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gOVERVIEW

PREFACE

On the Global Epidemic of CVD and Why Household Air Pollution Matters

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Almost one-half of the world's population, 3 billion people, who live in poverty, burn biomass or coal as fuel for cooking and heating inside their homes. The indoor fires release products of incomplete combustion into the air that cause such an intense degree of smoky indoor air that nearly 2 million people, mostly women and children, die every year from this exposure. The deaths from household air pollution (HAP) are currently attributed to 3 diseases: 1) acute pneumonia in children under age 5; 2) chronic obstructive pulmonary disease; and 3) lung cancer in adults, mostly women. The mortality risks from HAP will likely be updated in 2012 to include increasing evidence for significant cardiovascular risks that may almost double the estimated annual mortality from HAP. In the past few years, there has been progressive awareness of the importance of HAP in the global burden of disease and in its contribution to the global epidemic of noncommunicable diseases, including cardiovascular diseases. HAP represents a preventable environmental cause of noncommunicable diseases and its associated morbidity and mortality. In part, as a result of this increasing awareness, there has been development of a major public–private partnership, the Global Alliance for Clean Cookstoves. The Global Alliance consists of hundreds of partners including countries, nongovernmental organizations, and manufacturers with the goal to have 100 million homes adopt clean household energy by the year 2020. As this global partnership continues to evolve, this provides a unique opportunity for scientists, clinicians, and partners in the Global Alliance and other global organizations to prevent cardiovascular-related morbidity and mortality by reducing HAP across the entire lifecycle.

In September 2011, the United Nations (UN) hosted a high-level meeting on noncommunicable diseases (NCD) to address the prevention and control of NCD with a particular emphasis on low- and middle-income countries [1]. The only other time that the UN General Assembly provided such a focus to health was to address the global challenge of human immunodeficiency virus/acquired immunodeficiency syndrome in 2001. The epidemic of NCD including cardiovascular diseases has risen to such heights that in 2008, an estimated 36 million people died from NCD worldwide of a total of 58 million deaths [2]. Many of these deaths are thought to be preventable as known risk factors such as tobacco smoke exposure, unhealthy diets, lack of exercise, and overuse of alcohol are recognized to be present in almost 80% of all deaths [3]. Household air pollution (HAP) is also a preventable risk factor and this preface as well as the other contributions to this issue of *Global Heart* will make the case for the important role of HAP as a risk factor for cardiovascular diseases (CVD) and the opportunities that exist today to address these risks on a global scale.

CVD account for the greatest percentage of morbidity and mortality of all the NCD worldwide. These deaths as with the other NCD are greatest among those living in poverty in low- and middle-income countries. Thus, risk factors associated with poverty must be a key part of the discussion and understanding of why CVD and other NCD have reached such an epidemic level. In part, NCD have increased as a cause of worldwide deaths

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as communicable diseases have been better managed with improved access to antimicrobial therapies and vaccines; yet another contributing factor may well be the progressive adoption of Western-style diets and lifestyles, as well as increased availability of tobacco and alcohol over the past 50 years. Other risk factors may be less well appreciated, but perhaps more coincident with the NCD epidemic, including HAP from the burning of biomass, coal, or kerosene for household energy use including cooking, heating, and lighting.

Almost 3 billion people on the planet today continue to rely on such fuel sources that markedly increase toxic levels of air pollution levels in households and villages and may contribute as much as 40% to outdoor air pollution in major cities in low- and middle-income countries. Increasingly, this problem of HAP exposures to families is moving from the rural to the urban environment, with regional and global impacts of black carbon contributing to major climate and environmental degradation [4].

Thus, there are unique opportunities today to improve global health by improving the household air quality of the poor that can plausibly lead to a reduction in CVD and other NCD in future years. The spectrum of diseases from HAP exposure is similar to that of tobacco smoke exposure with risks for CVD, lung and upper airway cancers, and chronic respiratory diseases such as chronic obstructive pulmonary disease. However, the burden of HAP exposure is much greater for women and young children than for men due to the high percentage of time that women and children spend within and near their households. HAP is estimated to result in almost 2 million deaths (using data from 2004) from acute pneumonia in children under age 5 and chronic obstructive pulmonary disease and lung cancer in mostly adult women [5]. In 2012, the attributable deaths from HAP will probably be updated using data and will include, for the first time, the risk from CVD that almost doubles the estimated number of deaths globally. Prevention strategies to reduce deaths from CVD globally should include HAP as a major risk factor and should address how a clean and healthy household environment is an effective tool to promote human health. The good news is that there are multiple approaches underway that are forging partnerships across sectors such as governments, manufacturers, nongovernmental organizations (NGOs), and funders to achieve a coordinated and evidence-based approach to improve household air quality and to reduce NCD and other health risks for those living in poverty who currently use biomass or coal in their homes.

HAP AND ITS ADVERSE IMPACT ON HEALTH

HAP is invariably associated with poverty everywhere on the planet. Families living in poverty often struggle to find fuel to maintain the daily routine of their households to meet their needs for cooking, heating, and lighting. Sources of energy can vary depending on the local environment and factors such as an urban or rural setting and whether the household is in a mountainous region. Increasingly, fuel is becoming a commodity that is purchased in local markets and represents a substantial cost in the family budget. However, households may also forage for fuel when this is possible and, in areas that have been deforested, spend hours walking to collect fuel away from the safety of their homes and communities. This places women and children who collect fuel vulnerable to a variety of risks and injuries, but most commonly places women at risk for gender-based violence [6].

Households typically burn biomass, which includes wood, charcoal, crop residues, or dung, using either a traditional 3-stone fire or a primitive inefficient stove for cooking and heating. In most of these households, flues or chimneys are rarely available to vent the emissions to the outside. When they are available, they are difficult to maintain to work properly. Coal is also a common residential fuel source in China. In areas of higher altitude, heating is a major source of HAP and, in the presence of temperature inversions that may occur, can greatly exacerbate the HAP-associated outdoor air pollution. Indoor fires are also a major source of serious burns, especially when a liquid fuel such as kerosene is used.

As we already know the many health risks from inhaling tobacco smoke or outdoor air pollutants, it would seem obvious that exposures related to HAP would result in similar health risks. And yet, this has been an amazingly slow process to bring this issue to the attention of the world. The efforts of Kirk Smith at the University of California Berkeley and his scientific colleagues around the world have been doing so for the past 30 years with increasing success. They and others have demonstrated a variety of health risks associated with HAP [7]. These include those diseases associated with the mortality risks noted previously (such as acute pneumonia in children and lung and

chronic obstructive pulmonary disease in adults), and in addition, CVD, low birth weight, adverse pregnancy outcomes, probable impaired neurodevelopment and growth, other cancers possibly including cervical cancer, ocular disorders including catarracts, infections such as tuberculosis and burns and scalds [8].

EVIDENCE FOR HAP AS A RISK FACTOR FOR CVD

The American Heart Association concluded that the fine particulate matter $(PM)_{2.5}$ fraction of air pollution, a major component of both outdoor air pollution (OAP) and HAP, is a modifiable risk factor for CVD [9]. The evidence for this was garnered from decades of work studying the impact of OAP on cardiovascular risk. Even though $PM_{2.5}$ concentrations are much higher in HAP than in OAP, the relatively few studies on the impact of HAP on CVD resulted in an underestimation of the importance of this risk as a contributor to global mortality.

It is challenging to show a direct relationship between a pollutant exposure and any NCD, as the chronicity of the disease process by definition indicates years and decades of disease development, thereby precluding simple delineation of a cause-effect relationship between exposure and disease. Natural experiments can inform causal relationships by revealing changes in pollution levels with evidence of an impact on morbidity or mortality from a NCD. For example, when the government in Dublin, Ireland, banned the marketing and sale of high-polluting bituminous coal within the city of Dublin in 1990, it caused a 70% decrease in black smoke pollution over the subsequent 6 years that resulted in a marked decrease in both cardiovascular and respiratory deaths in each year following the ban [10]. Similarly, in the United States, implementation of U.S. Clean Air Act resulted in progressive reductions in OAP in major cities with a subsequent reduction in cardiovascular mortality [11,12]. More recently, when road traffic was curtailed during the 2008 Olympics in Beijing and OAP levels decreased significantly, there was a marked decrease in biomarkers of CVD in young adults [13]. Thus, there is compelling evidence that OAP at levels well below that observed with HAP are associated with significant cardiovascular-related morbidity and mortality.

What is the evidence for HAP to be associated with significant cardiovascular morbidity and mortality? There is both indirect and direct evidence for such risks. For example, as noted for OAP, tobacco smoke exposure levels in the home are significantly lower than occurs with HAP, suggesting that even higher exposure levels would logically be associated with increased disease risk [14]. Further, there is evidence that HAP exposure in women who are cooking using biomass fuels is associated with both hypertension and presence of biomarkers of cardiovascular risk [15]. More directly, in the RESPIRE (Randomized Exposure Study of Pollution Indoors and Respiratory Effects) study conducted in Guatemala, investigators using a cook stove and chimney intervention showed decreased blood pressure as well as improvement in ST-segment depression in women [16,17]. Very recently, there was a report of a cross-sectional analysis in China with more than 14,000 participants that, after acounting for potential confounders, determined that HAP is a likely risk factor for hypertension, coronary heart disease, stroke, and diabetes [18]. Thus, the evidence that HAP is joining the ranks of OAP and tobacco smoke as a major environmental risk factor for CVD is increasing, and even as this is being recognized, the challenges of successfully intervening not only on a household level, but also on a global scale loom in front of us.

EFFECTIVELY REDUCING HAP TO IMPROVE HUMAN HEALTH

As cooking is the major source of HAP, there has been great interest in reducing HAP by improving the efficiencies of cook stoves and fuels to reduce emissions and when possible to vent emissions to the outdoor environment. Advancing technologies in cook stoves have resulted in a new generation of stoves that burn biomass fuels or coal using reduced amounts of fuels (fuel efficiency) and by burning the fuel at much higher temperatures and with the proper mixture of air to burn off particles or gases that are the typical products of incomplete combustion (combustion efficiency). The use of less fuel is a major incentive to families to purchase an improved stove as fuel savings can reduce fuel costs and the stove can pay for itself in time. It is the increased combustion efficiency, however, that results in lower emissions that reduce exposures, and if sufficiently large, can reduce specific health risks and improve health. Thus, both types of efficiencies are important to consider by implementers and policymakers, but they are not identical. It is possible that improved stoves can save fuel and not necessarily significantly decrease

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emissions. To improve human health, the challenge is to have a marked reduction in emissions and, where appropriate, to vent these reduced emissions to the outside.

Importantly, the first completed randomized controlled trial using an improved cook stove and chimney intervention, the RESPIRE study in Guatemala, demonstrated that with as little as a 50% reduction in HAP, there can be a significant decrease in mortality from severe pneumonia [19]. This study is essentially a proof of concept that clean cooking solutions can significnatly reduce HAP within the community and can save lives. It is critical to move the field forward to develop more advanced and affordable technologies that meet the needs of families and improve the health of those living in poverty who are most at risk.

However, there are many challenges ahead. Sometimes improved stoves may not result in the exposure reduction expected. First, the proposed "improved stove" must be tested in both the laboratory and in the field to be certain that it is capable with proper use of achieving a marked reduction in emissions that ultimately reduces exposures to family members. Second, the type of fuel is often a major determinant of the fuel and combustion efficiencies. If a highly efficient stove meant for use with biomass pellets has instead fuels such as moist crop residues such as rice husks or debris collected along the roadside such as twigs or leaves, the emissions will be extremely high and the HAP will not be reduced. Third, families may continue to use their traditional stove or open fire if the improved stove only meets some of their cooking needs. In this case, a highly efficient stove with very low emissions will not provide a significant reduction in exposures, which is the determinant of health risk. The key to a successful cook stove or fuel intervention within a household is that the scientists, NGOs, governments, et cetera must first consider the opinion of the households and communities about their household energy needs and work with these communities to achieve a culturally acceptable and health-promoting solution. This takes time and a clear understanding of how the proposed solutions work within these environments, but the knowledge and trust gained can result in sustainable solutions that improve health and address the needs of the families living at the bottom of the planet's energy ladder. When successful, these household energy solutions can improve the likelihood that families can have more free time to develop other sources of economic growth, and women and children can have more time to become educated and pursue other opportunities and, for the purpose of this report, a chance to live healthier lives with a reduced risk for cardiovascular-related morbidity and mortality [20].

PARTNERSHIPS TO ADVANCE THE GOAL OF IMPROVING HUMAN HEALTH

There has been an interest by governments, funders, and NGOs for decades to reduce the impact of HAP on families and communities. Many have advanced our understanding of the types of stove or fuel interventions that can work and have a sustainable impact. The motivations for improving the quality of household air may vary from attempting to improve health, lessen deforestation or other environmental impacts, improve the economic conditions of the poor, or reduce the burden and risks to women and children who at times must walk miles away from the safety of their homes to gather fuel. Also, there is hope that by reducing the time required for cooking and fuel gathering, women will have more time for other activities that can improve their lives and that of their family members.

What has been missing is a forum to bring together the thousands of people and organizations to share ideas about what works and what does not. The U.S. government began to address this issue in 2002 when the U.S. Environmental Protection Agency organized the Partnership for Clean Indoor Air (PCIA) [21]. The PCIA has had several rounds of funding to support programs of improved stove and fuel implementation worldwide. It has held biennial forums for gathering of hundreds of participants to hear presentations, share concepts, and advance new research findings to improve the effectiveness of reducing HAP, with the most recent forum in Lima Peru in 2011. It has also launched stove testing sites worldwide and advanced the need for global standardization of stove performance culminating in the International Standards Organization hosting a meeting in The Hague in 2012 that resulted in the publishing an international working agreement for tiers of stove performance [22]. The PCIA is a valuable resource for those who wish to learn about the challenges and progress of developing effective and sustainable solutions for HAP [21].

In 2010, The U.S. government and other countries, foundations, and NGOs developed a public–private partnership with the United Nations Foundation to form the Global Alliance for Clean

Cookstoves [23]. The launch of the Global Alliance was announced by Secretary of State Hillary Clinton in September 2010 during the week of the UN General Assembly meeting in New York, with the Global Alliance committing to a goal of 100 million homes adopting clean cook stoves and/or fuels by 2020. The mission statement of the Global Alliance is "to save lives, improve livelihoods, empower women, and combat climate change by creating a thriving global market for clean and efficient household cooking solutions." In that regard, the U.S. National Institutes of Health and other partners organized a workshop to assess the state of the science related to HAP and to determine the critical research gaps and opportunities that can help inform the Global Alliance and its partners to develop strategies and implement programs that can effectively and sustainably "save lives" by reducing HAP to safe levels for human health [8].

One of the critical issues not yet solved regarding HAP is to know how "clean is clean" to improve health. In 2011, there was a landmark publication from a study in Guatemala that for the first time clearly documented that a cook stove and chimney intervention resulted in a clear exposure-response, noting that a minimum of a 50% reduction in HAP is required to save young children from dying of acute pneumonia [19]. Using the data from this study as well as other sources, the World Health Organization in 2012 proposed Indoor Air Quality guidelines for household fuel combustion that will provide an evidence-based reference for indoor air concentrations of pollutants that can reduce the risk of adverse health impacts. Knowing the vagaries of biology, the levels of pollutants that provide a margin of safety may differ depending on the specific health outcome being measured. Thus, cardiovascular risk over many years may reflect a different personal level of exposure than low birth weight or acute pneumonia that might occur over months. Nonetheless, this effort by the World Health Organization represents an important moment in time that sets a guideline for how clean is clean that will change as new data becomes available that better informs governments, NGOs, manufacturers, and others who are attempting to address this major preventable cause of CVD.

TOWARD A SOLUTION FOR REDUCING CVD RISK

This year, 2012, is the International Year of Sustainable Energy for All, a campaign of the United Nations to have all homes have access to modern and clean energy by 2030 [24]. This is one more important driver for change that will improve the lives of those living in impoverished conditions, and who by necessity only have access to the most primitive sources of energy for their homes. The outcomes of having children and adults live in homes with cleaner air quality may not only improve their economic condition and reduce the burden of local environmental degradation, but it may also represent a major opportunity to reduce a CVD risk factor that affects exclusively the poorest people on the planet.

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