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A DISCUSSION PAPER

CHILDREN'S ENVIRONMENT AND HEALTH IN EAST ASIA AND THE PACIFIC

SITUATION ANALYSIS AND CALL FOR ACTION



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Table of Contents

Summary	iv
1 Introduction	2
1.1 Children’s environmental health.....	2
1.2 Purpose of Discussion Paper.....	3
1.3 Scope and methodological approach.....	3
2 Key environmental risk factors to children’s health	5
2.1 Air Pollution (Ambient and Household).....	5
2.2 Climate change.....	6
2.3 Water and Sanitation.....	8
2.4 Hazardous Pesticides.....	9
3 Links between children’s environment and health	11
3.1 Key findings from Asia and Africa on health and environment links.....	11
3.2 Key Findings from six countries on links between health & environment.....	12
4 Discussion and Recommendations	19
4.1 Gaps & Challenges and Calls for Action.....	19
4.2 Governance, Policy, and Strategy for Children’s Environment and Health.....	21
5 Annexes	25
5.1 Sample Country Profiles.....	25
5.2 Data Sources for country profiles.....	29
5.3 Methods for meta-analysis and systematic review of children’s environmental health.....	32
5.4 References.....	34

Acknowledgements

The report was prepared by a research team at Seoul National University (SNU) and UNICEF EAPRO, based on the research conducted by SNU with financial support from UNICEF EAPRO.

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Summary

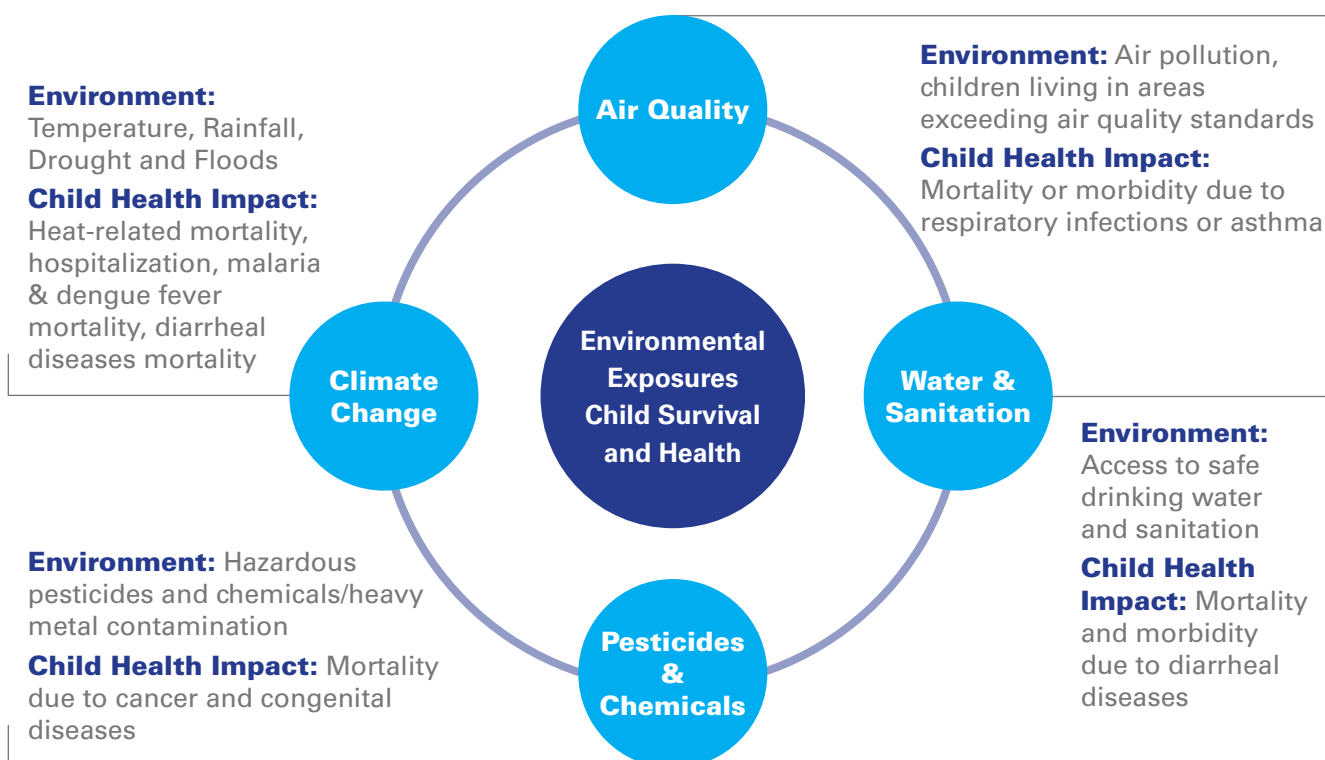
Background and Objectives

Children in East Asia and the Pacific are faced with multiple challenges posed by the climate crisis, environmental pollution and rising inequity. Today more than one in four childhood deaths under five years of age are attributable to unhealthy environments. 26% of the 5.9 million under-five deaths per year are attributable to the impacts of environmental factors such as air pollution, lack of adequate water and sanitation, hazardous chemicals and increasing exposure to the impacts of climate change. Countries in the East Asia-Pacific region have limited capacity and resources to deal with these emerging and persistent environmental health challenges. Although some improvements have been made in children's health in recent decades as a result of improvements to water and sanitation infrastructure and reduced indoor pollution in some settings, new and persistent threats to children's health are emerging in the 21st century. Climate change is increasing the frequency and intensity of extreme weather events. Slow onset changes such as sea-level rise and environmental pollution are worsening with an increasing use of hazardous chemicals and pollutants. Unsustainable urbanization is both increasing air pollution and crowding populations into poor urban settlements with limited access to safe housing, water and sanitation and limited access to health care. Poor households often live in environmentally polluted and climate hazard-prone areas.

In the meantime, despite the environmental and climate crisis affecting children's health, child and maternal health policies and interventions still mainly tend to focus on treatment and very little investment is made on prevention and reduction of environmental risks. There is a lack of integrated policy and investment practices addressing environmental and climate risk factors to child and maternal health in the region. This currently limited integration of child health and environment policies call for a much better understanding of the links between the environment and child health. In this context, UNICEF East Asia Pacific Regional Office has, in cooperation with the Seoul National University College of Medicine, undertaken a regional situation analysis of the available data and evidence on the links between environmental risk factors and children's health.

The main objective of this report is to improve understanding of the current situation of children's environmental health and burden of disease focusing on key environmental risk factors, namely, climate change, air pollution, chemicals, and water and sanitation in this region. This report is ultimately aimed at promoting integrated children's environment and health (CEH) planning and investment in countries and across the region.

The framework for analysis is based on the knowledge and understanding of the links between a child's environment and their health as illustrated below.



Methods applied in this report include undertaking a systematic review and meta-analysis of the literature, which are summarized into country profiles that demonstrate linkages between children’s health and environmental determinants such as air pollution, climate change, water and sanitation, and hazardous chemicals (see Annex 5.1). Additional information was sourced through multilateral data sources, a regional consultation workshop and a questionnaire from stakeholders in each country. The target countries of this regional analysis include Cambodia, Indonesia, Myanmar, The Philippines, Timor-Leste, and Vietnam. The environmental and health indicators included above are not at all exhaustive but indicate those data that are globally available during the time this report was prepared.

Main Findings

Multiple Environmental Risks to children’s health: Children in the countries studied in this report are exposed to multiple sources of environmental risk factors at the same time. **Air pollution** levels in all six countries are above the WHO guideline values and household solid fuel use is very high in all countries especially in rural areas. **Climate-related extreme events** such as flood, storm and drought result in disasters with adverse effects on child health. Flood is the major climate-related disaster affecting children’s health in the Philippines and Viet Nam. Storm is another climate hazard in the Philippines, while drought is also an important hazard in Cambodia and Viet Nam. Children are suffering from high levels of **unsafe drinking water** in Cambodia, Myanmar, and Timor-Leste and high levels of **unsafe sanitation** in Cambodia and Timor-Leste. Myanmar and Cambodia have shown an increasing trend of hazardous **pesticide** use with potential links to childhood cancer or other diseases.

Children’s Health Outcomes: These environmental risk factors are impacting on children’s health outcomes. **Mortality due to diarrhea** tended to increase with an **increase in precipitation** across the six countries. **Dengue fever mortality** increased in Cambodia, Philippines, and Viet Nam, and a positive correlation was observed with temperature. A decreasing trend of asthma and lower respiratory infections was observed across all countries, possibly linked to decreased household solid fuel use, which is still prevalent in these countries. There is a trend of increased reporting of **acute lymphoid leukemia** in Cambodia, Myanmar, Philippines, and Timor-Leste. Over 30% of children in Cambodia, Indonesia, Philippines, and Timor-Leste indicated **stunting in growth**.

Gaps and Challenges: Study and consultations in the region have resulted in the identification of main capacity gaps and challenges, and based on these findings, have established a Children’s Environmental Health monitoring framework and an agenda for action, that can be adapted to country context. Section 4 of this report outlines gaps, challenges and recommended actions and monitoring strategies for national and regional levels. The report has found that the capacity at the country level to respond to the environmental determinants of health is limited in relation to generation of evidence, science-based policy development, accountability for leadership & coordination, and financing environmental health infrastructure. There is also a need expressed by countries to develop a better understanding by leaders, the workforce and the public of the links between children’s environment and their health.

A Call for Action

Due to the main finding of the links between children’s health and environmental conditions, it is recommended that policy development and implementation will need to take place on three levels – the health sector, environment sectors, and cross-sectoral collaborations. Action and resource commitments nationally from health, environment and other sectors for action on CEH cut across the four policy domains of air quality, water and sanitation, hazardous chemicals and climate change. **The agenda for action on CEH includes development of CEH policy and plans, generation of evidence on the links between environment and child health, leadership and workforce capability building, cross-sector and public collaboration and communication, and monitoring and information sharing.** Governance arrangements vary across the Asia Pacific, but responsibilities for the development and implementation of the CEH agenda could be delegated and aligned across sectors and agencies both national and sub nationally (see *section 4* of this report). Regionally, we also propose regional action in the areas of technical support, data sharing and monitoring, advocacy and development of a Regional Action Plan on CEH. Given that **the poorest and most marginalized children are disproportionately affected** by pollution, climate change, poor water and sanitation and exposure to hazardous chemicals, there is a policy and practice imperative to urgently strengthen organizational and community capacity in East Asia Pacific to prevent and mitigate the impacts on the most vulnerable children of the environmental and social determinants of health.



1 | Introduction



1.1 Children's environmental health

The United Nations Children's Fund (UNICEF)'s vision for child health is a world where no child dies from a preventable cause and all children, and especially the most disadvantaged children, reach their full potential in health and well-being.¹ We cannot achieve this vision

if we do not effectively address the effects of climate change and environmental hazards on children's health.

Today more than one in four childhood deaths under five years of age are attributable to unhealthy environments. According to the World Health Organization (WHO), more than 88% of diseases attributable to climate change occur in children younger than 5 years of age. Particularly, 26% of the 5.9 million under-five deaths per year are attributable to the environment such as households without access to basic services such as safe water and basic sanitation, or that have high indoor air pollution due to the use of unclean fuel and inefficient cooking and heating technologies.² Diarrheal diseases, the second leading cause of death among children in this age group, are responsible for 361,000 children deaths every year due to poor access to clean sanitation, hygiene, and water,³ whose quality and availability are also affected by environmental degradation and climate change. Outdoor and indoor air pollution are directly linked to pneumonia and other respiratory diseases that account for almost one in 10 under-five deaths, making air pollution one of the leading dangers to children's health. However, developing countries in East Asia and the Pacific region have limited capacity and resources to deal with these emerging challenges. According to the WHO, mortality attributable to the environment varies significantly across the region, with **12.25 deaths per 100,000 being attributable to the environment in Japan, compared to 297.02 deaths per 100,000 in Myanmar.**⁴ **The most impoverished countries are confronted by the most significant environmental impacts on health.** This is thus an environmental justice issue as well.

Against this background, there is an urgent need to assist countries in the region to systematically identify and reduce key environmental and climate change risks. These risks can be managed through strengthening health systems and improving the environmental conditions that are affecting children's health and development. There are a number of relevant information and resource materials on the links between health and environment and climate change that are supported by WHO, UNICEF, UN Environment, and other partners,⁵ but many countries in the region still lack up-to-date country-specific, localized, and child-specific integrated sets of data. Furthermore, there is a need to enhance cross-sectoral coordination mechanisms for establishing a common understanding, and action framework for reducing environmental health risks and improving children's health and environmental outcomes.

In this context, UNICEF East Asia Pacific Regional Office in collaboration with Seoul National University (SNU) has initiated this regional analysis on children's health and environment in consultation with WHO and other partners.

1 UNICEF The UNICEF Vision and Mission for Children [https://www.unicef.org/publicpartnerships/files/UNICEF_Mission\(1\).pdf](https://www.unicef.org/publicpartnerships/files/UNICEF_Mission(1).pdf) [accessed Sept 9 2018]

2 World Health Organisation Inheriting a sustainable world? Atlas on children's health and the environment. Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO.

3 Diego Herrera, Alicia Ellis, Brendan Fisher, et al Upstream watershed condition predicts rural children's health across 35 developing countries Nature Communications volume 8, Article number: 811 (2017) <https://www.nature.com/articles/s41467-017-00775-2> [accessed September 9th 2019]

4 WHO 2017 op.cit.

5 WHO Children's Environmental Health Indicators (CEHI)



1.2 Purpose of Discussion Paper

The purpose of this discussion paper is to contribute to increased awareness and understanding of the current situation of children's environmental health and burden of disease, initially focusing on 4 key environmental risk factors identified in the region, namely, climate change, air pollution, chemicals, and water and sanitation. Provision of up-to-date country data and information in the Asia-Pacific region regarding children's environment and health will increase awareness and facilitate the development of national and regional action plans, strategies and monitoring systems, as well as contribute to improving collaboration and cooperation in addressing children's environmental health. With the scientific information and evidence from the country-specific situation analysis, this discussion paper aims to contribute to countries' efforts in developing strategies and implement targeted interventions and track the progress for addressing climate change and environmental risks to prevent and minimize negative effects on children's health and well-being.



1.3 Scope and methodological approach

The target countries of this review include Cambodia, Indonesia, Myanmar, The Philippines, Timor-Leste, and Vietnam. Methods applied included undertaking a systematic review and meta-analysis of the literature. This review and meta-analysis were undertaken to identify current evidence of the linkages of air pollution, climate change, water and sanitation with children's health. Linking data of environmental exposure to health outcomes have been generated using linear mixed models, followed by consultation with the relevant experts in the fields of environment, health, and policy. Additional information was sourced through multilateral data sources⁶, a regional consultation workshop held in February 2019 and a questionnaire from stakeholders in each country regarding solutions to the issues on children's health and environment. This information was then summarized into country profiles that demonstrate linkages between children's health and environmental determinants such as air pollution, climate change, water and sanitation, and hazardous chemicals (see Annex 1 for examples of CEH profiles). We have incorporated the country-specific data where appropriate to provide country-level status on 4 key environmental factors under this initial stage of the multi-country analysis.

⁶ The World Bank, World Health Organisation, Food and Agriculture Organisation, The Institute for Health Metrics and Evaluation



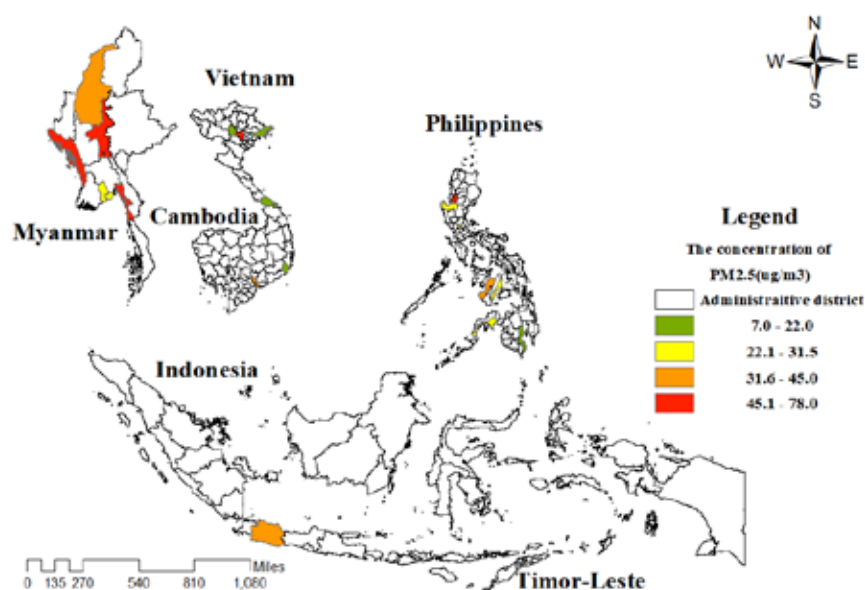
2 | Key environmental risk factors to children's health



2.1 Air Pollution (Ambient and Household)

As outlined in the introduction to this report, air pollution (both household and ambient) is one of the greatest threats to children's health globally. In terms of ambient pollution, fine particulate matter (PM_{2.5}) is the most health-harmful air pollutant.⁷ City-specific PM_{2.5} concentrations are shown in Figure 1. Some cities in Myanmar showed higher levels of the pollution, whereas other cities showed lower levels of PM_{2.5}. However, due to a lack of information on city-level PM_{2.5} concentrations in other countries, we were not able to make conclusions about the regional distribution of PM_{2.5}.

FIGURE 1 City-specific PM_{2.5} concentrations Cambodia, Indonesia, Myanmar, Philippines, TLS, & Viet Nam

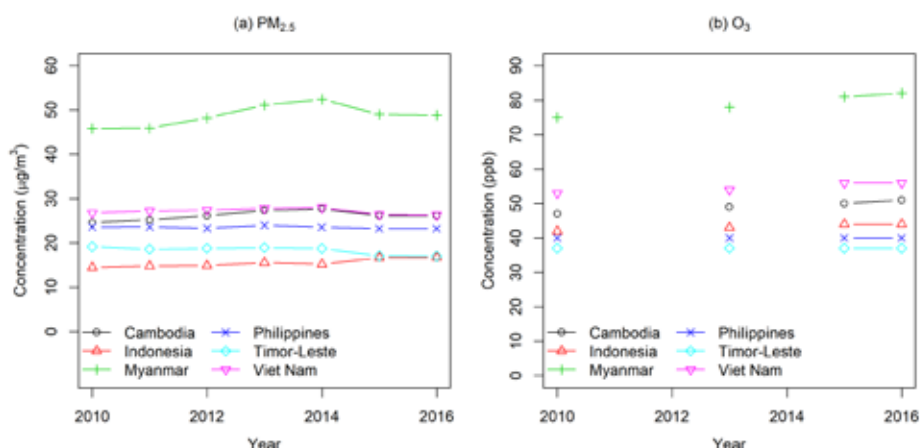


In 2016, **PM_{2.5}** concentration levels were highest in **Myanmar** (48.8 $\mu\text{g}/\text{m}^3$) and lowest in **Indonesia** (16.7 $\mu\text{g}/\text{m}^3$). The annual trends in Cambodia and Myanmar peaked in 2014 and have decreased since then. However, **Indonesia** has shown an increasing pattern since 2014. **O₃** concentrations in Myanmar showed the highest levels (82 ppb in 2016) among the six countries and demonstrated an increasing trend in **O₃** levels. Other countries showed similar ranges of PM_{2.5} and **O₃** between 2010 and 2016. Given rapid urbanization rates in the Asia-Pacific, with the percentage of the population living in urban areas projected to increase to 50% by 2026,⁸ the public health threat of air pollution is set to increase.

⁷ World Health Organisation Health, environment, and sustainable development <https://www.who.int/sustainable-development/cities/health-risks/air-pollution/en/> [accessed Sept 10th 2015]

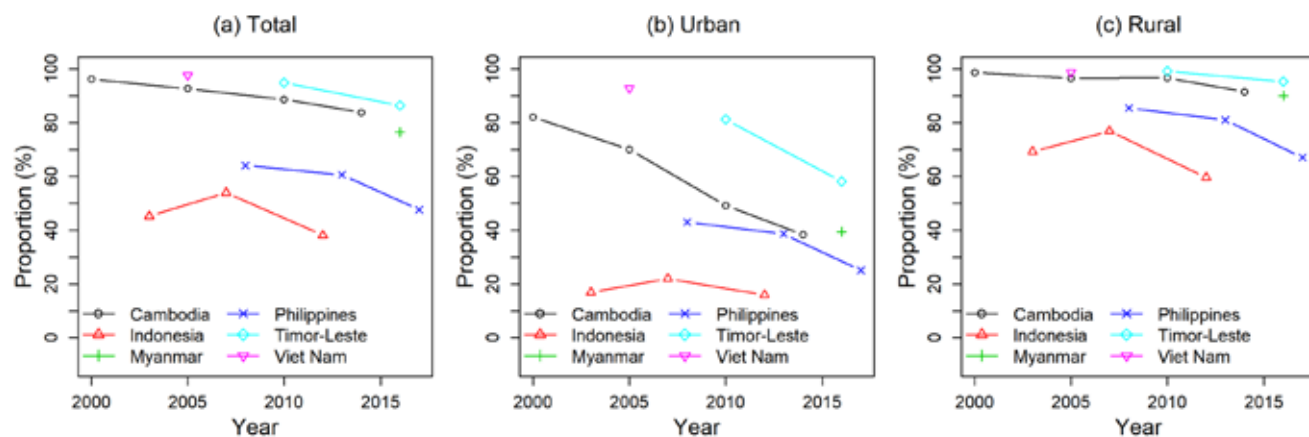
⁸ UNESCAP Urbanization trends in Asia and the Pacific 2013. <https://www.unescap.org/sites/default/files/SPPS-Factsheet-urbanization-v5.pdf> . Accessed 3 Apr 2019.

FIGURE 2 Annual trends of ambient pollution (PM_{2.5} and O₃) levels (2010-2016)



Household fuel use was categorized into two fuel types: clean and solid fuels. Clean fuels include gas and electricity. Solid fuels include agricultural crops, animal dung, charcoal, coal, firewood, straw, wood, and others. As figure 3 demonstrates, the temporal trend of solid fuel use is decreasing in most countries, although rural regions need improvement. The percentages of the total population that used solid fuels in 2014 were 84%, 38%, 77%, 48% and 86%, in Cambodia, Indonesia, Myanmar, Philippines and Timor-Leste, respectively. **The overall trend of the proportion of household solid fuel has been decreasing over 2000-2015. However, many countries in the region still have alarming levels of household solid fuel use polluting indoor air quality leading to childhood diseases and death. Timor Leste, Cambodia and Myanmar** are the countries with high levels of household sold fuel use and while the Philippines and Indonesia data show a significant improvement.

FIGURE 3 Proportion (%) of household solid fuel (2000-2016)



2.2 Climate change

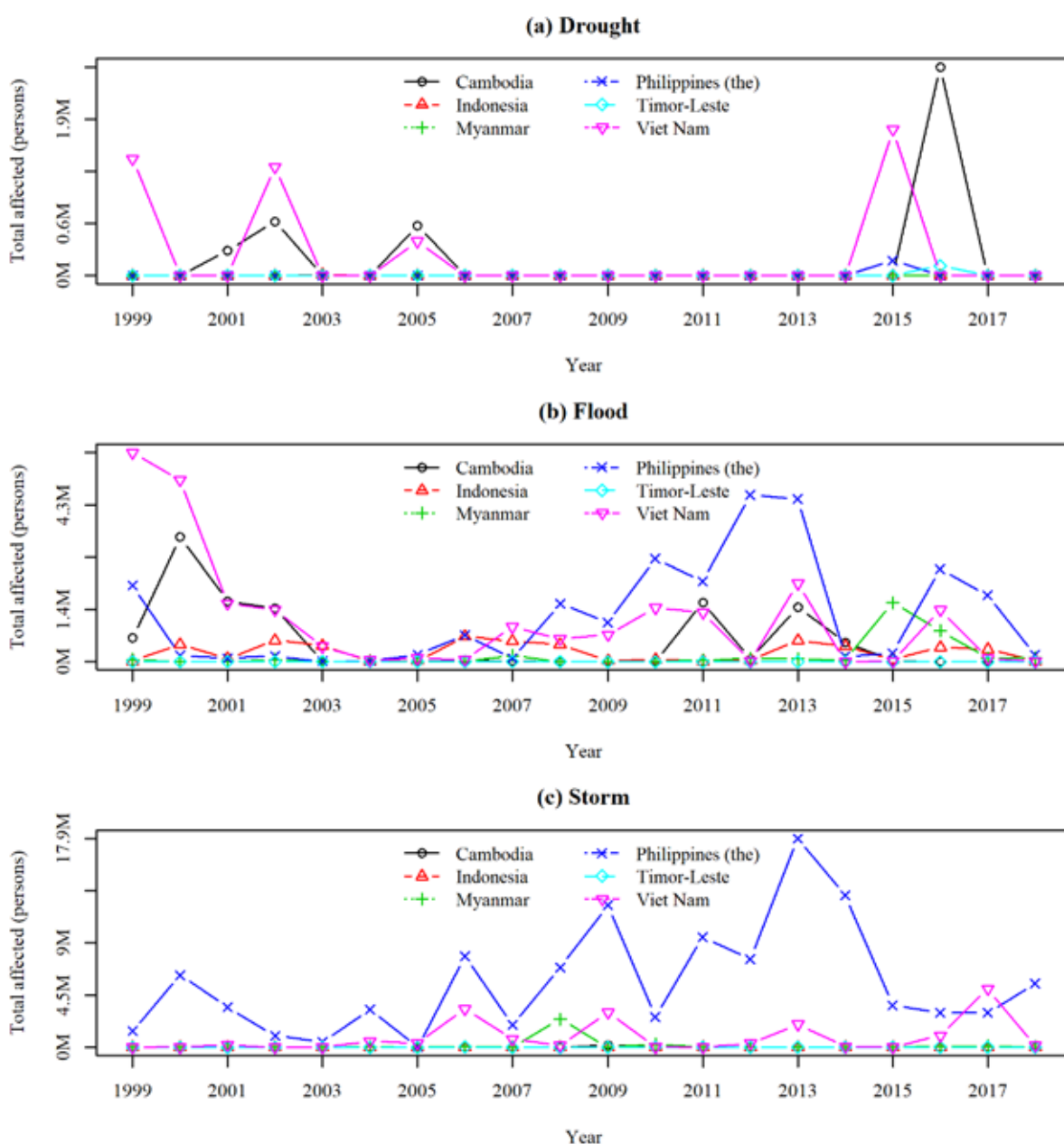
Variations in temperature and rainfall, and extreme weather events are predicted by climate change modeling. Projections from country-based assessments by WHO indicate increase in **temperatures, heatwaves, days per year with extreme rainfall (flood) and consecutive dry days (drought)**, all of which have implications for health and health system response.⁹ Current projections by the Inter-Governmental Panel on Climate Change (IPCC) indicate that the heavy precipitation events and increases in

⁹ World Health Organisation Health and Climate country profiles <https://www.who.int/globalchange/resources/country-profiles/en/> [accessed Oct 25th 2019]

the frequency, intensity, and/or amount of heavy precipitation are likely over many landmasses but are very likely in mid-latitude regions and wet tropical regions later in the 21st century.¹⁰ Given the demonstrated links between climate and health (see section 3.2), tracking of rainfall and temperature trends and extreme weather events will form an important component of an overall monitoring strategy to assess the health impacts of climate change.

As figure 4 illustrates, between 1999 and 2017, extreme weather events occurred across many of the study countries. In this period, the flood was a major climate-related disaster event in The Philippines and Viet Nam. The storm is another climate hazard in the Philippines, while drought is also an critical climate hazard in Cambodia and Viet Nam. The drought was severe in the early 2000s and mid-2010s in Viet Nam and Cambodia. Flood and storm were severe in the Philippines. Cambodia and Viet Nam experienced severe floods in 1999-2000 and 2011 and 2013. It is important to note that the data indicated below do not show spatial variations within the countries as **these climate indices vary significantly depending on locations and ecological regions.**

FIGURE 4 Total affected by natural disasters (drought, flood, and storm)



10 IPCC. Summary for Policymakers. Quoted in: WHO and UN Climate and Health Country Profiles – 2015 A Global Overview



2.3 Water and Sanitation

Countries need more improvements in safe drinking water and sanitation, especially in rural areas.

The growth of **urban poor settlements** in the major cities and towns of the region also poses threats in terms of inadequate public health infrastructure such as safe water and sanitation systems. As figure 5 illustrates, the proportion of the population with access to “at least basic” safe drinking water was less than **75% in Cambodia, Myanmar, and Timor-Leste**. Similarly, as figure 6 illustrates, Cambodia and Timor-Leste have less than 60% of “at least basic” sanitation services.

FIGURE 5 Percent of drinking water service in 2015

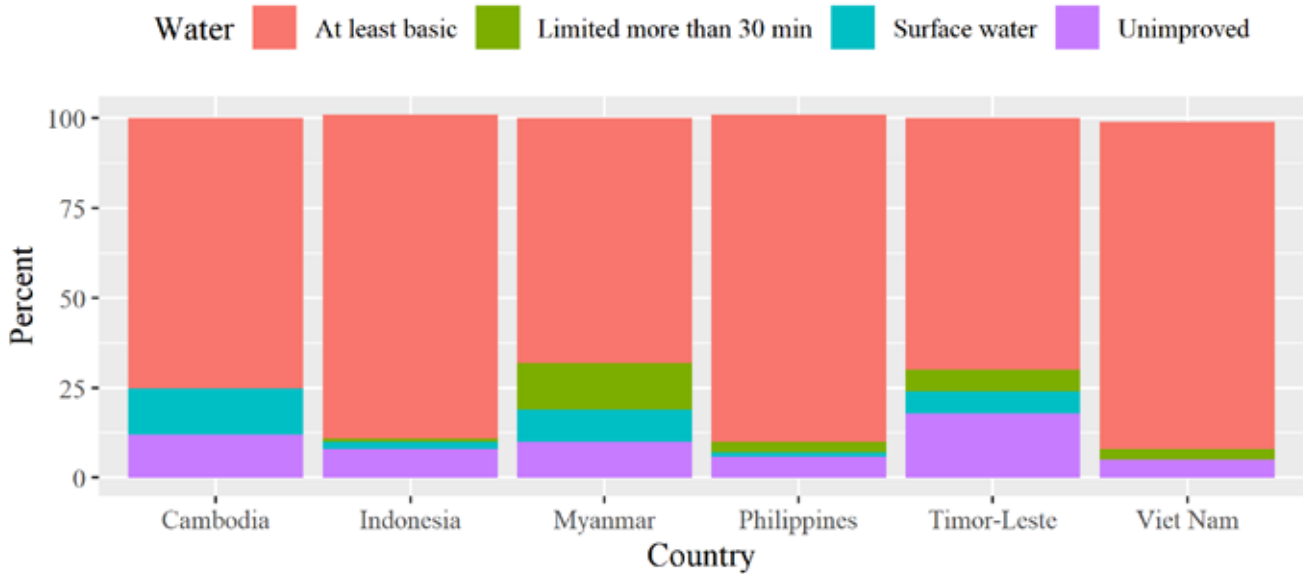
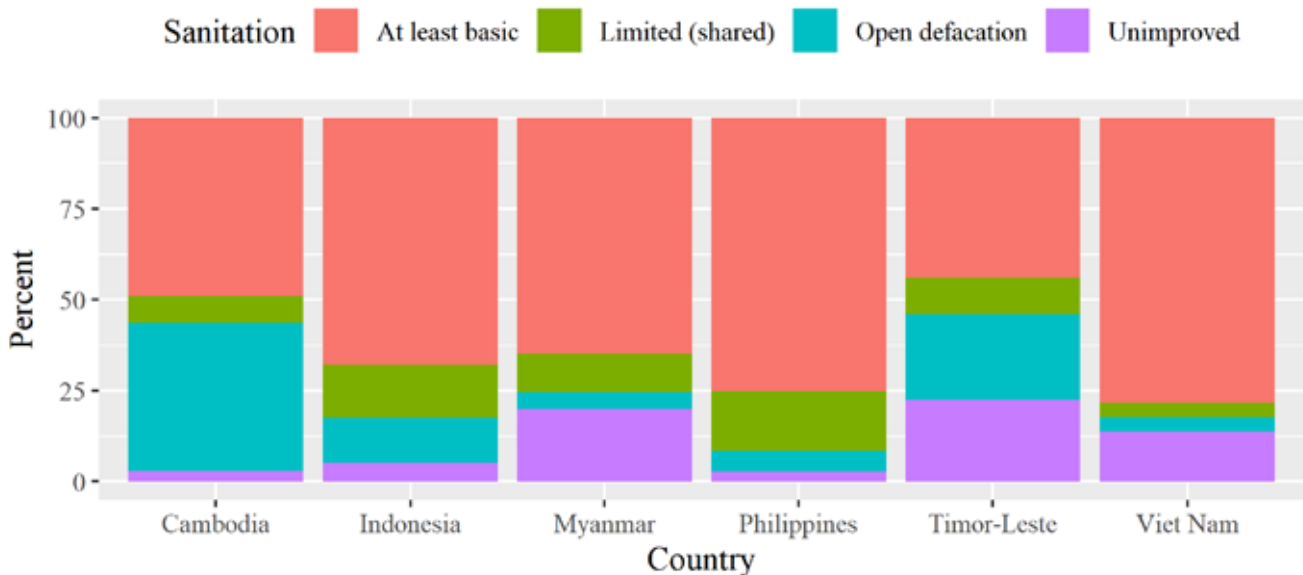


FIGURE 6 Percent of sanitation service in 2015



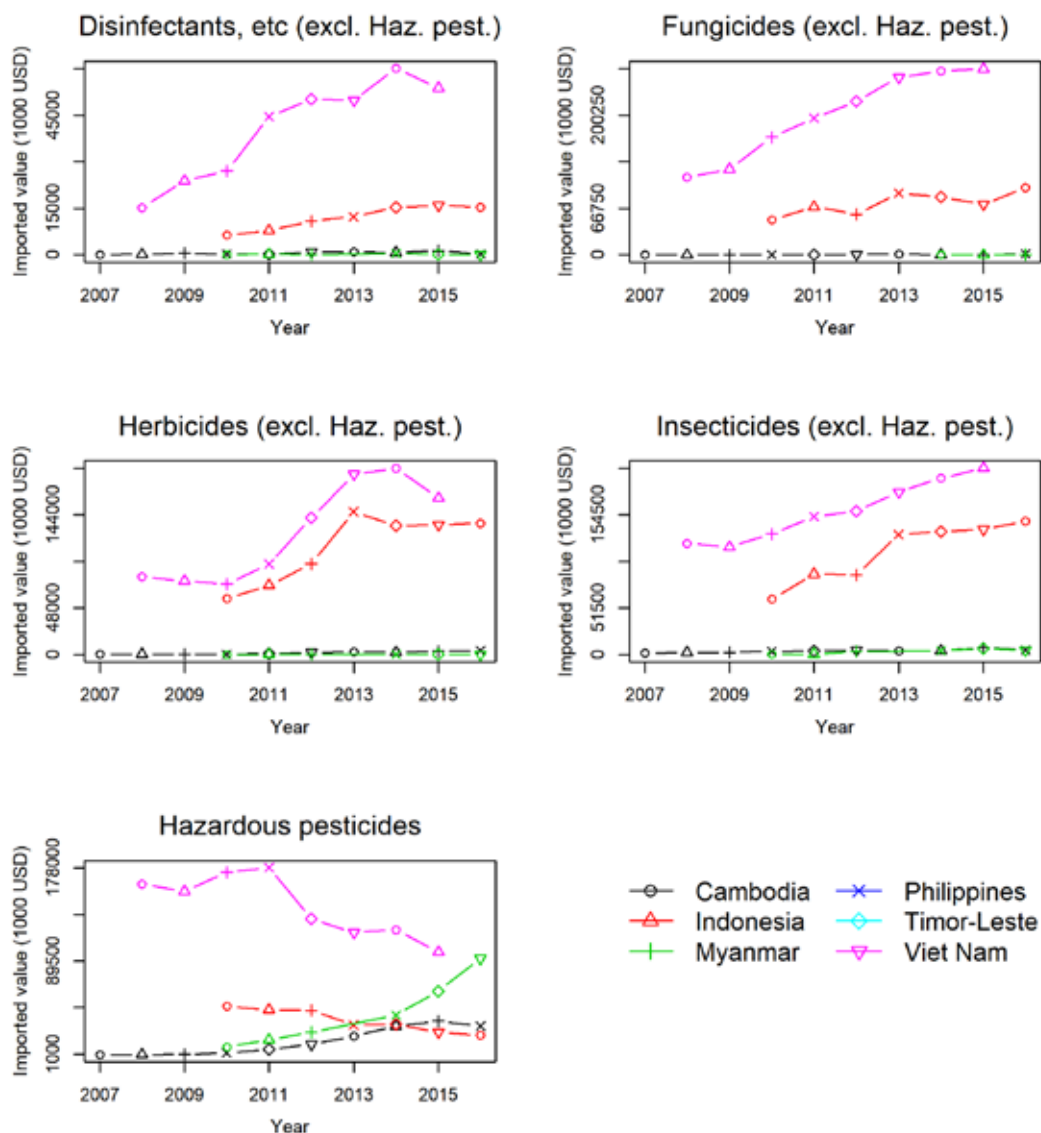


2.4 Hazardous Pesticides

Early exposure to some pesticides and other environmental contaminants can contribute to childhood cancers and can also contribute to cancer development in later life. Additionally, unsafe storage, use, and disposal of pesticides is the major contributor to acute childhood poisonings.¹¹

The import and use of both hazardous and non-hazardous pesticides are on the increase in many countries. As figure 9 illustrates, in Viet Nam and Indonesia, imports of *non-hazardous* pesticides are increasing. These countries also reduced imports of *hazardous pesticides*. Nevertheless, **Viet Nam** has the **highest imports of non-hazardous and hazardous pesticides** overall, followed by Indonesia. While most countries reduced imports of hazardous pesticides, both **Myanmar and Cambodia increased imports of hazardous pesticides** between 2007 and 2015.

FIGURE 7 Imported pesticide (1,000 USD)



¹¹ World Health Organisation 10 facts on children's environmental health https://www.who.int/features/factfiles/children_environmental_health/en/ [Accessed Oct 28th 2019]



3 | Links between children's environment and health

We collated evidence of air pollution and childhood respiratory diseases, climate change and vector-borne diseases, and water, sanitation and children's health from literatures published in Asia and Africa and performed meta-analyses for synthesizing results. We also analyzed currently available data across the six countries to confirm or compare the findings but found there is still a big gap in connecting environment and health data for the relevant countries in the region.



3.1 Key findings from Asia and Africa on health and environment links

The meta-analysis and systematic review of health from studies in Asia and Africa indicate links in many cases between environment and health. The following outlines actual or potential links according to the four categories of air quality and respiratory disease, climate change and vector-borne diseases, and water & sanitation and children's health.

3.1.1 Air Quality and childhood respiratory diseases

Exposure to $PM_{2.5}$ was significantly associated with increased risk of childhood respiratory morbidities such as pneumonia, acute lower respiratory infection (ALRI) and asthma hospitalizations. For example, a meta-analysis showed that every $10\mu g/m^3$ increment in $PM_{2.5}$ was associated with a 3% increase in pneumonia and ALRI hospitalization. Exposure to $PM_{2.5}$ was significantly associated with an increase in childhood asthma hospitalizations. Exposure to O_3 was also significantly associated with an increase in childhood asthma hospitalizations. From the meta-analysis of 5 studies, exposure to indoor air pollution by solid fuel use was significantly associated with an increased risk of childhood pneumonia and ALRI hospitalization compared to the use of electricity, natural gas or liquefied petroleum gas. It is important to note that there is increasing research evidence showing the effects of air pollution on fetal growth, pregnancy outcomes, neurodevelopmental disorders, and cognitive, endocrine and immune functions but this literature review did not include these other child and maternal health outcomes associated with air pollution.

3.1.2 Climate change, vector-borne diseases, and water-borne diseases

Climate change has been shown to affect the prevalence of vector-borne diseases. Rainfall is a risk factor for malaria infection. Compared to the dry season, the rainy season has been shown to lead to higher malaria incidence and higher hazard ratio respectively. For example, malaria incidence in Benin in West Africa was particularly high at the end of the rainy season (from April to July and from October to November) and relatively low in the first month of each rainy and dry season (from December to March and from August to September) in 6-59 months old children.

Rainfall increased clinical malaria risk when the monthly rainfall was above 100 mm. The time interval after the end of the rainfall is also a risk for malaria infection. Infections occurred 60 days after rainfall (<100 mm). Excess of rainfall is associated with a reduction in malaria incidence as it may flush out mosquito larvae and decrease ambient temperature. *Temperature* also plays an important role in the prevalence of malaria. It was found that there was a temperature threshold that increases the risk of clinical malaria. Extremely hot temperatures decreased the

risk of malaria infection, while warmer temperatures increased the risk below the threshold. *Flood* increased the overall risk of malaria. In particular, the risk was higher in areas near a flood-affected river. An increase of 30% in the risk of malaria was showed in the post-flood period in villages bordering a flood-affected river, compared with villages farther from a river.

As for dengue, the maximum weekly rainfall showed the strongest association with reported dengue cases, while the minimum temperature was positively correlated with the number of cases, with significant effects at lagged intervals of 1–3, 6, and 9–11 weeks (Lover et al, 2014).

Globally, the number of report dengue cases increased from 2.2 million in 2010 to over 3.34 million in 2016. There has been a sharp increase in 2019 in dengue cases in Cambodia, China, Lao PDR, Malaysia, the Philippines, Singapore, and Vietnam.¹² Suitable local temperature and high levels of precipitation are the factors most strongly associated with elevated dengue risk. These risks in the Asia Pacific are not only amplified by climate change, but also by rapid urbanization in the case of dengue, as urban settings provide the most ideal environmental conditions for the spread of the main dengue vectors.¹³

Further research on a global scale is needed to improve understanding of the links between climate change and vector-borne diseases. Flood incidences are also reported to have been associated with water-borne diseases affecting child health.

3.1.3 Water and sanitation and children's health

A meta-analysis of 12 intervention studies showed that water treatment interventions such as chlorination, solar disinfection, and various types of water filtration systems were effective in preventing diarrhea in children. Observational studies including longitudinal studies, cohort studies, case-control studies, and cross-sectional studies showed that *improved water sources significantly reduced the risk of childhood diarrhea*. Water treatment such as boiling and safer water storage altogether showed an overall preventive effect from diarrhea. Drinking water treatment (boiling or filter) or improved water sources lowered the risk of parasitic or bacterial infection in children. As expected, poor drinking water was shown by the studies to increase childhood mortality.

In summary, although we found some meaningful linkages between the environment and health in children in Asia and Africa, there was not enough scientific research and data undertaken in developing countries in Asia to reach scientifically solid conclusions regarding these linkages and clear understanding of pathways through which environmental risk factors affect child health outcomes. **There are huge data and research gaps in this field in the region.** This highlights the importance of building science and research capacity and generation of evidence in each country to highlight the risks of the environment to the health of children, to provide a more solid evidence base for policy and planning (refer to section 4 for the elaboration of potential strategies to address this issue).



3.2 Key Findings from six countries on links between health & environment

In order to address these data gaps, this section compares currently available data from the six study countries regarding links between the environment and health. This includes links between air quality and respiratory diseases (section 4.2.1), links between climate conditions and vector-borne diseases (section 4.2.2), and finally, links between safe water and diarrheal disease (4.2.3). Due to data limitations, the links between hazardous chemicals and childhood cancers are not included here. However, global studies are demonstrating associations or potential linkages between pesticide exposure and childhood cancers. It is estimated that 17% (7–42%) of all cancer disease burden, and 5% of all congenital disorders in children under five can be attributed

¹² World Health Organisation Fact Sheet on Dengue

¹³ Kristie L Ebi et al Dengue in a changing climate *Environmental Res.* Vol 151, November 2016, Pages 115-123

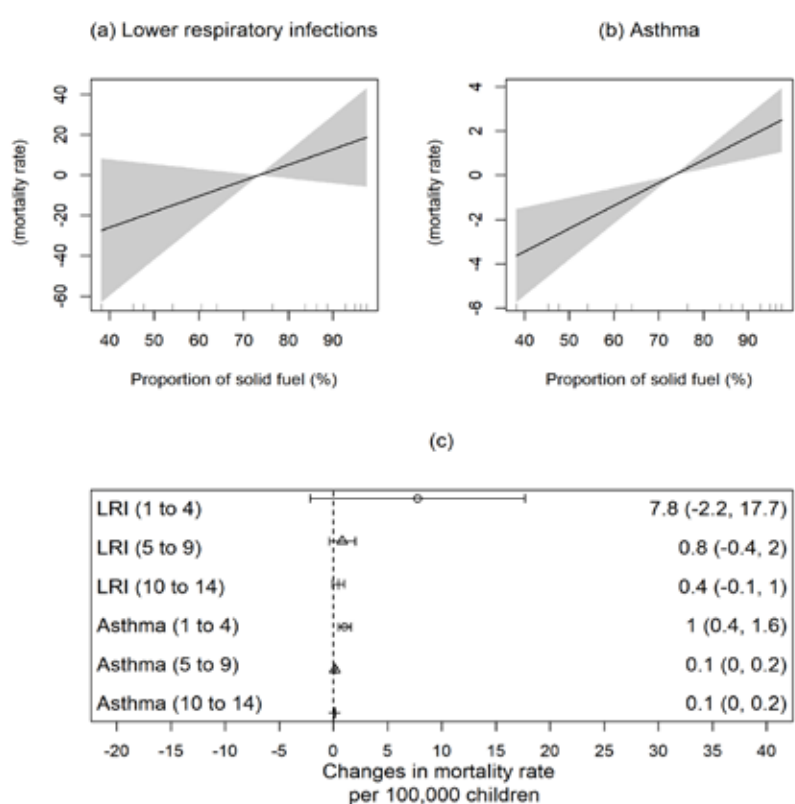
to environmental causes. As discussed earlier, household chemicals including pesticides are also common causes of childhood poisoning in lower- and middle-income countries.¹⁴

3.2.1 Air quality and respiratory diseases across the six countries

The World Health Organisation considers that air pollution currently poses the greatest environmental threat to children’s health globally. It is estimated that over 570,000 children die globally from respiratory diseases linked to indoor and outdoor air pollution and secondhand tobacco smoke.¹⁵ Rapid urbanization across the region has the potential to escalate the risk of outdoor air pollution. In addition, rates of indoor pollution linked to solid fuel use remain high in the region, especially in rural areas.

In this review, most of the six countries showed a high percentage of the use of household solid fuel. Figure 8 demonstrates the association between respiratory diseases and the proportion of solid fuel use throughout the six countries.

FIGURE 8 Links between use of household solid fuel and lower respiratory infections mortality



From figures 8, it is evident that the **higher the use of solid fuels**, the **higher the deaths due to lower respiratory infections (LRI) and asthma**. In the case of LRI, children under 5 showed a 7.8% increase per 10% increment of solid fuel use, but the relative risk was not statistically significant. Children aged 5 to 9 and 10 to 14 showed a 0.8% and 0.4% increase in the risk of LRI mortality, respectively. **Every 10% increment in solid fuel use shows a 1% increase in asthma mortality in children aged 1 to 4 years old** and a 0.1% increase in children aged 5 to 9 and 10 to 14 years old. We conclude that a further decrease in household solid fuel use can lead to a decrease in respiratory mortality in children. These findings align with published data on deaths attributable to pollution. In *Indonesia*, where both ambient pollution in cities and indoor solid fuel use in rural areas are reported to be very high, it is estimated that **23% of all deaths in 2012 were attributable to air pollution**. In the same year, it

14 World Health Organisation Don’t pollute my future! The impact of the environment on children’s health. Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO.

15 World Health Organisation 10 facts on children’s environmental health https://www.who.int/features/factfiles/children_environmental_health/en/ [Accessed Oct 28th 2019]

was estimated that **45% of the 23,500 child deaths due to lower respiratory infections were due to indoor pollution.**¹⁶ In *the Philippines*, there is a higher use of solid fuels in rural areas (71%), and three cities have air pollution levels in 2011 that were above the WHO guideline value. In the same year, it was estimated that **46% of the 12,700 child deaths from lower respiratory infections were due to indoor air pollution.**¹⁷

3.2.2 Climate variables and infectious diseases across the six countries

Climate change models anticipate highly variable precipitation patterns particularly in mid-latitudes and tropical regions. Higher temperatures, along with variable precipitation, accelerates microbial growth, transmission, and virulence, leading to changes in the seasonal and geographic distribution of disease. There are also changes in vector abundance and distribution. Flooding can result in the destruction of water and sanitation infrastructure and reduced access to quality water and sanitation services that are critical for children's health and development.

High temperature and precipitation changes can also result in lower food production in the tropics. All these factors combine to increase risks of food and water-borne diseases, increased mortality from dengue fever and malaria, and increased stunting and malnutrition in children.¹⁸

The linkages between climate variables such as precipitation and temperature and infectious diseases are discussed below. Figure 9 examines the relationship **between precipitation and children's mortality rate due to acute hepatitis A, dengue fever, diarrheal diseases, and malaria.** The mortality rate of acute hepatitis A [Figure 9 (a)] and malaria [Figure 9 (d)] decreased with an increase in mean precipitation. However, the mortality rate due to diarrheal diseases increased with an increase in precipitation. The percentage change in the age-specific mortality rate due to infectious diseases per 1 mm increment in precipitation is presented in Figure 9 (e). Although none of the associations were statistically significant, we observe **younger children (under 5 years old) were more influenced by the amount of precipitation than older children (5+ years old).**

16 WHO Indonesia Climate and Health Country Profile. <https://www.who.int/globalchange/resources/country-profiles/PHE-country-profile-Indonesia.pdf?ua=1> [Accessed October 25th 2019]

17 WHO the Philippines Climate and Health Country Profile. https://apps.who.int/iris/bitstream/handle/10665/208868/WHO_FWC_PHE_EPE_15.14_eng.pdf;jsessionid=687EAD5C3E750AA79E6165B95F0B00A7?sequence=1 [Accessed October 25th 2019]

18 World Health Organisation Climate and Health Country Profiles – 2015 A Global Overview

FIGURE 9 Links Precipitation and Infectious and Vector Borne Diseases

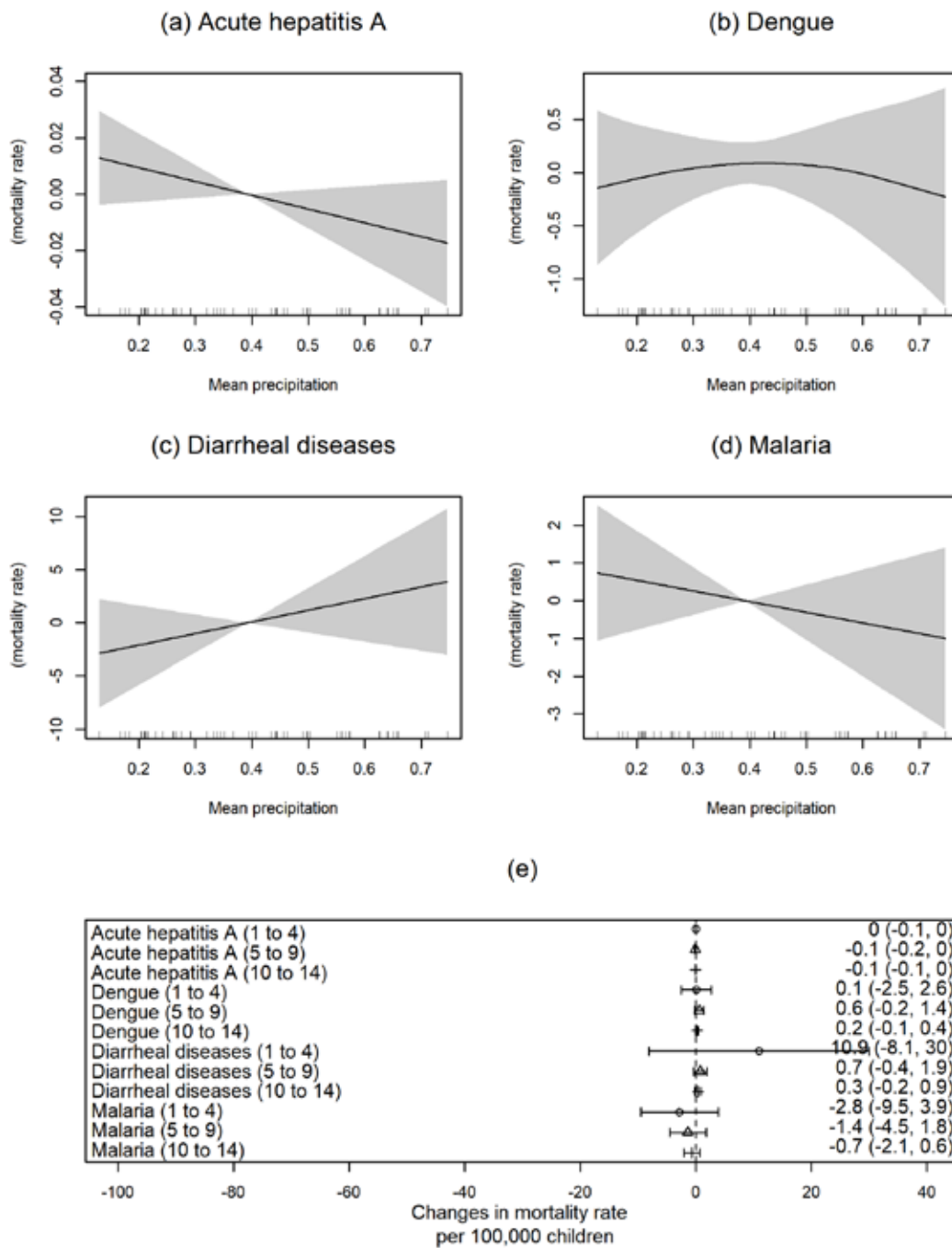
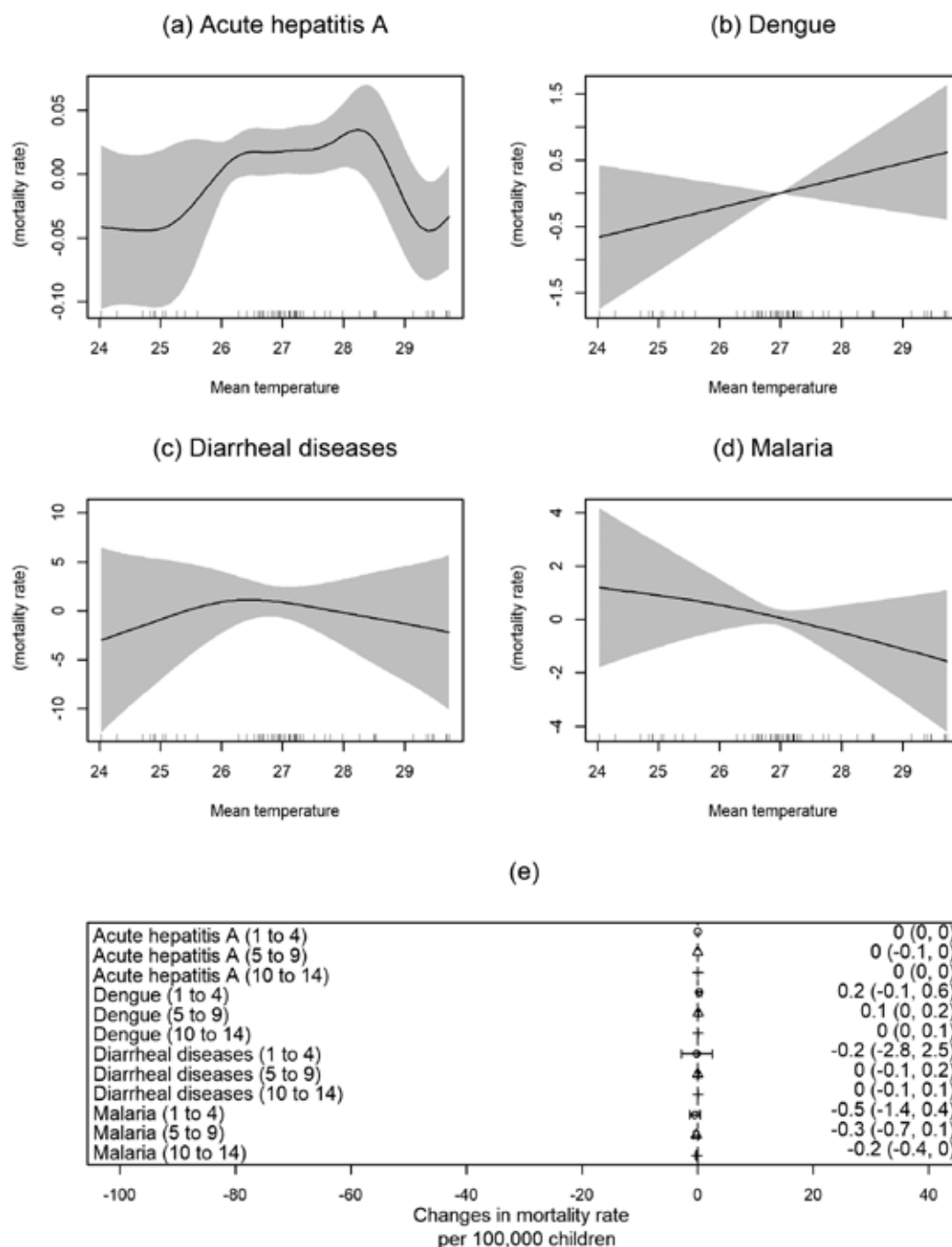


Figure 10 illustrates the relationships between **annual mean temperature and mortality rate** due to four infectious diseases in children. rate due to acute hepatitis A showed an increasing pattern between 25 °c and 28 °c and a decreasing pattern above 28 °c. While **dengue mortality showed a greater risk in higher temperature**, mortality due to diarrheal disease and malaria showed a lower risk at high temperatures.

FIGURE 10 Links between annual mean temperature (° C) and vector-borne diseases

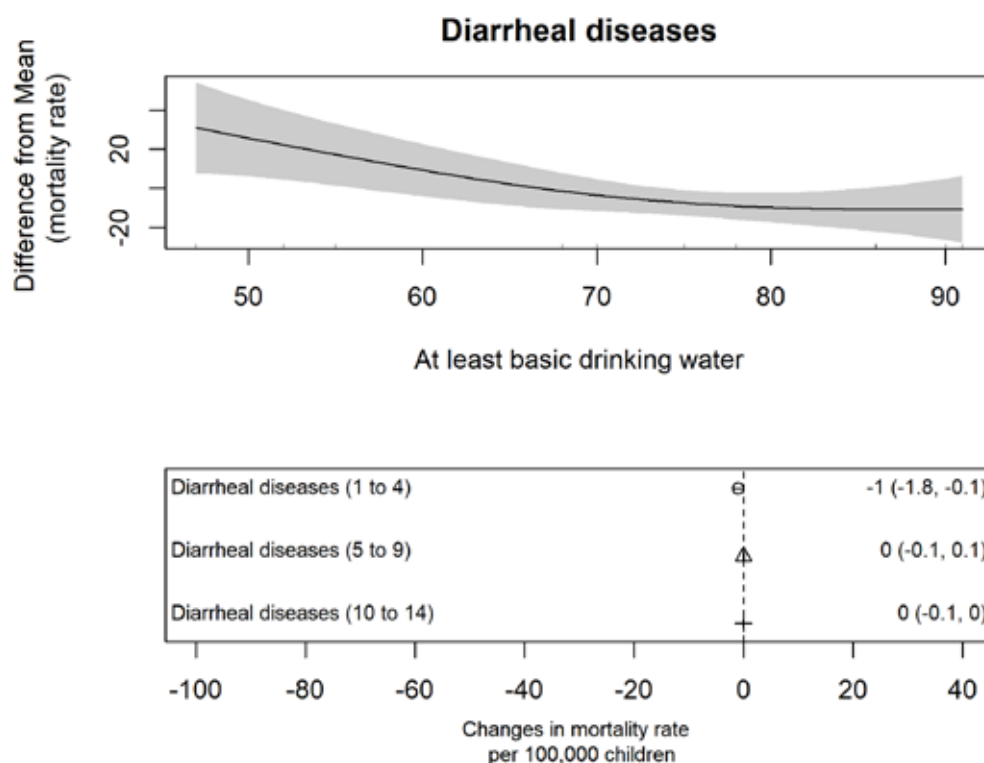


3.2.3 Drinking water and diarrheal diseases across the six countries

Diarrhea is one of the leading causes of child deaths under the age of 5 globally. An estimated 361,000 children under the age of five die globally from diarrhea, most of which is attributable to lack of access to safe water and sanitation.¹⁹

In this review, an association between access to at least basic drinking water (%) was negatively associated with children's mortality due to diarrheal diseases in children under 5. However, we did not observe a significant association in children older than 5 years old.

FIGURE 11 Links between access to drinking water (% of at least basic) and diarrheal diseases



¹⁹ World Health Organisation 10 Facts on Children's Environmental Health https://www.who.int/features/factfiles/children_environmental_health/en/ Accessed Oct 28th 2019



4 | Discussion and Recommendations



4.1 Gaps & Challenges and Calls for Action

The regional consultation workshop and country feedback identified main gaps and priorities for action under the four environmental domains of climate change, air quality, water and sanitation, and pesticides and chemicals.

In terms of **gaps in CEH research and action planning**, main themes across the four domains include lack of data sharing, lack of certainty on responsibility for management, and limited coordination between agencies. Limited capacity for weather forecasting and predictions of long-term trends, lack of capacity for consolidating data from different agencies, and limited capability to provide accurate inventories of household fuel use and imported pesticides were specific research and data gaps identified in consultations.

Given the evidence to support the linkages between children's health and the environment, establishing inter-agency mechanisms for management and communication, along with development of policies, programs and monitoring systems are considered by stakeholders to be top priority areas for action. The main gaps in monitoring related to limited data collection, and the related call for action in the areas of communication and research on child health and the environment

Specific **calls for action** identified in regional consultations include the following:

1. Development of Children's Environmental Health (CEH) policies, action plans and guidelines focusing on key environmental factors including climate change and health, indoor air pollution, handling and disposal of pesticides and in other areas identified as priority at the regional and country-levels
2. Identification of leadership of CEH policy & planning within environment and health sectors as well as relevant sectors
3. Building of capacity for data sharing and consolidation on CEH within and across sectors
4. Implementing research and education programs on the links between environment and health
5. Enhancing research and monitoring capacity across the CEH domains to provide an evidence base for action in the following areas:
 - a. Ambient air quality monitoring
 - b. Inventories of solid fuel use
 - c. Inventories of imported pesticides
 - d. Sector-specific climate data and information services for health and CEH relevant sectors
 - e. Water quality assessments and surveillance

Based on the identified gaps and calls for action, we propose children's environmental health indicators that can be adapted to each country's context. The main objective of the CEH data and information system is to assist countries and the region to track and implement priority health and environment actions to prevent, reduce and manage environmental risks to children's health. The children's environmental health indicators will provide information

on exposures, health outcomes, and policy actions. This will serve the purpose of improving national capacities in environmental risk management to support linked public health and environmental policies. The children's environmental health indicators should also help countries achieve SDG-related goals regarding environmental health, particularly for health and climate change, which need to be prioritized in national development plans. They can also be used to leverage investment and budgets for children's environmental health policies, programmes and services in national health plans and climate policies and financing mechanisms. After identification of priorities and through consultation with experts in the fields of environment and health, the indicators were selected from the following four domains: air quality (ambient air and household air), climate change, water and sanitation, and pesticides and chemicals.

Table 1 below illustrates environmental categories, exposure, and health indicators for the four domains of CEH. **Developing and agreeing on a set of CEH indicators nationally and regionally** will enable tracking of progress on the impacts of policy and programs on reducing the environmental health risk. This will also enable the development of **country profiles on CEH** (two examples of which are provided in Annex 1) to inform countries on policy and program impacts.

TABLE 1 Children's Environment and Health (CEH) Indicators

Category	Environmental Exposure Indicator	Child Health Indicator
AIR QUALITY		
Ambient air pollution	<ul style="list-style-type: none"> » Concentrations of air pollutants (e.g., PM2.5, PM10, or ozone) » Children living in areas exceeding WHO or national air quality standards 	» Annual mortality or prevalence rate due to LRI or asthma in children aged under 5 years
Household air pollution	<ul style="list-style-type: none"> » Percentage of children aged 0-5 years living in households using solid fuels » Percentage of children aged 0-5 years who are exposed to secondhand smoke 	
CLIMATE CHANGE		
Temperature	<ul style="list-style-type: none"> » Annual average Day and Night Land Surface Temperature » Annual mean of maximum temperature above a threshold temperature » Number of summer days when daily maximum temperature above a threshold temperature » Percentage of days when daily maximum temperature above 90th percentile » Annual count of days with at least 6 consecutive days when maximum temperature > 90th percentile 	<ul style="list-style-type: none"> » Heat-related mortality and Hospitalization » Malaria and dengue fever mortality » Diarrhea diseases mortality
Rainfall	<ul style="list-style-type: none"> » Annual or monthly average rainfall » Monthly maximum consecutive 1- or 5-day precipitation 	
Drought/Floods	<ul style="list-style-type: none"> » Annual average Normalized Difference Vegetation Index (NVDI) » Maximum length of dry and wet spell (dry and wet spells were determined by daily maximum precipitation < or ≥1mm) 	
WATER & SANITATION		
Water	» Percentage of safe drinking water service	» Mortality diarrhea diseases < 5 » Mortality of hepatitis A < 5
Sanitation	» Percentage of safe sanitation service	

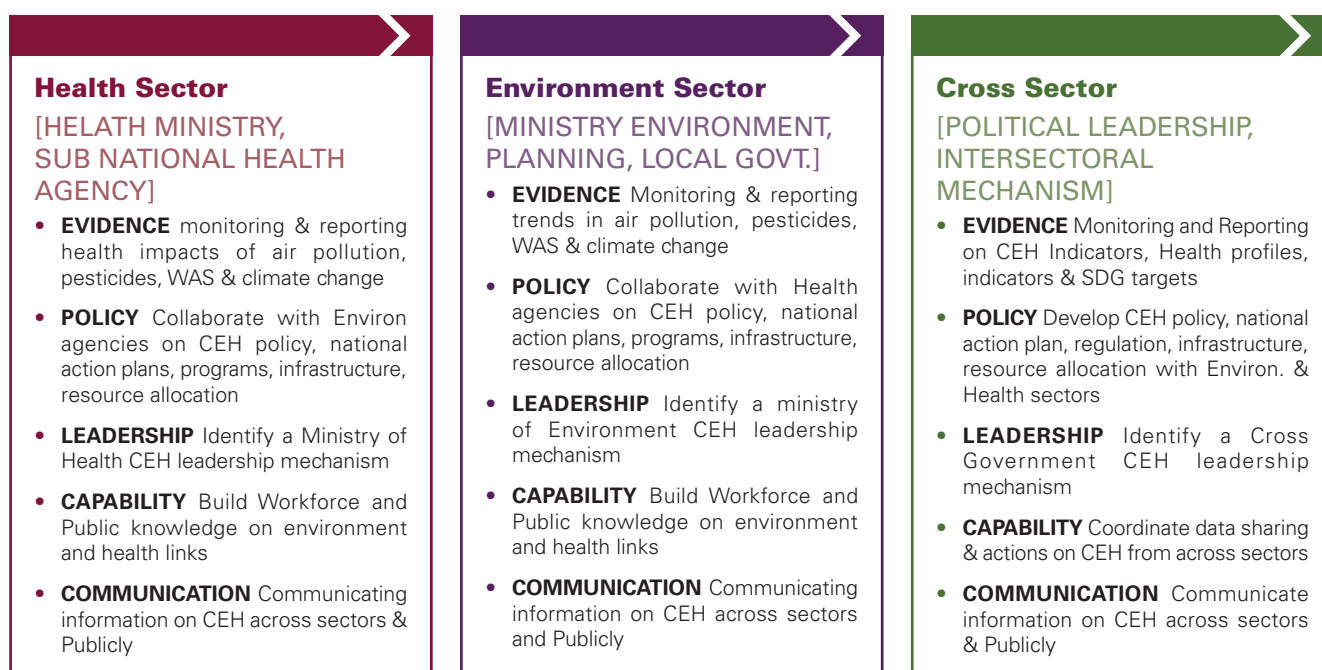
CHEMICALS		
Pesticide	» Amount of hazardous pesticide	» Mortality due to cancer and congenital diseases < 5
Chemicals/heavy metals	» Amount of heavy metal contamination	



4.2 Governance, Policy, and Strategy for Children’s Environment and Health

To translate the call to action into actual planning and implementation, we need policy development, cooperation and leadership at sub-national, national, regional and international levels. The figure below summarizes how **responsibilities for evidence generation, policy development, and action need to be shared and coordinated across health, environment, and cross-sector agencies**. The main areas for sharing policy and action include evidence generation, policy development, leadership on CEH, development of workforce capability and public communication. As many countries in the region are decentralizing, it is not only national governments that are accountable for protection of children, but also increasingly local governments and their civil society, private sector and development partners.

FIGURE 12 Cross-Sectoral Action Framework for Children’s Environmental Health



Both consultations and the systematic review have confirmed that more and better coordinated local and global data collection is required on environmental exposures and disease etiologies in vulnerable populations related to health impacts of the environment. A global, strategic, epidemiological effort is needed to fill gaps in our understanding of the relationship between environmental exposure and ill health in vulnerable populations by setting up study framework (e.g., children's cohort). A potential option proposed by international experts at the regional consultation workshop on children's health and environment in Seoul in Feb 2019 is the formation of a new international clearinghouse focused on tracking the global movement of highly toxic pollutants and on defining the health effects of environmental pollution.

We need to better understand the mechanisms and interactions between infectious agents, environmental exposures, and genetic predisposition to provide a stronger evidence base for the design of prevention intervention methods. What is also needed is a better understanding of the fraction of disease burden and primary care utilization that is attributable to environmental determinants of health.²⁰ Both approaches have the potential to contribute to better understanding of the links between environment and health, and thereby assist to advocate and guide public health action to address these determinants.

A regional action plan on CEH is required to strengthen international cooperation on children's health and environment, and to help accelerate regional and country-level cross-sectoral actions to prevent, reduce and manage environmental and climate change risks to children's health. Since it is the lowest socio-economic groups who experience the highest morbidity and mortality rates, regional action planning will also contribute to reduction in health inequalities. As is the case with national action on CEH, regional action on CEH will require the development of a mechanism to facilitate data collection, sharing and use. This could include for example the establishment of a data clearinghouse in the Asia Pacific to monitor action on children's environment and health. Potential strategies for advancing the agenda of regional dialogue and data sharing on CEH are outlined in the figure below.

FIGURE 13 Recommended Regional Actions to Support Countries on Children's Environment and Health

Regional Technical Guidance: Providing technical advice and guidelines on CEH through the UN agencies to support country-specific consultations and national action planning.

Regional Scientific Conferences: Conducting regular regional consultations and scientific conferences will promote dialogue among academia, civic groups, and government.

Regional Advocacy: Advocacy could occur through regional inter-governmental and cross-sectoral policy cooperation and coordination mechanisms such as the Asia-Pacific Regional Forum on Environment and Health and other relevant mechanisms in the region. It is desirable to designate a TWG on Children's Environmental Health in these mechanisms.

Regional Monitoring Systems: Establish a data clearinghouse in the Asia Pacific to monitor action on children's environment and health through priority indicators and updating of CEH country profiles.

Regional Action Planning: Developing a Regional Action Plan on Children's Environment and Health that would link to national action plans and provide a framework for monitoring CEH regionally as well as for technical support to countries in the region for CEH.

Regional financing mechanisms: Include children's environmental health in key health, environment and climate financing mechanisms to help shift financing and investment flows away from industries and economic activities increasing environmental health risks and mobilize necessary finance for priority risk reduction actions and solutions by health, environment and other sectors and partners.

20 Cheryl McMullen, Ashley Eastwood, Jeanette Ward Environmental attributable fractions in remote Australia: the potential of a new approach for local public health action Australian and New Zealand Journal of Public Health 2016 vol. 40 no. 2

In conclusion, although this report documents some improvements in environmental conditions and children’s health in the region, rapid urbanization, social inequalities and the impacts of climate change pose emerging threats to children’s health in the Asia Pacific. It is recommended that policy development and implementation will need to take place on three levels – the health sector, environment sectors, and through cross-sectoral collaborations, across the four policy domains of air quality, water and sanitation, hazardous chemicals and climate change. Evidence generation, leadership and accountability, and cross-organizational and sector cooperation are critical enabling factors for action. **To promote these developments, we also propose regional collaboration in the areas of technical support, data sharing and monitoring, advocacy and development of a Regional Action Plan on CEH.** Given that the poorest and most marginalized children are disproportionately affected by pollution, climate change, poor water and sanitation and exposure to hazardous chemicals, there is a policy and practice imperative to coordinate organizational and community capacity in the Asia Pacific to measure and mitigate the impacts on the most vulnerable children of the environmental and social determinants of health.



5 | Annexes

5.1 Sample Country Profiles

Cambodia

The percentage of household solid fuel use is >75% and the concentration of ambient particulate matter is above the WHO guidelines. Drinking water and sanitation has improved but is still unsafe. Regarding environmental health, while respiratory mortality and congenital disease mortality rates are declining, the mortality rates of dengue fever and acute lymphoid leukemia are increasing. Further improvement of solid household fuel can be linked to decreases in respiratory mortality. Decreases in diarrheal disease and hepatitis A mortality are with improved drinking water and sanitation. Malaria and dengue are associated with weather temperature and rainfall. With the increasing use of pesticides, there is a concern for the link between pesticide use and Acute Lymphoid Leukemia risk, although further studies are warranted to establish causal inference. Stunting among children under five years of age has declined since 1995 but is still present in just over 30% of the children. Cambodia has experienced frequent disasters including drought and flood.

Household Air Pollution

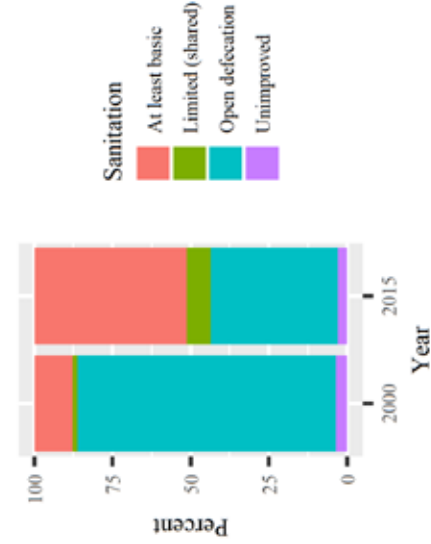
The temporal trend of clean fuel use is increasing. However, a large percentage of residents in the rural areas still used more solid fuels (91.5%) than clean fuels (8.3%).



Percentage (%) of household fuel in Cambodia
(Source: The Demographic and Health Survey Program Data(USAID 2018))

Water and Sanitation

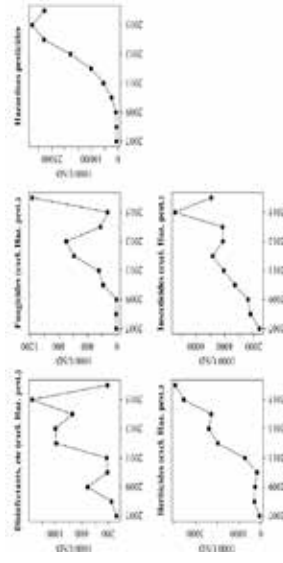
7% of the total population had piped water supplies in 2000, and 21% of the total population used piped water 15 years later, although piped water was still limited in rural areas (8%).



Percentage (%) of sanitation and safe drinking water service in Cambodia (Source: UNICEF Data: Monitoring the situation of children and women(UNICEF 2017))

Imported Pesticides

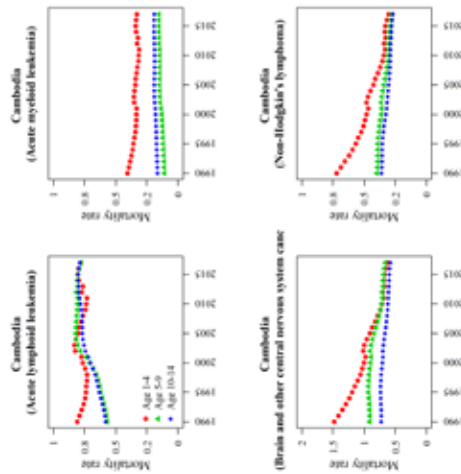
The major imported pesticide category in Cambodia were hazardous pesticides (23244.2 USD) between 2012 and 2016. Imports of pesticides have been increasing since 2007.



Imported pesticide in Cambodia (1,000 USD)
(Source: Food and Agriculture Organization of the United Nation (FAO 2018))

Cancer

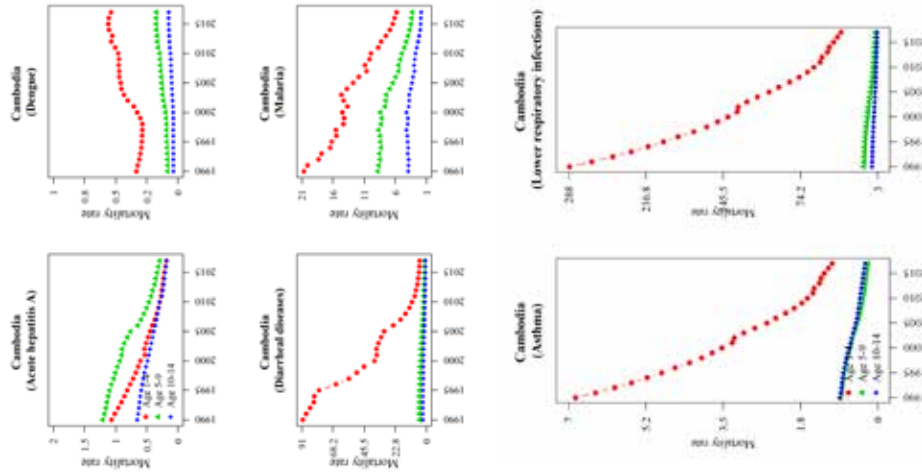
Mortality rate due to acute lymphoid leukemia increased among children aged five years and over. Other cancer mortality rates indicate a steady or declining trend.



Children's mortality rate per 100,000 childhood cancer (red circle: age 1-4; green triangle: age 5-9; blue diamond: age 10-14 years old) (Source: IHME GBD Results Tool(The Institute for Health Metrics and Evaluation 2018a)

Infectious Diseases & Environment

Mortality rates due to acute hepatitis A, diarrheal diseases, malaria have declined since 1990, but has increased for dengue. Asthma and lower respiratory mortality declined.



Children's mortality rate per 100,000 infectious & respiratory diseases in Cambodia (red circle: age 1-4; green triangle: age 5-9; blue diamond: age 10-14 years old) (Source: IHME 2018a)

Growth and Development

Stunting among children under 5 years of age has declined since 1995 but is over 30% of the children.

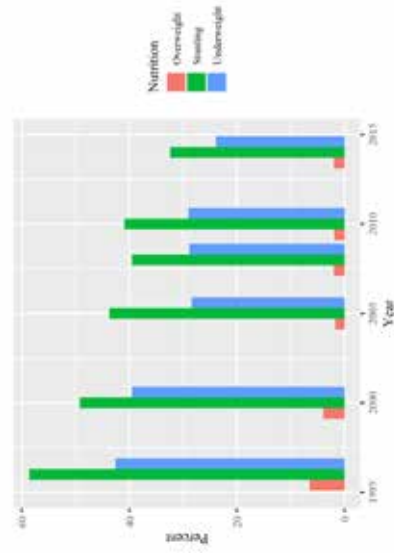


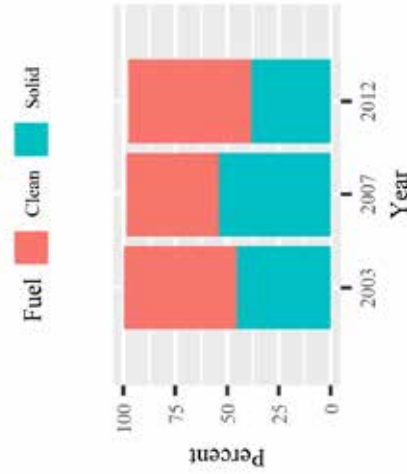
Figure 20 Growth and development of children under 5 in Cambodia (Source: The Demographic and Health Survey Program Data(USAID 2018)) (Refer to Annex 7.1. for definition of stunting, overweight, and underweight.)

Indonesia

Indonesia has made a significant progress in several environmental indicators such as access to drinking water and sanitation. In Indonesia, ambient air pollution, increasing temperature, and related natural disasters (flood, drought, storm) due to climate change are important issues. Although the child health situation is improving, respiratory illnesses and diarrheal diseases are still significant health problems. Challenges that remain include cross-sectoral coordination for managing air pollution in a decentralization context, as well as protecting children's rights to ensure children have a right to a safe and clean environment.

Household Air Pollution

About 59.9% of the total population used clean fuels in 2012. However, the use of more solid fuels is higher in rural areas (59.7%), where a smaller population proportion of the population uses clean fuels (39.5%).

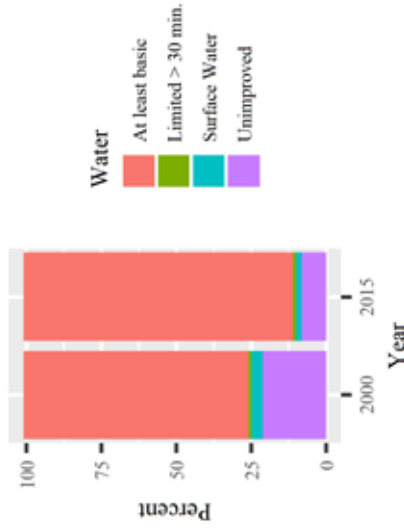


Percentage (%) of household fuel in Indonesia

(Source: The Demographic and Health Survey Program Data(USAID 2018))

Water

90% of the population had basic water service in 2015

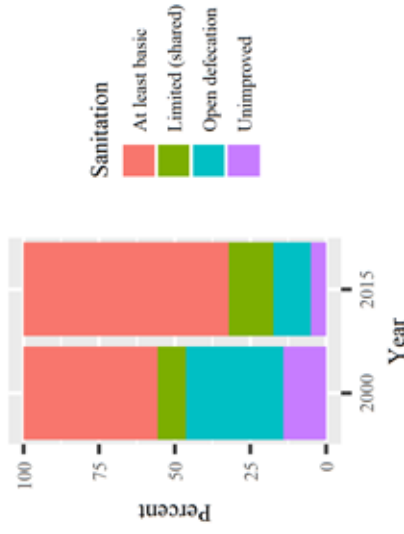


Percentage of (%) safe drinking water service in Indonesia

(Source: UNICEF Data: Monitoring the situation of children and women(UNICEF 2017))

Sanitation

31.3% had septic tanks in 2000, 53.2% used septic tanks 15 years later.

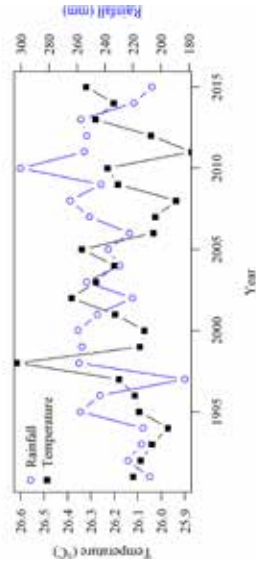


Percentage of (%) of sanitation service in Indonesia

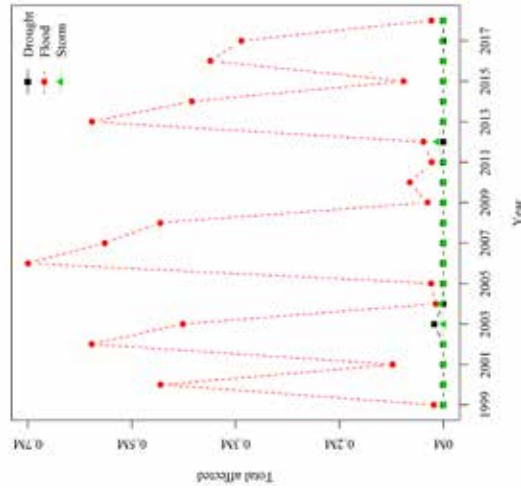
(Source: UNICEF Data: Monitoring the situation of children and women(UNICEF 2017))

Climate Change

Flood is the most severe natural disaster in Indonesia. In 2006, 69 thousand persons were affected by the flood. Annual mean temperature was highest in 1998 (26.6 °C), whereas annual rainfall was highest in 2010 (>300 mm).



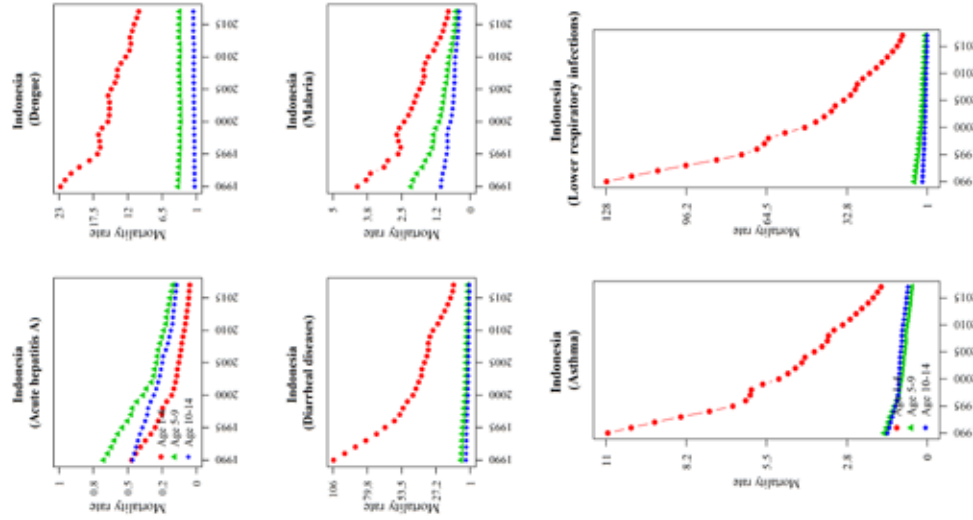
Annual trend of temperature (°C) and rainfall (mm) in Indonesia (Source: The Climate Change Knowledge Panel (World Bank Group 2018))



Total affected by natural disaster in Indonesia 1999-2017 (Source: EM-DAT(EM-DAT 2018))

Infectious Diseases & Environment

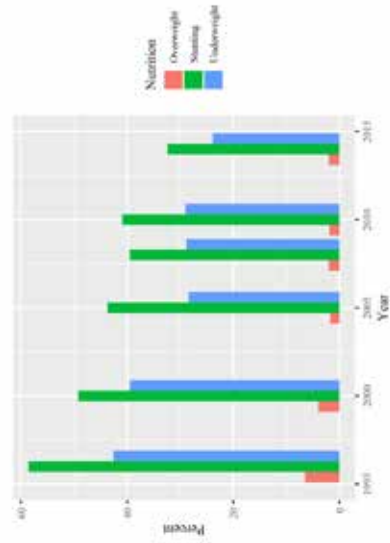
Mortality from hepatitis A, diarrheal A, dengue, malaria, asthma, and lower respiratory infections has declined since 1990.



Children's mortality rate per 100,000 due infectious & respiratory diseases in Indonesia (red circle: age 1-4; green triangle: age 5-9; blue diamond: age 10-14 years old) (IHME 2018a)

Growth and Development

Stunting among children under five years of age has declined since 1995 but is still above 35% of all children.



Growth and development of children under 5 in Indonesia (Source: The Demographic and Health Survey Program Data (USAID 2018))

5.2 Data Sources for country profiles

TABLE 8 Data source for country profile

Indicators	Category	Variables	Year/s data available	Data Source
Population indicators	Country Statistics	GDP (US \$) (billions)	2017	World Bank (World Development Indicators) https://databank.worldbank.org/data/views/reports/reportwidget.aspx?Report_Name=CountryProfile&id=b450fd57&tbar=y&dd=y&inf=n&zm=n&Country=VNM
		GDP growth (annual %)	2017	
		World Bank Economy classification	2017	WHO (GAPPD Indicators) https://www.who.int/test/others/gappd/#
		Neonatal mortality rate	2017	UNICEF Data: Monitoring the situation of children and women https://data.unicef.org/resources/dataset/drinking-water-sanitation-hygiene-database/
		Infant mortality rate	2017	
		Total under five deaths (N)	2017	
		Birth rate	2017	World Population Prospects 2017 https://population.un.org/wpp/Download/Standard/Fertility/
		Population density (persons per square km)	2015	World Population Prospects 2017 https://population.un.org/wpp/Download/Standard/Population/
		Population in thousands (N, millions)	2017	Human Development Reports http://hdr.undp.org/en/indicators/44206
		Child <15 year population thousands (N, millions)	2017	
		Child <5 year population thousands (N, millions)	2017	

Indicators	Category	Variables	Year/s data available	Data Source	
Environment Indicators	Climate change	Temperature (°C)	2006-2016	NOAA National Center for Environmental Information https://www.ncdc.noaa.gov/cdo-web/	
		Rainfall (mm)	2006-2016		
		Disasters (including floods, drought, epidemics) (N)	1999-2018		
	Ambient air pollution	Drought (N)			EM-DAT database https://www.emdat.be/emdat_db/
		Floods (N)			
		PM2.5 (µg/m³)	1990-2016	World Bank (PM2.5 air pollution, mean annual exposure) https://data.worldbank.org/indicator/EN.ATM.PM25.MC.M3?end=2016&start=2010&view=chart	
	Household air pollution	O3 (ppb)	1990-2016	IHME (State of global air) https://www.stateofglobalair.org/data/#/air/table	
		Cooking fuel	Various years ¹	Demographic and Health Survey Demographic and Health Survey https://dhsprogram.com/publications/publication-FR124-DHS-Final-Reports.cfm	
	Drinking water	Surface water (%)	Various years ²	WHO/UNICEF (Progress on Drinking Water, Sanitation and Hygiene) https://data.unicef.org/resources/dataset/drinking-water-sanitation-hygiene-database/ DHS Program https://www.dhsprogram.com/Publications/Publications-by-Country.cfm	
		Unimproved (%)			
		Limited service (%)			
		Basic service (%)			
		Safely managed (%)			
	Sanitation	Open defecation (%)	2007-2016	Food and Agriculture Organization of the United Nations http://www.fao.org/faostat/en/#data/RT	
		Unimproved (%)			
		Limited service (%)			
		Basic service (%)			
Safely managed (%)					
Pesticides	Imported pesticide (1,000 USD)				

Indicators	Category	Variables	Year/s data available	Data Source
Health indicators	Death (malaria, dengue, diarrhea, acute hepatitis A, asthma, lower respiratory infection, cancer, and congenital diseases)	Birth, neonatal, post neonatal, under five years, 5-9 years, 10-14 years	1991-2017	IHME (GBD Results Tool) http://ghdx.healthdata.org/gbd-results-tool
	Growth and development	Overweight	Various years ³	UNICEF/WHO World Bank (Joint child malnutrition estimates) https://data.unicef.org/topic/nutrition/malnutrition/ Stunting: Number of under-fives falling below minus 2 standard deviations (moderate and severe) and minus 3 standard deviations (severe) from the median height-for-age of the reference population Underweight: Number of under-fives falling below minus 2 standard deviations (moderate and severe) and minus 3 standard deviations (severe) from the median weight-for-height of the reference population Overweight: Number of under-fives above 2 standard deviations from the median weight-for-height of the reference population
		Stunting		
Underweight				

1 Cambodia (2000, 2005, 2010, 2014); Indonesia (2002-3, 2007, 2012); Myanmar (2015-16); Timor (2009-10, 2016)); Philippines (2008, 2013, 2017); Viet Nam (2005)

2 Cambodia (1994-2016); Indonesia (1980-2016); Myanmar (1995-2016); Philippines (1990-2014); Timor-Leste (2001-2013); Viet Nam (1989-2014)

3 Cambodia (1996, 2000, 2005, 2008, 2010, 2014); Indonesia (1987, 1989, 1992, 1995, 1998, 1999, 2000-2005, 2007, 2010, 2013); Myanmar (1991, 1994, 1995, 1997, 2000, 2003, 2009, 2016); Philippines (1987, 1990, 1992, 1993, 1998, 2003, 2008, 2011, 2013, 2021); Timor-Leste (2002, 2003, 2007, 2009, 2013); Viet Nam (1988, 1993, 1994, 1998, 1999, 2000, 2003-2008, 2010-2015)

5.3 Methods for meta-analysis and systematic review of children's environmental health

A. Systematic review

We searched PubMed and EMBASE with such keywords as the following for each sub-category. Selection criteria were 1) studied the association between the corresponding exposure for each sub-category and health effects in children; 2) published since 2000; 3) presented RR, OR, % change and 95% confidence interval or p-value; and 4) written in English; 5) peer-reviewed articles.

Sub-categories	Keywords
Air pollution and childhood respiratory diseases	(neonatal or postneonatal or infant or children) or ("household air pollution" or HAP or "indoor air pollution" or "solid fuel" or "cooking fuel" or "clean fuel" or "outdoor air pollution" or "air pollution" or "ambient air pollution" or AAP or "traffic-related pollution" or "particulate matter" or PM2.5 or ozone or O3) or (pneumonia or respiratory or asthma) or (Africa or Asia)
Climate change and vector-borne diseases	("global warming" or "climate change" or flood or "heat wave" or "cold wave" or "cold spell" or temperature or drought or rainfall) and (neonatal or postneonatal or infant or children) and (malaria or dengue) and (Africa or Asia)
Water/sanitation and children's health	"drinking water" and (children or infant or neonatal or postneonatal) and (diarrhea or mortality) and (Asia or Africa)

B. Study selection

	Air pollution and childhood respiratory diseases	Climate change and vector-borne diseases	Water/sanitation and children's health
Total identified studies	1,011	1,342	568
PubMed	828	549	445
EMBASE	182	793	123
Bibliographies	1	0	0
Excluded with duplicates	82	274	55
Articles after excluded duplicates	929	1,068	513
Excluded according to selection criteria	288	1,014	316
Articles reviewed including the full text	641	54	197
Excluded articles	594	39	153
Insufficient information	-	20	78
Irrelevant	-	15	44
Review, correspondence, comments	-	4	36
Articles included in the final analysis	47	15	39

C. Statistical analysis for meta-analysis

We used adjusted OR to pool OR and 95% CI from various studies, whenever possible. We used a random-effects model throughout our meta-analysis since the populations and study designs were heterogeneous across the studies. We used the DerSimonian and Laird method to calculate the pooled OR in a random-effects model. The heterogeneity test was performed using Higgins I^2 as the following, which represents the percentage of total variations within studies included in meta-analyses.

$$I^2 = 100\% \times (Q-df)/Q,$$

Where Q is Cochran's heterogeneity statistics and df represents the degrees of freedom. I^2 lies between 0% (no heterogeneity) and 100% (maximal heterogeneity). We used STATA (SE version 14.0) software package for statistical analysis (StataCorp, College Station, Texas, USA).

D. Limitation of meta-analysis

For the meta-analysis for air pollution and children's respiratory health, the number of studies for the association between air pollution and acute lower respiratory infection (ALRI) or pneumonia was scarce in Asia. There was no study available for the association between ozone and ALRI or pneumonia; thus, further studies in this area are needed in the future.

In the case of climate change and infectious diseases, the number of studies was not enough to conduct meta-analysis since the methods used for analysis in each individual study were extremely heterogeneous. Thus, we only conducted a systematic review for climate change and infectious disease. Meta-analysis for this topic is needed for future studies.

In the case of water/sanitation and children's health, although there were plenty of studies available for the review, since the methods to measure the quality of water and the health effects were heterogeneous, it was quite difficult to pool different studies together efficiently. Also, the number of studies conducted in Asian countries was limited compared to those conducted in Africa.

5.4 References

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Published: January 2020