

ANALYSIS BRIEF

Ambient PM_{2.5} Pollution: Health Impacts and Risk to ASEAN Children

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INTRODUCTION

Worldwide ambient air pollution arising from both domestic and trans-boundary sources has proven an unrelenting threat to both public health and the natural environment. Air pollution is ubiquitous, and especially so in countries that are rapidly developing where burning of biomass is prevalent, but is particularly concentrated in zones with intensifying urbanisation where en masse motor vehicle traffic is a substantial source contributor of fine-particulate combustion emissions. The Asia-Pacific region, specifically nations that comprise the Association of Southeast Asian Nations (ASEAN) has during the last twenty to 30 years seen accelerated economic and infrastructure development that has resulted in dangerously high levels of, and in some cases sustained seasonal particulate matter (PM) air pollution.

Air Pollution PM_{2.5}

Ambient air pollution comes in many forms. However, it is the fine-particulate type, specifically PM_{2.5} that is responsible for increased potential for deleterious effects due to the combination of its microscopic size (≤ 2.5 microns allows the individual particulates to cross alveolar tissue bypassing hepatic first-pass metabolism to directly enter the bloodstream), and chemical mixture that includes numerous toxic components including, but not limited to diesel soot, VOCs, PAHs, ultra fine dust, and various trace metals.

PM_{2.5} Environmental and Health Effects

In addition to the environmental impacts caused by ambient PM_{2.5}, that include depletion of soil nutrients, damage to forest and agricultural crops, and freshwater acidification a substantial body of epidemiologic and clinical data shows that PM_{2.5} is associated with an increased risk of cardio-pulmonary disease, asthma, decreased lung function, immune system-mediated inflammation, and cancer among other conditions. **PM_{2.5} air pollution-related mortality for children below age 5 in low and middle-income ASEAN nations is 138 times that of Canada and United States combined.**

ISSUE STATEMENT

Infant and pre-adolescent exposure to criteria air pollutants in particular to ambient PM_{2.5} poses an especially high degree of risk to human health as organ systems and physiologic processes are not yet fully developed, and thus not fully protective. Also, exposure intakes tend to be in higher dosing concentrations due to children’s relatively smaller physical size coupled with higher respiratory rates. The results of this children’s screening-level exposure evaluation aims to address likely health outcomes, and potential degree of risk associated with average daily exposures throughout the ASEAN region.

RESEARCH ANALYSIS AND FINDINGS

The results of this exposure evaluation paint a convincing (if not unequivocal) picture that average annual levels of ambient PM_{2.5} pollution throughout low to middle income (LTMI) ASEAN nations pose a substantial health risk, particularly to those in early years of life. *Figure 1.* shows average annual PM_{2.5}-related mortality data (from the 2018 WHO Air Pollution and Child Health report) for those <5 years (exclusively among the poorest LTMI) ASEAN member states range between 40 to over 90-fold higher than high-income ASEAN nations Brunei and Singapore. Similarly, when comparing average annual PM_{2.5}-related mortality for those <5 years among all LTMI ASEAN nations with the same age-specific cohort for developed nations Canada, Germany, Japan, and the United States combined there is an even more pronounced 103.6-fold difference in effect.

FIGURE 1.

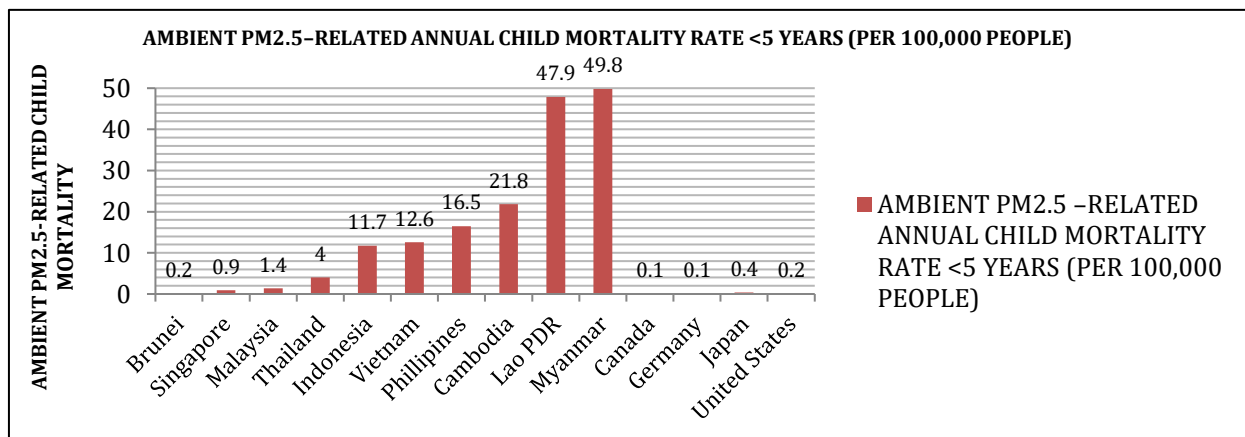
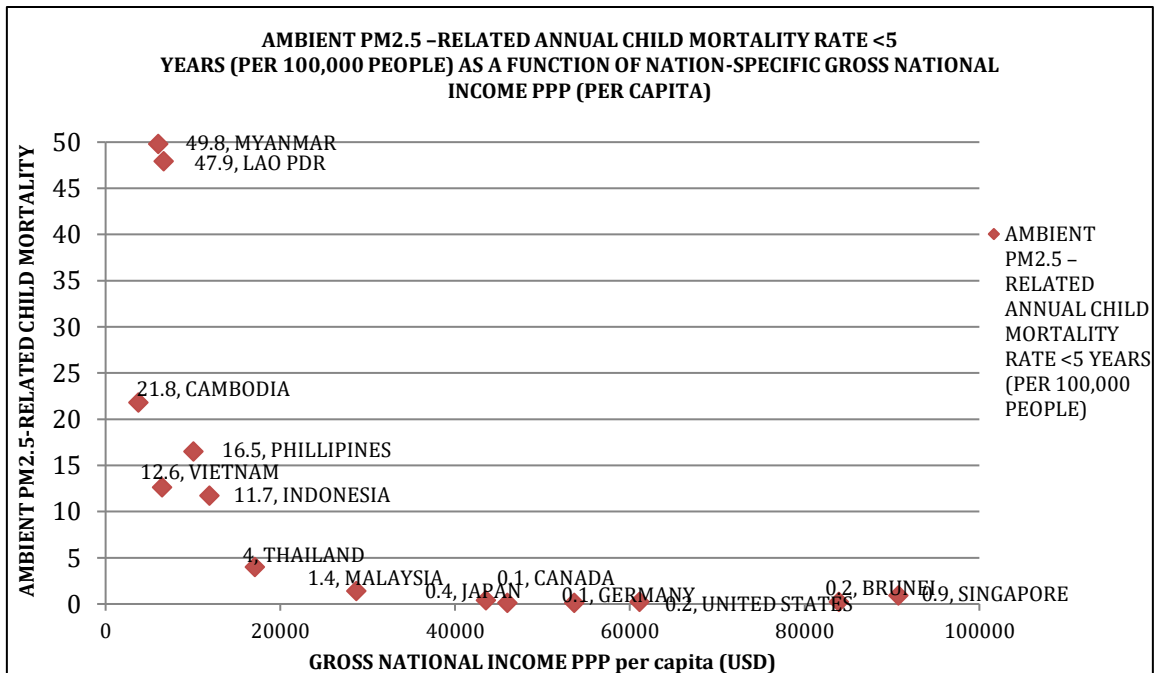


Figure 2. shows that nation-specific average annual PM_{2.5} –related child mortality (<5 years) is likely dependant on other factors beyond environmental exposure, and that gross national income maybe one proxy measure for how social-economic factors affect ecological and public health outcomes. The graph display indicates that nations with Gross National Income per capita (PPP) above \$40,000 (USD) per annum, i.e., socio-economically developed nations (mostly G7) have considerably lower average annual PM_{2.5} –related child mortality (<5 years) than LTMI ASEAN-member states. Average annual PM_{2.5} –related child mortality (<5 years) for LTMI ASEAN-member states is over 65 times higher than the four G7 + Brunei and Singapore, and a staggering 308 times higher when comparing Myanmar and Lao PDR (the 2nd and 4th poorest ASEAN-member states) with G7 + Brunei and Singapore. Although the data unequivocally points to an “income effect,” it does appear that other factors perhaps such as social infrastructure, political governance (transparency and corruption), rate of economic expansion, or rates of poverty may play a multi-variable role in affecting annual PM_{2.5} –related child mortality (<5 years) throughout LTMI ASEAN nations.

FIGURE 2.



The weight-of-evidence points to long-term health risks among early-years population group cohorts subject to daily ambient PM_{2.5} pollution exposure. This category of ambient PM air pollution is shown to be particularly harmful to infants and pre-adolescent children as their organ systems and physiology at these ages are still developing, making them especially sensitive to environmental exposures, and at higher risk for lifetime health outcomes that may include, chemical sensitivity-inducing allergic rhinitis, to asthma, and cardio-vascular problems and cancer.

Table 1. (on page 4) shows a cigarette-equivalent exposure from the corresponding average daily PM_{2.5} exposure dose for aggregated children's developmental stages (1 Month to <11 Years) derived from each ASEAN nation's average annual ambient PM_{2.5} pollution concentrations. The health effects of cigarette smoke (both primary smoke and environmental tobacco smoke, ETS) are well characterised. And as it turns out chemical components of cigarette smoke are quite similar to (if not identical to) PM_{2.5} air pollution. This allows for a quantitative conversion of PM_{2.5} concentrations to be expressed as numerical daily cigarette equivalents. Important to note is that annual average ambient PM_{2.5} concentrations for all ASEAN member-states (except Brunei) exceeded the WHO PM_{2.5} air quality guideline of 10 µg/m³. The data show that average annual PM_{2.5} air pollution exceedances above 24 µg/m³ converted to a greater than 1-cigarette equivalence per day among the aggregated children's cohort (1 Month to <11 Years) seen in Cambodia (24 µg/m³), Lao PDR (24.5 µg/m³), Thailand (26.2 µg/m³), Vietnam (29.7 µg/m³), and Myanmar (34.7 µg/m³). Indonesia, Malaysia, Singapore and Philippines averaged a 0.78-cigarette equivalence (among the same aggregated developmental-stage specific cohort) derived from an average annual ambient PM_{2.5} pollution concentration of 17.1 µg/m³ among the four ASEAN nations. This assessment outcome indicates that the theoretical children's cohort ages 1 Month to <11 Years throughout the ASEAN region (except Brunei) are effectively smoking the equivalent of either nearly one, or over 1 cigarette per day (nearly 1.7 cigarettes per day in the case of Myanmar) via PM_{2.5} air pollution exposure. This as a public health failure should be deemed unacceptable.

TABLE 1.

NATION	AVG. ANNUAL ASEAN NATION-SPECIFIC AMBIENT PM _{2.5} CONC. (µg/m ³)	NATION-SPECIFIC PM _{2.5} MEAN EXPOSURE DOSE (µg /kg/day) AGGREGATED DEVELOPMENTAL STAGES (1M TO <11Y)	AMBIENT PM _{2.5} CIGARETTE EQUIVALENTS (per day)
Brunei	5.8	0.46	0.26
Indonesia	15.6	1.24	0.71
Malaysia	16.0	1.27	0.73
Singapore	18.3	1.45	0.83
Philippines	18.4	1.46	0.83
Cambodia	24.0	1.91	1.09
Lao PDR	24.5	1.94	1.11
Thailand	26.2	2.08	1.19
Vietnam	29.7	2.36	1.35
Myanmar	34.7	2.96	1.69

The dataset in *Table 2*. shows the ASEAN region-specific average annual PM_{2.5} air pollution cigarette equivalent exposure for each of seven developmental stages within the children’s aggregated air pollution exposure cohort (1Month to < 11Years). The highest average daily 1-cigarette equivalent ambient PM_{2.5} exposure dose was seen in the children’s cohort for developmental stages 1 Year to 2 Years (3.29 µg/kg/day) and 2 Years to 3 Years (3.23 µg/kg/day). **However, the highest ambient PM_{2.5} cigarette equivalent (1.11) was seen in the youngest developmental stage (1 Month to < 3Months) with all seven developmental stages subject to exposure greater than a 1-cigarette equivalent per day. The low data situation applied to this assessment framework requires further evaluation with more statistical rigour. However, as a preliminary analysis the youngest developmental stage (within the aggregate) appeared most susceptible to PM_{2.5} exposure concentrations, and could be at highest risk for overall adverse health impacts.** Again, from a public health perspective these are air pollution exposure levels that must be reduced (if not prevented). Refer to TABLE 2. on page 6,

Table 2.

USEPA Guidance: Developmental Stages in Children (1M* TO <11Y*)	ASEAN REGION- SPECIFIC ANNUAL MEAN AMBIENT PM_{2.5} CONC. (µg/m³)	DEVELOPMENTAL STAGE-SPECIFIC ASEAN MEAN AMBIENT PM_{2.5} EXPOSURE DOSE (µg/kg/day) per day	AMBIENT PM_{2.5} 1-CIGARETTE EQUIVALENT EXPOSURE CONCENTRATION (µg/m³)	AMBIENT PM_{2.5} 1-CIGARETTE EQUIVALENT EXPOSURE DOSE (µg /kg/day)	AMBIENT PM_{2.5} CIGARETTE EQUIVALENTS (per day)	AMBIENT PM_{2.5} CIGARETTE EQUIVALENTS (per year)
PM _{2.5} DAILY µ EXP. DOSE (1MTO <3M)	23.6	0.09	22	0.081	1.11	405
PM _{2.5} DAILY µ EXP. DOSE (3M TO <6M)	23.6	0.24	22	0.219	1.01	369
PM _{2.5} DAILY µ EXP. DOSE (6M TO <12M)	23.6	1.33	22	1.24	1.07	391
PM _{2.5} DAILY µ EXP. DOSE (1Y TO <2Y)	23.6	3.53	22	3.29	1.07	391
PM _{2.5} DAILY µ EXP. DOSE (2Y TO <3Y)	23.6	3.48	22	3.23	1.08	394
PM _{2.5} DAILY µ EXP. DOSE (3Y TO <6Y)	23.6	2.77	22	2.58	1.07	391
PM _{2.5} DAILY µ EXP. DOSE (6Y TO <11Y)	23.6	1.70	22	1.58	1.08	394

CONCLUDING COMMENTS

Aggregated datasets from the collection of studies presented in the 2018 WHO Air Pollution and Child Health report along with the evaluations outcome from this screening-level exposure assessment strongly indicate that annual ambient PM_{2.5} air pollution concentrations in ASEAN in excess of WHO annual mean air quality guidelines pose a long-term existential challenge to populations and communities within this region. In particular, the analysis from this report point to some very disconcerting findings with respect to the observed impacts and estimated health risk associated with ambient PM_{2.5} air pollution exposure to ASEAN children, especially those who are in their early-years:

1. The overall PM_{2.5}-related child mortality (for those <5 years) among Low-to-middle income (LTMI) ASEAN member-states is profoundly higher than their age-related counterparts in high income ASEAN nations Brunei and Singapore, or G7 nations, Canada, Germany, Japan, and United States.
2. There appears to be pronounced “income effect” associated with PM_{2.5}-related child mortality for children <5 years. LTMI ASEAN nations appear to bear the brunt of overall particulate matter air pollution-related deaths among the youngest population cohorts when compared to high income ASEAN nations Brunei or Singapore, or when compared to select G7 nations, Canada, Germany, Japan, and the United States.
3. ASEAN children’s cohort ages 1 month to < 11 years appear to be exposed to a greater than 1-cigarette daily equivalent PM_{2.5} pollution exposure dose in Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam (for Myanmar the risk is nearly 2-cigarette equivalents)
4. Among all ASEAN nations children within each respective developmental stage are at risk from greater than 1-cigarette equivalent PM_{2.5}-related exposure per day.

The PM_{2.5}-related mortality impact and cigarette equivalence risk must be recognised as full and complete public health failures among all ASEAN member-state governments. The daily and annual levels of ambient criteria air pollutant concentrations and exposures among the most vulnerable demographic must be deemed a public health reality that is unacceptable. ASEAN member-states must no longer be negligent in addressing this issue lest they be deemed complicit in putting ASEAN children at risk.

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