.e. between 19.00 and 23.00, increased by 5 dB(A)
c the equivalent noise level during the night, i.e. between 23.00 and 07.00, increased by 10 dB(A).

between L_{etm} and annoyance score (a 'conservative' approach is one that tends to produce an underestimate of actual noise annoyance).

More than 13 000 assessments of noise annoyance were used to establish the relationship between L_{etm} and annoyance score. In each case, it was possible to link the assessment with the actual measured or calculated L_{etm} value of the noise in question.

This data was collected in NW Europe (Great Britain, Ireland, the Netherlands, Germany and (Northern) France). The correlation between L_{etm} and annoyance score in Figure 1 is 0.50 for traffic noise relationships taken together and 0.47 for impulse noise.

The proposed yardstick of environmental quality is calculated from the equivalent day, evening and nighttime noise levels per noise source. The L_{etm} value for a source of noise is also derived in this way. For each time of day, a 'weighted' combination has been set for the equivalent noise levels of various sources of noise. The 'weighting' was based on the above-mentioned exposure-response relationships. These indicate the

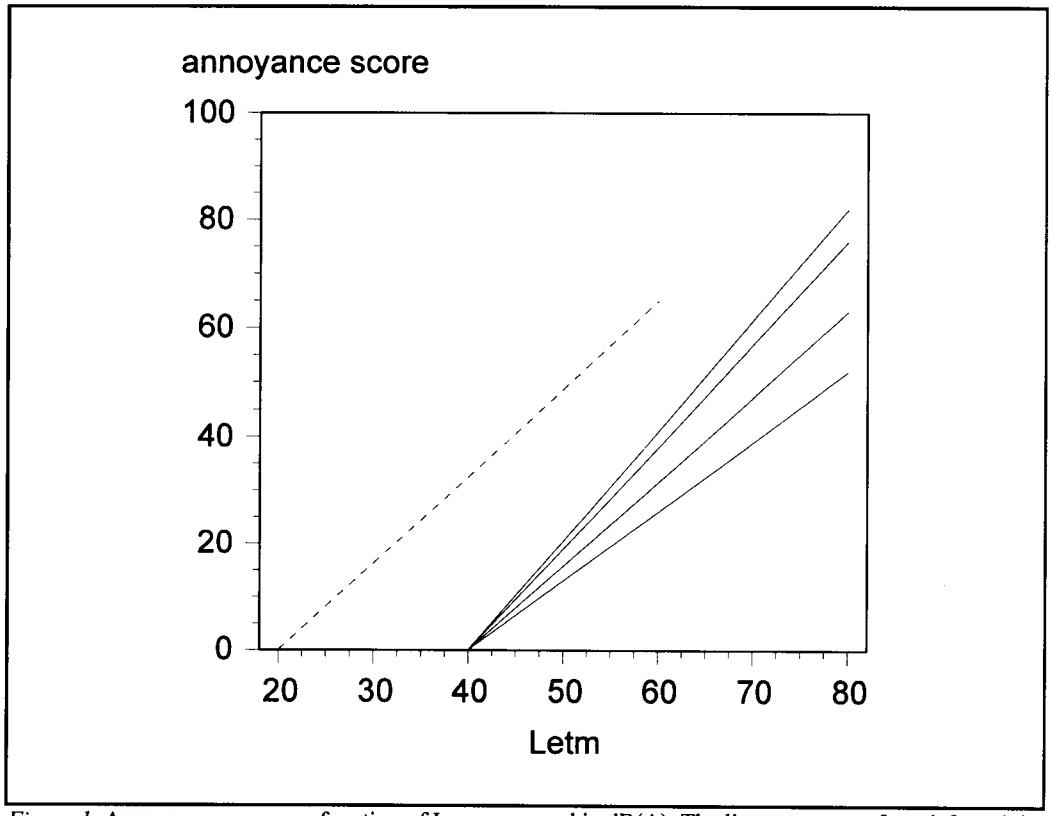

Figure 1 Annoyance score as a function of L_{etm}, expressed in dB(A). The lines represent, from left to right impulse noise (dashed), airtraffic, highway traffic, other road traffic (Mie93).

L_{etm} values at which different sources cause the same degree of annoyance. Of the results obtained for each time of day, as with L_{etm}, only the maximum value was used. The end result is termed the Environmental Quality Measure for Noise (MKM(noise)).

Odour

Exposure-response relationships have also been derived for the relationship between exposure to odour and annoyance (Mie93). One of the dosage measures used was $C_{99.5}$. This is the concentration, in odour units per m^3, that is exceeded 0.5 per cent of the time (44 hours annually). The relationships are based on data from Dutch research into six different types of odour sources. The relationship between $C_{99.5}$ and annoyance score is the same for five of the six types. Given a uniform degree of exposure, the annoyance produced by the sixth type was considerably higher than for the other types. This indicates that the annoyance established using a curve based on data from the five 'milder' sources could, in some cases, be an underestimate.

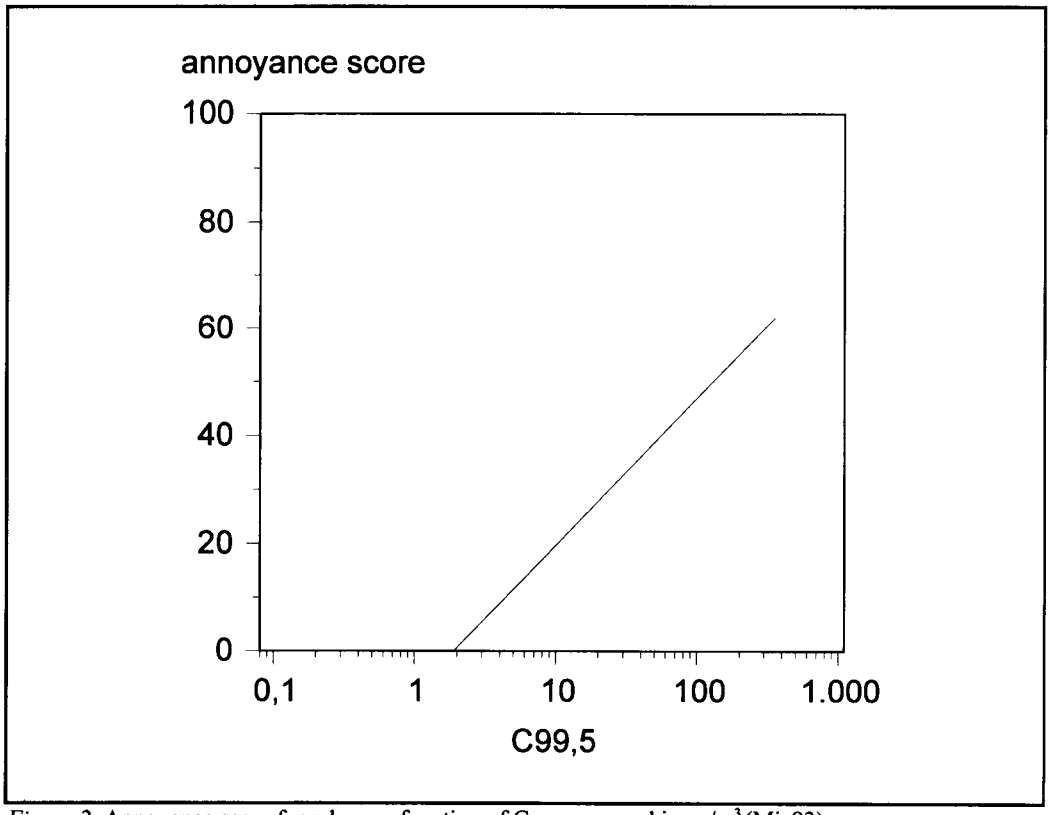

Figure 2 Annoyance score for odour as function of $C_{99.5}$ expressed in ge/m^3 (Mie93).

More than 3 000 assessments of odour annoyance were used to establish the relationship between $C_{99.5}$ and annoyance score. In each case, it was possible to link the assessment with the $C_{99.5}$ value of the odour exposure in question. The correlation coefficient for the relationship between $C_{99.5}$ and annoyance score in Figure 2 is 0.3.

Annex **E**

'Powerlessness' and 'Expert opinion'

As stated in the previous chapters, the Committee considers that there is no empirical scientific basis to support the construction of an EEI with health as the criterion.

Accordingly, anyone wishing to pursue the objective of categorizing sites with a single number must first discard any relationship between the EEI and the risk of damage to health. Such methods have been described in the literature.

Mental burden, 'environmental powerlessness'

Anxiety and related forms of psychological burden are an important aspect of health for those living in the neighbourhood of industrial plants. If this is to be included in an EEI, however, it must be measurable and quantifiable. One unit that might be of use in this connection is 'environmental powerlessness'. This unit (Cla93a) is measured by presenting the residents of a given site with carefully constructed lists of statements. The environmental powerlessness scale measures environmental exposure of industrial origin, air pollution, noise and accident risk. It also incorporates the so-called 'subjectivity' of environmental problems. Environmental powerlessness and the subjectivity of environmental problems are combined to yield a single indicator. This - subjective - indicator can be compared to measurements of various environmental components. A good correlation was found for some sites studied (Pli93). What is measured is the psychological burden produced by all regional environmental exposures combined.

'Expert opinion'

Teams of scientists can also rank various factors using an ordinal yardstick, based on non-quantifiable data. This approach can be used to evaluate the severity and magnitude of effects, the chance of recovery, and the degree to which the effects of an environmental exposure on people and the ecosystem can be managed. The ordinal scores are combined to yield a single total score. This is used to rank a given environmental risk against other environmental risks (Cla93b). This method can offer a solution to the problem of setting policy priorities in areas where insufficient scientific knowledge is available.