Public health impact of environmental pollution on children in North and South. A focus on air and metal pollution in Antwerp (Belgium) and Lubumbashi (DR Congo)

PhD thesis presented on February 17th 2023 at Ghent University, Belgium

Daan Van Brusselen [a]

Promoters: Dirk De Bacquer [b], Koen Van Herck [c], Benoit Nemery [d], Dirk Avonts [e]

[a] Consultant Tropical Paediatrics and Paediatric Infectious Diseases, ZAS Hospitals, Antwerp Belgium; Department of Public Health and Primary Care, Ghent University
[b] Faculty of Medicine and Health Sciences, Department of Public Health and Primary Care, Ghent University, Belgium
[c] Cancer Institute, UZ Leuven, Belgium
[d] Department of Public Health and Primary Care, Centre for Environment and Health, KU Leuven, Belgium
[e] Faculty of Medicine and Health Sciences, Department of Family Medicine and Primary Health Care, Ghent University and Domus Medica, Antwerp, Belgium

Daan.VanBrusselen@gza.be

Keywords

Infant ; child ; environmental pollutants ; particulate matter ; vulnerable populations ; developing countries ; asthma.

Research in context

Emerging infectious diseases like Zika, COVID and Ebola have shown clearly that disrupting ecological systems can lead to epidemics and pandemics. Therefore WHO developed the 'One Health' concept, an 'interdisciplinary approach stressing connections between human, animal and environmental health' (1). The distressing amount of environmental health problems from the last 20 years clearly shows that we must broaden our definition of 'public health', and include '**Planetary (One) Health**', focusing on the *(human and animal) health impact of disrupted ecosystems.* Currently we are not only facing climate change and its health consequences, but also a lack of water and land, diminishing biodiversity and different kinds of pollution. All these problems are closely connected. To understand all these challenges – and react to them – we need to increase collaboration between disciplines and countries, if we want to keep our planet (and its inhabitants) healthy (2, 3).

The magnitude of the current environmental problems is endangering humanity itself (by nutritional crises resulting in population displacement and conflict, pandemics and the serious health impact of pollution) (3). **Air pollution** and '**chemical / toxic substances**' (of which metals are the most important) are the **two most important 'areas of work**' of WHO's 'Public Health and Environment' (PHE) strategy (4). The purpose of this PhD thesis was to fill a few knowledge gaps about the health impact of air and metal pollution on children in the Global North and South.

Evidence before this PhD

It is well known in paediatrics that the first 1000 days (from conception onwards) are very important in terms of proper nutrition and (psychosocial) development (5, 6). In this thesis we aimed to demonstrate that also environmental '**early life exposures**' are very important. South African researchers from the 'Drakenstein Child Health Study' have shown that **antenatal exposure** to household air pollution (HAP) already affects the incidence and severity of '*lower respiratory tract illness*' (remark that they call it LRT 'illness' and not 'infection') in their offspring (7, 8). Antenatal outdoor 'ultrafine particle' (UFP; with an aerodynamic diameter < 0.1 micrometre) exposure was also linked to '*asthma development in children*' in the US (mostly when the exposure took place late in pregnancy) (9). Foetuses and infants are extremely vulnerable to pollution exposure because of their rapid development and immature immune system, particularly those in Low- and Middle-Income Countries (LMIC) where poverty and lack of resources compound the effects (10).

Environmental health effects are the largest in **disadvantaged or vulnerable populations**: this can be because of age (the youngest and the oldest are more 'fragile'), disease, race and poverty (11). There is a clear link between poverty and unhealthy living environment, also in Belgium (12). People in 'low resource settings' are even a lot more 'exposed' to several environmental pollutants than disadvantaged people in the global North, because there are less stringent environmental laws in LMIC (13).

Added value of this PhD and knowledge gaps

In our 'health impact assessment' (HIA) of 'Ringland' we have calculated that the impact of improved air quality by moving the entire Antwerp Ring Road into a tunnel, would especially have a significant impact on 'all cause' mortality (21 deaths, 95%CI 7-41, avoided annually in the population living in a perimeter of 1500m around the ring road), and on child lung function development (forced vital capacity improvements of 3-64ml in 356 of the 430 schools around the ring road) (14). In the 'BronchiolAir' study (in publication), we found a trend that children hospitalized for bronchiolitis appear to be more exposed to air pollution, but the study was too small to draw definite conclusions. This trend does however confirm that the already existing evidence from the US on the association between bronchiolitis and air pollution, does probably also count for the urban environment of Antwerp. Larger studies are needed to consolidate the impact of air pollution on bronchiolitis in Europe; and even more so in LMIC.

In a case-control study in a mining area in southern Katanga (Democratic Republic of the Congo, DRC), we were able to associate paternal occupational mining (OR 5.5; 95%CI 1.2-25), and concentrations of Mn (OR 1.7; 95%CI 1.1-2.7) and Zn (OR 1.6; 95% CI 0.9-2.8) in cord blood and placental tissue, with the incidence of (visible) birth defects in newborns (15). Prospective studies could help to establish a causal relationship between metal pollution and congenital malformations.

We have added data to the increasing evidence that 'early life exposure' to environmental pollutants, is harmful in the Global North and South. Until a few decades ago, pollution was not considered a major determinant of health among children. The health impact of air and metal pollution on children is becoming more clear in recent years. And even if some things (like the relationship between metals and birth defects in DRC that we have shown) are just associations, according to the 'precautionary principle', this is enough to start protecting children from environmental 'early life exposures'. Even if there is uncertainty about the nature and magnitude of potentially harmful effects of several pollutants, the credible threat of these agents to the paediatric population provides a rationale for taking precautionary measures to prevent this exposure (16).

Policy implications of all the evidence available

WHO, UNICEF and The Lancet recently called for action to put '**children in all policies**' to build a healthier and more equitable world for future generations. This is especially important for policies on environmental pollution (17). Fossil fuel combustion has become one of 'the world's most significant threats to children's health' (10). The 'Ringland' and 'BronchiolAir' studies confirm that the **individualized motorized traffic** (and the liberty associated with it) has become one of society's largest problems. Air pollution, but also pollution of water and soil (by fossil fuels, but recently also by metals for batteries), global warming, destruction of biodiversity and liveable urban space for roads and car parks are just a few of the negative effects of the automobile industry (18).

It is exaggerated to state that lithium-ion batteries are '*the new oil*', but – as part of the 'low-carbon future' – high amounts of cobalt and smaller amounts of copper are needed. They are extracted in countries like DRC. The increased production makes that more children (and adults) are exposed to high amounts of metals, especially in vulnerable countries like DRC. Our 'Katanga Malformations Congénitales' study has shown that even unborn children are at risk. We must therefore prevent that batteries destroy more lives than they save the climate (19, 20). On a *global scale* **Big Tech companies should be held responsible** not only for where their metals come from, but also become key stakeholders in a real circular economy, by becoming accountable for the recycling of their own mobile devices, laptops, etcetera, when they can no longer be used (cf. the Recupel initiative) (21).

An important component of environmental health in *LMIC*, is '**better housing**'. Better housing means that dwellings are *climate-proof*, i.e. less hot and mosquito-free, but also free of *household air pollution (HAP)*. HAP can be reduced by cooking on porches that are well ventilated, with nets not only to keep mosquitos out, but also to let the smoke escape (22).

In HIC technical solutions that reduce industrial emissions, proper urban cycling networks, good public transport systems, clean power sources (wind, water, sun) and isolation of houses are essential (10). A '**Modal Shift**' towards more active transport and '**Road pricing**' (these two are currently part of the 'Ringland' plan), but also '**Low Emission Zones**' **(LEZ)**, preferably associated with 'circulation plans', are only first steps. More and more cities recommend to leave personal cars (especially for non-urban residents) in '*park and ride zones*' outside of the city. These zones should be equipped with charging stations (for electric cars) and be a lot better connected to the heart of the city by public transport and shared bicycle systems. **Transforming 'car parks' into 'real parks'** could also have additional salutogenic effects. The WHO recommendation is that all people should have access to ≥ 0.5 hectare (ha) open green space within 300 m linear distance from their home. Recently, the '**3-30-300 rule**' (or 'Vancouver rule') has been proposed by urban planners: they state that 'everybody should be able to see at least 3 trees from their home, that all neighbourhoods should have at least 30% tree cover, and that everyone should have access to "a green area of at least one hectare" within 300 metres' (23). Adding blue spaces to this '3-30-300 rule', could even increase its impact.

It has already been shown many times that investing in Public Health works. The 'fiscal multiplier' for investments in public health is 4.3. This means that for every euro invested in Public Health, the society in the end gains 4 euros (24). So, societies investing in healthier (pollution free) environments for children will also benefit financially from this. For example, Copenhagen is planning **Cycle Super Highways**, to improve mobility and reduce air pollution in the capital region. The planned 'Bicycle Super Highways', around the city (>500 km of bike paths), could reduce public health expenses by 40 million euro every year (25). 'Historically, cycle paths are an artifact of car thinking' (26). Originally streets were 'meeting places'. In a lot of cities worldwide pedestrians and cyclists are 'reclaiming the streets', by initiatives like the 'Critical Mass Bike Ride' (26).

Traffic remains an important cause of diverse forms of pollution that harm children. When planning transport, the purpose should be to maximize social/health benefits, and to minimize harm. Therefore some people argue that we should 'phase out' cars from our lives. For almost all journeys cars can easily be substituted (think of Pontevedra, Amsterdam or Copenhagen) (27).

Measuring works: 'Clear indicators' can be helpful to identify which populations are most vulnerable (and where you should act first). In New York City, e.g., the city council mapped green space and the 'urban heat island' effect: on this basis they decided which communities are the most at risk for heat-related mortality/morbidity and where they should thus prioritize cooling policies (28). The same could be done for places and populations most at risk for air pollution.

You can be unlucky with your genes and get cancer despite living an ultra-healthy life. But statistically, with a healthy lifestyle you are 79% less likely to develop a chronic condition. 'Quick wins' are not smoking, exercising, keeping your BMI under 30 and a healthy diet (no red meat and prepared meat; lots of vegetables and seeds) (29). It is now becoming increasingly clear that a healthy lifestyle also includes avoiding 'early life exposures' to a combination of pollutants. Pollution is like a symphonic orchestra: there's only a concert when several instruments play together.

'Bird perspective' on this PhD

We have to broaden our definition of 'public health' with the concept of 'planetary health'. Everything is connected. Climate warming, loss of biodiversity, but also environmental pollution are closely related to global health problems like infectious disease outbreaks (COVID-19, LRTI…) and 'non-communicable diseases' (malnutrition, asthma, allergies, renal problems, several cancers…) (30).

We must mutualize the 'commons' again. 'Commons' or 'le bien commun' are the things that are not supposed to be anyone's property; it's what we all inherit from our parents and pass on to our children. It's about air, water, the underground (and by extension also our climate) (31). We have an intergenerational responsibility to keep them clean. These 'commons' are important in the Global North, but perhaps even more so in the Global South, because there are less stringent environmental laws in LMIC.

This doctoral research was needed because we often do not realize how early in life an unhealthy living environment can already have long-lasting consequences. Since foetuses and young children cannot do anything about this themselves, society has a tremendous responsibility. The trend to more sustainable cities and a healthier world has been set. It can be slowed down by some politicians and policy makers (often protecting privileges of a selected group), but it cannot be stopped anymore. A 'tailored approach' depending on where you are, is needed. Think global, act local.

REFERENCES

1. Rabinowitz PM, Pappaioanou M, Bardosh KL, Conti L. A planetary vision for one health. BMJ global health. 2018;3(5):e001137.
2. Planetary health alliance: goals 2021. Boston MA, USA2021 [cited 2023 Aug 02]. Available from: https://www.planetaryhealthalliance.org/planetary-health.
3. Myers SS, Pivor JI, Saraiva AM. The São Paulo Declaration on Planetary Health. Lancet (London, England). 2021;398(10308):1299.
4. WHO Public Health & Environment (PHE) Global Strategy Overview Geneva, Switserland: WHO; 2011 [cited 2023 Aug 02]. Available from: (http://www.who.int/phe/publications/PHE_2011_global_strategy_overview_2011.pdf?ua=1).
5. Barker DJ. Fetal origins of coronary heart disease. BMJ (Clinical research ed). 1995;311(6998):171-4.
6. Singh BSK, Danckaerts M, Van den Bergh BRH. Helping Families of Infants With Persistent Crying and Sleep Problems in a Day-Clinic. Frontiers in psychiatry. 2021;12:591389.
7. Nemery B, de Marie Katoto P. Protecting children's lungs by providing clean air during pregnancy? The Lancet Planetary health. 2017;1(8):e309-e10.
8. Vanker A, Barnett W, Workman L, Nduru PM, Sly PD, Gie RP, et al. Early-life exposure to indoor air pollution or tobacco smoke and lower respiratory tract illness and wheezing in African infants: a longitudinal birth cohort study. The Lancet Planetary health. 2017;1(8):e328-e36.
9. Wright RJ, Hsu HL, Chiu YM, Coull BA, Simon MC, Hudda N, et al. Prenatal Ambient Ultrafine Particle Exposure and Childhood Asthma in the Northeastern United States. American journal of respiratory and critical care medicine. 2021;204(7):788-96.
10. Perera F. Pollution from Fossil-Fuel Combustion is the Leading Environmental Threat to Global Pediatric Health and Equity: Solutions Exist. International journal of environmental research and public health. 2017;15(1).
11. United_Nations_Environment_Programme. Sixth Global Environment Outlook (GEO-6) Summary for Policymakers. Singapore: Cambridge University Press; 2019 [cited 2023 Aug 02]. Available from: (https://wedocs.unep.org/bitstream/handle/20.500.11822/27652/GEO6SPM_EN.pdf?sequence=1&isAllowed=y).
12. Hoe gezond is de lucht in Brussel? Ontdek de resultaten van CurieuzenAir. De Standaard. 2021.
13. Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu NN, et al. The Lancet Commission on pollution and health. Lancet (London, England). 2018;391(10119):462-512.
14. Van Brusselen D, Arrazola de Oñate W, Maiheu B, Vranckx S, Lefebvre W, Janssen S, et al. Health Impact Assessment of a Predicted Air Quality Change by Moving Traffic from an Urban Ring Road into a Tunnel. The Case of Antwerp, Belgium. PloS one. 2016;11(5):e0154052.
15. Van Brusselen D, Kayembe-Kitenge T, Mbuyi-Musanzayi S, Lubala Kasole T, Kabamba Ngombe L, Musa Obadia P, et al. Metal mining and birth defects: a case-control study in Lubumbashi, Democratic Republic of the Congo. The Lancet Planetary health. 2020;4(4):e158-e67.
16. Tickner JA, Hoppin P. Children's environmental health: a case study in implementing the precautionary principle. International journal of occupational and environmental health. 2000;6(4):281-8.
17. Dalglish SL, Costello A, Clark H, Coll-Seck A. Children in All Policies 2030: a new initiative to implement the recommendations of the WHO-UNICEF-Lancet Commission. Lancet (London, England). 2021;397(10285):1605-7.
18. Descamps P. Dossier: La ville défigurée. Ravages de l'automobilisme Le Monde Diplomatique. 2021.
19. Sovacool BK, Newell P, Carley S, Fanzo J. Equity, technological innovation and sustainable behaviour in a low-carbon future. Nature human behaviour. 2022;6(3):326-37.
20. Watts J. How the race for cobalt risks turning it from miracle metal to deadly chemical. The Guardian. 2019.
21. Sovacool BK, Turnheim B, Hook A, Brock A, Martiskainen M. Dispossessed by decarbonisation: Reducing vulnerability, injustice, and inequality in the lived experience of low-carbon pathways. World Development. 2021;137:105116.
22. Knudsen J. How to design houses in Africa that reduce diseases. 39th Annual ESPID Meeting; Geneva2021.
23. Konijnendijk C. The 3-30-300 rule for urban forestry and greener cities. Biophilic Cities Journal. 2021;4(2):2.
24. Reeves A, Basu S, McKee M, Meissner C, Stuckler D. Does investment in the health sector promote or inhibit economic growth? Globalization and health. 2013;9:43.
25. Cadence_team. Denmark's first cycling superhighway London, UK 2017 [cited 2023 Aug 02]. Available from: https://www.cadencemag.co.uk/news-denmarks-first-cycling-superhighway/
26. Schipper F, Emanuel M, Oldenziel R. Sustainable Urban Mobility in the Present, Past, and Future. Technology and culture. 2020;61(1):307-17.
27. Monbiot G. Cars are killing us. Within 10 years we must phase them out. The Guardian. 2019.
28. van den Broek d'Obrenan H, Huxley R. Measuring what matters: supporting cities in tackling climate and health challenges. The Lancet Global health. 2022;10(6):e788-e9.
29. Deschepper R. Je levensstijl als medicijn. Tielt, Belgium: Lannoo; 2022.
30. 3The_Lancet_Planetary_Health. Editorial. Turning point? . The Lancet Planetary health. 2020;4(12):e544.
31. Lotens W. De nieuwe coöperatie: tussen realiteit en utopie. Tielt, Belgium: Lannoo Campus; 2013.