THE MISSING PIECE

Why continued neglect of pneumonia
threatens the achievement of health goals

development initiatives

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The Missing Piece

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threatens the achievement of health goals

Acknowledgments

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Foreword

The world has made great gains in reducing the leading infectious disease killers.

Powerful tools including vaccines and medicines, and continual improvements in education, nutrition, water, sanitation and hygiene, and women's empowerment, have dramatically reduced infectious disease deaths among children. Adults too have benefited, as deaths from HIV/ AIDS, malaria, and TB have all fallen significantly from their peaks.

But infectious diseases still cause a massive burden of death and disability across the lifecycle, and very specific strategies are needed if countries are to achieve the ambitious communicable disease targets in the Sustainable Development Goals.

This report makes a strong case that pneumonia, which is now the leading infectious disease killer in the world by a wide margin, warrants concerted action. According to the latest Global Burden of Disease estimates, pneumonia caused 2.6 million deaths in 2017—three-quarters among the very young and the very old. Despite progress in reducing these deaths among children, many countries continue to struggle, and some are experiencing sharp rises in pneumonia deaths among adults, especially among the elderly.

To reduce these deaths the report urges national governments to adopt pneumonia control strategies, identify the populations most vulnerable to pneumonia, and ensure that they are fully protected with the pneumonia-fighting vaccines, diagnosis and treatments, including recommended antibiotics, oxygen, and/or therapeutic foods. The report also calls for coordinated action on the underlying risk factors for pneumonia death, most critically child wasting, but also air pollution, preterm birth, and smoking and alcohol use.

The move in many countries towards Universal Health Coverage (UHC) and the strengthening of primary health care systems presents a major opportunity for governments to invest in pneumonia prevention, diagnosis, and treatment. Governments who are able to fully cover the costs of pneumonia prevention and care for their most vulnerable populations will save many lives and significantly bend the curve of pneumonia mortality.

Global actors should support these national efforts to better align domestic health spending with disease burden, and ensure that countries have access to the most cost-effective tools to reduce pneumonia incidence and to ensure a speedy recovery for those who become ill. Greater effort is needed to drive the development and uptake of promising new tools, including the emerging RSV vaccines and monoclonals, which have the potential to prevent many pneumonia deaths among very young children, and a rapid diagnostic test for pneumonia that would remove a major obstacle to effective pneumonia treatment, rational antibiotic use, and continued antibiotic effectiveness.

The stakes are high. If pneumonia continues to be the "missing piece" in the infectious disease agenda, millions will still be dying in 2030 and many countries will have failed to achieve the health goals. But with a focused effort to fully protect the most vulnerable populations from pneumonia with the most cost-effective tools, countries can take one big step closer to ending the epidemic of communicable diseases and to fulfilling the grand promise of the sustainable development goals— ensuring healthy lives for all, at all ages.

Dr Keith Klugman
Director of Pneumonia
Bill & Melinda Gates Foundation

Overview

Pneumonia is a leading cause of death and disability in the world and the leading infectious disease killer, responsible for an estimated 2.6 million deaths in 2017, according to the Global Burden of Disease (GBD).

Most of these deaths (75%) are concentrated among two vulnerable populations—809,000 deaths are among children under five years and 1.1 million deaths are among adults aged over 70 years. Unlike other infectious disease killers, pneumonia deaths follow a "U-shaped curve" across the lifecycle. [1]

Two-thirds of pneumonia deaths cluster in a diverse group of 20 low, middle, and high income countries drawn mostly from Sub-Saharan Africa, South Asia, and high income regions. In low income countries, the burden of pneumonia deaths falls disproportionately on children under five years. In high income countries, it is adults aged over 70 years who shoulder the burden. Many middle income countries carry a "double-burden" of pneumonia deaths, losing large numbers of children and the elderly to pneumonia each year.

Despite recent gains in reducing child pneumonia mortality, deaths among adults are rising and the overall pneumonia burden is increasing in many countries, according to the GBD. Projected increases in risk-related pneumonia deaths, especially from air pollution, smoking, and alcohol use, together with population aging, will make it increasingly difficult for many countries to reduce pneumonia deaths. Further, progress in reducing pneumonia deaths has not kept pace with other leading infectious diseases in most countries.

Continued lack of action on pneumonia will prevent many countries from achieving the new sustainable development health goals by 2030. For these countries, pneumonia is the "missing piece" and the major barrier to reducing child

[1] Deaths from HIV/AIDS and TB follow an "N" shaped curve (deaths concentrate among adults of working age), while malaria deaths follow an "L" shaped curve (deaths concentrate among children under five years).

international development assistance to achieve pneumonia control. Increases in the historically low levels of Official Development Assistance (ODA) and private contributions will continue to be essential in the countries that are struggling with large burdens and/or very high rates of child pneumonia deaths and slow progress. External actors can best support these countries by working in direct partnership with governments and with non-government actors, including as part of initiatives and alliances such as the Global Financing Facility in support of Every Woman Every Child (GFF) and the Every Breath Counts Coalition.

Powerful champions are needed at local, national, and international levels to put pneumonia control high on the agendas of governments and the international health and development community. These champions should advocate for investments in pneumonia control strategies targeting the most vulnerable populations as part of UHC, and for the types of research and development (R&D) that will uncover breakthrough technologies with the power to deliver the next generation of improved pneumonia prevention, diagnostic, and treatment tools.

A world in which child pneumonia deaths have been driven close to zero and where pneumonia deaths among the elderly are rare in every country is achievable. It will be a world in which the vast majority of babies are born on time, where children everywhere have enough good food to eat, and where the air is cleaner for everyone. It will be a world where the most vulnerable infants and the elderly are fully protected with quality health care that is oriented to fight the leading threats to their survival. It will be a world where a child's death from infection is rare everywhere, and where we all enjoy longer, healthier lives.

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deaths to at least 25 per 1,000 births (Goal 3.2), to combatting the overall communicable disease burden (Goal 3.3), and to increasing access to quality healthcare services, essential medicines, and vaccines for all (Goal 3.8).

Specific pneumonia control strategies are needed to reduce the major risk factors and rapidly increase coverage of the interventions that are most cost-effective at preventing, diagnosing, and treating pneumonia, especially among children under five years and adults aged over 70 years. This "precision public health"[2] focus on pneumonia control in the most vulnerable populations has the potential to significantly accelerate achievement of health goals.

For countries struggling with child pneumonia deaths, reductions in child wasting, air pollution, and preterm birth, combined with full coverage of the pneumonia-fighting vaccines, improved diagnostic tools, and treatment with recommended antibiotics, oxygen, and therapeutic foods will save the most children's lives. Where the pneumonia burden falls among the elderly, reductions in air pollution, smoking, and alcohol use, together with improvements in vaccination, will be critical. Access to quality, affordable pneumonia diagnosis and care for elderly populations will increasingly be a priority in many countries. When new tools like a respiratory syncytial virus (RSV) vaccine become available, both very young and very old populations will benefit.

Leadership for developing, financing, and implementing pneumonia control strategies rests with the government agencies responsible for health in the high-burden countries. The current movement to introduce Universal Health Coverage (UHC) will contribute to pneumonia reduction by covering the costs of vaccination, diagnosis, and treatment, especially for the most vulnerable populations of children and the elderly. A health system that is effective at reducing both the incidence of pneumonia and pneumonia deaths is not only a quality health system, but a health system that delivers equity by serving the most vulnerable.

Some countries will continue to require

75%

Share of two vulnerable populations— children under five years and adults over 70 years—in pneumonia deaths

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[2] Precision public health can be defined as, "the application and combination of new and existing technologies, which more precisely describe and analyse individuals and their environment over the life course, to tailor preventive interventions for at-risk groups and improve the overall health of the population." See Weeramanthri TS, Dawkins HJS, Baynam G, et al. Editorial: Precision Public Health. Frontiers in Public Health 6 (2018) 121.

1

WHO DIES FROM PNEUMONIA?
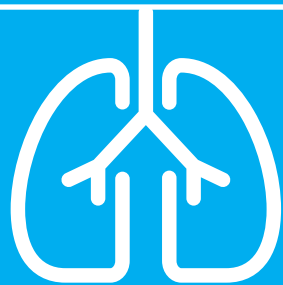
Pneumonia is a major cause of death and disability in the world. In 2017, pneumonia caused an estimated 2.6 million deaths and 106 million DALYs across all age groups, according to the Global Burden of Disease (GBD).[3] Pneumonia is the fourth leading cause of death after ischemic heart disease, stroke, and chronic obstructive pulmonary disease (COPD), and the fourth leading cause of Disability Adjusted Life Years (DALYs),[4] after neonatal disorders, ischemic heart disease, and stroke (Charts 1 and 2).

Chart 1: Pneumonia is the fourth leading cause of death in the world

Number of deaths, all ages (million)
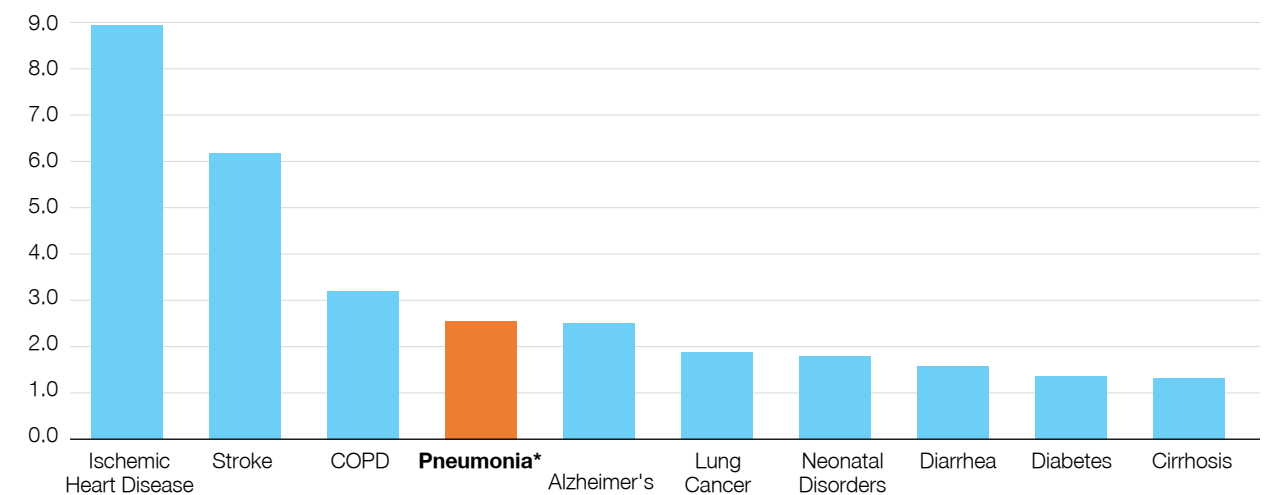
*Note "pneumonia" refers to the GBD category "lower respiratory infections" ; Source: Global Burden of Disease, 2017

Chart 2: Pneumonia is the fourth leading cause of Disability-Adjusted life Years (DALYs) in the world

Number of Disability Adjusted Life Years (DALYs), all ages (million)
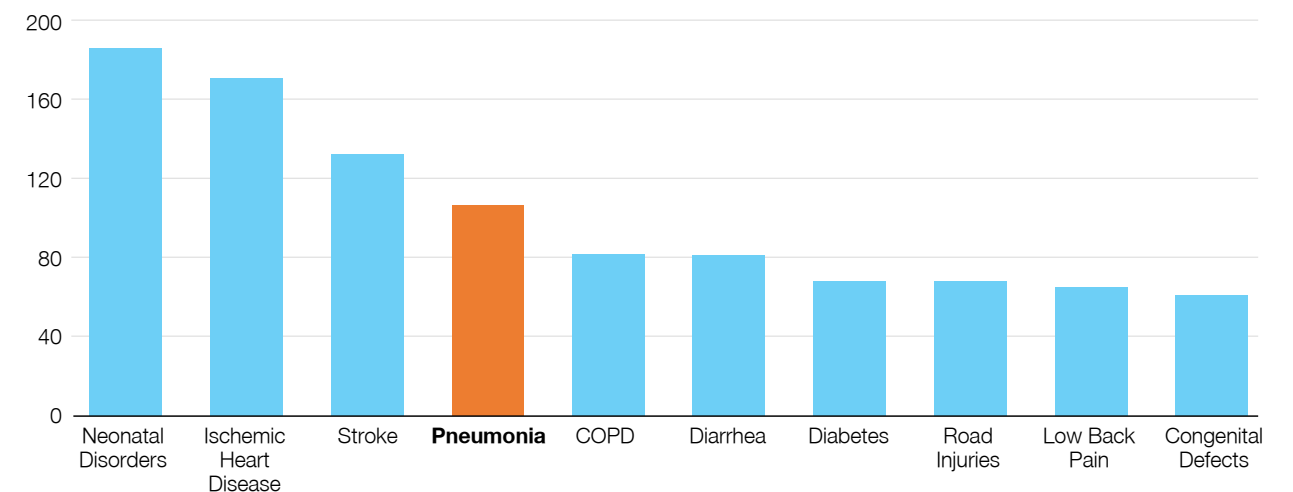
Source: Global Burden of Disease, 2017

[3] See Note (A) for an explanation of the GBD methodology.
[4] A measure of years of life lost due to sickness, disability, and early death.

Pneumonia is the leading infectious cause of death in the world. More people die from pneumonia than from diarrhea, TB, HIV/AIDS, and malaria (Chart 3). Meningitis, typhoid, hepatitis, sexually transmitted diseases (STDs), and measles are minor infectious disease killers compared to pneumonia, according to the GBD.

Pneumonia deaths are concentrated among the very young and the very old. Three-quarters (1.94 million) of the estimated 2.6 million pneumonia deaths that occurred in 2017 were among children under five years and adults aged over 70 years. In that year, the GBD estimates that 809,000 children under five years and 1.13 million adults over 70 lost their lives to pneumonia (Chart 4).

Unlike other leading infectious diseases, pneumonia deaths follow a "U-shaped" curve, with death rates spiking among children and the elderly (Chart 5).

Chart 3: Pneumonia is the leading infectious cause of death in the world

Number of deaths, all ages

2.56M Pneumonia	

1.57M Diarrhea
1.18M Tuberculosis
0.95M HIV/AIDS
0.62M Malaria
0.29M Meningitis
0.14M Typhoid
0.13M Acute Hepatitis
0.12M STDs
0.10M Measles
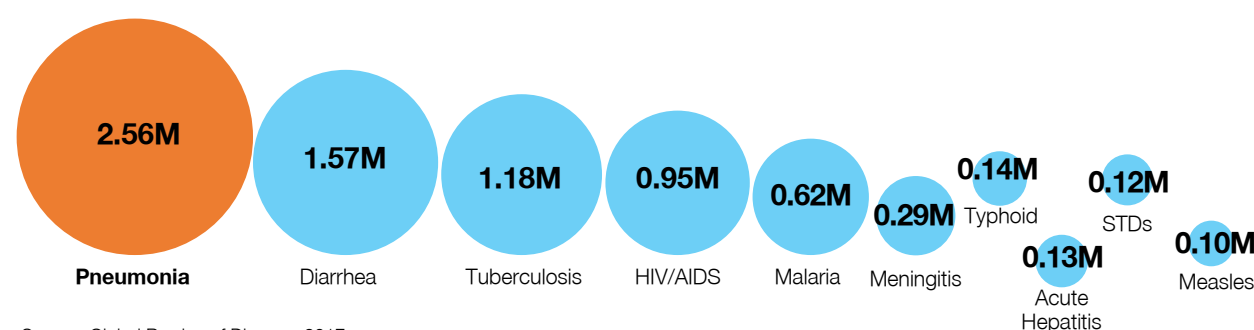
Source: Global Burden of Disease, 2017

Chart 4: Pneumonia deaths concentrate among children under five and adults over 70

Number of pneumonia deaths, various age groups

44K 5-14 years

170K 15-49 years

406K 50-69 years

809K 0-4 years

1.1M 70+ years
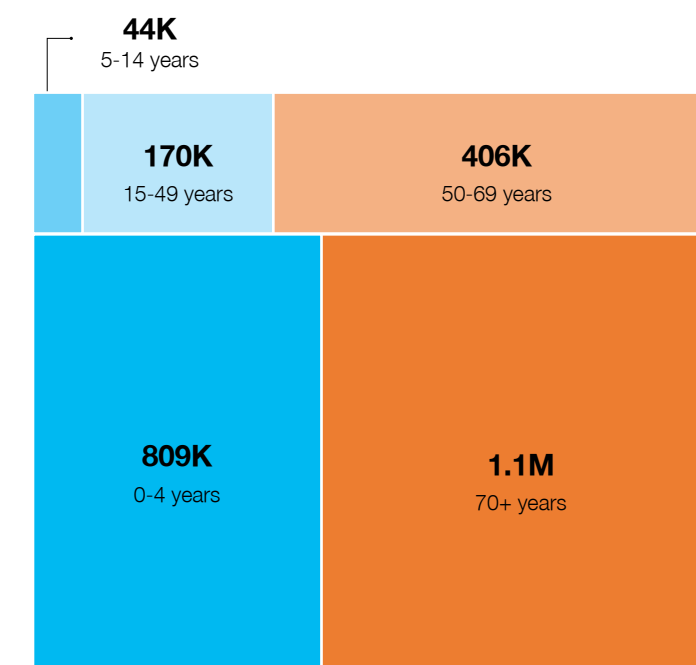
Source: Global Burden of Disease, 2017

Chart 5: Rates of pneumonia death follow a "U-shaped curve" across the life-cycle

Number of pneumonia deaths per 100,000 population

440.6 <1 yr
37.1 1-4 yrs
3.4 5-14 yrs
4.4 15-49 yrs
30.8 50-69 yrs
261.0 70+ yrs
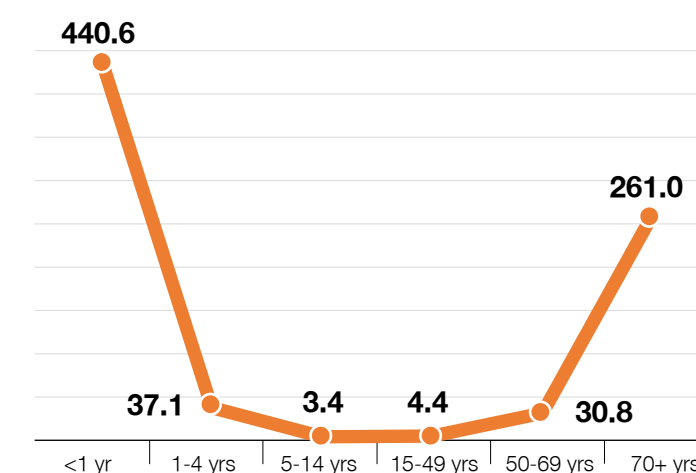
Source: Global Burden of Disease, 2017

Chart 6: Pneumonia is the second leading cause of death among children under five

Number of deaths, 0-4 years
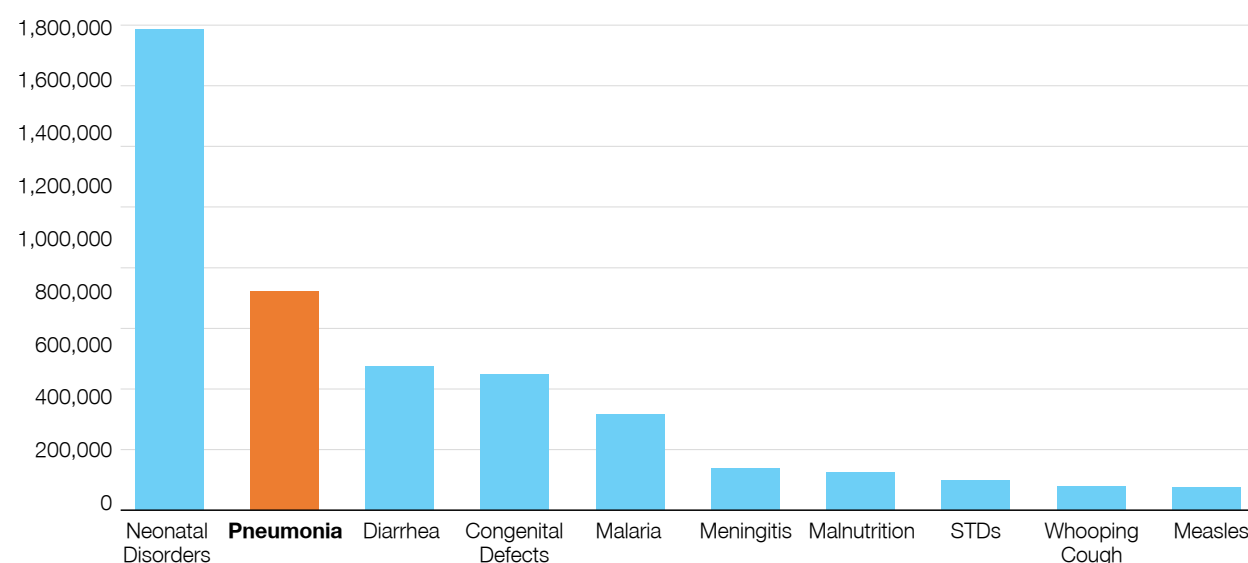
Source: Global Burden of Disease, 2017

25%

Childhood pneumonia deaths that happen in the first month of life

In contrast, deaths from HIV/AIDS and tuberculosis follow an "N" shaped curve, with deaths concentrating among adults of working age, while malaria deaths follow an "L" shaped curve, with deaths concentrating among children under five years.

Pneumonia is the second leading cause of death among children under five years, after neonatal disorders, which includes all newborn deaths from preterm birth, birth trauma, newborn sepsis, and other causes. Pneumonia is the leading infectious cause of death among children, and is responsible for many more child deaths than diarrhea, malaria, meningitis, STDs (primarily syphilis), whooping cough (pertussis), and measles (Chart 6). Pneumonia deaths are concentrated among the very young, with 75% (608,000) occurring among children under 12 months of age. 25% (217,000) of all childhood pneumonia deaths happen in the first month of life, according to the GBD (Chart 7).

Chart 7: Three-quarters of all child pneumonia deaths occur in the first year of life

Number of pneumonia deaths, various age groups
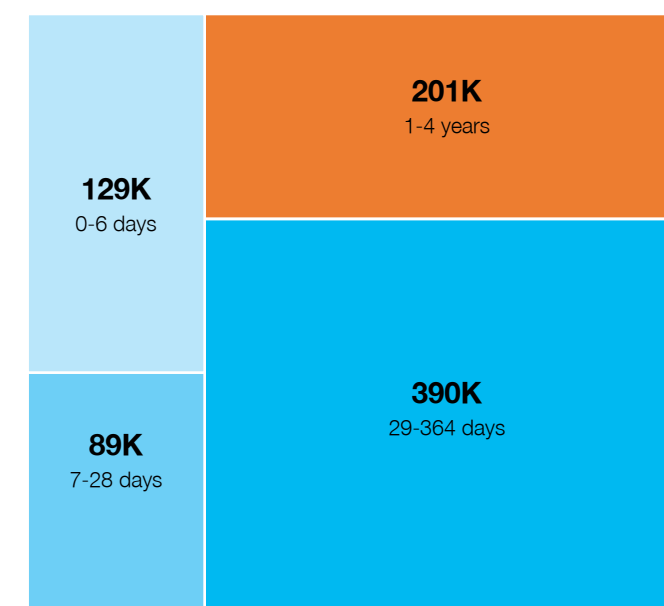
Source: Global Burden of Disease, 2017

Pneumonia is the fifth leading cause of death among adults aged over 70 years and was responsible for an estimated 1.1 million deaths in 2017. Only ischemic heart disease, stroke, Alzheimer's, and COPD caused more deaths than pneumonia. Pneumonia is the leading infectious disease killer of the elderly by a wide margin. Diarrhea, the second leading infectious cause of death among the elderly, caused 624,000 deaths, and is the only other infectious disease included among the top ten killers of adults aged over 70 years in the GBD (Chart 8).

Chart 8: Pneumonia is the fifth leading cause of death among adults over 70

Number of deaths, 70+ years
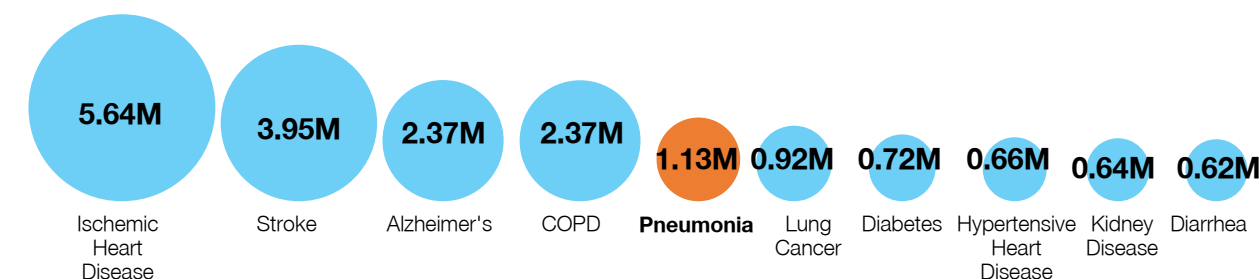
Source: Global Burden of Disease, 2017

Pneumonia kills significantly more males than females, largely due to higher numbers of pneumonia deaths among males aged 0 to 6 days and 15 to 69 years. These additional male deaths more than offset the higher number of female pneumonia deaths among adults aged over 70 years (Chart 9). Rates of pneumonia death per 100,000 population are also higher for males across all age groups, except among children one month to 14 years. All of the leading infectious disease killers cause more deaths among males than females, with the exception of diarrhea and measles, according to the GBD. For example, additional male deaths represent 41% of all TB deaths, 31% of all STD deaths, 20% of all acute hepatitis deaths, 16% of all typhoid deaths, 13% of all malaria and meningitis deaths, 12% of all HIV/AIDS deaths, and 9% of all pneumonia deaths.

The majority of pneumonia deaths can be

Chart 9: Pneumonia kills more males than females in most age-groups

Number of pneumonia deaths, various age groups   ● Males ● Females
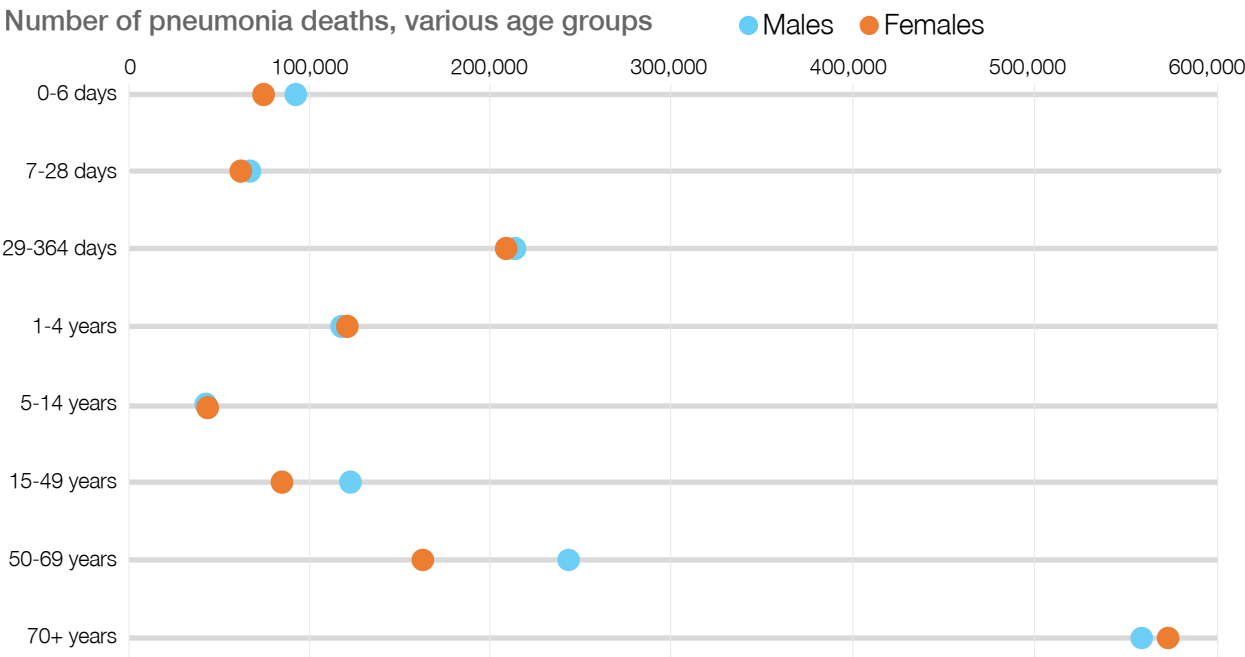
Source: Global Burden of Disease, 2017

Chart 10: Air pollution, child wasting, and smoking are the leading risk factors for pneumonia death

Number of pneumonia deaths, all ages

459K	433K	426K	265K	188K	179K	129K	119K	114K	93K
Household Air Pollution	Outdoor Air Pollution	Child Wasting	Smoking	Handwashing	Secondhand Smoke	Short Gestation	Child Stunting	Alcohol Use	Child Underweight
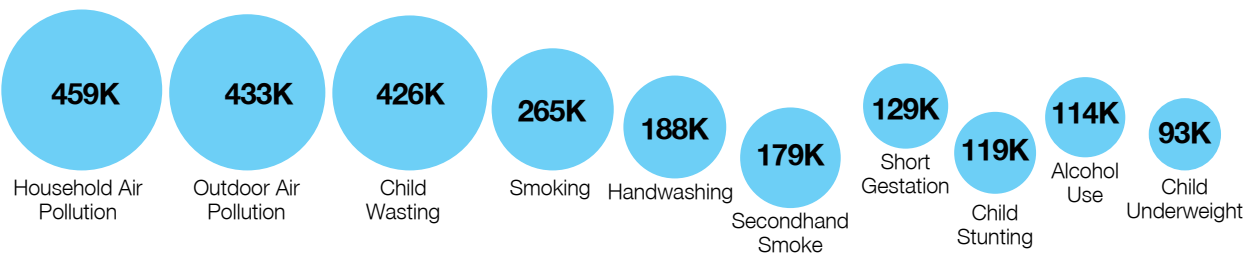
Source: Global Burden of Disease, 2017

809,000

Number of children under five years who lost their lives to pneumonia in 2017

attributed to specific risk factors, especially to behavioral and environmental factors, as defined by the GBD.[5] Behavioral risks contribute to an estimated 1.1 million pneumonia deaths, followed by environmental risks, which are a factor in 1 million pneumonia deaths. Major behavioral risks include child wasting, smoking, lack of access to handwashing, exposure to secondhand smoke, and short gestation. Major environmental risks include exposure to outdoor and household air pollution (Chart 10).

The leading risk factors for pneumonia death vary by age and by gender. Among children under five years, child wasting, air pollution, and short gestation are the major risk factors (Chart 11). For adults aged over 70 years, air pollution, smoking, and exposure to secondhand smoke are the major risk factors (Chart 12). The major risk factors for pneumonia deaths are similar for males and females with several important exceptions. Smoking and alcohol use contribute to a much higher number of male pneumonia deaths, while household air pollution and exposure to secondhand smoke contribute to more pneumonia deaths among females (Chart 13).

Chart 11: Wasting, air pollution, and short gestation are the leading risk factors for pneumonia death among children under five

Number of pneumonia deaths, 0-4 years
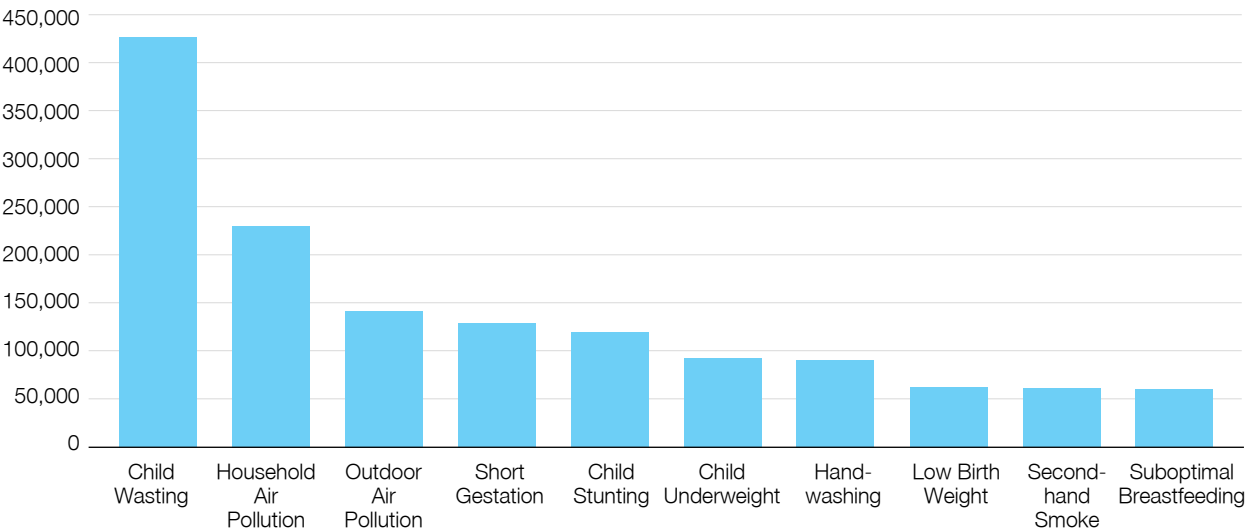
Source: Global Burden of Disease, 2017

[5] Note the category of "behavioral" risks in the GBD includes low birth weight and short gestation.

Chart 12: Air pollution, smoking, and secondhand smoke are the leading risk factors for pneumonia death among adults over 70

Number of pneumonia deaths, 70+ years
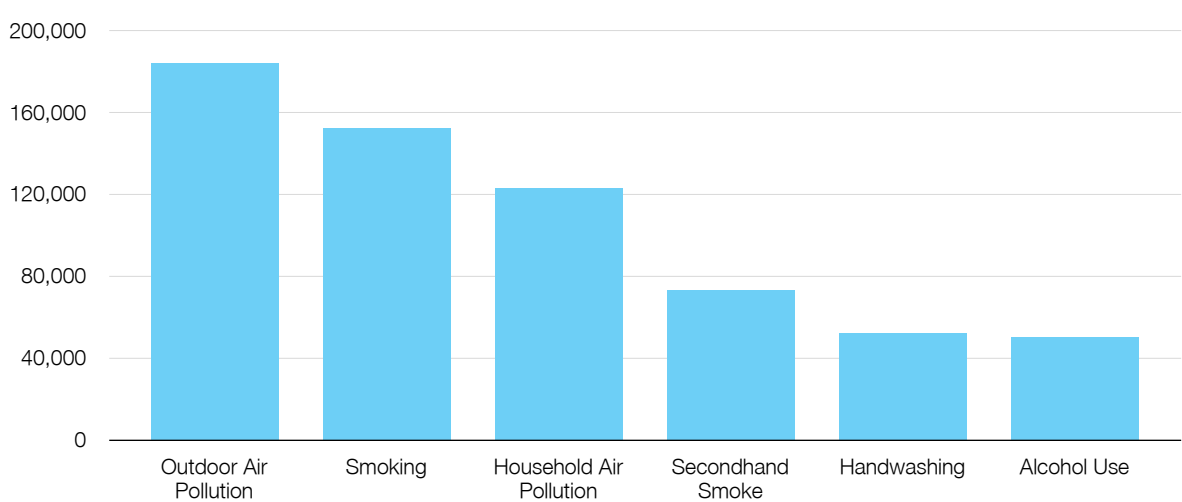
Source: Global Burden of Disease, 2017

Chart 13: Risk-related pneumonia deaths are similar for males and females, except for smoking, alcohol use, and air pollution

Number of pneumonia deaths, all ages

● Males ● Females
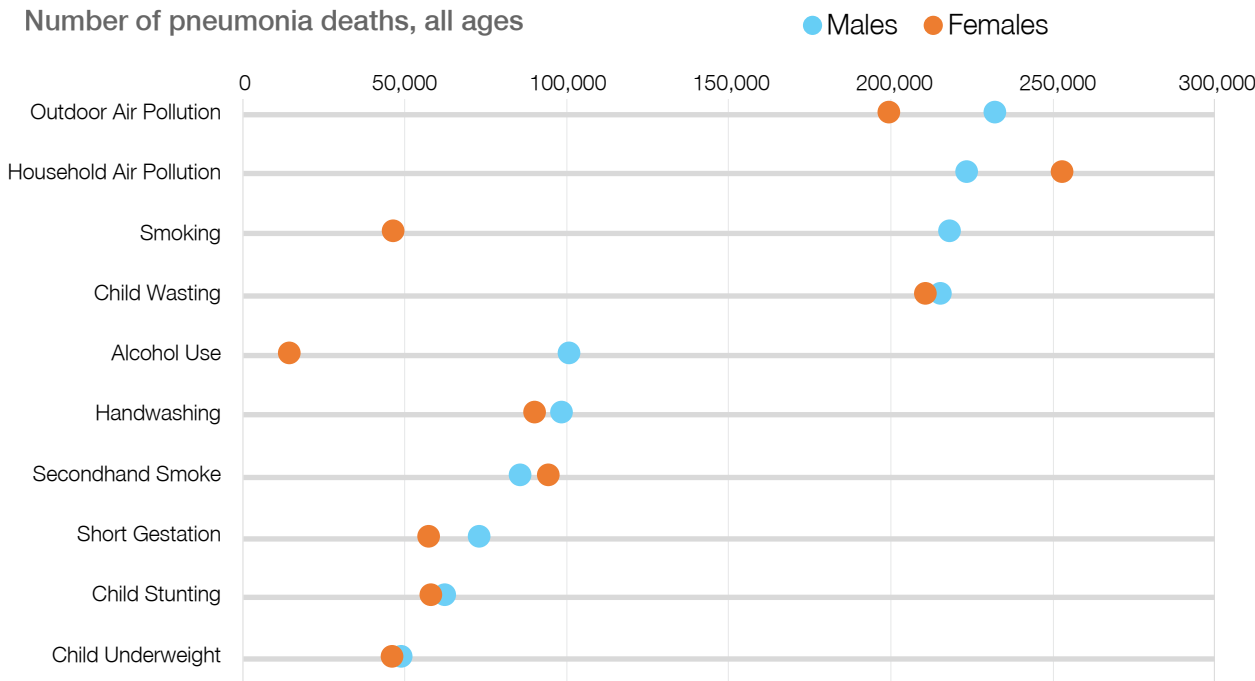
Source: Global Burden of Disease, 2017

THE STORY SO FAR...

Pneumonia is the leading infectious disease killer in the world, responsible for an estimated 2.6 million deaths and 106 million DALYs in 2017, according to the GBD. Deaths cluster among the most vulnerable)—young children under five years and adults over 70 years. Pneumonia kills an estimated 809,000 children under five—three-quarters of whom are under 12 months of age—and 1.1 million adults over 70 years. More males than females die from pneumonia and rates of pneumonia death are higher for males. The populations most at risk of death from pneumonia include children exposed to acute malnutrition (wasting), air pollution, and short gestation (preterm birth), and elderly populations exposed to air pollution and smoking, including secondhand smoke. Smoking and alcohol use contribute to many more pneumonia deaths among males, while exposure to household air pollution and secondhand smoke contribute to more pneumonia deaths among females.

New developments: Defining pneumonia

Defining the etiology (exact cause/s) of pneumonia in children has been very challenging due to the inability of sampling the area of infection in most cases. Recent evidence is helping elucidate pneumonia etiology in children. Data from randomized controlled vaccine studies have helped define the fraction of pneumonia due to leading bacterial causes including Haemophilus influenzae type b (Hib) and Streptococcus pneumoniae but more knowledge is needed to determine other causes, including viral, particularly among the most vulnerable children. The Pneumonia Etiology Research for Child Health (PERCH) aims to determine risk factors and etiology for severe and very severe pneumonia in children hospitalized in seven different countries including Bangladesh, Kenya, The Gambia, Mali, South Africa, Zambia, and Thailand. Additionally, the Child Health and Mortality Prevention Surveillance (CHAMPS), aims to determine the causes of overall deaths in children and the etiology of fatal cases of pneumonia.

These studies, as well as others striving to determine the etiology of pneumonia in children, are critical to inform the development of more effective prevention, diagnostic, and treatment strategies in the most vulnerable populations of children.

PERCH is led by the International Vaccine Access Center (IVAC) at the Johns Hopkins Bloomberg School of Public Health. CHAMPS is led by the Emory Global Health Institute at Emory University, both with support from the Bill & Melinda Gates Foundation.

Learn more

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Levine OS, O'Brien KL, Deloria-Knoll M, et al. The Pneumonia Etiology Research for Child Health Project: A 21st Century Childhood Pneumonia Etiology Study. Clinical Infectious Diseases, 2012.

Farag TH, Koplan JP, Breiman RF, et al. Precisely Tracking Childhood Death. The American Journal of Tropical Medicine and Hygiene, 2017.

2

WHERE DO MOST PNEUMONIA DEATHS OCCUR?
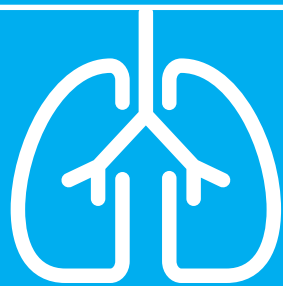
The 2.6 million deaths from pneumonia are concentrated in Sub-Saharan Africa, South Asia, and South East Asia. Sub-Saharan Africa is home to the largest number of pneumonia deaths, followed by South Asia, and South East Asia. Pneumonia deaths are also high in the High Income region. Pneumonia causes fewer deaths in Latin America and the Caribbean, North Africa and the Middle East, and Central Europe, Eastern Europe, and Central Asia.[6]

In Sub-Saharan Africa, pneumonia deaths are concentrated among children, while in the High Income region, pneumonia deaths are concentrated among adults aged over 70.

60% of pneumonia deaths in Sub-Saharan Africa are among children under five years, while 86% of pneumonia deaths in the High Income region are among adults aged over 70 years. In contrast, South Asia and South East Asia carry a "double burden" of pneumonia mortality, with significant deaths among both children and the elderly. For example, in South Asia 40% of pneumonia deaths are among children under five and 34% are among adults over 70 years, while in South East Asia 14% of pneumonia deaths are among children and 60% are among the elderly. Latin America and the Caribbean, North Africa and the Middle East, and Central Europe, Eastern Europe, and Central Asia all have "double burdens" of pneumonia (Chart 14).

Chart 14: Pneumonia deaths concentrate in specific regions among specific age groups

Number of pneumonia deaths, various age groups

Legend: ■ 0-4 years ■ 5-14 years ■ 15-49 years ■ 50-69 years ■ 70+ years
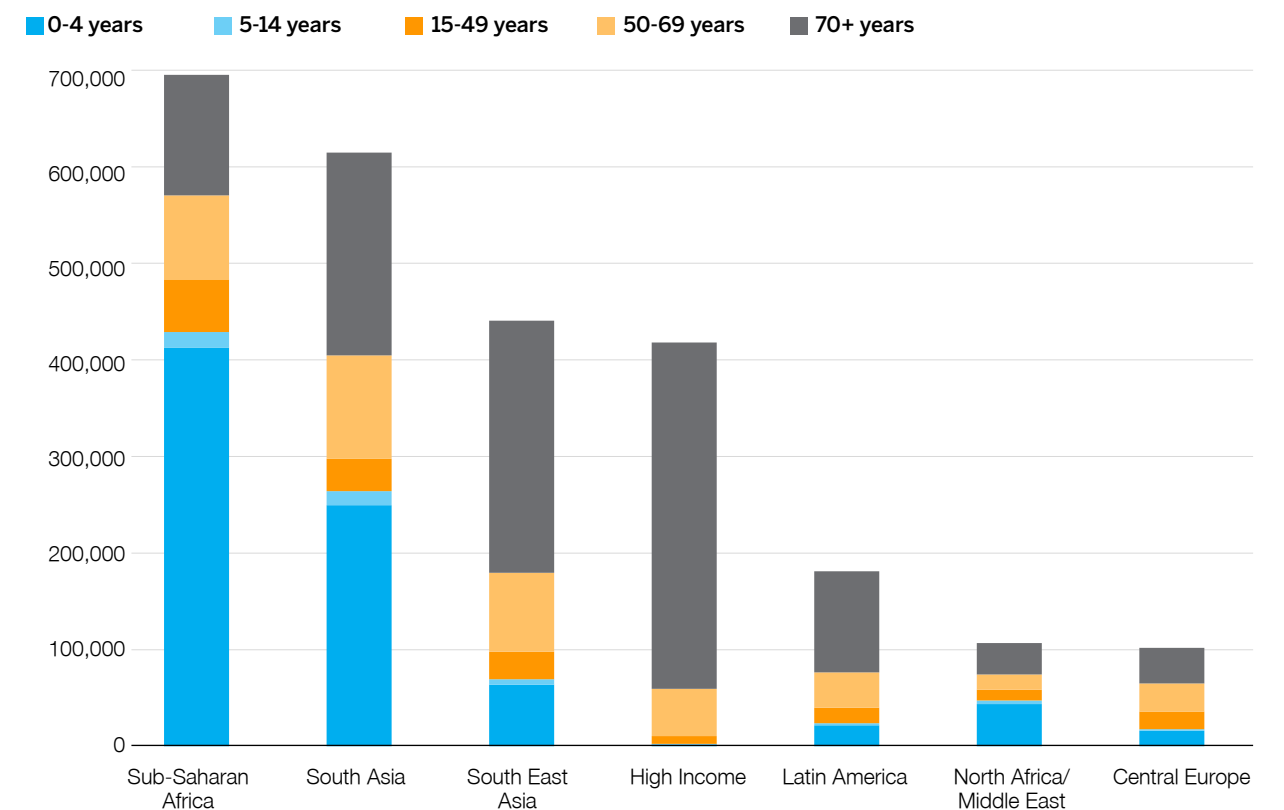
Source: Global Burden of Disease, 2017

[6] Regions are based on the GBD's seven "Super Regions". See Note (B) for a list of countries in each region

60%

Children under five as a proportion of all pneumonia deaths across Sub-Saharan Africa

Number of pneumonia deaths, various age groups

■ 0-4 years   ■ 5-14 years   ■ 15-49 years   ■ 50-69 years   ■ 70+ years

Source: Global Burden of Disease, 2017

Two-thirds (1.7 million) of pneumonia deaths are further concentrated in a group of 20 low, middle, and high income countries drawn mainly from Africa, Asia, and high income countries. Among these countries, India is the stark outlier with 507,000 pneumonia deaths—20% of all global pneumonia deaths—followed by Nigeria, China, Japan, and the USA. There are six countries from Africa in the top 20 (Nigeria, the Democratic Republic of Congo, Ethiopia, Tanzania, South Africa, and Kenya) and six high income countries (Japan, USA, the UK, Russia, Germany, and Argentina), South East Asia is home to four countries on the list (China, the Philippines, Indonesia, and Thailand), South Asia to three (India, Pakistan, and Bangladesh), and Latin America to one (Brazil).

The vast majority of pneumonia deaths in the high income countries occur among the elderly, as do more than 50% of pneumonia deaths in

China, Brazil, and Thailand. In contrast, over 50% of pneumonia deaths in Nigeria, Pakistan, the Democratic Republic of Congo, Ethiopia, Bangladesh, and Tanzania are among children under five years. Three of the high-burden countries are dealing with significant burdens of pneumonia death among both the very young and the very old, including India, Indonesia, and the Philippines. In contrast, Russia, South Africa, and Kenya are struggling with a high proportions of pneumonia deaths among their working age populations. 27% of pneumonia deaths in Russia are among 15 to 49 year olds, as are 18% and 12% of pneumonia deaths in South Africa and Kenya respectively (Chart 15).

In three-quarters of the high-burden countries, pneumonia kills more males than females. However in India, Bangladesh, the USA, the UK, and Argentina, more females die from pneumonia. The largest gap is in India, where pneumonia kills

Chart 16: Gaps between female and male pneumonia deaths are widest in India

Number of pneumonia deaths, various age groups   ● Males, India   ● Females, India
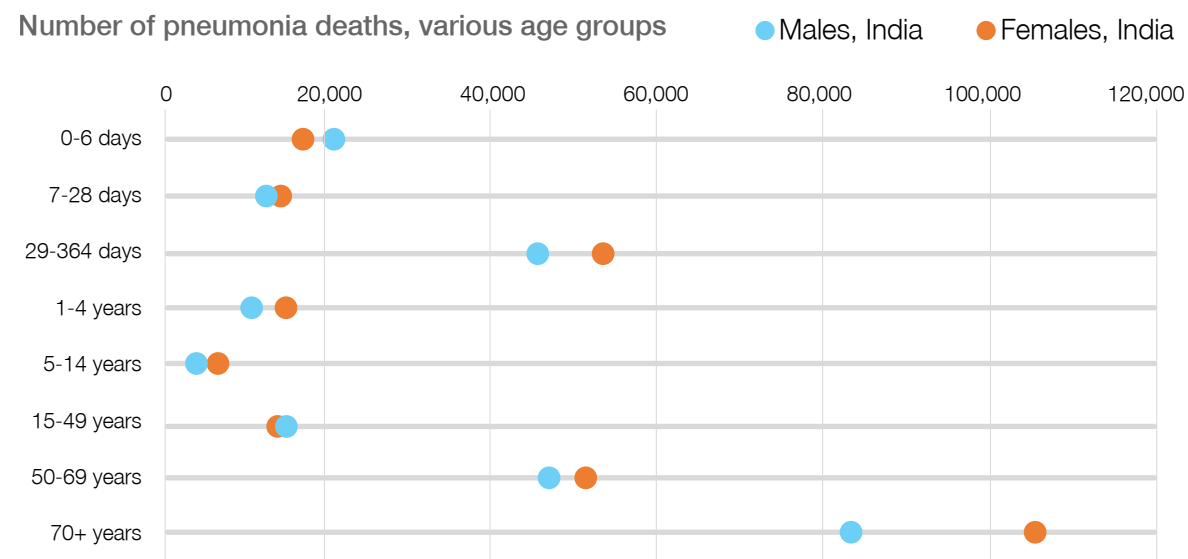
Source: Global Burden of Disease, 2017

an estimated 38,000 more females than males. These additional female deaths cluster among girls aged one month to 14 years of age, and among elderly women over 70 years (Chart 16). In Bangladesh, the USA, the UK, and Argentina, additional female deaths are due to larger populations of elderly females. However, in India, this is not the case, as rates of pneumonia death are higher for females across all age groups, except 15 to 49 years.

Pneumonia deaths are often further concentrated in specific populations within countries but estimates of sub-national pneumonia mortality for every country do not yet exist. Ideally, estimates of pneumonia mortality by age, gender, and cause would be available at the lowest administrative unit in every country, typically at the district or county levels. Until this data becomes available, governments struggling with high-burdens of child pneumonia death can use sub-national estimates of child mortality and child wasting as proxy indicators, especially when pneumonia is the leading killer of children under five years. To determine the location of their most vulnerable populations, countries struggling with high burdens of adult pneumonia deaths can identify their elderly populations where exposure to air pollution, and smoking and alcohol use are most prevalent.

507,000
Number of pneumonia deaths in India—20% of all global pneumonia deaths

THE STORY SO FAR...

Two-thirds of pneumonia deaths are concentrated in a diverse group of 20 low, middle, and high income countries spread across Africa, Asia, and High Income regions. While pneumonia mortality in some of these countries concentrates among children or the elderly, others carry a "double burden" of deaths. In most of these countries, males are more likely to die from pneumonia than females with the exception of India, where pneumonia death rates among girls and elderly women are higher. Pneumonia deaths are further concentrated within countries and there is an urgent need for maps that identify the populations at greatest risk of pneumonia death, by age, gender, and cause. These maps would be a critical tool for governments to more effectively target prevention, diagnosis, and treatment services to accelerate the achievement of health goals.

New Developments: Mapping pneumonia

The development of high resolution maps that pinpoint exactly where pneumonia deaths cluster within nations has the potential to transform the impact of interventions, rapidly accelerate mortality declines, and close health inequities. The Institute for Health Metrics and Evaluation (IHME) is advancing the development of these tools and has applied advanced Bayesian geostatistical tools to map patterns of child growth failure at 5 x 5 kilometer resolution across 51 Africa countries. This analysis reveals large concentrations of malnourished children across southern Niger, northern Nigeria, Chad, South Sudan, southern Ethiopia, northern Kenya, and Somalia.

Work is underway to map child mortality at the same 5 x 5 kilometer resolution. Expanding this "precision public health" mapping to include child pneumonia deaths in the high-burden pneumonia countries has the potential to improve the targeting of pneumonia prevention, diagnosis, and treatment efforts and dramatically accelerate national achievement of child survival goals. Precision public health maps that reveal the elderly populations most at risk of pneumonia death would also help many middle and high income countries reduce large and growing pneumonia burdens among adults.

Precision public health mapping is led by the Geospatial Analysis Team at the Institute for Health Metrics and Evaluation (IHME) and their partners.

Learn more

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Utazi CE, Thorley J, Alegana VA, et al. High resolution, age-structured mapping of childhood vaccination coverage in low and middle income countries. Vaccine, 2018.

3

ARE PNEUMONIA DEATHS DECLINING FAST ENOUGH?

Pneumonia deaths declined by 25% between 1990 and 2017, from an estimated 3.4 million to 2.6 million, according to the GBD. This decline was driven by children under five years, where pneumonia deaths fell by 66%. Deaths also fell among older children. In contrast, deaths among adults aged over 15 years increased over the period, most sharply among adults aged over 70 years where pneumonia deaths rose by 94% (Chart 17). While much of this increase was driven by aging populations, little progress was made in reducing the rate of pneumonia deaths among adults over the period (Chart 18).

Pneumonia deaths have fallen more slowly among males than females. Since 1990, the number of male pneumonia deaths has fallen by 24% compared to 27% among females. This has widened the gender gap from 96,000 additional male pneumonia deaths in 1990 to 125,000
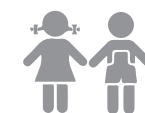
Chart 17: Pneumonia deaths have fallen among children under 15 but risen for all other age groups

Number of pneumonia deaths, various age groups

■ 1990 ■ 2017

Change ▶ -64% -68% -51% 12% 59% 94%
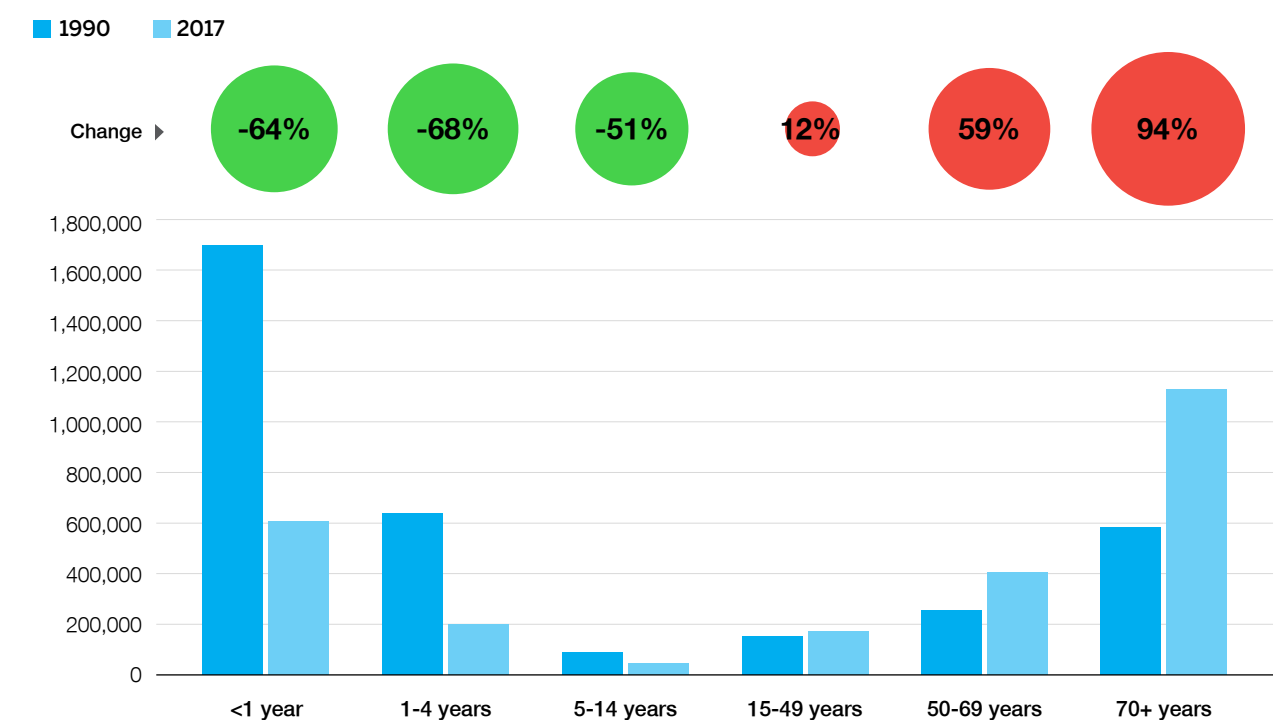
Source: Global Burden of Disease, 2017

Chart 18: Rates of pneumonia death have fallen sharply among children under five in contrast to other age groups

Number of pneumonia deaths per 100,000 population

■ 1990 ■ 2017

Change ▶ **-66%** **-70%** **-57%** **-21%** **-17%** **-9%**

| | <1 year | 1-4 years | 5-14 years | 15-49 years | 50-69 years | 70+ years |
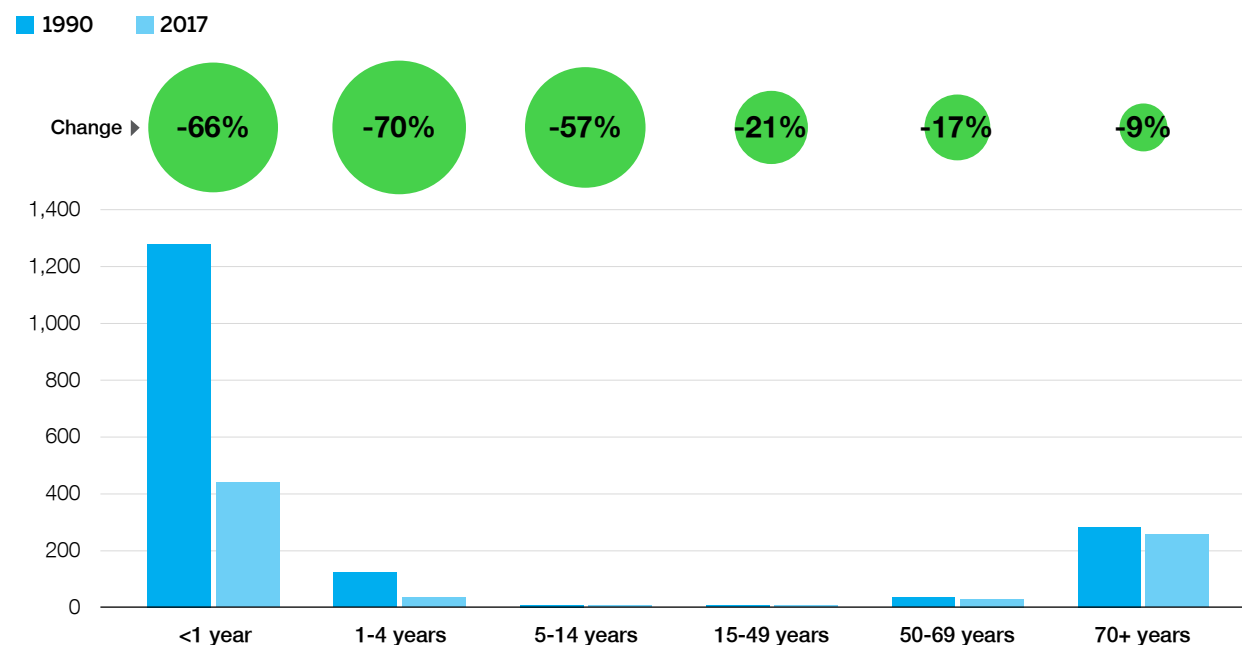
Source: Global Burden of Disease, 2017

Chart 19: Numbers of pneumonia deaths have fallen in all regions except High Income, and Latin America and the Caribbean

Number of pneumonia deaths, all ages

■ 1990 ■ 2017

Change ▶ **-12%** **-39%** **-50%** **62%** **2%** **-43%** **-14%**

| | Sub-Saharan Africa | South Asia | South East Asia | High Income | Latin America | North Africa/ Middle East | Central Europe |
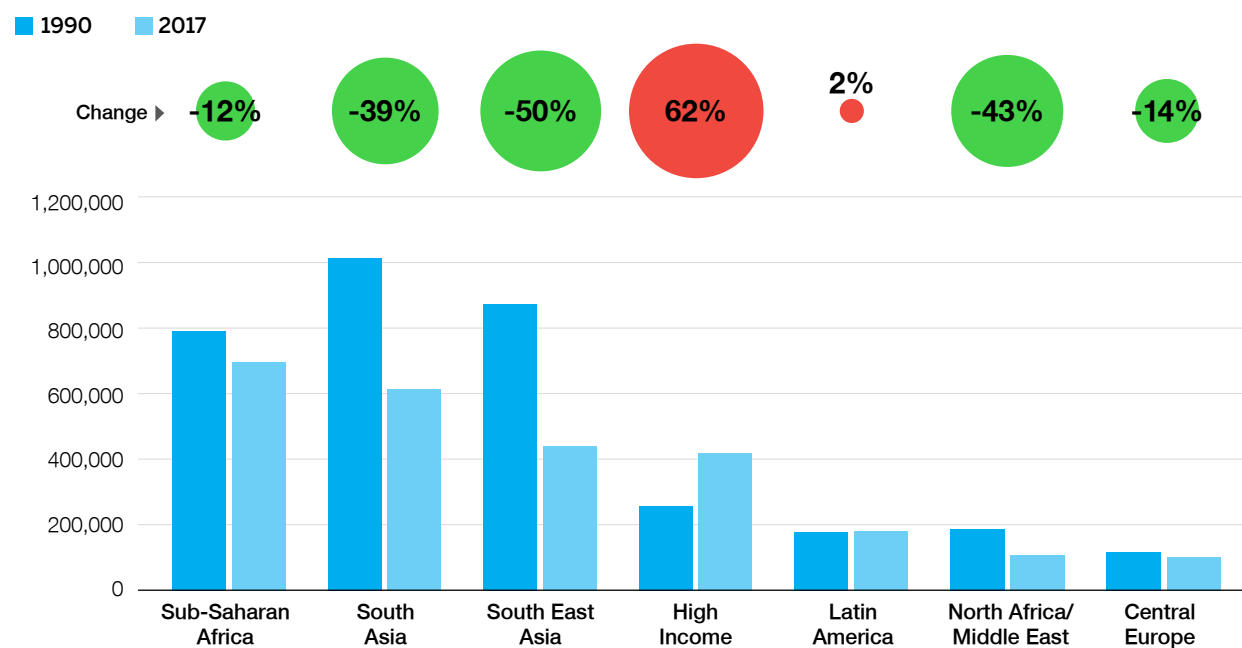
Source: Global Burden of Disease, 2017
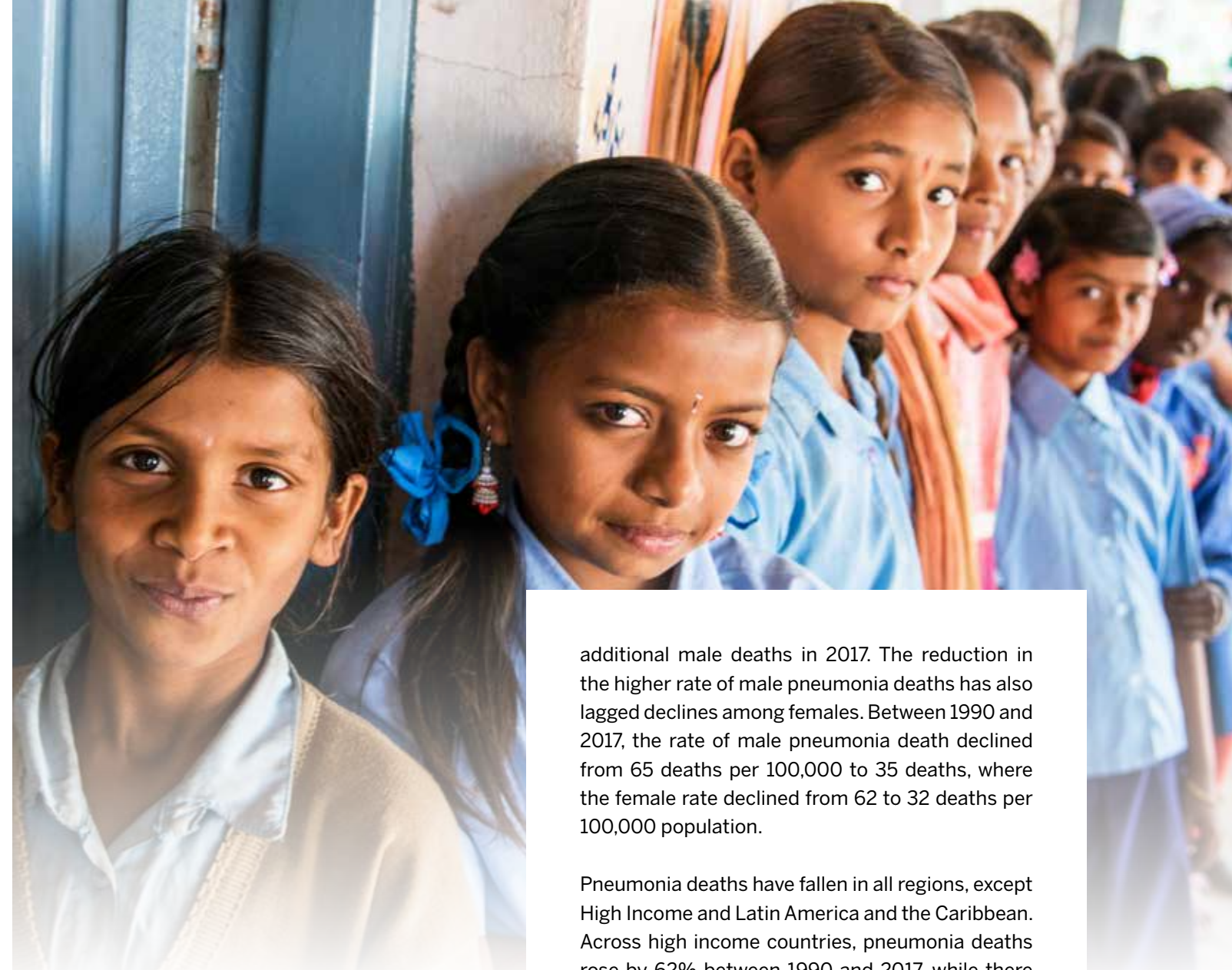
additional male deaths in 2017. The reduction in the higher rate of male pneumonia deaths has also lagged declines among females. Between 1990 and 2017, the rate of male pneumonia death declined from 65 deaths per 100,000 to 35 deaths, where the female rate declined from 62 to 32 deaths per 100,000 population.

Pneumonia deaths have fallen in all regions, except High Income and Latin America and the Caribbean. Across high income countries, pneumonia deaths rose by 62% between 1990 and 2017, while there was little change in the number of deaths across Latin America and the Caribbean. In contrast, sharp declines in pneumonia deaths were estimated across South East Asia, North Africa and the Middle East, and South Asia, where deaths fell by 50%, 43%, and 39% respectively, according to the GBD. In contrast, pneumonia deaths in Sub-Saharan Africa declined by just 12% and by 14% across Central Europe, Eastern Europe, and Central Asia (Chart 19).

Pneumonia deaths have risen in half of the 20 high-burden countries, with increases ranging from 3% in the Philippines to 74% in Argentina, according to the GBD. The steepest increases occurred in five high income countries, including Japan, the USA, the UK, Argentina, and Germany, driven by aging populations. However, pneumonia deaths also rose in Russia, the Philippines, Thailand, Brazil, and the Democratic Republic of Congo. For example,

25%

Decline in pneumonia deaths between 1990 and 2017, from an estimated 3.4 million to 2.6 million

Chart 20: Numbers of pneumonia deaths have risen in 10 of the 20 high-burden countries

Number of pneumonia deaths, all ages   ■ 1990 ■ 2017

Country	Change
Japan	**102%** ●
USA	**38%** ●
Brazil	**27%** ●
Philippines	**3%** ·
DRC	**11%** •
UK	**12%** •
Thailand	**169%** ●
Russia	**55%** ●
Argentina	**278%** ●
Germany	**57%** ●

Source: Global Burden of Disease, 2017

Chart 21: Numbers of pneumonia deaths have fallen in 10 of the 20 high-burden countries

Number of pneumonia deaths, all ages   ■ 1990 ■ 2017

Country	Change
India	**-32%** ●
China	**-66%** ●
Nigeria	**-6%** ●
Pakistan	**-35%** ●
Ethiopia	**-47%** ●
Indonesia	**-61%** ●
Bangladesh	**-73%** ●
Tanzania	**-23%** ●
South Africa	**-3%** ·
Kenya	**-6%** ●

Source: Global Burden of Disease, 2017

between 1990 and 2017 the number of pneumonia deaths in Thailand rose from an estimated 13,500 to 36,000, while pneumonia deaths in the Democratic Republic of Congo rose from an estimated 53,000 to 59,000 (Chart 20). In the remaining 10 high-burden countries, pneumonia deaths fell, with reductions ranging from 3% in South Africa to 73% in Bangladesh. The reductions in pneumonia deaths achieved by Bangladesh, China, Indonesia, and Ethiopia, between 1990 and 2017 are remarkable (Chart 21).

Declines in pneumonia deaths in the high-burden countries between 1990 and 2017 were driven by reductions in deaths among children under five years. Child pneumonia deaths fell in every high-

Chart 22: Pneumonia deaths among children under five have fallen in all of the high-burden countries

Number of pneumonia deaths, 0-4 years   ■ 1990 ■ 2017

Country	Change
India	-67%
Nigeria	-11%
Pakistan	-49%
DRC	-14%
Ethiopia	-62%
China	-94%
Bangladesh	-84%
Tanzania	-48%
Philippines	-68%
Indonesia	-87%
Kenya	-47%
Brazil	-87%
South Africa	-70%
Russia	-83%
USA	-61%
Thailand	-90%
Argentina	-69%
Japan	-68%
UK	-64%
Germany	-76%
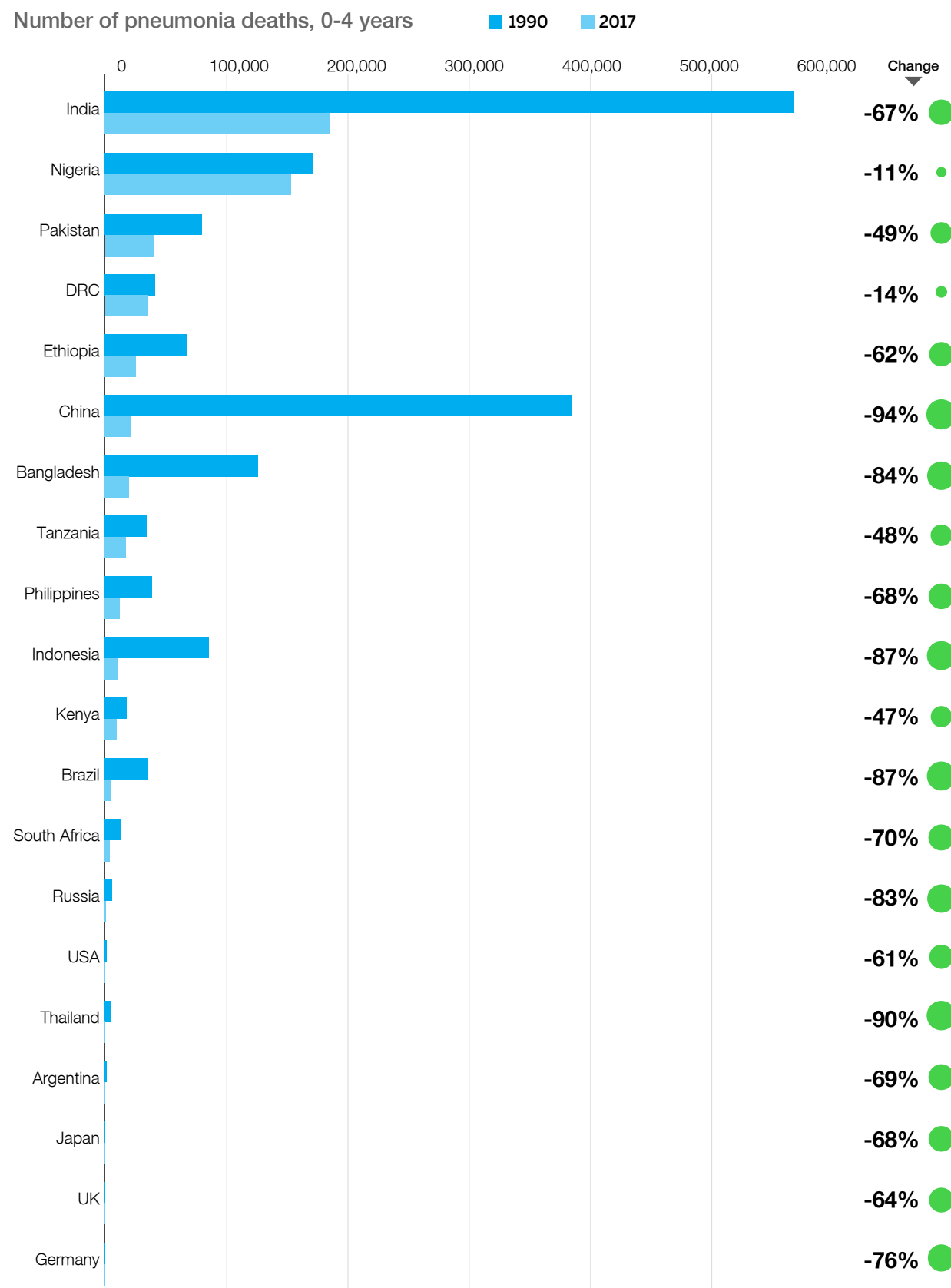
Source: Global Burden of Disease, 2017

Chart 23: Pneumonia deaths among adults over 70 have risen in all of the high-burden countries

Number of pneumonia deaths, 70+ years   ■ 1990 ■ 2017

Country	Change
India	168%
China	45%
Japan	123%
USA	37%
Brazil	257%
Philippines	179%
UK	14%
Thailand	453%
Argentina	429%
Germany	64%
Indonesia	92%
Nigeria	28%
Bangladesh	61%
Ethiopia	55%
Russia	55%
South Africa	132%
DRC	120%
Pakistan	57%
Tanzania	93%
Kenya	93%
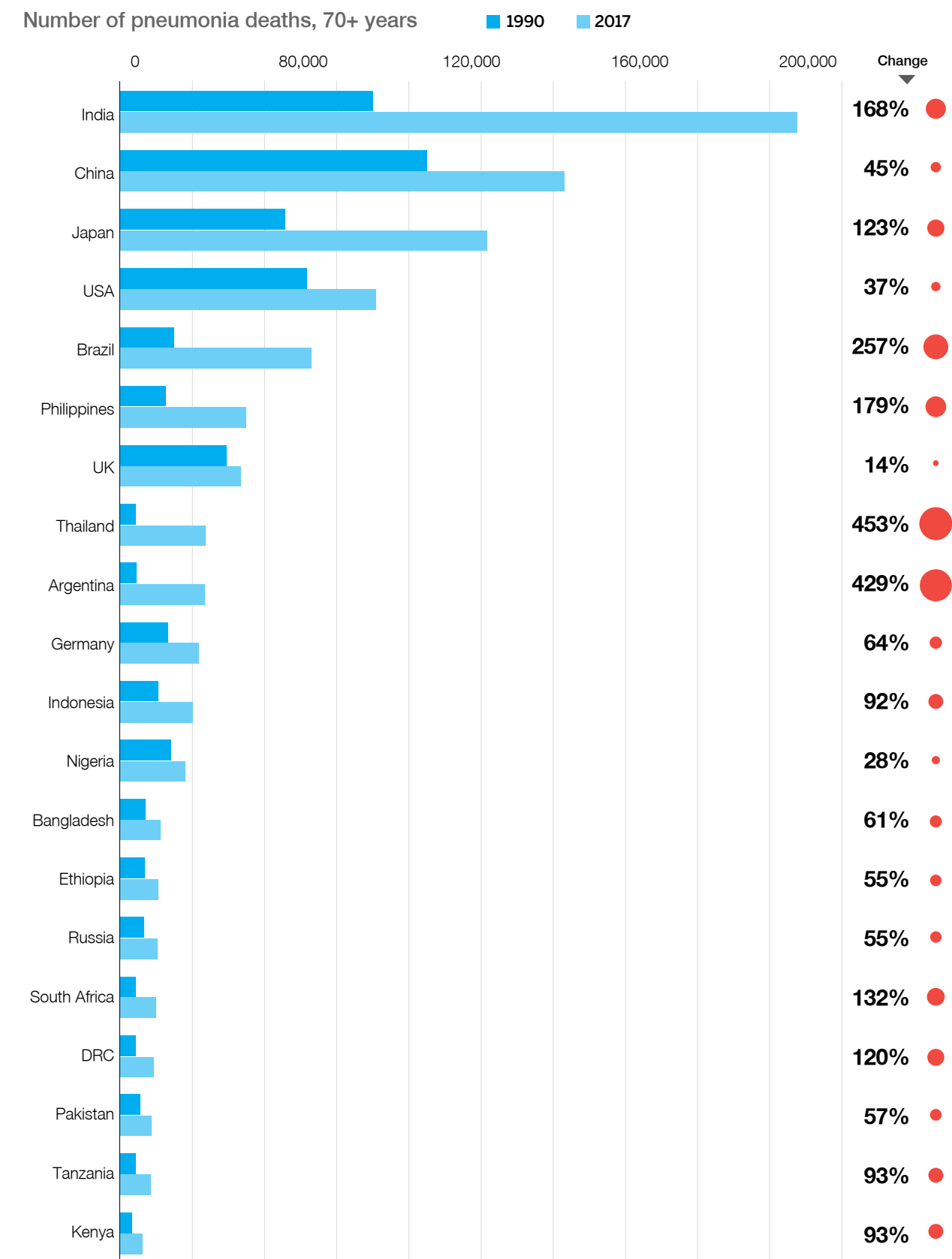
Source: Global Burden of Disease, 2017

burden country, with declines ranging from 11% in Nigeria to 94% in China. Only four of the 20 countries did not manage to reduce child pneumonia deaths by more than 50%, including Nigeria, the Democratic Republic of Congo, Pakistan, and Kenya (Chart 22). In stark contrast, numbers of pneumonia deaths among those aged over 70 years rose sharply in all of the high-burden countries, ranging from 14% in the UK to 453% in Thailand (Chart 23). These sharp increases reflect the aging of the population in these countries and offset the impressive declines in child pneumonia deaths, especially in the Philippines and Thailand.

Progress in reducing pneumonia deaths has not kept pace with other leading infectious disease killers. The 25% decline in pneumonia deaths since 1990 is lower than the declines for tetanus (88%), measles (86%), HIV/AIDS (47% since the peak of the AIDS epidemic in 2003), whooping cough (46%), typhoid (41%), diarrhea (39%), meningitis (38%), and TB (26%). Among the leading infectious disease killers, only malaria has recorded a slower rate of decline than pneumonia, according to the GBD. The declines in deaths from sexually transmitted diseases (STDs) and acute hepatitis were also lower than pneumonia, but together these contributed to less than 10% of deaths caused by pneumonia (Chart 24).

16

High-burden countries that reduced child pneumonia deaths by more than 50% between 1990 and 2017

Chart 24: Pneumonia deaths have fallen more slowly than other infectious killers

Number of deaths, all ages ■ 1990 ■ 2003 ■ 2017

Change between 1990 and 2017

Disease	Change
Pneumonia	-25%
Diarrhea	-39%
Tuberculosis	-26%
HIV/AIDS	-47%
Malaria	-8%
Meningitis	-38%
Typhoid	-41%
Acute Hepatitis	-14%
STDs	-15%
Measles	-86%
Whooping Cough	-46%
Tetanus	-88%
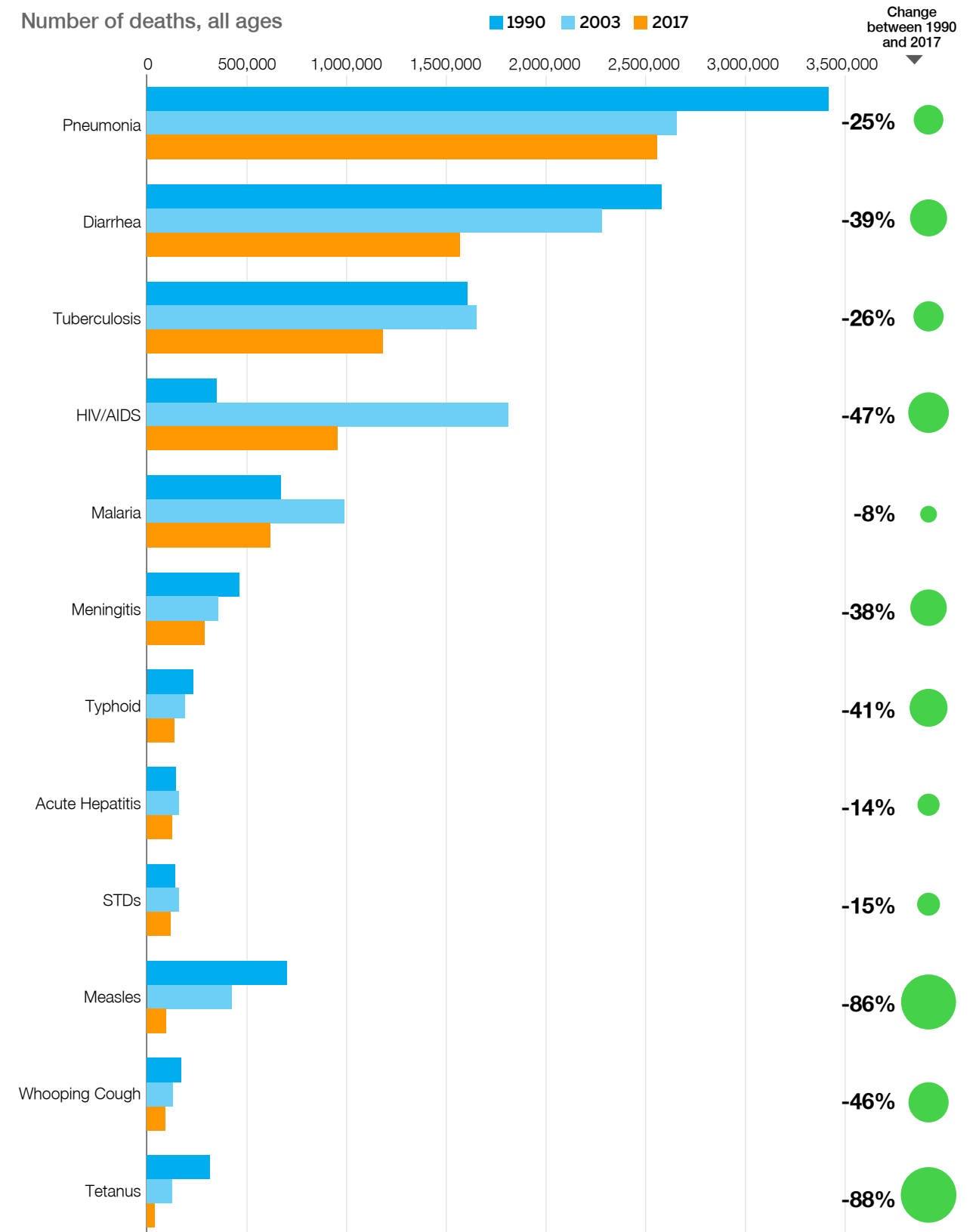
Source: Global Burden of Disease, 2017

Chart 25: Five high-burden countries will struggle to end preventable child pneumonia deaths by 2030

Number of pneumonia deaths, 0-4 years
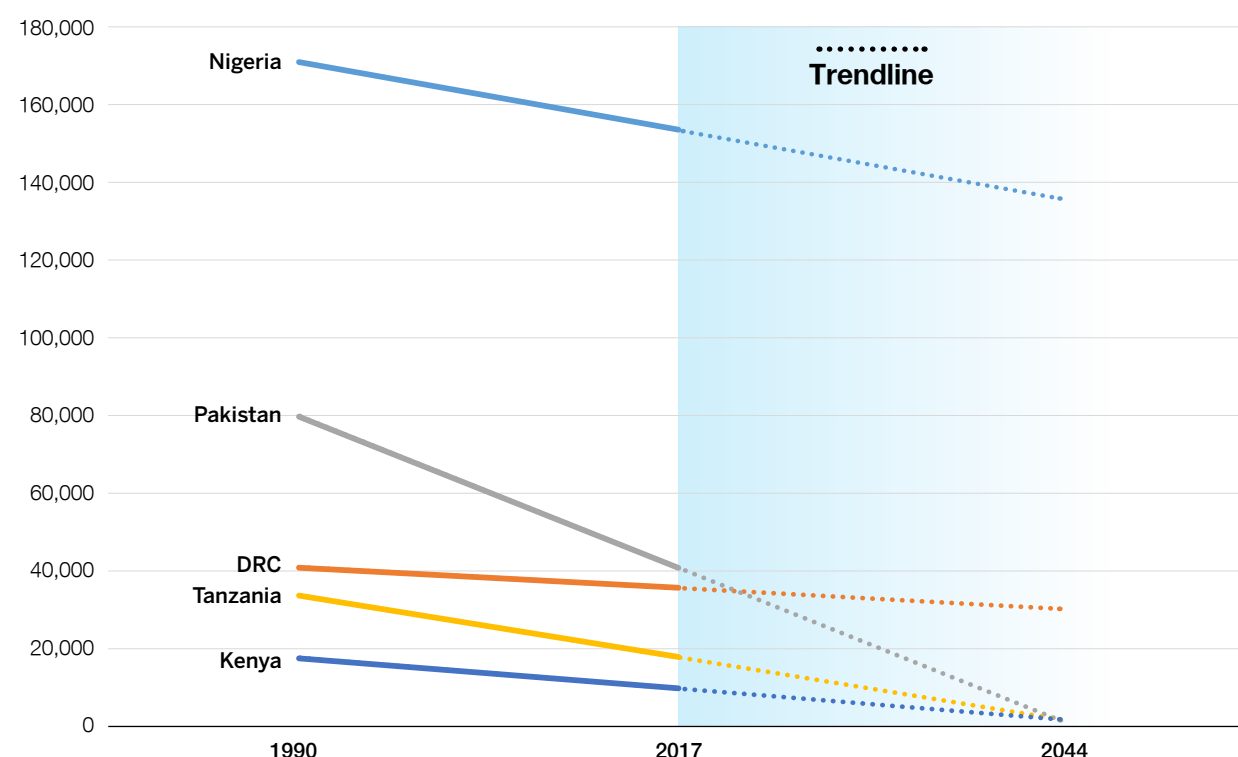
Source: Global Burden of Disease, 2017

As a result of these slower declines, many countries will struggle to reduce child pneumonia deaths to the levels required for achievement of the sustainable development goal for child survival. To achieve this goal, countries must reduce their Child Mortality Rates to below 25 child deaths per 1,000 live births by 2030. This is consistent with the World Health Organisation (WHO) target of 3 child pneumonia deaths per 1,000 live births.[7] At current rates of progress, five of the high-burden countries will not achieve this goal, including Nigeria, the Democratic Republic of Congo, Pakistan, Tanzania, and Kenya (Chart 25). Many other countries, most of them in Sub-Saharan Africa, will also fail to achieve this goal. Of special concern are the countries where more than 3,000 children are dying from pneumonia each year and where there has been little or no progress in reducing these deaths since 1990. For example, at current rates of progress, in 2030 more than 100,000 children will still be dying from pneumonia across Chad, Burkina Faso, Madagascar, Niger, South Sudan, Mali, Cote d'Ivoire, Somalia, Zimbabwe, Cameroon, Guinea, Burundi, the Central African Republic (CAR), Benin, and Sierra Leone (Chart 26).

Similarly, the countries with rising burdens of pneumonia deaths among adults, and especially among the elderly, will struggle to achieve the sustainable development goals relating to communicable disease reduction, and access to healthcare for all. Achieving these goals will be challenging for those countries where deaths among adults over 70 years have risen by more than 60% since 1990, including India, the Philippines, Brazil, Thailand, Argentina, and South Africa.

[7] This is the target set in the Global Action Plan for Pneumonia and Diarrhea (GAPPD), World Health Organisation (WHO) and UNICEF, 2012.

Chart 26: Many smaller countries will struggle to end preventable child pneumonia deaths by 2030

Number of pneumonia deaths, 0-4 years
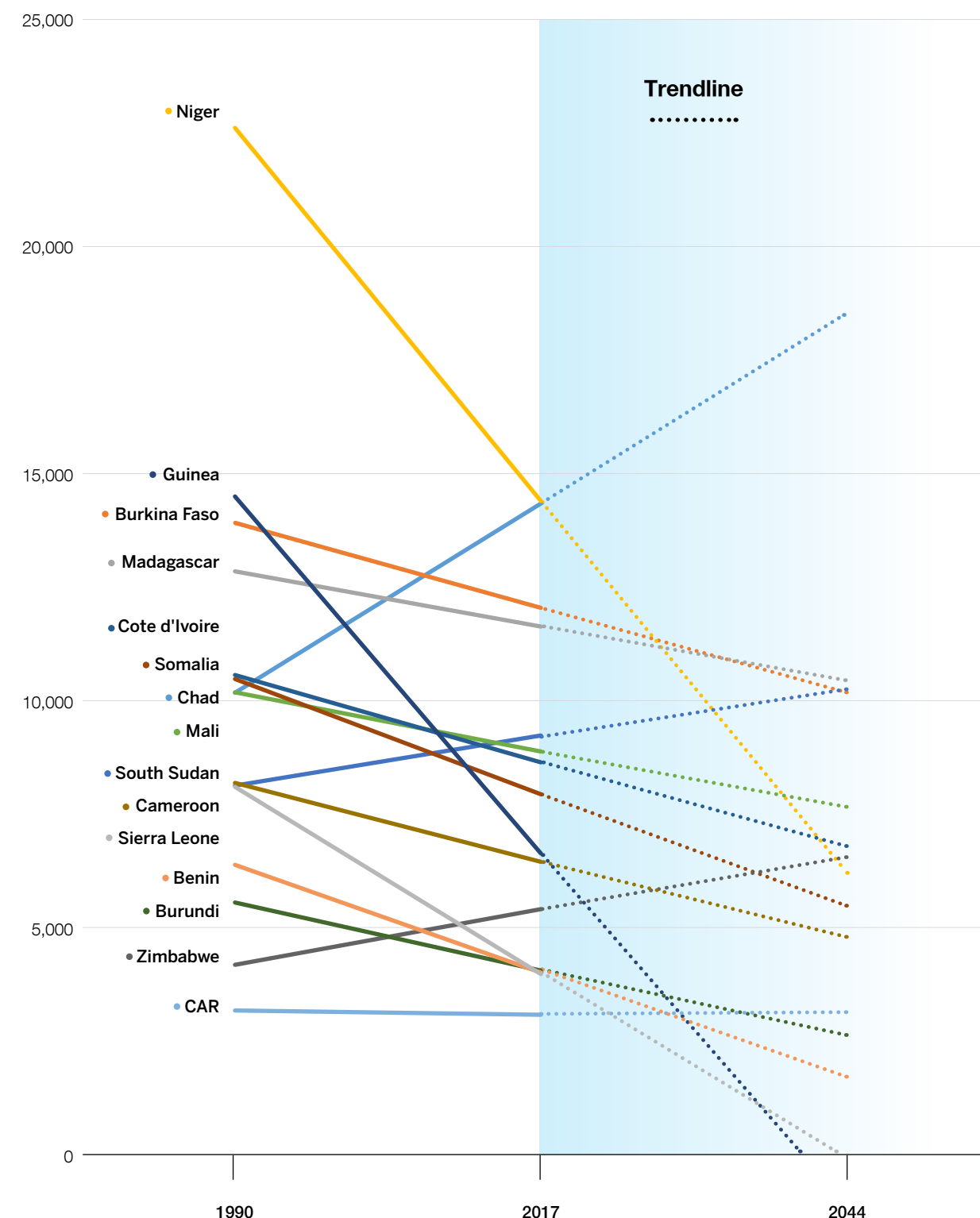
Source: Global Burden of Disease, 2017

THE STORY SO FAR...

Despite substantial progress in reducing child pneumonia deaths, increases in adult pneumonia deaths, especially among the elderly, are contributing to a rising burden of pneumonia in many countries. Among the 20 countries with the largest numbers of pneumonia deaths, deaths are rising in half. Further, progress in reducing these deaths is not keeping pace with declines in other leading infectious disease killers. The gender gap in pneumonia deaths has also widened, with more males than females dying from pneumonia each year. The slow pace of progress in reducing pneumonia deaths poses a significant challenge for the achievement of the sustainable development health goals, especially the child survival (3.2), communicable disease reduction (3.3), and access to healthcare (3.8) goals. These challenges will be most acute in the countries with large burdens and/or very high rates of child pneumonia deaths—almost all of them in Sub-Saharan Africa—and in the countries with sharp increases in the number of pneumonia deaths among the elderly, most of them high income.

New Developments: sustainable development health Goals

At current rates of progress, it will be very difficult for most of the high-burden pneumonia countries to achieve the sustainable development health goals that they adopted in 2015. Countries where child pneumonia death rates remain stubbornly high, and where progress is slow, will struggle to achieve Goal 3.2—reducing child mortality to at least 25 deaths per 1,000 live births. Countries with high and rising rates of pneumonia deaths among adults will be hampered in their efforts to curb communicable disease deaths (Goal 3.3). And countries that cannot provide access to, "quality healthcare services, essential medicines and vaccines" for all, including for pneumonia prevention, diagnosis and treatment, will fail to achieve Goal 3.8.

But if governments prioritized action on pneumonia as part of national child survival agendas, infectious disease strategies, and health system reform, and targeted action to the most vulnerable populations of children under five and adults over 70 years, great progress towards the health goals is possible. Despite this, not one of the official Voluntary National Reviews of sustainable development goal progress submitted to the United Nations by 11 of the high-burden pneumonia countries mentions pneumonia. As long as pneumonia remains the "missing piece" in national efforts to reduce child mortality and the communicable disease burden, and to provide universal access to quality health services, many countries will undermine their own efforts to achieve the health goals.

The United Nations and its agencies lead efforts to monitor and report progress on all 17 Sustainable Development Goals (SDGs), and countries regularly report progress in Voluntary National Reviews.

Learn more

Murdoch DR, and Howie SRC. The global burden of lower respiratory infections: making progress, but we need to do better. Lancet Infectious Diseases, 2018.

McCollum ED, King C, Hammitt LL, et al. Reduction of childhood pneumonia mortality in the Sustainable Development Goal era. Lancet Respiratory Medicine, 2016.

Watkins K. Saving lives with equity—the efficient route to the SDGs. Lancet, 2017.

4

HOW EFFECTIVELY ARE PNEUMONIA DEATHS BEING PREVENTED?
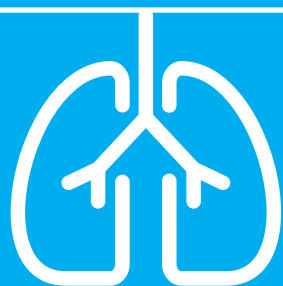
To reduce pneumonia deaths to the levels required for achievement of the sustainable development health goals, countries will need to minimize risk factors and improve coverage of the most effective prevention, diagnosis, and treatment interventions, especially among the most vulnerable populations. Although there has been progress in reducing risk-related child pneumonia deaths, large populations of children remain exposed to malnutrition, air pollution, preterm birth, and other risks, especially across Sub-Saharan Africa and South Asia (Chart 27).

The most urgent priority is to reduce child wasting. More than 70% of the estimated 50 million wasted children in the world live in the high-burden pneumonia countries. India alone is home to 25 million wasted children, Nigeria to 3.5 million,

Indonesia to 3.3 million, Bangladesh to 2.2 million, and the Democratic Republic of Congo to 1.2 million. There are also large populations of wasted children in the Philippines, Tanzania, and Kenya.[8] Wasted children are further concentrated within countries. For example, wasting rates across India range from 6% to 28%, from 4% to 23% across Ethiopia, and from 3% to 18% across Nigeria. These very high wasting rates far exceed the new target of 3% by 2030.[9]

Reducing children's exposure to air pollution, especially in the countries where a majority of households do not have access to clean fuels and technologies for cooking, where outdoor air pollution rates are above safe levels, and where smoking prevalence is high, will also be critical.[10] Half of the high-burden pneumonia countries have rates of access to clean household energy

Chart 27: Risk-related child pneumonia deaths are declining

Number of pneumonia deaths, 0-4 years   ■ 1990   ■ 2017

	Child Wasting	Household Air Pollution	Outdoor Air Pollution	Short Gestation	Child Stunting	Child Underweight	Hand-washing	Low Birth Weight	Second-hand Smoke	Suboptimal Breast-feeding
Change	-68%	-73%	-51%	-58%	-74%	-77%	-62%	-54%	-79%	-70%
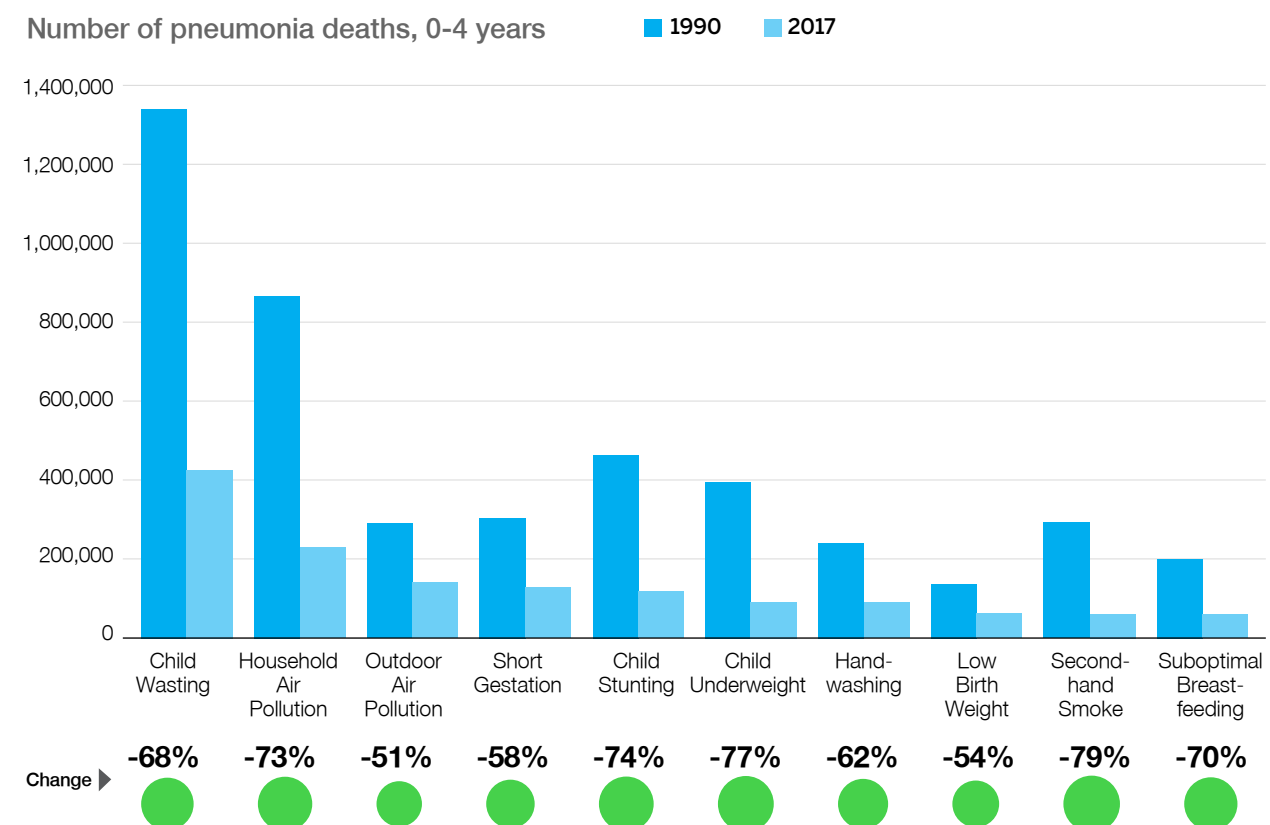
Source: Global Burden of Disease, 2017

8   An estimate is not available for Pakistan.
9   This extends the World Health Assembly target of 5% child wasting by 2025 to 3% by 2030.
10   UNICEF. Clear the air for children: the impact of air pollution on children, 2016.

Chart 28: Risk-related pneumonia deaths among adults over 70 are increasing

Number of pneumonia deaths, 70+ years

■ 1990 ■ 2017

Change ▶ 144% 33% 4% 50% 56% 99%

Outdoor Air Pollution | Smoking | Indoor Air Pollution | Secondhand Smoke | Handwashing | Alcohol Use

Source: Global Burden of Disease, 2017

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below the global average of 60%. Rates in Asia range from 18% in Bangladesh, to 41% in India, 43% in Pakistan and the Philippines, and 58% in Indonesia. Rates in Sub-Saharan Africa are much lower. For example, less than 5% of households in Nigeria, the Democratic Republic of Congo, Ethiopia, Tanzania, and Nigeria, cook with clean fuels and technologies, according to the WHO.[11] Reducing smoking and outdoor air pollution levels will also be important.

Preterm birth reductions will also help reduce pneumonia deaths among newborns. The vast majority of the estimated 15 million preterm (before 37 weeks gestation) babies are born in the high-burden pneumonia countries. India is home to an estimated 3.5 million preterm births, followed by 1.1 million in China, 800,000 in Nigeria, 750,000 in Pakistan, 670,000 in Indonesia, 520,000 in the USA, 420,000 in Bangladesh, 350,000 in the Philippines, 340,000 in the Democratic Republic of Congo, and 280,000 in Brazil. Rates of preterm birth across these countries are above the global average of 11 per 100 births, except in China (7),

and Brazil (9).[12] Although there is progress in reducing deaths from preterm birth complications, much greater efforts are needed to reduce rates of preterm birth itself, as these babies remain especially vulnerable to infections, including to pneumonia. An estimated 217,000 newborns die from pneumonia in the first month of life, 60% of those in the first week after birth, according to the GBD.

In contrast to risk-related child pneumonia mortality, deaths among adults aged over 70 years are rising, especially from outdoor air pollution, alcohol, and smoking (Chart 28). Efforts to reduce exposure to outdoor air pollution and smoking and alcohol use among the most vulnerable elderly populations will be important in many of the high-burden countries. Reducing outdoor air pollution will be especially critical in India, China, Thailand, Japan, the Philippines, and Argentina, where elderly pneu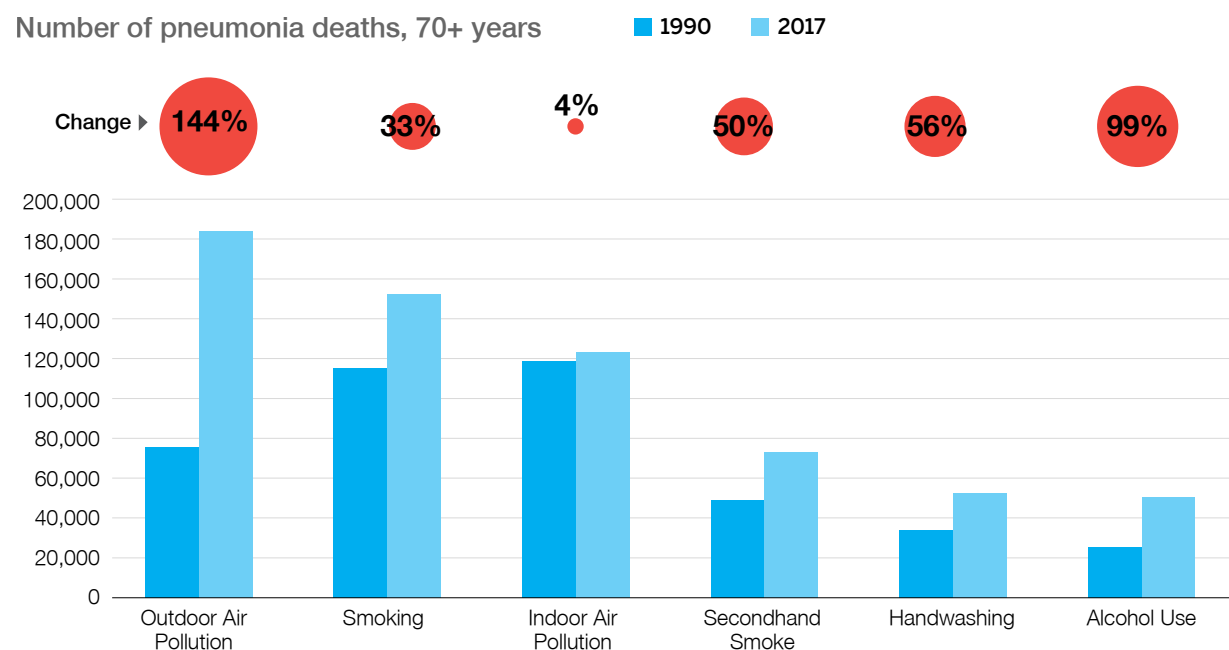monia deaths from exposure to outdoor air pollution have risen sharply. Similarly, reducing smoking prevalence in India, China, Germany, the Philippines, and Argentina should slow the rising

rates of pneumonia death among the elderly. Of special note, alcohol use as a risk factor in elderly pneumonia deaths is rapidly increasing in China, Thailand, the USA, Japan, Brazil, Russia, and the UK. Continued efforts to reduce alcohol consumption should help reduce pneumonia deaths among adults, especially in these countries.

Beyond risk reduction strategies, there are very effective technologies to prevent, diagnose, and treat pneumonia. Chief among prevention tools are a group of pneumonia-fighting vaccines which include the pneumococcal conjugate vaccine (PCV), the Haemophilus influenzae type B vaccine (Hib), the measles vaccine, influenza vaccines, and an emerging vaccine to prevent respiratory syncytial virus (RSV). The PCV and the Hib vaccine are particularly powerful because they target the major bacterial causes of severe pneumonia among children, and are especially effective at reducing deaths.[13] Measles vaccination remains critical, as pneumonia as a complication of measles is a risk in the countries where less than 90% of children are fully protected and in countries where historically high rates of measles coverage are slipping.[14]

Flu vaccines are also important as Influenza A and B viruses are common viral causes of pneumonia, especially in adults.

It is important to note that an RSV vaccine, when available, could considerably accelerate declines in child pneumonia mortality, especially among the youngest babies. A recent study estimated that global deaths due to RSV could be as high as 118,200, and that the virus is responsible for 3.2 million hospital admissions and 59,600 in-hospital deaths among children under five years; almost half (27,300) among babies under six months of age. Further, a study from Buenos Aires revealed estimates of RSV-associated deaths among babies under six months that were much higher than previous estimates. In this study, 9.6% of all at-home deaths among children under five years were associated with RSV infection.[15] Although there is currently no licensed RSV vaccine, more than 15 RSV vaccines are currently being assessed in clinical trials and a vaccine should be available for introduction in less than five years.[16] This vaccine should be highly effective at reducing pneumonia deaths among babies in the first months of life, and will also benefit the elderly.

24%

Careseeking rates in Nigeria—the lowest among high-burden countries—followed by 31% in Ethiopia

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11 Sustainable Energy for All (SE4All) database, World Bank, 2017.
12 March of Dimes, PMNCH, Save the Children, WHO. Born Too Soon: The Global Action Report on Preterm Birth. Eds CP Howson, MV Kinney, JE Lawn. WHO. Geneva, 2012.

14 The WHO reported a 4-fold increase in measles cases in Europe in 2017 including large outbreaks (100 or more cases) in 15 of 53 countries. The Centers for Disease Control and Prevention (CDC) reported measles outbreaks in 21 USA states in 2018. The CDC said the majority of people who contracted measles were unvaccinated.
15 Caballero MT, Bianchi AM, Nũno A, et al. Mortality in children in the community associated with acute respiratory infections. Journal of Infectious Diseases, 2018.
16 Shi T, McAllister DA, O'Brien KL, et al. Global, regional, and national disease burden estimates of acute lower respiratory infections due to respiratory syncytial virus in young children in 2015: a systemic review and modeling study. Lancet 390 (2018) 946-958.

Table 1: Pneumonia vaccine coverage rates among children under five remain low in many high-burden pneumonia countries (2017)

High-burden pneumonia countries	PCV (3 doses) Children <5 years	Hib vaccine (3 doses) Children <5 years	Measles vaccine (2 doses) Children <5 years
India	Unknown	88%	77%
China	Unknown	Unknown	99%
Nigeria	36%	42%	Unknown
Japan	99%	99%	95%
USA	93%	93%	94%
Brazil	84%	93%	41%
Philippines	61%	88%	80%
Ethiopia	68%	73%	Unknown
DRC	79%	81%	Unknown
Pakistan	75%	75%	45%
UK	92%	94%	88%
Tanzania	97%	97%	79%
Indonesia	0%	79%	63%
Russia	70%	Unknown	97%
Thailand	Unknown	Unknown	95%
Bangladesh	97%	97%	96%
South Africa	60%	66%	60%
Argentina	76%	86%	89%
Kenya	71%	82%	35%
Germany	84%	93%	93%

Source: WHO/UNICEF, 2018

At full coverage among children under five years, the pneumonia-fighting vaccines could prevent more than half of all child pneumonia deaths and also reduce deaths among adults, especially the elderly. Studies have shown that when children are fully vaccinated against the leading causes of pneumonia, deaths among adults, and especially among the elderly, also fall.[17] Vaccination is a critical pneumonia control strategy for all high-burden countries, and especially cost-effective for countries struggling with double burdens of pneumonia.

Despite the potential of vaccination to prevent a majority of pneumonia deaths among children

and to significantly reduce the burden among adults, coverage is low in many of the high-burden countries (Table 1). Globally, 44% of children are protected with three doses of the PCV, 72% of children receive three doses of the Hib vaccine, and 67% receive two doses of the measles vaccine, according to the WHO. Among the high-burden pneumonia countries, PCV coverage is below 44% in India, China, Nigeria, Thailand, and Indonesia.

While Hib and measles vaccine coverage is above global averages in most of the high-burden countries, of concern is the lower coverage of both vaccines in the countries that are home to half of all child pneumonia deaths—India, Nigeria, Ethiopia,

the Democratic Republic of Congo, Pakistan, and Indonesia. Despite strong increases in coverage of the measles vaccine and a sharp decline in measles deaths in recent decades,[18] further efforts are needed to close remaining measles coverage gaps and to prevent historically high coverage rates from falling. Rates of influenza vaccine coverage are also low. Although the WHO does not provide national estimates of flu vaccine coverage, country estimates reveal suboptimal coverage among children and the elderly.[19]

Full vaccination of vulnerable populations with the pneumonia-fighting vaccines is essential but not sufficient to achieve pneumonia control.[20] Even at

full coverage, hundreds of millions of children and adults will still contract pneumonia each year; their survival dependent on timely access to accurate diagnosis and effective treatment. Yet rates of careseeking, diagnosis, and treatment in many countries are low, especially among children. Just 60% of children under five years with symptoms of pneumonia are taken to an appropriate healthcare provider, according to UNICEF.[21] In the high-burden countries, careseeking rates are as low as 24% in Nigeria, 31% in Ethiopia, and 42% in the Democratic Republic of Congo and Bangladesh (Table 2).

Increasing careseeking is a critical first step to closing pneumonia diagnosis and treatment
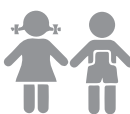
Table 2: Rates of care seeking for children with suspected pneumonia are suboptimal in many high-burden pneumonia countries (2011-17)

High-burden pneumonia countries	% children <5 years
India	73%
China	Unknown
Nigeria	24%
Japan	Unknown
USA	Unknown
Brazil	50%
Philippines	64%
Ethiopia	31%
DRC	42%
Pakistan	64%
UK	Unknown
Tanzania	55%
Indonesia	75%
Russia	Unknown
Thailand	80%
Bangladesh	42%
South Africa	88%
Argentina	94%
Kenya	66%
Germany	Unknown

Source: WHO/UNICEF, 2011-17

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17 Shiri T, Datta S, Madan J. et al. Indirect effects of childhood pneumococcal conjugate vaccination on invasive pneumococcal disease: a systematic review and meta-analysis. Lancet Global Health 5 (2017) PE51-E59.

18 Between 1990 and 2017, measles deaths declined by 86% from an estimated 700,438 to 95,290, according to the GBD. Over the same period the proportion of one year olds with two doses of the measles vaccine increased from less than 15% to 67%, according to the WHO.

19 For example, influenza vaccination rates among adults aged over 65 years in the high-income countries range from 35% in Germany, to 51% in Japan, to 69% in the USA, and 71% in the UK, according to the OECD. In the USA, 60% of children under 17 years received the influenza vaccine in 2016, according to the Centers for Disease Control and Prevention (CDC).

20 le Roux DM, Myer L, Nicol MP, et al. Incidence and severity of childhood pneumonia in the first year of life in a South African birth cohort: the Drakenstein Child Health Study. Lancet Global Health 3 (2015) PE95-E103.

21 Global Action Plan for Pneumonia and Diarrhea (GAPPD), World Health Organisation (WHO) and UNICEF, 2012.

gaps and will require attention to a range of factors including levels of adult female literacy and household agency,[22] the costs of seeking healthcare for sick children (financial and time), and the low levels of trust in the health system, which are related to quality of care.[23] Among these, female literacy is extremely important as studies have repeatedly shown that the more educated a mother, the greater the chances her children will survive childhood.[24] In many of the countries struggling with child pneumonia deaths, literacy rates among women are below 50%, including in Nigeria (41%), Pakistan (44%), and Ethiopia (29%). Literacy rates are even lower among women in the high-rate pneumonia countries, especially in Niger (9%), Chad (14%), South Sudan (20%), Benin, Mali, Guinea (22%), CAR (25%), and Sierra Leone (25%), according to UNESCO.

Even when the vast majority of children with suspected pneumonia are taken to a healthcare facility, accurate diagnosis, appropriate prescription, and availability of quality and affordable treatment is particularly challenging in low resource settings. Cost-effective diagnostic tools that can correctly identify the children at greatest risk of death from pneumonia, or the source of their infection (viral or bacterial, or both), do not yet exist. And very effective tools like pulse oximetry that can identify children with hypoxemia by measuring oxygen levels in the blood—a strong predictor of severe illness—exist but are not in wide use. In the absence of widely available diagnostic tools, pneumonia is often clinically diagnosed through the assessment of signs and symptoms, and many cases go undetected or are incorrectly classified. A recent study showed that among children who sought care in Malawi, only one out of five with pneumonia was correctly diagnosed.[25]

It is difficult to determine antibiotic coverage for children with pneumonia as no reliable indicator

44%

Proportion of children who are fully protected with three doses of the pneumococcal vaccine (PCV)

exists for routine use across settings.[26] Some studies continue to report very low coverage of antibiotics among children with pneumonia across low and middle income countries and very low usage of the WHO recommended antibiotic—amoxicillin dispersible tablets.[27] Other studies report wide use, and overuse, of antibiotics in both community and hospital settings.[28] While some countries permit community health workers to dispense antibiotics for children with pneumonia, others do not, and where some countries do permit community dispensation, the recommended antibiotic is often unavailable. A study by Results for Development showed that less than half of public health facilities in Tanzania stocked the recommended treatment for non-severe pneumonia—amoxicillin dispersible tablets—and nearly two-thirds of these facilities had experienced stock-outs in the previous 90 days. Even at the hospital level, availability of amoxicillin dispersible tablets was not substantially higher. The study also found that in private drug shops, where a large proportion of careseeking for pneumonia in Tanzania occurs, no retailer had amoxicillin dispersible tablets.[29]

Until an acceptable indicator to measure antibiotic coverage among children with pneumonia becomes available, countries will need to determine their own antibiotic coverage gaps and adherence to recommended antibiotics. Some countries will expose large gaps in antibiotic treatment that need to be closed, while others will uncover over-use of inappropriate antibiotics and a heightened risk of antimicrobial resistance. While at the global level greater access to antibiotics for sick children could prevent more deaths than are currently caused by antimicrobial resistance, this situation may fast be changing.[30] This is another reason why wider vaccine coverage together with improved diagnostic tools are so critical, because they have the potential to reduce the need for antibiotics and to better target antibiotics to the children who really need them, reducing the risk of antimicrobial resistance.

Access to oxygen in hospitals is also severely limited across many of the high-burden pneumonia countries, especially those in Sub-Saharan Africa and South Asia.[31] A recent study by the Clinton Health Access Initiative (CHAI) of 78 hospitals across three states in Nigeria found that only 2% had pulse oximeters and 25% of pediatric wards had functional oxygen systems. The study concluded that among the children with pneumonia who reached a health facility, 47% of non-severe pneumonia cases were missed, only 4% of severe pneumonia cases were correctly diagnosed, and just 1 in 10 children received the oxygen they needed. In Ethiopia, the situation was only slightly better. 45% of hospital pediatric wards had pulse oximeters and 64% had fully functional oxygen delivery devices. However, only 14% of the hospitals studied had standard operating procedures on oxygen use or health care workers trained in oxygen therapy, and only 41% had biomedical engineers and technicians who

could maintain oxygen equipment.[32] High rates of mortality among children with pneumonia in hospital settings across Sub-Saharan Africa have also been reported in Kenya,[33] Malawi,[34] and Uganda,[35] suggesting similar problems with access to medical oxygen.

Further, treatment rates for wasted children are alarmingly low. Just one in four of the 17 million severely wasted children in the world are admitted to treatment programs, according to the United Nations.[36] Funding to care for children with severe wasting is often short-term and focused primarily on humanitarian situations and few health systems integrate the diagnosis and treatment of child wasting with other health services, such as vaccination and treatment for pneumonia. Improved growth monitoring at the point of vaccination could help identify children at risk of severe wasting and in need of preventive treatment, and therapeutic nutrition could be a routine part of treatment for children with severe pneumonia.

Data measuring pneumonia diagnosis and treatment rates among the elderly are not routinely collected by governments or the United Nations, however studies indicate wide gaps also exist, especially among elderly populations in low resource settings.[37] Antibiotic overuse is a growing problem among adults in high income countries, where better diagnostic tools could also improve the rational use of antibiotics and their continued efficacy. More national data is needed on careseeking, and access to proper diagnosis, antibiotics, oxygen and therapeutic nutrition among elderly populations with pneumonia. Better measurement and routine tracking of pneumonia prevention, diagnostic, and treatment rates is critical to create national accountability and measure progress in all of the high-burden countries.

22 In this context, "agency" refers to a mother's power to make decisions within the household relating to her child's health, especially seeking care, paying for care, and administering medicines.

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THE STORY SO FAR...

The slow rates of progress in reducing risk factors, increasing coverage of the pneumonia-fighting vaccines, and closing careseeking, diagnosis, and treatment gaps in many of the high-burden countries are compromising the achievement of health goals. Countries with high child pneumonia burdens must focus more on reducing child wasting, air pollution, and preterm birth, while increasing coverage of the pneumococcal, Hib and measles vaccines, and closing gaps in careseeking, diagnosis, and treatment. Countries with high elderly pneumonia burdens must focus on reducing outdoor air pollution and smoking and alcohol use, while increasing coverage of the pneumococcal and influenza vaccines. When RSV vaccines become available they should be part of pneumonia control efforts, as their potential to reduce pneumonia deaths will likely be significant. Similarly, as new diagnostic tools that can rapidly and accurately identify the children and adults most at risk of death from pneumonia become available, countries should adopt them and remove one of the major obstacles to effective pneumonia treatment, rational antibiotic use, and continued antibiotic effectiveness.

New Developments: diagnosing pneumonia

In recognition of the urgent need for better diagnostic tools to reduce pneumonia deaths, improve antibiotic coverage, and reduce the rising threat of antibiotic resistance, the Acute Respiratory Infection Diagnostic Aid (ARIDA) project is supporting the introduction of automated tools that offer health workers in low resource settings more accurate and easy-to-use tools to identify children with symptoms of pneumonia. Multimodal devices that simultaneously measure respiratory rate, oxygen saturation, malnutrition, non-invasive hemoglobin, and temperature could accelerate mortality declines by better targeting antibiotics and oxygen treatment to the children who need them. Studies have shown that new diagnostic tools do work in low resource settings and, with the right support, health workers can use these new tools to improve pneumonia management.

To further spur innovation, Unitaid is soliciting proposals for tools to aid in the identification of severely ill febrile children at the primary care level, which is expected to improve pneumonia outcomes by identifying at risk children who need referral for treatment, especially with oxygen. Other groups are working on the holy grail of pneumonia diagnostics—a rapid diagnostic test that could distinguish bacterial from viral pneumonia at the point of care. In the absence of better tools, the high rates of missed and incorrect pneumonia diagnoses will continue, contributing to poor health outcomes for children and adults, to antibiotic misuse, and to medicine wastage across low, middle, and high income countries.

ARIDA is sponsored by UNICEF, funded by "la Caixa" Foundation, and implemented by Malaria Consortium.

Learn more

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HOW ADEQUATE ARE INVESTMENTS TO REDUCE PNEUMONIA DEATHS?
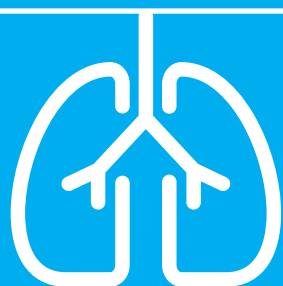
The vast majority of spending on health is national. In most of the high-burden pneumonia countries, domestic spending covers more than 90% of health spending, and only the Democratic Republic of Congo, Tanzania, Kenya, Ethiopia, Bangladesh, and Nigeria rely on external financing to cover more than 10% of their healthcare spending. Among these, the Democratic Republic of Congo relies the most on external health financing (39%), followed by Tanzania (37%), Kenya (19%), Ethiopia (15%), Bangladesh (11%), and Nigeria (10%), according to the WHO. [38]

Across the high-burden pneumonia countries, spending on healthcare varies widely, from 2.6% of GDP in Bangladesh to 16.8% of GDP in the USA, and from $US20 per person in the Democratic Republic of Congo to $US9,536 in the USA. Healthcare spending is highest in the countries where pneumonia deaths concentrate among the elderly, and lowest in the countries with very high child pneumonia burdens, where out-of-pocket healthcare costs are particularly high, ranging from 33% in Kenya to 72% in Nigeria and Bangladesh (Table 3).

Determining what proportion of domestic healthcare spending is allocated to preventing, diagnosing, and treating pneumonia is extremely difficult, especially in low resource settings where public access to government budget information

Table 3: Spending on health in the high-burden pneumonia countries varies widely

High-burden pneumonia countries	Health spending % of GDP	Health spending $US per capita	Out-of-pocket costs % of health spending
India	3.9	63	65
China	5.3	426	32
Nigeria	3.6	97	72
Japan	10.9	3,733	13
USA	16.8	9,536	11
Brazil	8.9	780	28
Philippines	4.4	127	54
Ethiopia	4.0	24	38
DRC	4.3	20	37
Pakistan	2.7	38	66
UK	9.9	4,356	15
Tanzania	6.1	32	26
Indonesia	3.6	112	48
Russia	5.6	524	36
Thailand	3.8	217	12
Bangladesh	2.6	32	72
South Africa	8.2	471	8
Argentina	6.8	998	18
Kenya	5.2	70	33
Germany	11.2	4,592	13

Source: WHO, 2017

[38] WHO, External health expenditure (EXT) as percentage of current health expenditure (CHE), Global Health Observatory, 2015.

84%

Proportion of households who had to borrow money and/or sell assets to pay for hospital care for a child with pneumonia in a Bangladesh study

is very limited. Where health budgets are available, pneumonia is rarely mentioned. For example, the two countries with the largest burdens of child pneumonia deaths—India and Nigeria—do not prioritize pneumonia in national health budgets, although they contain many references to other leading infectious killers including malaria, HIV/AIDS, TB, and hepatitis.[39]

The high out-of-pocket costs that many households pay to treat children with pneumonia are a reflection of the very low levels of government spending on pneumonia prevention, diagnosis, and treatment. Studies have shown that households in low and middle income countries incur considerable, and often catastrophic, costs for pneumonia treatment, especially when hospital care for sick children is involved.[40] For example, a study in Bangladesh found that 75% of families spent more than 50% of their monthly expenditure on hospital costs for a child with pneumonia. 84%

had to borrow money and/or mortgage and sell household assets to pay for hospital care. In an Ethiopian study, an estimated 11% of pneumonia cases were considered "catastrophic" in their effect on household budgets.[41]

The movement to introduce Universal Health Coverage (UHC) is a major opportunity to better align national health spending with burden of disease, to increase government spending on pneumonia, and to reduce out-of-pocket costs. Specific allocations in government health budgets for the prevention, diagnosis, and treatment of pneumonia, especially in the high-burden pneumonia countries, would not only accelerate achievement of health goals, but would alleviate a significant cause of household poverty—the catastrophic healthcare costs associated with sick children and other family members.[42] The inclusion of careseeking for children with suspected pneumonia as one of the 16 tracer indicators for the

sustainable development goal relating to universal health coverage is particularly promising.[43]
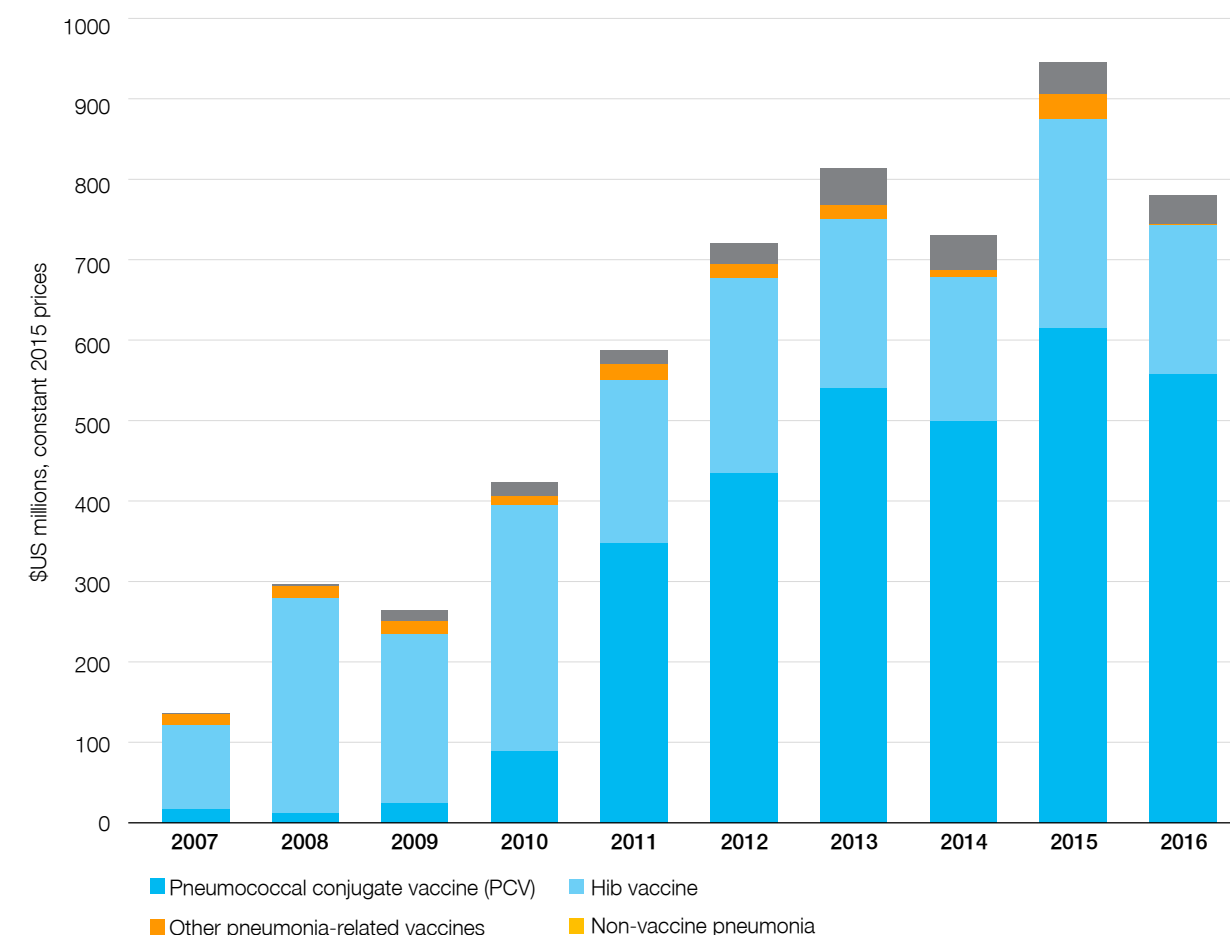
In the absence of adequate national spending to reduce pneumonia deaths, many low and middle income countries have relied on Official Development Assistance (ODA) from high income countries together with philanthropic support from private funders including the Bill & Melinda Gates Foundation (BMGF).[44] Between 2007 and 2016, ODA for pneumonia rose from $US136 million to $US733 million, totaling $US5.3 billion over the period. Including contributions from the

BMGF, total international development assistance for pneumonia was $5.7 billion, according to an analysis conducted by Development Initiatives.[45] More than 95% of this assistance was to finance the pneumonia-fighting vaccines in low resource settings, especially the PCV and Hib vaccine.

More than half ($US3.1 billion) of all development assistance for pneumonia over the period was for the introduction of one vaccine—the PCV—where spending rose from $US18 million in 2007 to $US559 million in 2016 (Chart 29). Financing for the PCV was boosted in 2009, when the governments

Chart 29: Most international development assistance for pneumonia has supported vaccine introduction

Legend:
- Pneumococcal conjugate vaccine (PCV)
- Hib vaccine
- Other pneumonia-related vaccines
- Non-vaccine pneumonia

Source: Development Initiatives, OECD CRS, 2018

39 Federal Republic of Nigeria, Health Appropriations, 2016 and India National Health Plan, 2017.
40 See Memirie ST, Metaferia ZS, Norheim OF, et al. Household expenditures on pneumonia and diarrhoea treatment in Ethiopia:a facility-based study. British Medical Journal Global Health 1 (2017) e000166, Sadruddin S, Shehzad S, Bari A, et al. Household Costs for Treatment of Severe Pneumonia in Pakistan. The American Journal of Tropical Medicine and Hygiene 87 (2012) 137-143, Zhang S, Sammon PM, King I, et al. Cost of management of severe pneumonia in young children: systematic analysis. Journal of Global Health 6 (2016) 010408, and Sultana M, Sarker AR, Mahumud RA, et al. Economic Burden Of Household For Treating Severe Pneumonia Among Under Five Children In Bangladesh. Value in Health 20 (2017) A498.
41 See International Vaccine Access Centre (IVAC). Pneumonia & Diarrhea Progress Report. Driving Progress Through Equitable Investment and Action, 2017.
42 Verguet S, Pecenka C, Johansson KA, et al. Health Gains and Financial Risk Protection Afforded by Treatment and Prevention of Diarrhea and Pneumonia in Ethiopia: An Extended Cost-Effectiveness Analysis, in Black R, Laxminarayan R, Temmerman, M et al. Disease Control Priorities, Reproductive, Maternal, Newborn, and Child Health. World Bank, 2016.

43 See Hogan DR, Stevens GA, Hosseinpoor AR, et al. Monitoring universal health coverage within the Sustainable Development Goals: development and baseline data for an index of essential health services. Lancet Global Health 6 (2018) PE152-E168, and World Health Organisation and the World Bank. Tracking Universal Health Coverage. Global Monitoring Report, 2017.
44 Together, ODA and BMGF financing is described as "development assistance" throughout this report.
45 See Note (C) for an explanation of Development Initiatives methodology.

of Italy, the UK, Russia, Canada, Norway, and the Bill & Melinda Gates Foundation pledged $US1.5 billion to procure the vaccine through a financing mechanism called the Advanced Market Commitment (AMC). The AMC has accelerated PCV development and manufacturing at affordable prices for low resource countries and to date, 142 countries have introduced the vaccine, 58 with Gavi support.
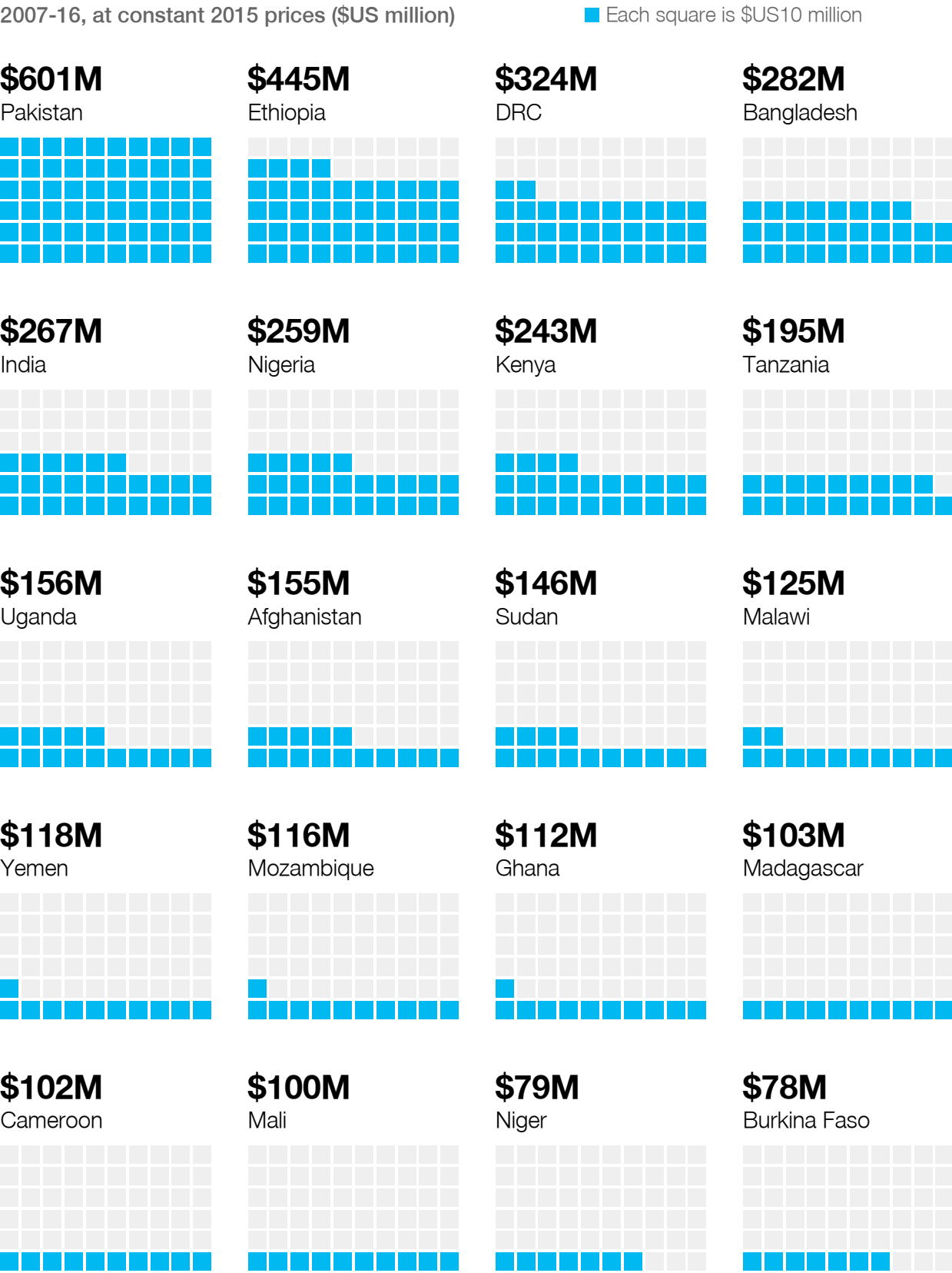
Most pneumonia-related international development assistance is provided by a small group of governments, including the UK, Canada, Australia, the USA, and Norway. Most private support is provided by the BMGF, and a small group of foundations including the Children's Investment Fund Foundation, "la Caixa" Foundation, Comic Relief, and others. Due to the focus on vaccine spending, the majority of these donors channeled their funds through Gavi, the Vaccine Alliance. Between 2007 and 2016, more than 85% of pneumonia assistance flowed to countries through Gavi. Other channels included UN agencies (principally UNICEF), large international non-government organizations including PATH Vaccine Solutions, Population Services International

(PSI), and others, as well as universities including Johns Hopkins University in the USA, the Murdoch Children's Research Institute in Australia, and others.

The regions and countries where child pneumonia deaths are concentrated received the majority of pneumonia-related international development assistance. Between 2007 and 2016, 59% of all pneumonia-related development assistance went to Africa and 31% to Asia. The five countries with the largest numbers of child pneumonia deaths (India, Nigeria, Pakistan, the Democratic Republic of Congo, and Ethiopia) were all within the top six recipients of development assistance to pneumonia. Bangladesh, Tanzania, and Kenya were also among the leading recipients. Indonesia was the only high-burden child pneumonia country that did not receive significant funding for pneumonia (Table 4). Pneumonia development assistance also benefited the high-rate pneumonia countries. However it is notable that several of the countries most off-track to reduce child pneumonia deaths by 2030 were not in the top 30 recipients including Chad, South Sudan, Somalia, Guinea, CAR, and Sierra Leone.

Table 4: Most of the top 20 recipients of development assistance for pneumonia are in Sub-Saharan Africa

2007-16, at constant 2015 prices ($US million)   ■ Each square is $US10 million

$601M
Pakistan

$445M
Ethiopia

$324M
DRC

$282M
Bangladesh

$267M
India

$259M
Nigeria

$243M
Kenya

$195M
Tanzania

$156M
Uganda

$155M
Afghanistan

$146M
Sudan

$125M
Malawi

$118M
Yemen

$116M
Mozambique

$112M
Ghana

$103M
Madagascar

$102M
Cameroon

$100M
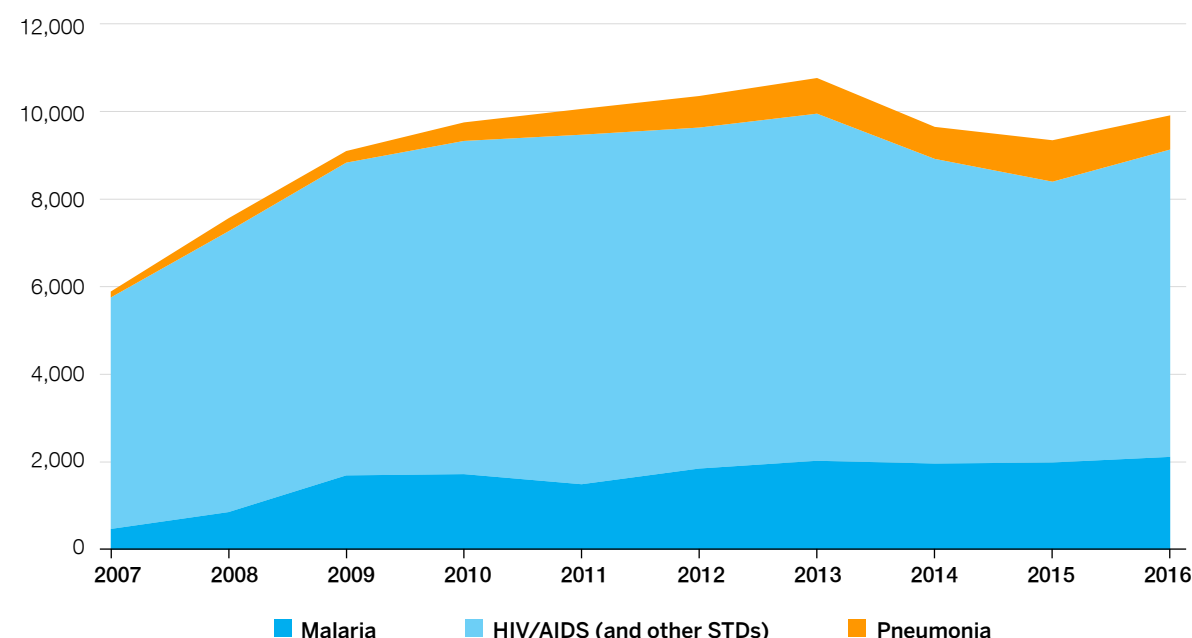Mali

$79M
Niger

$78M
Burkina Faso

Source: Development Initiatives, OECD CRS, 2018

Chart 30: Development assistance for pneumonia is well below other leading infectious diseases

$US millions, constant 2015 prices

- Malaria
- HIV/AIDS (and other STDs)
- Pneumonia

Source: Development Initiatives, OECD CRS, 2018

Although pneumonia-related development assistance has been critical to the introduction of both the PCV and the Hib vaccine in many high-burden countries, the low levels of development assistance allocated to pneumonia diagnosis and treatment are very concerning in the context of the wide coverage gaps that exist. Just 4% ($US236 million) of pneumonia-related support was spent on non-vaccine activities, including diagnosis and treatment support, between 2007 and 2016, according to Development Initiatives.

Further, the overall levels of support allocated to pneumonia pale in comparison to other leading infectious killers and relative to pneumonia's disease burden. For example, between 2007 and 2016 development assistance allocated to fighting HIV/AIDS,[46] and malaria was $US70.5 billion and $US16.2 billion respectively, while pneumonia attracted $US5.7 billion (Chart 30). Of the total $US92.4 billion, HIV/AIDS received 76%, malaria 18%, and pneumonia 6%. These vastly different amounts were not well aligned with disease burden as HIV/AIDS and malaria cause 12% and 8% of all infectious disease deaths while pneumonia causes more than 25%, according to the GBD. A better alignment between both ODA and private investments for health and disease burden would not only improve health outcomes, but also the cost-effectiveness of resource allocation.

6%

Pneumonia's share of international development assistance for infectious diseases despite causing more than 25% of infectious disease deaths

THE STORY SO FAR...

Current levels of investment in pneumonia by both national governments and international development agencies are inadequate for the rapid reductions in pneumonia deaths required by the sustainable development health goals. Despite significant growth in vaccine financing, especially for the PCV and the Hib vaccine in high-burden countries, wide gaps in vaccine coverage still exist. Of special concern are the very low levels of domestic spending and development assistance spent on improving pneumonia diagnosis and treatment. In the absence of government financing and external support, the burden continues to fall on households who pay very high out-of-pocket costs to care for sick children. The introduction of Universal Health Coverage is a major opportunity to correct the historically low levels of government spending on pneumonia prevention, diagnosis, and treatment. Where insurance fully covers the costs of vaccination, diagnosis, and treatment for the most vulnerable children and the elderly, major health gains can be made. For the countries who will still need external support to finance pneumonia control, the more closely aligned ODA and private investments are with national disease burdens, the more cost-effectively they will contribute to country efforts to improve population health.

New Developments: financing pneumonia

Pneumonia is a highly cost-effective investment for governments seeking to improve health and health equity through the introduction of Universal Health Coverage (UHC). Due to the very large populations affected, the relative affordability and effectiveness of treatments, and the wide gaps in coverage, investments in pneumonia can prevent many deaths at relatively low cost. Save the Children has argued that no disease illustrates as powerfully as pneumonia why UHC is so critical to the achievement of national child survival goals, and has called on governments to ensure that full access to pneumonia prevention and treatment is included in national UHC efforts.

New efforts are underway to support countries to invest more in the health of women, children, and adolescents. For example, the Global Financing Facility in support of Every Woman Every Child (GFF) empowers governments to bring partners around the table to invest in high-impact but historically under-funded areas such as sexual and reproductive health and rights, newborn survival, adolescent health, and nutrition. The GFF Trust Fund catalyses increases in domestic resources alongside the World Bank's loan financing, and other external financing.

The GFF also supports governments to track progress, learn, course-correct and continually improve. The GFF is an opportunity for eligible countries to improve pneumonia prevention, diagnosis, and treatment services and seven of the high-burden countries are already working with GFF support, including Bangladesh, the Democratic Republic of Congo, Ethiopia, Indonesia, Kenya, Nigeria, and Tanzania, and more are eligible (e.g. India, Pakistan, and the Philippines).

Universal Health Coverage is now a global movement led by the World Health Organisation (WHO). The Global Financing Facility is led by the World Bank.

Learn more

Zhang S, Incardona B, Qazi SA, et al. Cost–effectiveness analysis of revised WHO guidelines for management of childhood pneumonia in 74 Countdown countries. Journal of Global Health, 2017.

Save the Children, Fighting for Breath. A call to action on childhood pneumonia, 2018.

Global Financing Facility, Annual Report. Country-powered Investments For Every Woman, Every Child and Every Adolescent, 2017-2018.

6

WHERE WILL FUTURE BREAKTHROUGHS COME FROM?

The development of breakthrough technologies that improve the quality and cost-effectiveness of pneumonia prevention, diagnosis, and treatment would hasten the achievement of health goals. However, the level of research and development (R&D) spending on pneumonia is low. Between 2000 and 2015, pneumonia received just $US3 billion (3%) of the $US100 billion that public and philanthropic funders in the G20 countries invested in infectious disease research, according to analysis conducted by the Research Investments in Global Health (ResIn) study.[47] HIV/AIDS, TB, malaria, and diarrhea all received more investment. The authors concluded that pneumonia R&D is underfunded compared to other infectious disease R&D (Chart 31).

According to the ResIn analysis, pneumonia R&D did rise between 2000 and 2015—from $US67 million to $US484 billion—driven by strong growth in research on pneumonia vaccines and treatments. In fact, the majority of the $US3 billion invested in pneumonia R&D over the entire 16 year period was allocated to vaccine research ($US858 million), followed by treatment ($US839 million). In contrast, diagnostics received just $US164 million over the period. Between 2000 and 2007, the majority of pneumonia R&D supported pre-clinical research, but afterwards funding shifted to

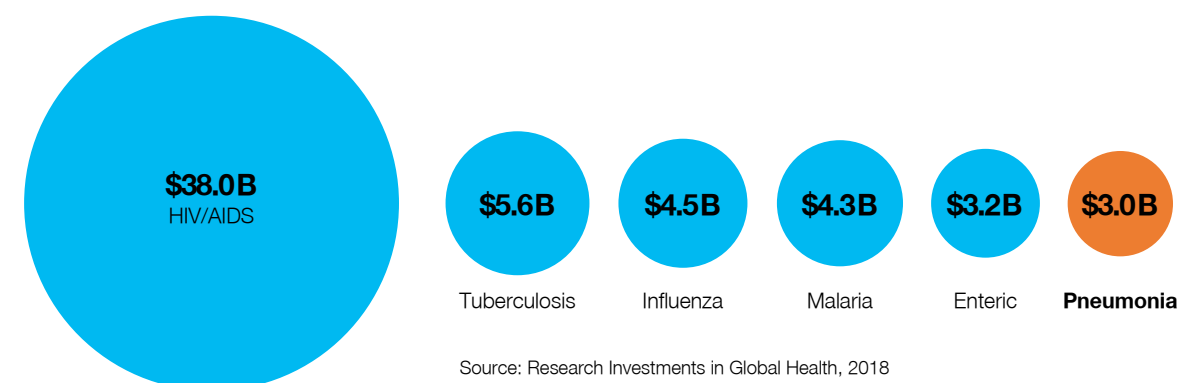support public health R&D and clinical trials.

Just three funders provided most pneumonia R&D funding, including the Bill & Melinda Gates Foundation (BMGF), the USA National Institutes of Health (NIH), and the Innovative Medicines Initiative (IMI), a project of the European Commission. The BMGF was the major funder of vaccine-related pneumonia R&D, providing $US545 million (64%) between 2000 and 2015, while the IMI was the single largest funder of treatment R&D due to two large trials in treatments for Staphylococcus aureus and Pseudomonas aeruginosa infections in 2013 and 2015 respectively. These trials cost $US523 million; 17% of all pneumonia R&D funding between 2000 and 2015. The NIH was the largest funder of pneumonia diagnostic R&D spending $US54 million over the period, followed closely by the EU ($US 43 million), and the BMGF ($US39 million).

Of concern, just 8.4% of pneumonia R&D ($US258 million) over the period was focused on low income countries, mostly in Sub-Saharan Africa (60%), and South Asia (40%). High-burden child pneumonia countries were the focus of more than half of this investment, especially India, Nigeria, Pakistan, Ethiopia, South Africa, Kenya, the Democratic Republic of Congo, and Tanzania. Other African nations with leading research facilities, including

Chart 31: Pneumonia R&D receives less funding than other infectious diseases

$US billions, 2000-2015

| $38.0B HIV/AIDS | $5.6B Tuberculosis | $4.5B Influenza | $4.3B Malaria | $3.2B Enteric | $3.0B **Pneumonia** |

Source: Research Investments in Global Health, 2018

47 Research Investments in Global Health (ResIn), Sizing Up Pneumonia Research: Assessing Global Investments in Pneumonia Research 2000-2015, 2018.

The Gambia and Uganda, also received funds. In fact, The Gambia received more pneumonia R&D funding than any other Sub-Saharan African country. The low and middle income high-burden pneumonia countries that did not receive significant pneumonia R&D include Bangladesh, Indonesia, and the Philippines.

Approximately one third ($US1.04 billion) of pneumonia R&D between 2000 and 2015 was targeted to pediatric research, the majority by the BMGF. Funding for this age-group increased from $US1 million in 2000 to $US370 million in 2015; representing 76% of all pneumonia R&D in that year. In contrast, 1.4% ($US43 million) of pneumonia R&D over the period was allocated to research relating to the elderly. It is important to note that the majority of pneumonia R&D ($US1.9 billion) was not targeted to any specific age-group and that much of this research could have had the potential to benefit all age groups. However, with rising burdens of pneumonia among the elderly in most countries, it will be increasingly important that more R&D dollars are allocated to this population.

Despite the rise in pneumonia R&D funding, the current levels of investment, the small number of funders contributing significant funds, and the tiny proportions targeted to research on the most vulnerable populations are a major concern. Investments are needed that are commensurate with pneumonia's infectious disease burden, specifically in the areas where breakthroughs could save the most lives.[48] Critical research topics include how specific risk factors (child malnutrition, air pollution,[49] and preterm birth) impact pneumonia deaths, why careseeking is still so low in so many settings, which risk factors are the strongest predictors of death in children and the elderly, how to most cost-effectively diagnose pneumonia and deliver treatments (e.g. pulse oximetry, antibiotics, oxygen, and therapeutic foods) in both community and hospital settings, and how to reengineer the delivery of vaccines, diagnostics, and medicines to reduce the costs of prevention and care. Several trials are currently underway that will advance understanding on some of these questions,[50] but the vast majority are not currently the subject of adequate R&D.

Another issue that has been consistently raised is the need to better understand the role of co-morbidities as risk factors for pneumonia death. It is well known that malnutrition significantly increases the risk of death from pneumonia, especially among children, and studies have shown the prevalence of multiple pathogens (viral and bacterial) in children who die from pneumonia in hospital settings, but the interplay of these conditions and pathogens is not well understood.[51] The presence of chronic diseases, as well as neurological conditions, in pneumonia deaths among the elderly also warrant more attention. The knowledge generated by a serious effort to advance understanding on all of these areas is needed to inform the next generation of technologies that will enable governments to make faster progress towards ending preventable pneumonia deaths.

3%

Share of infectious disease R&D allocated to pneumonia between 2000 and 2015

48 Rudan I, El Arifeen S, Bhutta ZA, Black RE, Brooks A, Chan KY, et al. Setting Research Priorities to Reduce Global Mortality from Childhood Pneumonia by 2015. PLoS 8 (2011) e1001099.
49 A recent study found that outdoor air pollution contributed to 22% of child deaths in Africa. See Heft-Neal, A, Burney J, Bendavid E, et al. Robust relationship between air quality and infant mortality in Africa. Nature, 2018.
50 See the Household Air Pollution Health Outcomes Trial, supported by the NIH, the Bill & Melinda Gates Foundation, the Global Alliance for Clean Cookstoves (GACC), and the Global Alliance for Chronic Diseases (GACD), and the Enhanced Management of Pneumonia in the Community (EMPIC) trials, led by WHO in Bangladesh, Ethiopia, India, and Malawi. The trials are testing the benefits of an "enhanced" approach to community case management for pneumonia, and the use of pulse oximetry by community health workers.
51 See Mulholland K. Commentary: Comorbidity as a factor in child health and child survival in developing countries. International Journal of Epidemiology 34 (2005) 375–377, and Oliwa JN, Karumbi JM, Marais B, et al. Tuberculosis as a cause or comorbidity of childhood pneumonia in tuberculosis-endemic areas: a systematic review. Lancet Respiratory Medicine 3 (2015) P235-243.

THE STORY SO FAR...

Current levels of pneumonia R&D, the number of funders, and the proportions targeted to the most vulnerable populations in the high-burden countries are inadequate to answer the major research questions and drive the next wave of technological innovation. Levels of R&D allocated to pneumonia are very low relative to pneumonia's disease burden, and to the levels spent on other infectious diseases. Just 3% of infectious disease R&D was allocated to pneumonia between 2000 and 2015. This lack of investment has contributed to both the slow pace of technological innovation in pneumonia interventions and to the slower rate of decline in pneumonia deaths. Major research questions remain, relating to risk factors—including co-morbidities—careseeking, intervention coverage, and service delivery. Without greater R&D investment, the technologies needed to increase the effectiveness and reduce the costs of pneumonia prevention and care will not be developed. More R&D funding, more funders, and a greater focus on vulnerable populations are needed to develop the next generation of pneumonia-fighting tools. Strategies to support the introduction and use of new technologies in the high-burden populations will also be critically important.

New Developments: pneumonia innovations

In recognition of the need for better tools to prevent, diagnose, and treat pneumonia, the Pneumonia Innovations Network (PIN) is a global network of over 150 organizations committed to the development and adoption of technologies with the greatest potential to reduce pneumonia deaths. With low levels of R&D support to pneumonia, the PIN is an effort to rally more innovators and investors to develop and support next generation solutions with the power to accelerate declines in pneumonia deaths. The PIN has a special focus on advancing innovations in five areas, (1) diagnostics/prognostics, (2) pulse oximeters and oxygen therapy, (3) childfriendly antibiotics, (4) nutrition therapy, and (5) air pollution reduction.

The Network hosts a website, conducts bimonthly webinars, and shares a monthly newsletter with members to increase the levels of collaboration across governments, companies, universities, foundations, UN agencies, and NGOs. The PIN hosted the first Pneumonia Innovations Summit in 2015, highlighting innovations in respiratory rate timers, pulse oximeters, oxygen therapy, and child-friendly antibiotics, as well as technologies to reduce air pollution and improve child nutrition, especially among preterm babies. The PIN encourages all members to raise awareness about pneumonia throughout the year, especially on World Pneumonia Day, November 12th each year.

The Pneumonia Innovations Network (PIN) is hosted by Save the Children.

Learn more

Ginsburg AS, Sadruddin S, Klugman KP. Innovations in pneumonia diagnosis and treatment: a call to action. Lancet Global Health, 2013.

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WHAT DOES SUCCESS IN THE FIGHT AGAINST PNEUMONIA LOOK LIKE?

Ultimate success in the fight against pneumonia will be achieved when child pneumonia deaths have fallen below 3 per 1,000 births in every country and where pneumonia is a tiny proportion of overall infectious disease deaths. This will not be achievable in every country by 2030 without dramatic improvements in vaccination, diagnosis, and treatment coverage, as well as reductions in the leading risk factors for pneumonia, especially in the countries with large populations of vulnerable children and the elderly.

The key to success is to fully protect these populations with the pneumonia-fighting vaccines, and to ensure access to the most effective diagnostic tools, including pulse oximetry, and treatments, including amoxicillin, oxygen, and therapeutic nutrition when needed. Specifically, countries should be aiming for above 90% coverage of the PCV, Hib, measles, and influenza vaccines, and RSV vaccines when available, paying particular attention to high coverage among the children and adults at greatest risk of death from pneumonia. Striving for 100% careseeking rates by families, routine access to new diagnostic tools including pulse oximetry and the recommended

antibiotics at the primary healthcare and hospital levels, and provision of oxygen in 100% of hospitals are also important targets.

Further, countries should be working to reduce the major risk factors for pneumonia death, by significantly reducing child wasting rates, preterm birth rates, and outdoor air pollution, and by increasing the use of clean cooking fuels and technologies. Setting ambitious national targets for reducing smoking and alcohol use will also help reduce pneumonia deaths across the life-cycle.

Achieving pneumonia control will require a new approach to the financing of pneumonia prevention, diagnosis, and treatment. Universal Health Coverage (UHC) is a major opportunity to provide a package of pneumonia prevention and treatment services and to ensure that the children and elderly populations most at risk of death are fully covered for the cost of these services. Because investments in pneumonia control strengthen the way health systems work for children and the elderly, they not only benefit all-cause child mortality and prolong lifespans, but improve the equity in the health system by targeting two of the populations most vulnerable to sickness and death. In this way, the

90%
Target coverage rates for pneumonia-fighting vaccines, diagnosis, and treatment services as part of UHC

Countries	% decline in child pneumonia deaths (1990-2017)	% children wasted 0-4 years (latest)	% households access to clean fuels for cooking (latest)	% children PCV coverage 3 doses (2017)	% children Hib vaccine coverage 3 doses (2017)	% children measles vaccine coverage 2 doses (2017)	% children with pneumonia seeking care (latest)
Turkey	97%	1.7%	No data	96%	96%	86%	No data
Chile	93%	30.0%	92.3%	93%	93%	90%	No data
Thailand	89%	5.4%	74.4%	No data	No data	99%	83%
Peru	88%	1.0%	75.1%	80%	83%	66%	62%
Kazakhstan	85%	3.1%	95.3%	98%	99%	99%	81%
Bangladesh	84%	14.3%	17.7%	97%	90%	83%	42%
Mozambique	71%	6.1%	3.7%	80%	99%	60%	50%

Source: Global Burden of Disease, 2017, WHO/UNICEF, World Bank, latest

rate of pneumonia mortality reduction could be used as an indicator of a quality health system that also delivers on equity.

Countries that require additional support to provide this level of pneumonia protection should work in partnership with efforts like the Every Breath Counts Coalition. The Coalition includes more than 30 organizations who have joined forces to support governments to end preventable child pneumonia deaths by 2030. With an initial focus on ten countries,[52] the Coalition is working with governments to, (1) identify the most critical gaps in the prevention, diagnosis and treatment of child pneumonia, (2) develop national strategies to close those gaps by investing in the most cost-effective interventions, and (3) mobilize partners to support the implementation of the strategy. In this context, the Coalition will advocate for national adoption of best practice pneumonia prevention, diagnosis, and treatment indicators, and their inclusion in the national pneumonia control strategies. Coalition members are also working on the development of an agreed set of pneumonia indicators that will allow governments to consistently measure and report progress on pneumonia mortality reduction.

Success is possible. In each region of the world, there are countries that have reduced child pneumonia deaths by more than 70% since 1990, according to the GBD. These countries are very different in many ways, but share three key achievements. First, they have all been able to achieve and sustain high rates of coverage of the pneumonia-fighting vaccines. Second, most have reduced child malnutrition, and particularly child wasting, to relatively low levels, although Bangladesh still has a long way to go. Third, most have made improvements in ensuring households have access to clean energy for cooking and heating, although both Bangladesh and Mozambique need improvement (Table 5). Further, these countries have achieved relatively high rates of adult female literacy (above 70%), with the exception of Mozambique. Finally, all seven countries score highly on universal health coverage relative to regional averages, according to the WHO and World Bank.[53]

[52] Nigeria, Chad, Mali, Niger, Angola, Democratic Republic of Congo, Somalia, Ethiopia, Pakistan, and Afghanistan.
[53] Tracking Universal Health Coverage: Global Monitoring Report, 2017.

New Developments: controlling pneumonia

Governments seeking to reduce pneumonia deaths to the levels required to achieve the sustainable development health goals should implement pneumonia control strategies. These strategies should determine the number of pneumonia deaths that need to be prevented by 2030, identify the most-affected populations, and the deadliest causes and risk factors. The strategies should assess baseline levels of coverage of the pneumonia-fighting vaccines, diagnostic, and treatment services, and set targets and devise plans to close the gaps. Tools like the geospatial mapping techniques from IHME and the Lives Saved Tool (LiST) from the Johns Hopkins Bloomberg School of Public Health are critical resources for governments in the development of pneumonia control strategies.

Pneumonia control strategies should be implemented in the context of broader national health system reforms, including Universal Health Coverage (UHC), child survival plans and the expansion of integrated management of childhood illnesses at both the community and hospital levels, as well as health sector plans to provide quality care to aging populations. The Federal Government of Nigeria is currently developing a pneumonia control strategy as part of its national child survival agenda, its national vaccine strategy, and its pioneering effort to increase access to pulse oximetry and oxygen.

The Federal Government of Nigeria's National Strategy for the Scale-Up of Medical Oxygen in Health Facilities 2017-2022 is being implemented by the National Ministry of Health.

Learn more
Federal Republic of Nigeria, National Strategy for the Scale-Up of Medical Oxygen in Health Facilities 2017-2022.

Estimates of the global, regional, and national morbidity, mortality, and etiologies of lower respiratory infections in 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016.

Save the Children, Fighting for Breath: A call to action on childhood pneumonia, 2017.

CALL TO ACTION

Pneumonia control is achievable, and essential, if the world is to deliver on its promise to, "ensure healthy lives and promote well-being for all at all ages".[54] Ushering in a new era of pneumonia control will require major changes in the way governments, companies, United Nations and multilateral agencies, non-government organizations, universities, and all stakeholders committed to achieving the sustainable development health goals work together. But what must countries do to end preventable pneumonia deaths by 2030?

Five critical changes are required:

1. CONTROL

National governments with the highest burdens of pneumonia should commit to developing pneumonia control strategies by 2020. These strategies should set annual national pneumonia mortality reduction targets and outline a plan for how to achieve these targets by 2030. The plans should set target coverage rates for the major prevention, diagnosis, and treatment services and also target reduction rates for the major risk factors associated with pneumonia deaths. Pneumonia control strategies would be part of overall national health plans and linked to any existing child survival, vaccination, nutrition, air pollution, quality healthcare, and anti-microbial resistance efforts.

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[54] Sustainable Development Goal 3.

tests, pulse oximetry and oxygen delivery, malnutrition, air pollution, and preterm birth. Organizations that aim to foster innovation in pneumonia, including the Pneumonia Innovations Network (PIN), should be supported and expanded as part of the overall effort to accelerate the pace of technological development.

What does success look like? 20% of infectious disease R&D is allocated to pneumonia-related activities by 2025, with the majority targeted to vulnerable children and the elderly in the high-burden countries.

4. PARTNER

Governments and non-government actors should work together to achieve pneumonia control as part of overall national efforts to achieve the sustainable development health goals. National governments should mobilize coalitions from the public and private sectors to drive progress on pneumonia control within their own borders, and the international health and development community should coordinate transnational efforts. These efforts should ensure that pneumonia control efforts are integrated with the larger infectious disease, child survival, health innovation, and health system strengthening agendas at national and global levels.

What does success look like? Every high-burden country has a network of government and non-government actors working to achieve pneumonia control as part of larger national efforts to achieve the sustainable development health goals.

5. CHAMPION

Pneumonia has been called "a global cause without champions", which "barely registers on the radar of global health priorities".[55] New champions at the local, national, and international levels must emerge, especially from governments, business, and civil society in the high-burden countries. Regular pneumonia summits, led by these new champions, should bring together the prevention, diagnosis, and treatment communities to shine a bright light onto progress (or lack of) to the ambitious goal of ending preventable pneumonia deaths by 2030, to share learnings from the various national pneumonia control efforts underway, and to discuss the latest R&D findings and breakthrough innovations.

What does success look like? The inaugural International Pneumonia Summit is held in 2019 with strong representation from the high-burden countries, donor governments, UN and multilateral agencies, business, and civil society.

What does success look like? All 20 high-burden pneumonia countries have launched pneumonia control strategies by 2020 and are publishing progress annually.

2. SUPPORT

National governments should at least fully cover the costs of the pneumonia-fighting vaccines, diagnosis, and treatment services for the most vulnerable populations of children and the elderly as part of Universal Health Coverage (UHC). Where domestic UHC efforts cannot fully cover the cost of protecting vulnerable populations, external financing initiatives should support national efforts, including by targeting the most vulnerable populations.

What does success look like? All of the high-burden countries that have UHC by 2030 provide full protection for pneumonia prevention, diagnosis, and treatment services for vulnerable populations, and at least 10% of international development assistance for health is allocated to pneumonia-related activities by 2025.

3. INNOVATE

National governments, donor governments, and non-government actors should increase investments in pneumonia R&D, targeting breakthroughs in the areas where cost-effective new technologies could prevent the most pneumonia deaths, including rapid diagnostic

55 See Watkins, K and Sridhar, D. Pneumonia: a global cause without champions. Lancet 392 (2018) P718-719.

Notes A
Global Burden of Disease methodology

The Global Burden of Disease (GBD) uses clinician-diagnosed pneumonia or bronchiolitis as the case definition for lower respiratory infections (LRI). Etiologies include influenza, respiratory syncytial virus (RSV), Streptococcus pneumoniae, and Haemophilus influenzae type b.

Two primary types of input data are used to estimate lower respiratory infections. The first is lower respiratory infection incidence and prevalence data from a systematic literature review, hospital inpatient and outpatient data, claims data from the USA, and population-representative surveys. The second type of data is on the etiologies of LRI. Influenza and respiratory syncytial virus population attributable fractions were informed by a systematic literature review of

the proportion of LRI cases that are positive for each pathogen. Haemophilus influenzae type B (Hib) and Streptococcus pneumoniae (pneumococcal pneumonia) are informed by a systematic review of vaccine efficacy and effectiveness studies.

Lower respiratory infection mortality was estimated in the Cause of Death Ensemble model (CODEm) platform. CODEm is a Bayesian statistical model and uses spatial priors from a hierarchical structure to inform the mortality models. CODEm is based on five general principles: identifying all available data, maximizing the comparability and quality of the dataset, developing a diverse set of plausible models, assessing the predictive validity of each plausible individual model and of ensemble models, and choosing the model or ensemble

model with the best performance in out-of-sample predictive analysis.

CODEm produces a large suite of models based on either cause fraction or mortality rate, uses linear and space-time Gaussian process regression (ST-GPR), and a covariate selection process. Each sub-model is evaluated using out-of-sample predictive validity. 30% of the data are excluded from the initial model fits and 15% are used to evaluate component models and 15% used to build the ensembles. The sub-models are ranked using 15% of the data based on their out-of-sample predictive validity. The proportion weighting of the ensemble sub-models is evaluated using the remaining 15% of the hold-out data. Detailed information on this process can be found in Foreman KJ, Lozano R, Lopez AD, Murray CJ. Modeling causes of death: an integrated approach using CODEm (Population Health Metrics, 2012), and in GBD 2016 Mortality Collaborators. Global, regional, and national under-five mortality, adult mortality, age-

specific mortality, and life expectancy, 1970-2016: a systematic analysis for the Global Burden of Disease Study 2016 (Lancet, 2017).

LRI mortality is estimated for 23 age groups, 774 locations, both sexes, and every year from 1990-2017. LRI mortality is estimated separately for males and females and for children under five years and older than five years due to expected underlying differences in the risk of mortality between these age groups. Data-rich and data-poor geographic locations are modeled separately and hybridized for a global model.

The only substantive changes to the cause of death estimation for LRI in GBD 2017 were the addition of new cause of death data and inclusion of several additional covariates. The ratio of mortality in bacterial to viral etiologies was updated for GBD 2017 and the new results substantively increase the attribution of influenza and RSV to LRI deaths.
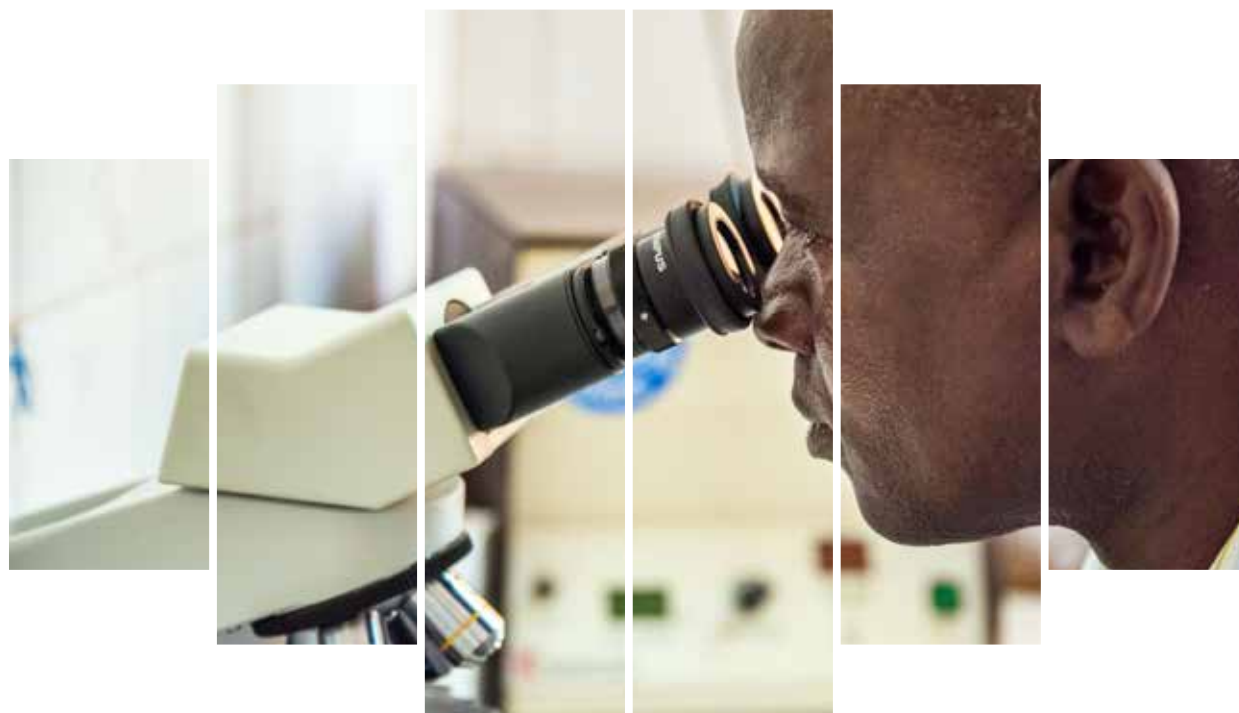
Notes B
Global Burden of Disease super regions

Super regions
Sub-Saharan Africa

Central	East	South	West	
Angola	Burundi	Botswana	Benin	Liberia
Central African Republic	Comoros	Lesotho	Burkina Faso	Mali
Congo	Djibouti	Namibia	Cameroon	Mauritania
Democratic Republic of Congo	Eritrea	South Africa	Cape Verde	Niger
Equatorial Guinea	Ethiopia	Swaziland	Chad	Nigeria
Gabon	Kenya	Zimbabwe	Cote d'Ivoire	Sao Tome and Principe
	Madagascar		The Gambia	Senegal
	Malawi		Ghana	Sierra Leone
	Mozambique		Guinea	Togo
	Rwanda		Guinea-Bissau	
	Somalia			
	South Sudan			
	Tanzania			
	Uganda			
	Zambia			

South Asia

Bangladesh Bhutan India Nepal Pakistan

High Income

Asia-Pacific	Americas	Europe		
Australia	Canada	Andorra	Greece	Netherlands
New Zealand	USA	Austria	Greenland	Norway
Brunei	Argentina	Belgium	Iceland	Portugal
Japan	Chile	Cyprus	Ireland	Spain
Singapore	Uruguay	Denmark	Israel	Sweden
South Korea		Finland	Italy	Switzerland
		France	Luxembourg	United Kingdom
		Germany	Malta	

South East Asia, East Asia, and Oceania

South East Asia		East Asia	Oceania	
Cambodia	Philippines	China	American Samoa	Papua New Guinea
Indonesia	Seychelles	North Korea	Micronesia	Samoa
Laos	Sri Lanka	Taiwan	Fiji	Solomon Islands
Malaysia	Thailand		Guam	Tonga
Maldives	Timor-Leste		Kiribati	Vanuatu
Mauritius	Vietnam		Marshall Islands	
Myanmar				

Central Europe, Eastern Europe, and Central Asia

Central		East Asia	Oceania	
Europe	Macedonia	China	American Samoa	Papua New Guinea
Albania	Montenegro	North Korea	Micronesia	Samoa
Bosnia and Herzegovina	Poland	Taiwan	Fiji	Solomon Islands
Croatia	Romania		Guam	Tonga
Czech Republic	Serbia		Kiribati	Vanuatu
Hungary	Slovakia		Marshall Islands	
	Slovenia			

Latin America and the Caribbean

South America	Central America	Caribbean	
Bolivia	Colombia	Antigua and Barbuda	Guyana
Ecuador	Costa Rica	The Bahamas	Haiti
Peru	El Salvador	Barbados	Jamaica
Brazil	Guatemala	Belize	Puerto Rico
Paraguay	Honduras	Bermuda	Saint Lucia
	Mexico	Cuba	Saint Vincent and the Grenadines
	Nicaragua	Dominica	Suriname
	Panama	Dominican Republic	Trinidad and Tobago
	Venezuela	Grenada	

North Africa and the Middle East

North Africa	Middle East		
Algeria	Afghanistan	Lebanon	Tunisia
Egypt	Iran	Palestine	Turkey
Libya	Bahrain	Oman	United Arab Emirates
Morocco	Iraq	Qatar	Yemen
Sudan	Jordan	Saudi Arabia	
	Kuwait	Syria	

Notes C
Development Initiatives methodology

To determine spending levels of pneumonia-related Official Development Assistance (ODA and private sector (Bill & Melinda Gates Foundation) funding to pneumonia, Development Initiatives used expenditure reported to the OECD DAC Creditor Reporting System (OECD CRS) and applied the methodology used by the Institute for Health Metrics and Evaluation (IHME) and published in "Pushing the Pace: Progress and Challenges in Fighting Childhood Pneumonia", 2014.

As there are no pneumonia specific fields (e.g. sub-sectors) in the OECD DAC reporting directives for specific reporting to pneumonia, Development Initiatives applied IHME methodology to capture donor activities on ODA and private funding to pneumonia by applying a pneumonia relevant key-word-search on CRS descriptive fields: project title, short description, and long description. Positive returns were classified into: 'Vaccine' (vaccine related ODA or private funding to pneumonia), 'full' (other activities focused fully on pneumonia), 'partial' (ODA partially related to pneumonia) and 'reject' based on a review undertaken on all returned activities.

1. Vaccine related pneumonia ODA

Vaccine-related ODA included activities holding project titles or descriptions that indicated the disbursement was on vaccines relevant to pneumonia, specifically those including pneumococcal vaccine, Haemophilus influenza Type B (Hib) vaccine, pentavalent vaccine, and tetravalent vaccine (with Hib component), and other vaccines with Hib component. Relevant activities could encompass a focus across multiple areas within the descriptive fields including vaccine supply, support, procurement, immunization, pilot studies, support for country decision making, and vaccine research and development. The Hib component of funding for pentavalent vaccines and Tetra DTP-Hib vaccines was calculated using UNICEF vaccine price data applied to the total value of the relevant disbursements. This is based on IHME methodology with component fractions updated for recent years. Analysis on proceeds to Gavi is sourced from data for annual contributions and proceeds to Gavi through 31 March 2017, provided on the Gavi website.

2. Full non-vaccine related pneumonia ODA

Full (non-vaccine) activities included projects with titles or descriptions that indicated the entire project was going towards pneumonia. Examples of these activities include pneumonia control, treatment, prevention, and R&D (non-vaccine related).

3. Partial non-vaccine related pneumonia ODA

Partial (non-vaccine) activities included projects with titles and descriptions indicating that the project was partially directed towards pneumonia. Specifically, these were activities noting an element of focus towards pneumonia in descriptions which also included other areas of focus such as diarrhea, TB, HIV or malaria, and were also not reported under a purpose code based with a specific focus towards a non-pneumonia component stated. For these activities a proportion was applied on the disbursement marked as 'partial' based on a subjective review of the project title and description. Proportions were decided based on the number of areas of focus around which pneumonia was mentioned. For example, a project which contained a focus on diarrhea and pneumonia had a share of 50% applied to the disbursement.

4. Reject

A decision was taken not to include certain activities returned from the word-search in the analysis. These were generally multi-sector activities which mentioned a pneumonia related key-word in the description whilst being reported at a split component level to a sector not relevant to pneumonia (e.g. malaria control). Examples of such activities include a malaria control sector project description which states 'pneumonia' as contextual background to a country setting or an activity undertaken on research relating to 'Contagious Bovine Pleuropneumonia'.

Note this analysis does not include bilateral development cooperation data from providers not reporting to the OECD DAC system; including Brazil, India, China, and South Africa. As such the estimates may underestimate total international development financing to pneumonia (depending on the extent of the activities relevant to the pneumonia from these providers). Furthermore, ODA from certain non-DAC donors reported on the OECD DAC system can at times hold less detail compared to DAC donors, increasing the likelihood any relevant ODA from these providers will be omitted from the word-search based methodology.

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