Early-Life Social and Economic Adversities on Health

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1 Introduction

With more than 9 out of 10 pollution-related deaths occurring in low- and middle-income countries, the Lancet Commission on pollution and health states it bluntly: pollution disproportionately kills the poor and the vulnerable [1] with children at higher risk due to the cumulative effects of antenatal and early life exposure. This chapter aims to delineate the mechanisms through which these exposures, in particular during the first 1000 days of life, influence children's health throughout the life course. Key concepts such as the life course approach, social determinants of health, and health inequity are explained alongside their relevance to environmental health and disease using a case study of informal settlements in Freetown, Sierra Leone.

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Y. Xia (ed.), *Early-life Environmental Exposure and Disease*,
https://doi.org/10.1007/978-981-15-3797-4_10

Box 1 Types of Environmental Pollutants Associated with Health Risks [1]

- Air
  - Household air
  - Ambient particulate
  - Ambient ozone
- Water
  - Unsafe sanitation
  - Unsafe source
- Occupational
  - Carcinogens
  - Particulates
- Lead
- Soil, heavy metals, and chemicals

2 Sustainable Development, Child Health, and Pollution

Pollution, child health, and early life adversity are closely linked. This is recognised explicitly in the Sustainable Development Goals (SDGs), the United Nation's accountable targets to equitably and sustainably improve the lives of the world's population [2]. The SDGs are a set of 17 goals that make global and interconnected commitments to improve human health and well-being, through specific targets that act on inequality, climate change, pollution, and peace (Box 2). Within goal 3 (good health and well-being), target 3.9 is a specific call to environmental action in the context of health to "substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination". In the UNICEF 2019 report "Progress for Every Child", these targets are organised into five child-relevant domains. Within one of these domains, *every child lives in a clean and safe environment* (with indicators on reliance on clean fuels; deaths from air pollution and disasters; and access to safe drinking water, sanitation, and hygiene), it finds that progress worldwide towards every child living in a clean and safe environment by 2030 is mixed, with many indicators requiring acceleration to be achieved (Fig. 1).

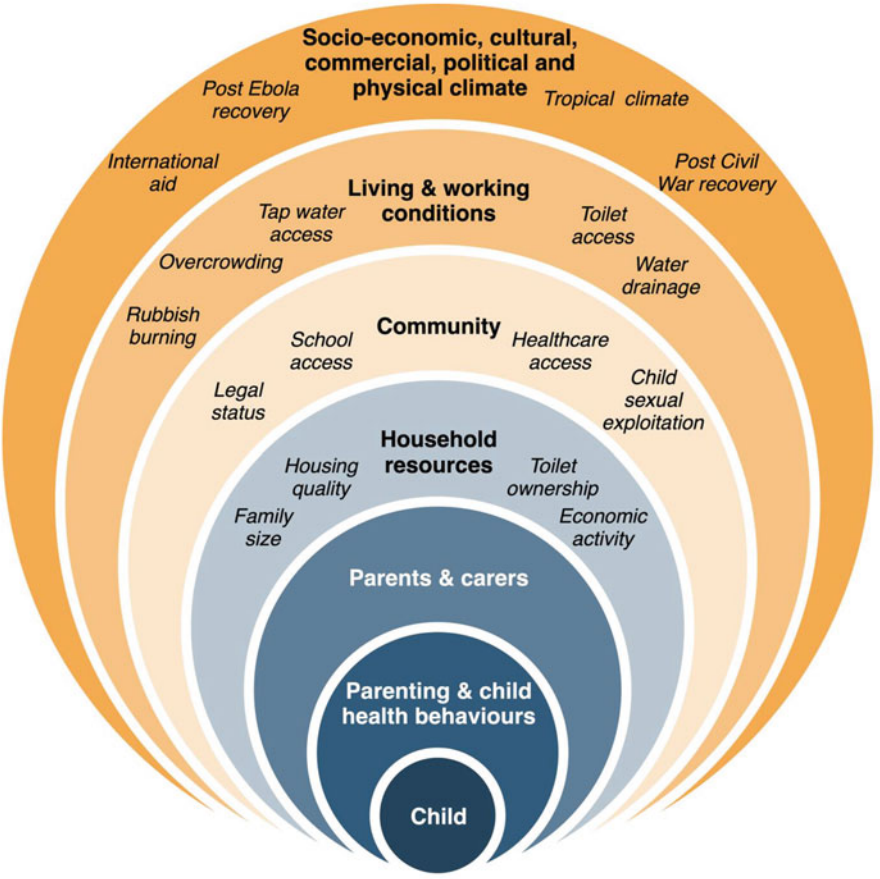

Fig. 1 This is a socioecological model of determinants of child health [3] using examples from the case study on informal settlements in Sierra Leone. The child is represented at the centre, and concentric circles represent a hierarchy of increasingly structural factors

Box 2 Pollution-related Sustainable Development Goals

- **Target 2.4** – "...progressively improve land and soil quality"
- **Target 3.9** – "substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination"
- **Goal 6** – Clean water and sanitation
- **Goal 7** – Affordable and clean energy
- **Target 9.4** – "...adoption of clean and environmentally sound technologies and industrial processes..."
- **Goal 11** – Sustainable cities and communities

(continued)

Box 2 (continued)
- **Goal 12** – Responsible production and consumption
- **Goal 13** – Climate action
- **Goal 14** – Life below water
- **Goal 15** – Life on land

3 How Adversity, Pollution, and Health Are Linked

Box 3 Definitions
- **Life course epidemiology**: The study of disease risk in later life carried by biomedical, psychological, or environmental exposures in earlier life; or disease risk carried forward over generations
- **Intergenerational effects**: Disease exposures in an individual that are associated with increased risk of disease among their offspring
- **First 1000 days**: A critical period in child development from conception to age two when brain development and growth occur most rapidly, and window of opportunity when interventions can mitigate life-long effects of harmful environmental exposures
- **Accumulation of risk**: The increasing probability of a disease outcome with the cumulative effect of multiple exposures, each independently associated with that outcome
- **Chains of risk**: Increasing probability of a disease outcome as certain exposures increase the risk of further exposures

Individual health is influenced by societal factors. These are known as the social determinants of health: the material, psychosocial, structural, and behavioural "conditions in which we are born, grow up, work and live" [3] that exert protective or harmful downstream effects on individual health. Put simply, they are the potentially modifiable "causes of the causes" of ill-health [4], interacting to mitigate or exacerbate one another (Fig. 2).

Identifying how societal factors influence health can be complex, especially if exposures are separated from outcomes by long periods of time. Life course epidemiology originated from the *foetal origins* hypothesis that antenatal exposures during critical periods of in utero life "programmed" organs and systems to be more vulnerable to chronic disease in adulthood, as opposed to a focus on adult health behaviours alone predicting adult health outcomes. The emphasis is on the timing and links between different exposures and disease at different stages of the life course. [5] A key concept is the *accumulation of risk* or *chains of risk* from repeated or multiple different exposures over time. This is visualised in Fig. 3 [5].

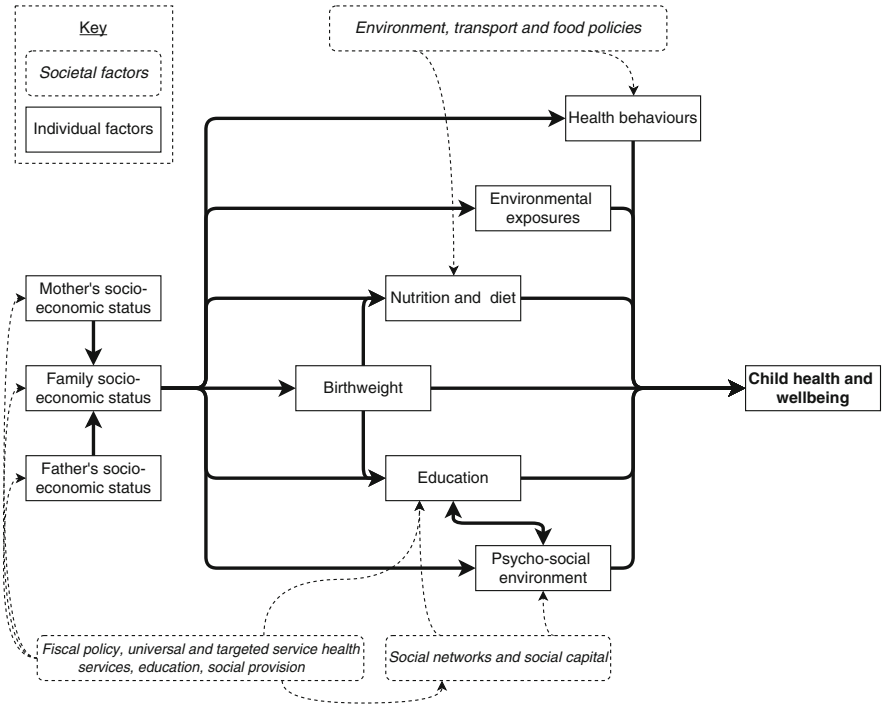

Fig. 2 This flow diagram is replicated from a review of the social determinants of child health [7]. The researchers used observational data to propose an explanatory pathway for how social risk factors exert influence on health outcomes throughout the life course, including the temporal relationship between these factors, such as intergenerational effects. In the diagram, "environmental exposures" refers to pollution, which we define here in Box 1. Infections such as diarrhoeal diseases, respiratory disease, and malaria play a crucial role in child health and well-being but are not directly referenced

The case study below highlights how children growing up in poverty face the double jeopardy of increased exposure to toxic pollutants. During the first 1000 days from a child's conception to their second birthday, children are particularly vulnerable to toxic environmental exposures. Examples include the disease risk carried by teratogens in utero and neurotoxins during infancy. This critical period is a time when the brain is developing most rapidly and is becoming more complex, interconnected, and organised. During this period, it is thought to be more malleable under environmental influence, either for better or for worse. Exposures are embodied and carry long-term disease risks. If not corrected during this period, stunting tends to be irreversible, with effects throughout the life course and across generations. Stunted growth in girls is carried forward in adulthood and in their offspring [6]. Conversely, the first 1000 days can also be thought of a *window of opportunity* to intervene to mitigate socially patterned disease exposures. Positive interventions in

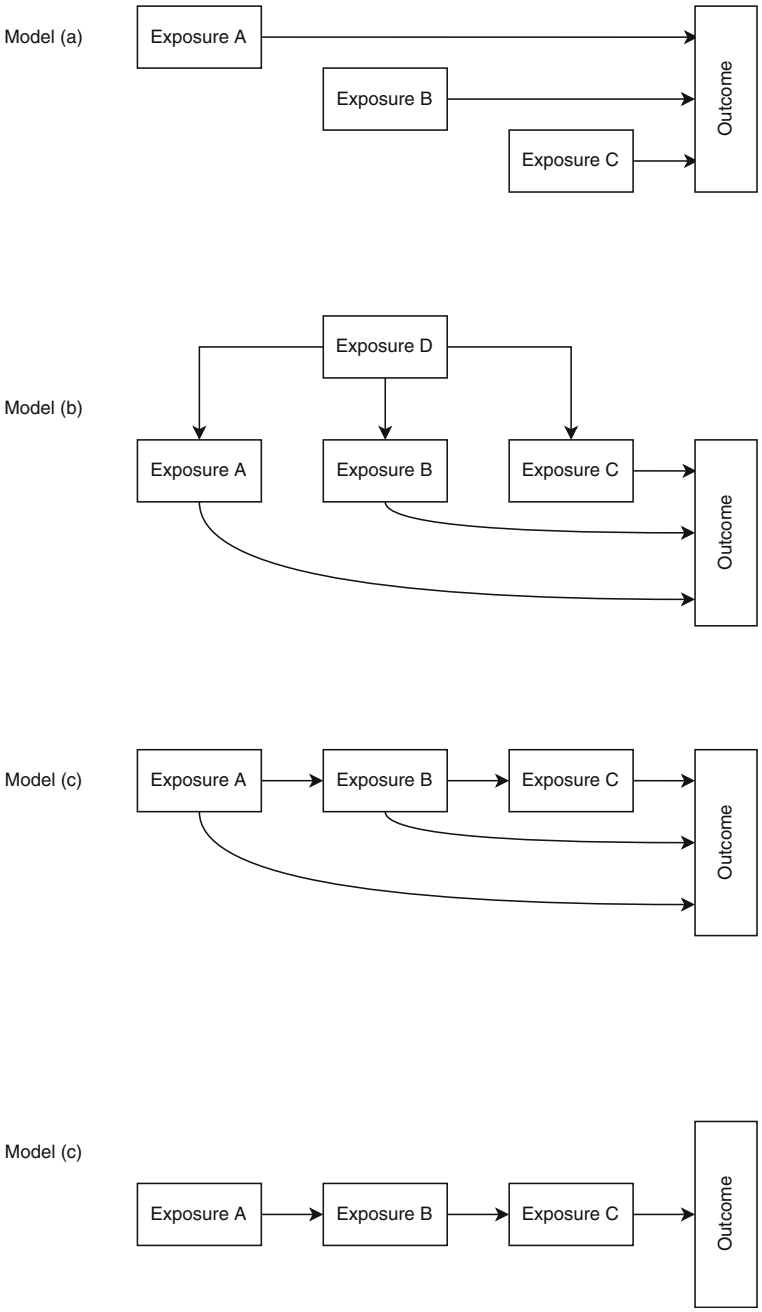

Fig. 3 Accumulation of risk [5]
Model (a) shows that multiple different exposures may occur sequentially but be independently associated with the outcome of interest.
Alternatively, as per Model (b), exposures may group together because they are each associated with some other risk factor as well as with the long-term outcome.

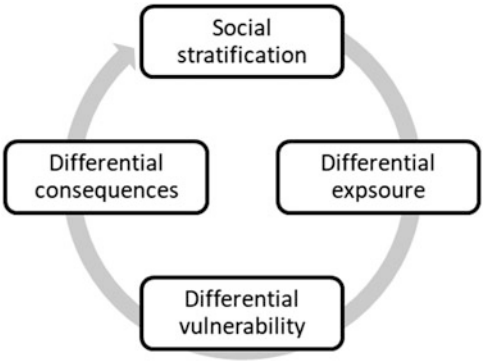

Fig. 4 Mechanisms of health inequity
Social stratification: Individual children's socioeconomic circumstances are made unequal by prevailing political, cultural, and economic structures
Differential exposure: Disadvantaged children take a greater share of health risks
Differential vulnerability: Early life adversity exposes children to worse outcomes from the same risk factors compared with their counterparts
Differential consequences: Impacts of ill-health have greater effects on the well-being and life chances of disadvantaged children

this period can have long-lasting effects to improve health throughout life and across generations.

4 Case Study: Informal Settlements in Freetown, Sierra Leone

This case study considers informal settlements in Freetown, Sierra Leone, as an example of how environmental injustice interacts with health inequity and mediates health risks. Informal settlements in the Sierra Leonean capital Freetown proliferated during the horrific 1992–2002 civil war when people living in rural areas were displaced to the relative safety of the Freetown peninsular. Since the war, economic forces have meant that internal migration and urbanisation have continued for Sierra Leone's population of 7,396,000 people. Densely populated informal settlements such as Dwarzak and Moyiba in the hills around Freetown and on reclaimed

Fig. 3 (continued) Another key concept is chains of risk whereby certain exposures give rise to a given probability of further exposures, as in Models (c) and (d). Model (c) implies each exposure independently carries a risk of disease, as well as accumulating risk by increasing the probability of further exposures;
Model (d) implies a causative chain leading to a trigger event which leads to disease whereby earlier exposures have minimal influence on risk without the final link.

mangroves in its coastal areas such as Cockle Bay, Kroobay, and Portee-Rokupa are home to large proportion of Freetown's urban poor (Picture 1).

Sierra Leone has very high child mortality rates, despite drastic improvements versus one and two decades ago (see Table 1). In Freetown's informal settlements, rates are likely to be even more dire. Child mortality in Sierra Leone is largely driven by infection in the first 1000 days and beyond, particularly malaria, lower respiratory infections, and diarrhoeal diseases (see Table 2). Epidemiological and demographic data at the local level is difficult to collect in these areas, but one study of verbal autopsies sought from community members in Freetown informal settlements suggested that the leading reported cause of death in neonates was pneumonia, and in children up to 5 years was malaria followed by pneumonia [10]. The Sierra Leone Urban Research Centre [11] recently reported the findings of their mixed methods study on the health impacts of living in Freetown's informal settlements, which informs the following discussion of the multitude of socially mediated pollution exposures that harm child health.

Picture 1 Crocodile River, Kroobay, Freetown, Sierra Leone. Photographer: Dominic Chavez

Table 1 Mortality estimates for Sierra Leone [8]

Deaths/1000 live births (90% CI)	1998	2008	2018
Neonatal: First 28 days of life	52 (45 to 59)	44 (38 to 50)	33 (24 to 43)
Infant: Birth to age 1	147 (139 to 155)	117 (110 to 124)	78 (66 to 91)
Under 5: Birth to age 5	244 (227 to 262)	180 (167 to 195)	105 (85 to 128)

Table 2 Top five causes of death by age in Sierra Leone, 2008 to 2017 [9]

1 to 7 days	8 to 28 days	29 days to 1 year	1 to 4 years
Neonatal disorders	Neonatal disorders	Malaria	Malaria
Congenital birth defects	Lower respiratory infections	Lower respiratory infections	Lower respiratory infections
Lower respiratory infections	Malaria	Diarrhoeal diseases	Diarrhoeal diseases
Syphilis	Congenital birth defects	Congenital birth defects	Protein-energy malnutrition
Diarrhoeal diseases	Diarrhoeal diseases	Protein-energy malnutrition	Congenital birth defects

Local geography makes the Freetown peninsular one of the rainiest parts of West Africa, and flooding is a constant risk for residents: however, the inhabitants of informal settlements are extremely vulnerable in particular. Deforestation and dense settlement in the hills around Freetown undermine the soil structure, increasing the risk of flooding and landslides. This is compounded by a lack of effective drainage. Landslides and flash flooding in 2017 killed at least 500 people and displaced over 5900. The most significant event was a six-kilometre mudslide that destroyed 300 homes. Although not directly related to pollution as defined here (see Box 1), environmental factors like deforestation and housing quality that have a direct deleterious effect on the health of children and their families are interacting with social factors like population density, urban migration, and poverty.

Informal settlements located on reclaimed mangroves in coastal areas of Freetown are less than a metre above sea level leaving children and their families at constant risk of flooding. Pools of standing water provide ideal conditions for Anopheles mosquitoes, with malaria being one of the leading causes of childhood mortality in Sierra Leone (see Table 2). Water distribution through PVC piping, which is vulnerable to damage, runs through areas where open defecation takes place, leaving children and their families with limited access to clean water sources and vulnerable to diarrhoeal disease. Water pumped from boreholes is highly saline and residents face long waits for tap water with variable availability. The burden of collecting water often falls to boys and girls: adolescent girls are coerced into what one author describes as "transactional sex" in return for quicker access to water [12]. This exposes them to the possibility of adolescent pregnancy and the health risks associated with it for both the mother and her child, as well as psychological trauma, injury, and sexually transmitted infections.

Diarrhoeal diseases are a leading driver of child mortality in Sierra Leone (see Table 2). Cholera, typhoid, and coliforms are spread rapidly in part because of a lack of good quality sewerage infrastructure. In general, toilet ownership for residents in these communities is uncommon with shared toilets being the norm. Most human waste is destined for pits, streams, or the sea. This leads to significant coliform contamination of water sources, which is compounded by flooding during rainy

season. The same streams which are contaminated with human waste are regularly used as water sources for laundry and bathing.

In the absence of effective infrastructure for household waste disposal, these communities face a build-up of refuse. Children often play in piles of waste, which include not only domestic waste but especially hazardous materials like clinical waste from health facilities. This potentially exposes them to the risk of injury, heavy metal poisoning, chemical burns, and infections. If waste has not been discarded into the streams, it is discarded into the sea as a form of land reclamation.

Commonly, this household waste is piled up and burnt in the open. Regularly seen rising from certain areas of the city, smog is a visual reminder of the poisonous cocktail of particulates and invisible noxious gases accumulating from several different combustion sources. As seen in Table 2, pneumonia is a leading cause of childhood death in Sierra Leone. From 2018 to 2019, a diesel burning power station on a converted cargo ship was moored close to the shore of Kroobay to meet Freetown's energy deficit. There is strong evidence that ambient air pollution, diesel in particular, harms the respiratory health of children especially; for example through pneumonia and exacerbations of asthma, and through life course effects via maternal exposure during pregnancy and via laying the foundation for cardiovascular disease in adulthood [13–16]. At the same time, solid fuels are the primary energy and cooking source for many households. Solid fuel use is strongly associated with childhood pneumonia and bronchiolitis, with children and women particularly vulnerable to exposure [17–19].

5 Child Health Inequity and Its Mechanisms

Box 4 Definitions

- **Horizontal equity**: a group of people with equal need are treated in an equal way
- **Vertical equity**: different groups with different needs are treated in proportionately different ways
- **Inequity**: "differences among groups that are unnecessary, avoidable, unfair and unjust" [20].
- **Health inequity**: unjust and avoidable differences in how the burden of health outcomes such as low birth weight, under five mortality, infectious disease, or asthma are shared in society
- **Child health equity**: a goal that sees all children having an equal opportunity to be healthy, regardless of the circumstances in which they are born; related to a domain of Sustainable Development Goals, that *every child thrives and survives* [21].

The increased exposure to toxic pollutants described in the case study is driven by poverty and other social factors. It leads to increased burden of disease among children growing up in these informal settlements. Not only is this increased burden unfair, it is also avoidable. It is estimated that under five mortality among Freetown's urban poor could be reduced by 80% through improvements in children's living environment [22]. These socially determined health inequities are thought to be mediated by four overarching mechanisms [23].

The principal mechanism is *social stratification*, whereby inhabitants of Freetown's informal settlements lack the social, financial, and political capital to escape hazardous and perilous living conditions. This leads to *differential exposure*, with wealthier communities in Freetown able to afford to have clean water delivered, or live in accommodation with a safe functioning toilet, reducing children's exposure to harmful environmental hazards. This is compounded by *differential vulnerability*, for example their increased exposure to ambient and household air pollution and associated risk of respiratory infection is made worse by their stunted physiological reserve due to poor nutrition or low birth weight. Early life adversity leads to *differential consequences*. When they get sick, their access to medical care is not adequate. Because they have not received planning permission, these settlements are seen by local and central government as illegal, which disempowers poor families even further and inhibits communities' access to the limited amount of public services that do exist. These factors in turn have effects on school attendance, work-readiness, and future employment, embedding social inequalities yet deeper to lead to *further social stratification* and perpetuate the *chain of risk* across generations.

6 Conclusion

Box 5 Key Points of This Chapter

- Health risks and health outcomes are not distributed equally in society
- Children living in poverty are disproportionately affected by the health risks of pollution
- Health and disease are in part socially determined, as opposed to being influenced only by individual factors
- The social determinants of health are the multifactorial "causes of the causes" of disease and interact with each other to have downstream effects on health
- Early life exposures have effects throughout the life course as well across generations, and there are epidemiological tools to establish these associations

This chapter has hopefully highlighted how environmental exposures in childhood, especially in the first 1000 days, interact with poverty and other social factors to impact on children's health throughout the life course. The early years are a critical period. Growing up in poverty and challenging environments leads to exposure to pollutants. These have a direct adverse effect on health through infection, growth, and brain development, as well as interacting with the indirect effects of social factors such as poor quality housing and dense population. These factors have a feedback effect, for example a child who has poor light and who can't concentrate due to malnutrition will be less work ready and less able to have the means to mitigate these factors to improve the health of their own children. Improvements in child health require improvements in the social milieu in which they grow up. There are opportunities to intervene during this period to reduce burden of disease both in childhood and in later life.

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