Airborne Particulate Matter and Public Health

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BACKGROUND

Outdoor air quality is an increasing concern globally with expanding industrial and transportation emissions. The World Health Organization (WHO) has declared that Particulate Matter (PM) in ambient outdoor air affects more people than any other pollutant. Chronic exposure to particles contributes to the risk of developing or dying from serious disease. (WHO 1) The effects of PM on health occur at levels of exposure currently being experienced by most urban and rural populations in both developed and developing countries. Burning fuel results in two phases of emissions, both containing the highly toxic polycyclic aromatic hydrocarbons (PAHs). In addition to the "particulate phase," there is a "gas phase" containing other air pollutants such as acrolein, benzene, and formaldehyde, which also contribute to disease. (EPA 1, EPA 2) The combustion of fossil fuel for electricity and transportation, especially coal and diesel, are major contributors to outdoor air pollution.

Image courtesy of SAL Limited.

WHAT IS PARTICULATE MATTER?

Particulate Matter (PM), is composed of very small, solid and liquid particles, formed from the incomplete burning of fossil fuels, such as coal, diesel, gasoline, and biomass. PM2.5 measures 2.5 microns in diameter or less; PM10 are particles 10 microns or smaller. PM consists of a complex mixture of Polycyclic Aromatic Hydrocarbons (PAHs), soot, black carbon, absorbed water, aerosolized sulfuric acid droplets, other acids, nitrogen, sulfur, organic material, metals, and other toxic substances. PAHs are absorbed by the sponge-like particles and carried by them deeply into the smallest compartments of the lung (alveoli) where they gain direct access to the bloodstream and may then contribute to various diseases in organs distant from the lungs, including the fetal placenta.

The World Health Organization (WHO) reports that there is not a threshold below which no damage to human health is observed. Their guidelines for maximizing health within the constraints of a modern world are that PM2.5 should not exceed an average of 25 micrograms per cubic meter of air (25mcg/m3) in a 24-hour period, and not exceed an average annual exposure of 10mcg/m3. (WHO 1)

To put this into perspective, the PM2.5 for Portland, Oregon in January, 2014 ranged from 30-76, while, during same month, the PM 2.5 in Beijing, China was over 600. In Harbin, China in October of 2013 (the start of the heating season), the PM2.5 was over 1000mcg/m3 (Guardian). The major contributors to this astronomically high PM2.5 in China are burning coal and vehicle exhaust.

HOW DOES PARTICULATE MATTER AFFECT PEOPLE?

The fine and ultrafine particles less than 2.5 microns (PM2.5) are particularly important in triggering disease because they penetrate deeply into the alveoli of the lungs. Diesel particulate matter, submicronic in size, has particularly damaging potential (Li). Some inhaled particles are taken up by macrophages, resulting in lung inflammation. The final common pathway of the pathologic effects of exposure to particulate matter, as well as gas phase pollutants, appears to be inflammation. (Avogbe, Bellavia, Dominici, Li, Mustafic, Peters 2011, Pieters). The effects of inflammation on various body organ systems are complex, but increased levels of particulate matter are associated with a number of ill health effects including: increased cancer rates, especially lung and breast (Beeson, Crouse, Demetriou, Dockery, Pope, Wei, WHO 2), congenital lung, heart and immune system anomalies in children (Gauderman, Picciotto Vrijheid), increased rates of asthma, worsening of preexisting asthma and chronic obstructive pulmonary disease (COPD) (Carlsten, Gowers, Delamater, HEI Panel, Trasande), higher rates of heart attacks and strokes (Chen, Dominici, Lie, Mustafic, Qian, Wellenius, Shaw), and higher rates in children (exposed prenatally) of neurodevelopmental disorders such as autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), lowered IQ, and adverse behaviors. (Becera, Chiu, Newman, Perera 2013, Perera 2009, Roberts, Volk 2013, Volk 2011). Not surprisingly, the most vulnerable populations are pregnant women, children, people that already have pulmonary diseases like COPD or asthma, and the elderly.

Image courtesy of The Daily Reporter.

WHAT ARE CURRENT ISSUES IN THE PACIFIC NORTHWEST?

A recent study from the University of Washington, evaluating air quality as a result of increased coal transportation by rail in the Pacific Northwest, found that living within 25 meters of two rail lines in the Blue Ridge Seattle neighborhood was associated with significantly increased exposure to diesel particulate matter (DPM) and airborne coal dust. A proposed 50% increase in diesel train traffic (if coal terminals are built in coastal harbors) is projected to similarly increase small particulate matter exposure. When added to regional background emissions, this increase would bring total concentrations higher than the new US National Ambient Air Quality Standards (NAAQS). (Jaffe) In addition, a sharp increase in mile-long trains already transporting oil through the region has considerably increased airborne diesel emissions. In 2013, 19,065 tank cars moved more than 11 million barrels of oil through Oregon, according to annual reports that railroad companies submitted to the Oregon Department of Transportation, up from 2012 when 5,491 cars moved 2.9 million barrels... In 2007, railroads moved just 659 tank carloads of oil. (Oregon Live) Furthermore, several energy companies are actively pursuing permits to build enormous oil and gas storage tanks in Northwest ports which, if allowed to proceed, would dramatically increase diesel exhaust from even more trains traversing Oregon and Washington.

KEY AMERICAN MEDICAL SOCIETIES AND THE WORLD HEALTH ORGANIZATION HAVE ISSUED POSITIONS ON PARTICULATE MATTER AND HEALTH:

The American Heart Association (AHA) in 2010 updated and summarized its 2004 Scientific statement position: "The overall evidence is consistent with a causal relationship between PM2.5 exposure and cardiovascular morbidity and mortality. This body of evidence has grown and has been strengthened substantially since publication of the first AHA scientific statement and, … because the evidence reviewed supports that there is no safe threshold, it appears that public health benefits would accrue from lowering PM2.5 concentrations even below present-day (EPA standards), if feasible, to optimally protect the most susceptible populations." (Brook)

The American College of Obstetricians and Gynecologists (ACOG) together with the American Society of Reproductive Medicine (ASRM) in October 2013 issued a statement, "The evidence that links exposure to toxic environmental agents and adverse reproductive and developmental health outcomes is sufficiently robust, … individuals alone can do little about exposure to toxic environmental agents, such as from air and water pollution, … calling for timely action to identify and reduce exposure." (ACOG)

The American Academy of Pediatrics (AAP) issued a policy statement linking ambient air pollution to adverse health outcomes in children and recommended the National Ambient Air Quality Standards (NAAQS) be promptly reviewed and revised to protect children. (AAP, 2004, reaffirmed 2009)

In October 2013, WHO's International Agency for Research on Cancer (IARC), classified both outdoor air pollution, as a whole, and particulate matter, on its own, as carcinogenic. Therefore, it is vital to implement efficient policies to reduce exposure to pollution worldwide. (World Health Organization (WHO 2) and American Cancer Society).

SPECIFIC DISEASES ASSOCIATED WITH EXPOSURE TO HIGHER LEVELS OF PARTICULATE MATTER IN AIR POLLUTION

Cancer — Studies relating cancer risk and particulate matter:
- exposure to ozone and PM correlated with development of and mortality from lung cancer (Beeson, Dockery, Pope)
- increased biological markers associated with risk of lung cancer (Demetriou)
- increased oxidative DNA damage predictive of cancer risk (Avogbe)
- increased rates of breast cancer (Crouse, Wei)

Cardiovascular — Studies have linked increased particulate matter with increased cardiac disease:
- increased cardiovascular disease mortality and morbidity in both short term and long term exposures to PM 2.5 (Brook)
- increased hospital admissions for serious cardiac arrhythmias (Peters 2000)
- increased probability of admission for acute myocardial infarction (Mustafic, Peters 2001)
- increased ischemic heart disease, arrhythmias, congestive heart failure (Dominici) and bio markers (HRV) associated with increased cardiac morbidity and mortality (Pieters)
- increased hospital admissions and death from heart failure (Shaw)
- increased risk of congenital cardiac anomalies in children (Vrijheid)

Cerebrovascular — Studies have shown links between particulate matter and adult brain effects:
- increased hospital admissions for strokes(Dominici, Lue, Wellenius 2005)
- significant increase in stroke mortality associated with increase in PM (Chen, Qian)
- increased risk of stroke associated with increased exposure to small PM, black carbon, and nitrous dioxide (Wellenius 2012)
- increased risk of stroke and death from stroke for post menopausal women (Miller)
- structural brain damage and cognitive deficits in middle-aged and older adults (Wilker)

Neurodevelopmental — Studies associating in-utero exposure to particulate matter and:
- increased incidence of autism spectrum disorder (ASD) (Becerra, Kalkbrenner, Raz, Roberts, Volk 2013, Volk 2011)
- increased incidence of behaviors associated with attention deficit hyperactivity disorder (ADHD) (Chiu, Newman, Perera 2014, Peterson)
- lowered IQ (Calderón-Garcidueñas, Perera 2009, Jedrychowski)
- increased behavioral symptoms of anxiety, depression, social problems, rule breaking, and aggression (Perera 2013)
- neurobehavioral development in children benefited from the shutdown of a coal-burning plant (Perera 2008, Tang)

Pulmonary — Studies have demonstrated the effects of particulate matter on the lungs:
- decreased lung function (WHO 3)
- inhibited lung development in children and adolescents and measurable airway inflammation (Gauderman)
- increased asthma rates and worsening of preexisting asthma and chronic obstructive pulmonary disease (COPD), resulting in increased hospitalization (Carlsten et al., Gowers, Delamater, 2012; HEI Panel, Pandya, Trasande)

General —
- increased mortality from cardiac, respiratory and kidney disease in all members of communities with coal exposure (Hendryx 2007, Hendryx 2010, Hendryx 2008, Hendryx 2009)
- long term exposure linked to decreased life expectancy from cardiopulmonary mortality (Krishnan, WHO 4)
- prenatal exposures linked to altered immune system development (Hertz-Picciotto)

WHAT YOU CAN DO TO PROTECT YOUR FAMILY AND COMMUNITY

The World Health Organization has stated, “Most sources of outdoor air pollution are well beyond the control of individuals and demand action by cities, as well as national and international policymakers in sectors like transport, energy, waste management, buildings and agriculture.” With that in mind, here are some tips to protect your health:

1. Use a portable air purifier in your home (Look to consumer organizations for specific product information).
2. Do the best you can to protect your and your family’s health from the consequences of inflammation by observing good health habits: Get plenty of sleep and daily exercise, eat six servings of fruits and vegetables daily, consult your health advisors.
3. Push in the air recycle button on your car dash when traveling on motorways around other vehicles.
4. Work for change with environmental and neighborhood groups (examples: The NW District Association of Portland recently negotiated an agreement with local developers to meet EPA’s highest standards for diesel exhaust emissions, by using exhaust treatment devices during a local construction project. Neighbors for Clean Air negotiated with an industry in the Northwest Portland neighborhood to reduce its toxic air emissions, by installing giant vacuum cleaner bags to capture particulates, and air monitoring equipment in the neighborhood.)
5. Work for policy change with local and regional governments, and legislatures. Ideas for starters (inspired by the Oregon Environmental Council): Request “No diesel engine idling” policies, retrofitting of older diesel engines with pollution control devices, advocate for the use of ultra-low sulfur diesel fuel for Oregon, continue negotiating improvement in the emissions standards of heavy-duty, off-road diesel engines, request that all vehicles are using the best available technology for emission control, and that grant funds are available to assure this, especially for small businesses.

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