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Environmental inequalities among children in Europe—evaluation of scientific evidence and policy implications

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Background: Socio-economic inequalities in the living environment are major contributing factors to health inequalities. Consequently, protecting children from undesirable environmental exposures by taking socio-economic conditions into account has been identified as a policy priority area in Europe. This review aims to evaluate the evidence on environmental inequalities among children in Europe and to discuss its policy implications. **Methods:** A systematic literature search was conducted in various literature databases. Further sources for information were reviews, international reports and working documents for a WHO expert meeting on environmental inequalities in 2009. One major inclusion criterion for publications was consideration of socio-economic factors as influencing factors, not merely as confounder. **Results:** The overall pattern based on the available fragmentary data is that children living in adverse social circumstances suffer from multiple and cumulative exposures. A low socio-economic position is associated with an increased exposure of children to traffic-related air pollution, noise, lead, environmental tobacco smoke, inadequate housing and residential conditions and less opportunities for physical activity. For most topics and exposures reviewed here there were no studies investigating the modification of the exposure-response function by socio-economic factors. Due to a variety of methodological approaches and studies on one hand and lack of data for many topics and countries on the other hand it was not possible to quantify the magnitude of environmental inequalities. **Conclusion:** Action is needed along the whole causal pathway of the social divide in environmental hazards with priority to policy measures aiming at removing socially determined differences in environmental conditions.

Keywords: exposure, health inequalities, pollution, social determinants, socio-economic position

Introduction

Health inequalities are one of the main challenges for public health throughout Europe. People with lower levels of education, occupation and/or income tend to die at a younger age, and to have a higher prevalence of most types of health problems.[1,2] The impact of socio-economic inequalities in the living environment and in exposure to environmental pollution has increasingly been recognized as a major contributing factor in the production of health inequalities.[3–5] In addition to exposure variation by socio-economic position (exposure differential), socio-economic factors may modify the health effects by influencing individual's vulnerability (susceptibility differential).[6] Besides nutrition or access to quality health care, psychosocial stress has been proposed to be a key component. When not counterbalanced by resources, place-based and individual-level stressors may lead to increased vulnerability to environmental exposures.[7,8]

It seems to be a common pattern that poor children are confronted with widespread environmental inequalities in terms of accumulation of multiple environmental risks.[9] The cumulative risk of environmental exposures can contribute both directly and indirectly to a variety of adverse health outcomes in children.[10] The influence of socio-economic factors on exposure and susceptibility of children to environmental factors has been widely recognized and the burden of disease attributable to environmental factors among children and adolescents in Europe has been estimated.[11]

Consequently, protecting disadvantaged children from undesirable environmental exposures was identified as a policy priority area (Declaration and Children's Environment and Health Action Plan for Europe (CEHAPE), adopted at the Fourth Ministerial Conference on Environment and Health held in Budapest in 2004).[12] The CEHAPE recommends a multisector approach to address the multidimensional aspects of poverty as a necessary policy approach for protecting children's health.

The aim of this review was to evaluate the latest evidence on environmental inequalities among children in Europe and to discuss its policy implications.

Methods

This publication is a summary of a review which was prepared by the authors for the WHO expert meeting on 'Environment and health risks: the influence and effects of social inequalities' at the WHO European Center for Environment and Health in Bonn, Germany, in September 2009. The expert meeting was part of the preparatory process towards the forthcoming Fifth Ministerial Conference on Environment and Health taking place in Parma, Italy, in March 2010. The aims of the expert meeting were to review and discuss the evidence presented in the background documents and to develop policy recommendations on possible countermeasures.

One starting point of this work was the review of the impact of socio-economic factors on environmental exposures and children's health in Europe within the EU-funded network PINCHE (Policy Interpretation Network on Children's Health and Environment).[6,13] PINCHE focused on the four

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Table 1 Systematic literature search: terms and results

Database	Results: number of publications		
Search terms	**Published since 2000**	**Without duplicates, only Europe (after first scan of title and abstracts)**	**After application of exclusion criteria**
Medline (MeSH term)			
Socio-economic factors AND environmental pollution AND children[a]	877	364	54
Social justice AND environmental exposure AND children[a]	17	1	1
Social justice AND environment AND children[a]	15	2	2
Environmental justice (all fields) AND children[a]	150	8	8
PsychINFO			
Environment AND socio-economic AND child	15	1	1
environmental justice AND child	17	0	0
SocINDEX			
Child AND environmental pollution OR environmental exposure OR environmental justice	69	1	1
Current Contents Connect (CCC), Social Science Citation Index + Science Citation Index + Arts & Humanities			
Child AND environment AND social within categories: pediatrics OR public, environmental & occupational health OR environmental sciences & ecology OR geography	127	13	13
Total		390	80

a: includes the MeSH terms child; child, preschool; infant; adolescent

themes indoor and outdoor air pollution, carcinogens, neurotoxicants and noise.

The literature for this review was retrieved from three sources:

(i) a systematic literature search of reviews and original articles published in peer-reviewed journals,
(ii) international reports by WHO, EU and other organizations (a list of these reports is given as supplementary data at *Eurpub* online) and
(iii) the drafts of topical review papers prepared 2009 for the above-mentioned WHO expert meeting.

The systematic literature search was conducted in May 2009 in the Medline database, in Science Citation Index, Current Contents, SocINDEX and PsychINDEX. Search terms and results are presented in table 1. Abstracts were further evaluated by using the following inclusion criteria:

(i) Original studies conducted in Europe (including countries of the former Soviet Union and Israel) or reviews;
(ii) English language, published 2000–May 2009;
(iii) Age group 0–18 years (children and adolescents);
(iv) Socio-economic differences in children's environmental exposures or environmental health at an individual- or area-level must be described in the abstract. The mere inclusion of indicators of socio-economic position as potential confounder in analyses or the description of the sociodemographic characteristics of the study population was not sufficient. Thus the focus of the literature search were the two basic mechanisms exposure variation and effect modification by socio-economic position and
(v) Exposures: in principle, all kinds of environmental exposures were considered with a focus on outdoor and indoor air pollution, environmental tobacco smoke, lead, noise, housing/built environment (including impact on physical activity), water pollution and waste.

After excluding duplicates and after the first screening of abstracts and titles to exclude original studies from outside Europe, in total, 390 abstracts were eligible for further evaluation. After this precise evaluation of the abstracts, 80 publications remained for further analysis (table 1, a list of these references is given as supplementary data at *Eurpub* online).

According to a definition by WHO,[14] throughout this review the term 'inequalities' is used for mere description of socio-economic differences in environment and health between groups of people without any further valuation. The term 'inequities', which is used in the section on policy implications, refers to those inequalities that are avoidable or can be redressed and are assumed to be unjust. The term 'socio-economic position' is used as comprehensive term regardless of which socio-economic indicator such as parental education or household income was used in a study.

Though this review concentrated on the period from birth until adolescence, it is acknowledged that the prenatal development is an important critical window for exposures.[15]

Results

Overall, the systematic literature search yielded among the 80 relevant publications only 21 original, peer-reviewed studies in Europe published since 2000 and analysing the relationship between socio-economic factors, children's environmental exposures and/or environmental health as a main topic. The remaining 59 studies were excluded for the following reasons: non-European country, socio-economic factors considered only as confounder without indication of numbers in table or text, no original study.

Evidence of socio-economic differences in the living environment and in exposure to environmental pollution (exposure variation)

Most of the studies on housing in several European countries demonstrated that poor and less affluent population groups are most exposed to environmental risks within the private home (e.g. biological and chemical contamination, temperature problems, sanitary equipment) as well as within the residential context (e.g. closeness to polluted areas, lack of urban amenities and public safety, neighbourhood incivilities such as litter) (Fairburn & Braubach, background document for the WHO expert meeting 2009, to be published on the occasion of the Fifth Ministerial Conference on Environment

and Health in Parma, March 2010). Especially in Eastern Europe deteriorating housing conditions were observed. Concerning waste sites for e.g. on community level hazardous sites and illegal waste disposals are disproportionately often located in more deprived areas in several European countries such as UK, France and Italy (Martuzzi et al., background document for the WHO expert meeting 2009, to be published on the occasion of the Fifth Ministerial Conference on Environment and Health in Parma, March 2010).[16]

A recent review of the evidence on environmental inequalities in Germany confirmed this overall pattern of more adverse housing conditions in socially disadvantaged.[17] For example, single oven heating, crowding, damp housing and living near roads with heavy traffic was associated with a lower socio-economic position in several cross-sectional studies in school beginners.[18,19]

There is some evidence in Europe that ethnically marginalised children tend to live, play and go to school in more environmentally hazardous areas. This has been described especially for central and eastern Europe and ethnic minority groups like Roma who live more often on or near waste sites, floodplains and suffer from lack of provision of basic utilities including clean running water.[20,21]

Characteristics of the built environment such as heavy traffic in residential areas and living in segregated marginalised neighbourhoods shorten the radius within which children can be active and reduce the activities in their living space. Socially disadvantaged people and those who live in neighbourhoods of lower socio-economic status (deprived areas) may have limited opportunities for physical activity.[22] Fear of traffic can be a powerful deterrent to parents' allowing their children to walk or cycle to school or play outdoors, especially in deprived areas, because poorer children are more likely to live in urban areas with poor road safety and high-speed traffic.[23]

Resources like parks or green areas which encourage physical activity and so indirectly influence health status are rare in disadvantaged residential areas, and when available, quality is usually low.[10] Data from Germany indicated that parents with a lower socio-economic position felt more often impaired by a lack of accessible green space in their living environment in both urban and rural settings.[19]

Environmental tobacco smoke (ETS) is an important and well-studied issue of children's exposure to indoor air pollutants. The evidence on social inequalities in children's ETS exposure is consistent across several countries: social disadvantage is associated with a higher or rather more frequent pre-natal and post-natal exposure of children to ETS.[13,17,24–26]

The protection of children against toxic chemicals in the environment is a major public health challenge[27] but scientific evidence on the relationship of socio-economic position and exposure to chemicals is scarce in Europe. One exception is lead: overall recent reviews of data in Europe showed that children from families living in adverse housing conditions or with lower socio-economic position have higher blood lead levels.[13,17] Poor housing quality and poor socio-economic position have been acknowledged as one of other determinants of higher blood lead levels in children.[28] However, single studies or certain populations may give conflicting results. For example, a study in Swedish adolescents found no social differences in blood lead levels.[29]

For children, recent reviews of data in Europe summarized that children in lower socio-economic position live more often in areas with decreased air quality and more often near streets with heavy traffic.[13,17] Chaix et al.[30] showed in a spatial scale study located in Malmö, Sweden, a gradient in the exposure of children to NO_2 at home and at school from the highest levels in children living in low income areas (mean roof level annual NO_2 concentration 21.8 $\mu g/m^3$ at home, 19.7 $\mu g/m^3$ at school) to lowest levels in high income areas (13.5 $\mu g/m^3$ at home, 13.7 $\mu g/m^3$ at school). A study in three districts in Moscow, Russia, demonstrated that children living in a highly polluted area were more disadvantaged than children in a district with low air pollution.[31] In Germany, social differences in terms of higher exposure mainly to traffic-related air pollution have been repeatedly shown for children.[17,19,25]

In accordance with the fact that socially disadvantaged families tend to live more often near busy roads, noise annoyance due to traffic is often higher in people with a lower socio-economic position.[17] The German Environmental Survey 2003/06 for Children demonstrated that socially disadvantaged children aged 8–10 years felt more often annoyed by road traffic noise than children in higher socio-economic position.[32] Moreover, besides social inequalities in noise annoyance there are social inequalities in exposure to noise: a recent study showed for children living in Munich that there is an association between relative poverty and high traffic noise exposure estimated by noise maps.[33]

Results of the Heathrow Airport Study, UK, showed that children from high-noise schools were more likely to be non-white and to speak another language than English as first language at home. The proportion of children from manual social class households and deprived households were also slightly higher in the high-noise schools.[13]

Evidence of socio-economic differences in children's susceptibility to environmental exposures (effect modification)

In general, due to the developing of their organs and systems children are more vulnerable to environmental exposures compared to adults. Children have disproportionately high exposures to many environmental toxicants because they drink more water, eat more food and breathe more air per unit of body weight compared to adults.[27] Young children also tend to have a living area closer to the ground or floor, resulting in a somewhat different exposure to some air pollutants or to contaminated soil than that in a large, upright person. Children's metabolic pathways, especially in foetal life and in the first months after birth, are immature. Therefore children's ability to metabolize, detoxify and excrete environmental agents differs from that of adults. Early exposure gives time enough for long latency agents to produce adverse health effects. Finally, children are less aware of the risk and have less control over their environment than adults.[34]

Thus, social inequalities impart a disproportionate elevation in hazard to deprived population groups at all ages, but again this is particularly true for children from poor households and deprived communities. The peculiar vulnerability of children to environmental agents acts by multiplying the effects of social inequalities.

Within this systematic literature search there have been no original studies among children in Europe identified which investigated the interaction between socio-economic factors and most of the environmental exposures. Therefore the question to what extent disadvantaged children, besides being disproportionally exposed to environmental risks, are also more vulnerable to its impacts cannot comprehensively be answered until now.

In case of lead exposure it has been stated that children growing up in disadvantaged circumstances showed lead associated developmental deficits at lower blood or tooth lead levels than more advantaged children. Also the deficits

were of greater magnitude in disadvantaged children and these children were less able to compensate or recover from lead associated neurodevelopmental deficits.[35]

The RANCH study on road traffic and aircraft noise exposure and children's cognition and health in schools around airports in the Netherlands, Spain and the UK gave mixed results for effect modification. On one hand there was no effect modification by socio-economic position concerning the association of aircraft noise exposure at school and impairment in reading comprehension.[36,37] On the other hand, van Kempen et al.[38] reported higher annoyance due to aircraft and road traffic noise at school in children of mothers with higher educational status and the effect of road traffic noise on cognitive tests on episodic memory was stronger for children living in crowded homes.[36]

Greater relative impacts of air pollution on mortality risk associated with long-term exposure have been demonstrated for disadvantaged adults.[39] Several studies in European countries have been published on the effect of socio-economic position on the air pollution—health relationship in adults (Deguen & Zmirou-Navier, background document for the WHO expert meeting 2009, to be published on the occasion of the Fifth Ministerial Conference on Environment and Health in Parma, March 2010). Data of a study on infant mortality in Mexico for example indicated a higher vulnerability of disadvantaged children to the adverse effects of air pollution.[40] However, there is no study explicitly investigating effect modification of socio-economic position on the relationship between air pollution and health among children in Europe.

Discussion

Methodological considerations

At several levels of compiling and evaluating the evidence for this review, insufficient information and bias may have led to an impairment of its significance. The systematic literature search based on key words and MeSH terms and the exclusion of articles with the mere statement in the abstract that analyses were adjusted for social factors might have resulted in the loss of some information on environmental inequalities given in a publication's main text. In environmental epidemiologic studies, socio-economic factors are mostly regarded as potential confounders and considered only for adjustment in statistical analyses.[41]

There is certainly a language bias of our review. Studies especially from Eastern Europe and not published in English might have been missed. There may be also a publication bias if only studies showing inequalities were published and thus retrieved in the systematic search. Bias might have already been introduced due to study design of the original studies included in this review: selection bias by socio-economic position is quite common in epidemiologic studies. There may be an underestimation of the extent of social inequalities in environmental exposures especially in secondary data analyses if socially disadvantaged people tend to take part less often. Otherwise, information bias due to underreporting of adverse environmental conditions by socially disadvantaged people may occur.

Comparability of studies may be limited due to variations in study design (including e.g. geographic measurement scales, study population, time frame) and in definitions of socio-economic indicators, environmental exposures and health outcomes. The main obstacle for quantifying the magnitude of social inequalities in environmental conditions is the diversity of concepts and methods to define socio-economic position on one hand and of estimating exposure on the other hand. Especially the differences between the European countries in the conceptualization of socio-economic position and in educational systems were a constraint to quantify the results. Moreover, there is no widely approved method to define socio-economic position of children and adolescents within and across countries. Therefore choice of indicators of socio-economic position, method of exposure assessment, and size and choice of a study area may affect the magnitude and even direction of associations observed.[42–44]

Due to the variety of methodological approaches and studies and lack of data for many topics and countries/European regions it was not possible to conclude an overall assessment and to quantify the magnitude of environmental inequalities among children and adolescents in Europe.

For the interpretation of evidence it has to be considered that not all observed socio-economic differences in environmental conditions and exposures may have a health impact on its own but may be only effective in situations of multiple exposures. Furthermore, the aspect of salutogenic (health promoting) impacts of the environment on children's health and how environmental resources may counterbalance

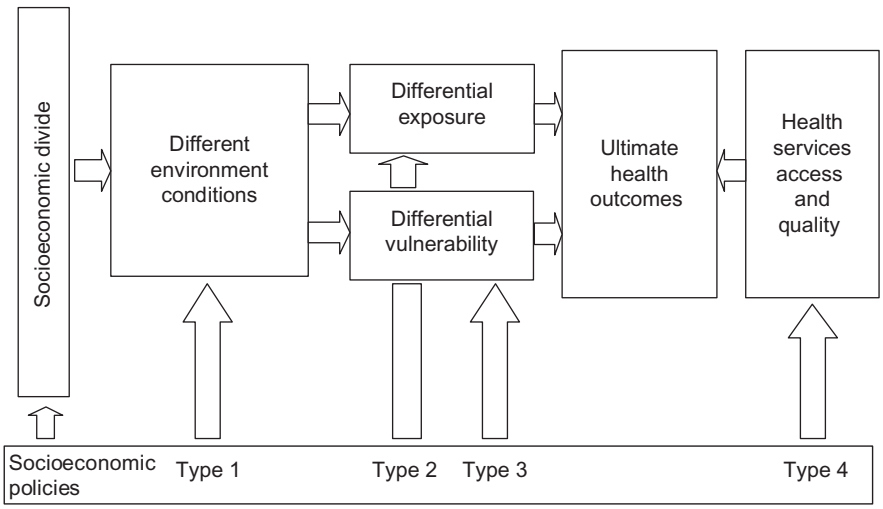

Figure 1 Policy approaches to address the main causal pathways of environmental inequity (modified from Commission on Social Determinants of Health[46])

Table 2 Addressing environmental inequity among children and adolescents in the CEHAPE priority areas: examples of four policy approaches and relevant responsible authorities

Policy approach	Action (examples)	Responsible authorities
CEHAPE priority area: indoor air pollution		
Reducing sources of pollution in deprived communities and households	– Plan urban development to minimize exposure to polluting industries and heavy road traffic	– Local administrative authorities
	– Provide financial incentives for improved heating systems and safer fuels at household level	– National and local legislating bodies
Reducing exposure at individual level	– Provide information, education and communication at community and household level on ways to reduce exposure in children with special emphasis on poor communities	– National and local health and environment authorities – Community health services
Reducing susceptibility to pollutants' effects	- Implement policies to prevent prenatal exposure to ETS, to reduce inborn susceptibility to post-natal exposure to air pollutants	– National and local legislating bodies – National and local health and environment authorities – Health professionals
Reducing health consequences	– Quality health services for respiratory diseases	– National and local health authorities – Health services
CEHAPE priority area: water and sanitation (W&S)		
Reducing sources of pollution in deprived communities and households	– Improve W&S facilities in poor communities (houses, schools and daycare centers) and provide financial incentives to W&S improved facilities in private houses	– National and local administrative authorities – National and local legislators
Reducing exposure at individual level	– Information, education and communication on ways to reduce exposure in children (e.g. washing hands, etc.) with special emphasis on poor communities	– National and local health and environment authorities – Health professionals
Reducing susceptibility to pollutants' effects	– Improve infant and young child nutrition	– National and local health authorities – Health professionals
Reducing health consequences	– Provide quality health services for diarrhoeal diseases	– National and local health authorities
CEHAPE priority area: chemicals		
Reducing sources of pollution	– Ban lead from gasoline, implement ban on PCBs and other POPs	– International agreements – National legislators
Reducing exposure at individual level	– Information, education and communication on ways to reduce exposure in children (e.g. monitor PCBs content of soil and food and advise accordingly) with special emphasis on poor communities	– National and local health and environment authorities
Reducing susceptibility to pollutants' effects	– Improve early child development by appropriate parental practices to reduce susceptibility to adverse neurodevelopmental effects caused by post-natal exposure to neurotoxicants	– National and local health and education authorities – Health professionals
Reducing health consequences	– Train health professionals in early recognition of signs and symptoms of lead intoxication – Implement biomonitoring in at risk populations	– National and local health and environment authorities
CEHAPE priority area: physical activity		
Reducing adverse environmental conditions	– Improve availability of playgrounds and safe walking or cycling paths to school	– Local administrative authorities
Reducing exposure at individual level	– Promote physical activity and reduce time of exposure to TV and computer screens	– National and local health authorities – Health professionals
Reducing susceptibility to risk factors	– Improve infant and young child nutrition	– National and local health authorities – Health professionals
Reducing health consequences	– Train health professionals and school personnel in promotion of physical activity and infant and young child nutrition	– National and local health and education authorities
	– Improve therapy of obesity and its health consequences	– Health professionals

environmental threats has not been comprehensively studied in the context of social inequalities.

Policy implications

This review nevertheless points to the importance of socio-economic factors in determining differential health outcomes in children as a result of environmental exposure. The need for action to address environmental inequity particularly among children has been recognized by the 53 WHO member states of the European region in the Fourth Ministerial Conference on Environment and Health, held in Budapest in 2004.

Actions to address environmental inequity among children may be included into four main policy approaches, according to their primary aim:

(i) policies aimed at reducing the socially determined differences in environmental conditions in settings where children live;
(ii) policies aimed at reducing the socially determined differences in individual children's exposure to hazardous environments;
(iii) policies aimed at reducing the socially determined differences in children's susceptibility to specific environmental pollutants and risk factors and

(iv) policies aimed at reducing the socially determined differences in the access to quality diagnostic, treatment and rehabilitation services for children who suffer the health consequences of being exposed to hazardous environments.

These four policy approaches should be seen as a continuum along the causal pathways of environmental inequity, from the distal socio-economic causes, to the increased susceptibility and exposure that characterize socially deprived children in particular, to the proximal factors related to access and quality of care (figure 1).

Type 1 actions, by acting upstream in the causal pathway of environmental risk, generally achieve a stable and sustainable risk reduction and therefore have the greatest long-term preventative potential. Type 2 and type 3 actions have a more limited scope and should not be seen as standalone interventions. Yet, the potential of nutrition and early child development policies to reduce the susceptibility and effects of exposure to unsafe and unhealthy environments cannot be neglected. Type 4 actions are clearly remedial rather than preventative, although they may still be quite important to save lives and prevent disabilities in the case of injuries and severe intoxications. Examples of type 1–4 actions addressing the four priority goals of the CEHAPE are provided in table 2. The table also provides a generic (the responsible authorities may not be the same across the 53 countries included in the WHO European region) indication of what kind of authorities could be responsible for developing and implementing the relevant policies and interventions.

Furthermore, an equity approach to children's environmental health should be adopted concerning environment and health information systems and IEC (information, education, communication) strategies. This could further enable stakeholders such as developers or teachers as well as parents to be aware of environmental inequalities and to contribute to improvement of children's environmental health.

Conclusion

Based on the available fragmentary evidence for Europe the main finding of this review is that there is a common pattern that children living in adverse social circumstances suffer from multiple and cumulative exposures, are more susceptible to a variety of environmental toxicants and often lack environmental resources/goods and other resources such as access to quality health care to counterbalance environmental threats and reduce their health consequences. This challenge requires a broad and cross-sectoral engagement to address the combination of factors, from the socially determined adverse environmental conditions to the social divide in exposure susceptibility and access to health care, which are responsible of environmental inequity among children. Children's health and environment lie at the centre of sustainable development. Protecting children from environmental hazards now will be of benefit to the well-being of the population as a whole in the long term.[45]

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Conflicts of interest. None declared.

Key points

- Children living in adverse socio-economic circumstances in Europe suffer more often from multiple and cumulative environmental exposures and are likely more susceptible to a variety of toxicants.
- There are still numerous knowledge and research gaps to fill to be able to assess the magnitude of environmental inequalities among children in Europe and the interaction between socio-economic position, multiple and cumulative environmental hazards, and community stressors.
- Research on social inequalities in exposure and susceptibility to hazardous environments should be complemented with research on social inequalities in environmental salutogenic resources and a community-based participatory research strategy.
- It is important to incorporate a child focused equity lens in environment information systems and in IEC activities.
- Specific actions to reduce socially determined differences in children's exposure, susceptibility and health consequences should be combined with upstream progressive policies to reduce the social divide, starting from the earliest years.

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