Community noise: a fundamental ingredient of an environmental health performance indicator (CHERIO)

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Summary
Various environmental factors can affect the health of the population in communities. We developed an environmental health risk indicator, the Cumulative health-based environmental risk indicator for outdoor pollutants (CHERIO) to rank the local potential risk and to compare the consequences of various policy alternatives. Noise from transport and industrial sources, and air pollution are currently the fundamental ingredients of CHERIO. We illustrate in this paper one of CHERIO's features, its (potential) use as benchmark for environmental health performance of municipalities, and discuss its opportunities and limitations.

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1. Introduction

An array of problems and opportunities, but limited funds: policy makers are confronted daily with the task to allocate their budget to the most salient issues in society. Agenda setting and policy prioritization in the field of environment and health are influenced by many factors: regulatory limit values that have to be met, worries in society about a new emerging risk, health care costs or the latest media hype. However, most policy makers agree that the risk of health loss due to environmental exposure ranks high on the list of factors that should be considered when planning environmental health policy. We developed an environmental health risk indicator, the 'Cumulative health-based environmental risk

indicator for outdoor pollutants' (CHERIO) to rank the local potential risk of environmental exposures and to compare the consequences of various policy alternatives. CHERIO is an indication of the environmental quality in a given residential address from a health perspective. This paper addresses the methodology of CHERIO for community noise. We demonstrate one of CHERIO's features, its (potential) use as benchmark for the environmental health performance of municipalities, and discuss the opportunities and limitations of the indicator.

2. Methods

CHERIO's basis is not entirely 'new' but should be seen as a new combination of the elements of existing methods. It aims to be scientifically sound, easily interpretable and spatially presentable.

The inner core (scientific foundation) is based on the global burden of disease concept [1] which enables to express the health risks of exposures in the same unit. The outer layer (presentation) is based on the City and environment Health Impact Assessment score [2]. As input data, the CHERIO needs exposure data for each environmental factor on a spatial scale (preferable at residential addresses) for the area of interest. Other data, like severity weights or demographic information, are predefined in the CHERIO calculation. If the effects of a policy intervention are assessed, there is also a need for data about the consequence of the intervention on the exposures.

CHERIO is based on the individual time lost each year due to ill-health, disability or early death due to environmental exposure. The loss related to individual environmental agents can be accumulated at the same location since we expressed their effects in the same scale. We defined CHERIO as percentage of the average time lost each year due to ill-health, disability or early death due to all diseases, by each inhabitant. We assigned score classes and associated color code to fixed ranges of percentages, similar to the City and environment Health Impact Assessment score [2]. The score classes were chosen to range from <4% to ≥ 11 % (and 1% classes in between) for the cumulative risk and from <0.33% to ≥ 2.67 % (and 0.33% classes in between) for the risk of individual environmental exposures, since in the Netherlands these ranges seem to capture the variation in the CHERIO when looking at the current selection of environmental factors (see next paragraph).

In theory, the concept of the CHERIO can be applied to all spatially distributed environmental exposures that may cause a risk for health and for which a DALY can be calculated. We have currently implemented the concept for a selection of spatially distributed environmental factors: noise from road traffic, railways, aircrafts and industrial sources and particulate matter and nitrogen dioxide. In addition, we added the Dutch national average impact of exposure to benzene, dioxins, second-hand tobacco smoke, formaldehyde, lead, ozone and radon as 'background' environmental risk in the Netherlands [3] to CHERIO.

Highly sleep disturbed, cardiovascular morbidity and mortality, and cognition (for aircraft noise only) were taken into account as health endpoints in the calculation of CHERIO for noise. For highly sleep disturbed the exposure response relations for road traffic and railway noise described by Miedema and Vos [4] were used. We applied the exposure response relation for road traffic noise also for industrial noise, since the exposure response relations for (severe) annoyance from road traffic noise [5] and from noise from industrial sources [6] are similar. For aircraft noise, we used an exposure response relation that was derived from a local study around Amsterdam Schiphol Airport in 2002 [7]. The exposure response relations were applied from 25 dB L_{night}. We used a severity weight of 0.06 (the median of the medians of the studies from Van Kempen, from De Hollander and from Müller-Wenk [8]. Adults were considered as the population at risk.

The years lost due to disability by cardiovascular morbidity and the years lost due to cardiovascular mortality were modelled in the Dutch population of 20 years and older for a period of 20 years with the National Institute for Public Health and the Environment Chronic Disease Model [9]. With this model, the health impact for several risk factors can be assessed. We used hypertension as risk factor for acute myocardial infarction, stroke and heart failure and the associated disability and mortality [10]. The prevalence of hypertension was changed according to the exposure-response relations taken from meta-analyses for road traffic

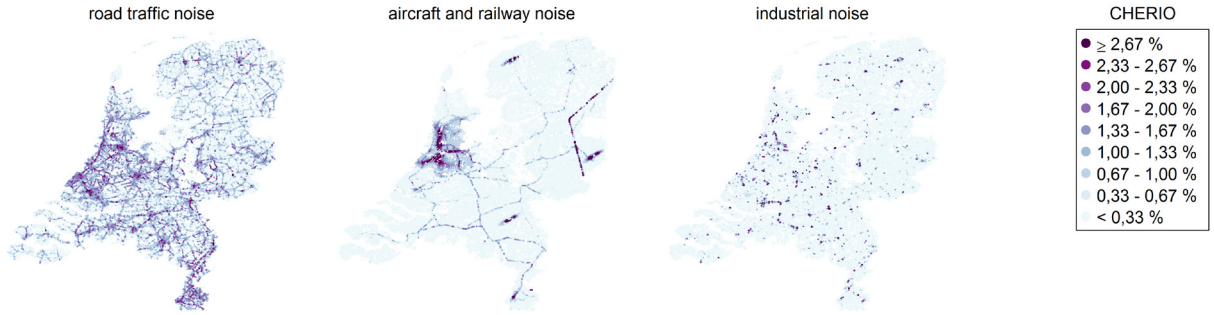

Figure 1 CHERIO of various noise sources in the Netherlands

[11] and aircraft noise [12] to produce a relation between the noise level and a response in Daly per year per person. Since the number of studies on noise from railway and from industrial sources and hypertension is limited, we used the modeled exposure response relation for road traffic noise also for these noise sources. For all 4 noise sources a threshold of 50 dB L_{den} was applied.
The effect of aircraft noise on reading impairment was also converted into a response in Daly year per person. Based on data from the RANCH study [13] reading impairment was defined as the lowest 10 percentile of the test scores. Subsequently a exposure-response relation was derived [14]. A baseline prevalence of 10% and a severity weight of 0.006 [8] was used for children from 7-17 year old.
For air pollution, the years lost due to mortality were modelled [9] using exposure-response relations for particulate matter and nitrogen dioxide from a recent Dutch study [15].
We converted the response in Daly per year per person into a more comprehensible scale, since one of the objectives was to develop an indicator that is easily understood by policy makers. We chose to express the time lost due to environmental agents relatively as percentage of the total time lost due to disability and early death due to all diseases each year in the Dutch population.

3. Results

Figure 1 shows the environmental quality from a health perspective (CHERIO) for various noise sources ‘distributed´ over the Netherlands. The infrastructure of the noise sources in the Netherlands is clearly visible, in particular for aircraft noise and road traffic noise in the agglomerations.

The mean CHERIO in the Netherlands for road traffic noise is 0.54%, for aircraft noise 0.12%, for railway noise and for industrial noise each 0.08%.

Since the health risks are expressed in the same scale, the risks from various environmental factors can be cumulated at the residential address. In Figure 2 the population distribution of the cumulated CHERIO of noise, air pollution and ‘background’ is given for the Netherlands.

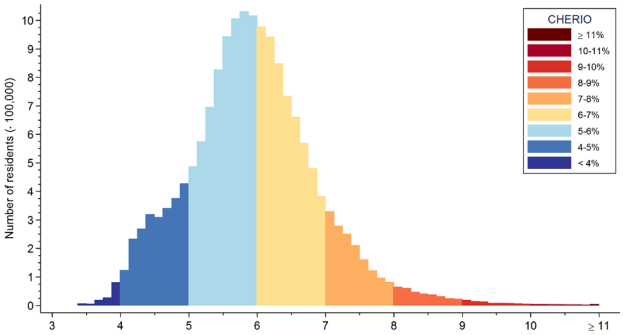

Figure 2 Population distribution of cumulative CHERIO in the Netherlands.

The mean (cumulated) CHERIO is about 6%. Together, noise and air pollution contribute to approximately 90% to the mean CHERIO in the Netherlands.

From Figure 2, it becomes clear that the CHERIO various throughout the Netherlands. There are places with a less favorable environmental health quality than others. The interquartile range of CHERIO at the residential address is 5.4-6.5%. More than a twofold difference in the CHERIO is found for the 1 (4.0%) and 99 (8.6%) percentile and almost a threefold difference for the 0.1 (3.7%) and 99.9 (10%) percentile.

The spatial variation of the CHERIO can be mapped with a much higher spatial resolution than shown in Figure 1. In Figure 3, an example is given for the municipality of Utrecht where we plotted the mean (cumulative) CHERIO per 6-digit postal code (on average, 15 residential addresses). Due to its central position, Utrecht is an important transport hub for both road and rail traffic.

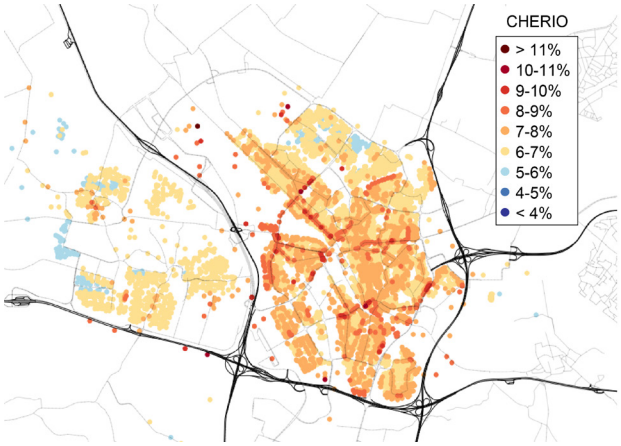

Figure 3 Cumulative CHERIO in the municipality of Utrecht.

The mean (cumulative) CHERIO is in Utrecht 6.8%; The CHERIO for community noise is 1.2% with 0.80% for road traffic noise, <0.01% for aircraft noise, 0.18% for railway noise and 0.11% for industrial noise. These results illustrate that the environmental quality in Utrecht is less advantageous than average in the Netherlands. Almost half of the difference in cumulative CHERIO (6.8 versus 6.0% as country average) is related to the exposure to community noise (1.1% versus 0.8% as country average).

With maps such as shown in Figure 3, environmental health risk hot spots can be easily identified. For the cumulated CHERIO as well its sub categories, estimated changes related to scenarios can be presented on a map with the same level of details as in Figure 3. So the benefits of policy scenario can be made clear for policy makers and lay people.

Another feature of CHERIO is that it can be used for benchmarking so that policy makers in for example municipalities are encouraged to take (cost effective) measures to change the environmental quality in a more healthy direction. This is illustrated in Table I which gives for the ten largest municipalities in the Netherlands the cumulative CHERIO and the CHERIO for community noise. Also the CHERIO is presented as benchmark. As basis for the benchmark we took the rank of the CHERIO of a municipality among the ordered CHERIO's of the forty largest municipalities in the Netherlands.

Table I. CHERIO of the ten largest municipalities in The Netherlands and their rank among the largest forty municipalities

Municipality (ranked according to size)	*CHERIO (% and rank)*	
	Cumulated	*Comm. Noise*
1. Amsterdam	7.63 (1)	1.85 (2)
2. Rotterdam	6.90 (3)	0.87 (19)
3. 's-Gravenhage	6.36 (14)	0.73 (29)
4. Utrecht	6.77 (6)	1.10 (8)
5. Tilburg	6.36 (15)	0.88 (17)
6. Eindhoven	6.41 (11)	0.84 (22)
7. Almere	5.45 (34)	0.56 (38)
8. Breda	6.23 (21)	0.80 (25)
9. Groningen	5.30 (37)	0.88 (16)
10. Haarlem	6.29 (19)	1.15 (6)

If we compare the municipalities with the highest and lowest cumulated CHERIO in Table I (Amsterdam and Groningen), we see that community noise is responsible for half of this difference. The difference in cumulated CHERIO is 2.3%; the difference in the community noise related CHERIO 1.0%

4. Discussion

CHERIO scores of various environmental factors can be cumulated to identify environmental health risk hot spots. The scores can be displayed on a map and can easily be interpreted (for example by comparing them to the average CHERIO in an area or by color coding). CHERIO scores can also be summed and averaged over populations. As illustrated in this paper, this makes it in potential possible to benchmark municipalities nation-wide or for example agglomerations European-wide on their cumulative environmental health risk performance, or on their performance for underlying environmental factors (like 'total' community noise or – source specific- road traffic noise).

In The Netherlands, air pollution contributes the most to the mean CHERIO. However when the variation in mean CHERIO between municipalities is studied, it becomes clear that a substantial part of the variation can be attributed to community noise. This illustrates that community noise is from a health perspective an important component of the environmental quality at the local level and therefore a necessary ingredient of CHERIO.

The CHERIO is based on the same concept as DALYs [1]. Most uncertainties that relate to DALY estimations are therefore also (implicitly) present in the CHERIO. For example, not all potential health effects and environmental factors are included, due to lack of data and/or knowledge [3]. Although we consider annoyance as a health effect, noise annoyance was not included in the calculations. We did not attribute a severity weight to this endpoint in line with the most recent WHO report on burden of disease calculations for environmental noise [16]. We intend to carry out a stakeholder consultation about how to treat noise and odor annoyance in CHERIO, since prevention and control of annoyance is one of the basic principles in Dutch legislation on noise and odor.

The CHERIO is calculated for an 'average Dutch person', and not for the specific or expected population in the region of assessment. We have chosen this approach because a) there are often no health data available for a specific population and b) health effects of environment exposures can occur at specific time periods of the life-course (like cognitive effects in children, increasing risk of mortality in the older population). It is therefore defendable to calculate the effects for 'any' Dutch citizen instead of for the population that 'just happens to live' in a certain area at a certain point in time and that may have moved 5 years later.

The CHERIO is meant as an 'index' to compare different situations or scenarios. The uncertainties are not reflected in the final score, i.e. there are no confidence intervals or other statistical uncertainty analyses. This does not mean that uncertainties do not exist, and therefore the CHERIO can only be used as a crude indication of the environmental health quality from a health perspective at a specific location or in a certain area. We realize that there is a risk that the CHERIO oversimplifies complex environmental health issues. However, this risk is no bigger than with most environmental health impact indicators.

General limitations of integrated environmental health impact indicators remain in CHERIO. These include 1) the underlying uncertainties (see above); 2) the simplification of a complex reality; 3) the need for contextual information in order to correctly interpret the outcomes; and 4) the imprecision of the results when presented in limited scoring intervals and color codes. Also, the CHERIO is not suited yet to show potential health benefits of the environment, e.g. of quiet areas or green spaces, because well-established exposure-response relationships do not exist yet for health benefits. If exposure-response relationships become available and the exposure indicators can be linked to the home address, these types of positive effects could easily be implemented which would allow for more integrated assessments. We foresee that health risks related to noise from wind farms, ground level ozone, Extreme Low Frequency radiation (power lines) and heat stress can be added to CHERIO in the near future.

5. Conclusions

CHERIO combines the advantages of the scientifically sound global burden of disease approach and of the user-friendly City and environment Health Impact Assessment score to estimate and spatially present environment quality from a health perspective.

Noise from transport and industrial sources is an important component for CHERIO, since a substantial part of the variation in the CHERO of municipalities can be attributed to community noise.

CHERIO is a promising indicator for scientists, public health practitioners and policy makers. Case studies, user tests, stakeholder consultation and extension of the number of environmental factors included are needed in order to widen use and usability of CHERIO.

Acknowledgement

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