UTAH PHYSICIANS for a HEALTHY ENVIRONMENT

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2017 REPORT ON AIR POLLUTION AND HEALTH RESEARCH

When UPHE was formed in 2007, we committed ourselves first and foremost to delivering a message on air pollution and public health based strictly on the science. As we searched through the research, we were all struck by the parallels between the health consequences of air pollution and those of cigarette smoking. The parallels between those two types of pollution exposure have only grown closer in the last 11 years. What follows is a summary of key medical research from the past year, and a reiteration and expansion of concepts that have been strengthened by this research.

* * *

We have often recited the evidence that there is no safe level of air pollution. Even at levels that fall far below national standards, indeed even the levels that approach our ability to measure them in the atmosphere, we see statistical and biologic evidence of impaired health.

The "no safe level of pollution" tenet and the parallel to cigarette smoking was solidified in a study published two weeks ago called a meta-analysis (i.e. a combining of the statistical findings of over 141 previous studies), which showed this remarkable result: Smoking one cigarette a day increases a person's risk for coronary artery heart disease 48-74% for men, and even more for women, 57-119%. The risks for strokes were a little less but showed a similar pattern. Overall the combined risks of smoking just one cigarette a day increases the risk of stroke and heart attack much more than we would have previously thought, specifically, almost half of the risk of smoking a full pack a day, i.e. 20 cigarettes.[1] Stated another way, the first few cigarettes smoked do far more damage <u>per cigarette</u> than the rest of the pack. The inevitable conclusion to be drawn is that reducing smoking is not enough to protect one's health, even one cigarette a day matters.

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Like with cigarettes, the most recent air pollution research points in the same direction. There is a non-linear relationship between air pollution and impaired health. Per unit of air pollution, the health consequences are even greater at low levels. This fact has public policy implications. All air pollution matters, there is no “off season” for air pollution, and while current air quality standards are helpful, they are inadequate in protecting public health. All air pollution that can be removed from the Wasatch Front airshed will benefit public health regardless of the baseline air quality.

We have divided the past year’s research into several categories below.

HEART, LUNGS, AND BLOOD VESSELS

Air pollution’s effect on the heart and blood vessels is central to its overall impact on human health. While air pollution is only one of several risk factors, the cumulation of a person’s risk factors are multiplicative rather than additive, which increases the urgency of reducing all of them.[2]

About 10 years ago it became well established that acute and chronic particulate pollution exposure were independent risk factors for heart disease and strokes because they inflamed the blood vessels. In the last 5 years we learned that acute particulate exposure can exert its effects through the microcirculation, the tiniest part of the blood vessel network, too small for interventions like surgery or angioplasties, and we learned that the diameter of these tiny blood vessels is almost immediately narrowed by acute air pollution inhalation. [3]

The common denominators of damage to the blood vessels and probably the other organs as well, are twofold. One, chemical mediators of inflammation are triggered in the lung by inhaling harmful gases and particulate pollution and then distributed throughout the blood stream and eventually the entire body. Two, in the case of particulate pollution, the particles themselves, and in some cases atmospheric chemicals attached to those particles, are translocated from the lungs to the blood stream and then delivered to the rest of the body in like manner.

This past year we learned important details about what happens to air pollution nanoparticles once inhaled. Within 15 minutes these particles are detectable in the blood, liver and urine, and they can remain in the body for as long as three months or more. The very smallest particles, 5 nanometers, were the ones most likely to be distributed throughout the body.

Furthermore, when inhaled, particles preferentially accumulate in the lining of the blood vessels, specifically at sites of existing atherosclerosis and inflammation, which is likely to contribute further to the narrowing of critical blood vessels and increases the risk of plaques and debris rupturing and obstructing blood flow downstream. This new information provides a clear blueprint for the link between air pollution and heart attacks and strokes.[4]

We learned that even in healthy, college-age students, particulate air pollution at levels typical of our winter inversions, activates a complex interaction between the brain, pituitary gland, nervous system, adrenal glands, and kidneys which results in elevated blood pressure, production of stress hormones, inflammation, insulin resistance, and increased serum cholesterol and fatty acids. [5]
No doubt this is a primary mechanism by which chronic exposure increases blood pressure and shortens life span.[6]

We learned more about air pollution's adverse impact on the pumping mechanism of the heart, [7] increasing vulnerability to heart failure, [8] and the compromising of the heart's ability to maintain a normal rhythm. [9]

More studies were published showing air pollution increased rates of stroke [10,11] and increased rates of hospitalization for all causes, but especially for respiratory and heart problems.[12] Like other studies on mortality, the rate of increase per unit of exposure, was even greater at PM 2.5 levels below 8 ug/m3. The current annual EPA standard is 12. Note that background levels of PM2.5 are about 5 ug/m3.

New clinical studies provided increased evidence of what these biological processes do to individual and public health. Multiple studies demonstrated that air pollution causes premature death.[13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23] Research published in 2017 continues to expand the body of work demonstrating a strong connection between exposure to outdoor air pollution and adverse effects on lung function in infants, older adults, in both healthy individuals and those with asthma or smoking related lung disease (COPD).[24] Air pollution is directly toxic to the respiratory tract, degrading the inside lining of the nose, [25] and causing DNA damage and cell death within the lungs. [26]

Overwhelming evidence from around the world shows that both long-term and short-term exposure to pollution at the levels frequently encountered along the Wasatch Front can both cause and exacerbate lung disease across all ages. Levels of pollution below current EPA standards still cause important health effects, including increased risk of death. These effects are seen even following short-term exposure (on the order of a few days) to PM2.5 levels below 25 mcg/m^3.

What is now a landmark study, published in one of the most prestigious medical journals, found increased mortality in older adults following even modest increases in PM2.5 levels. These effects were particularly evident in those at the lower end of the socioeconomic spectrum. [27] Similarly, an important study in the New England Journal of Medicine showed that chronic exposure to what we currently label as "acceptable" levels of PM2.5 or ozone was associated with increased risk of death for older individuals. [28] These studies add confirmation to previous research that there is no safe level of air pollution.

Another important study evaluated the effect of taking a 2-hour walk in two different environments on symptoms and chemical markers of vascular health in older individuals with and without heart and lung disease. Overall, walking in a low pollution environment had significant health benefits that were lost when walking in an urban environment with higher levels of pollution. [29] There were quantitative relationships between levels of individual pollutants (such as PM2.5) and these effects. Thus, air pollution appears to counteract the beneficial effects of even mild exercise.

Physician researchers at the University of Utah and Intermountain Medical Center found that the risk of pneumonia and the severity of this illness (including ICU admission and need for critical care) was increased in response to a few days of increased PM2.5 levels.[30] Again, these effects were seen even at levels below EPA standards. These researchers identified the health care costs associated with these cases of severe pneumonia and estimate that improvements in air quality would both improve health and save millions of dollars in healthcare costs.

Ozone, our primary summer pollutant, increases the risk of hospitalization for heart attacks and has most of the same consequences as particulate pollution. [31, 32]

ENDOCRINE DISORDERS

Numerous new studies added to the evidence that air pollution contributes to metabolic disorders, especially type II diabetes. [33,34,35,36,37,38] Many of these studies found that pollution in utero can set the stage for obesity, type II diabetes and impaired glucose metabolism later in life. [39,40,41,42]

CANCER

The World Health Organization declared air pollution the most important environmental cause of cancer. Several new studies strengthened the relationship between air pollution and cancer, i.e. liver cancer, [43] survival of liver cancer, [44] breast cancer, [45, 46, 47, 48] lung and bladder cancer, [49,50] and malignant brain tumors. [51]

REPRODUCTIVE HEALTH

New studies added to previous research showing air pollution impairs all aspects of human reproduction, likely via endocrine and hormonal impacts of chemicals attached to particulate matter. Sperm production and sperm quality are affected, [53, 54] in particular, a decrease in sperm carrying the y chromosome, which translates into a drop in the percentage of male newborns. [55] Air pollution also affects menstruation in teenage girls. [56]

BRAIN

Beyond air pollution's connection to strokes, more and more studies are showing that air pollution has a profound adverse impact on the brain at every stage of life, from as early as the first trimester to the very elderly.

We now have a second study showing that tiny pollution nanoparticles from fossil fuel combustion end up inside our brains. Once there they can cause brain damage, disrupting cellular and intracellular architecture. This undoubtedly contributes to the many clinical studies that show impaired brain function, loss of memory, loss of intellectual abilities, behavior problems, and more degenerative brain diseases in people exposed to more air pollution. [57]

Two more studies showed a connection between air pollution and autism.[58, 59] The first study showed that the affect could be mitigated by maternal extra consumption of folic acid during pregnancy. Attention span and memory in school children is impaired by the air pollution they breathe on the way to school. [60,61,62] Air pollution is associated with increases in the delinquent behavior of adolescents, much like lead, [63] and we should be just as concerned about lead in the air our children breathe as we are about lead in the water they drink.[79] Air pollution and a more deprived social environment combine to contribute to lower intellectual scores in children. [64]

More studies showed air pollution's strong association with Alzheimer's, dementia, and the anatomic changes in the brain associated with these disorders. [65,66,67,68] Air pollution has been calculated to be responsible for about 20% of Alzheimer's disease overall, adding an especially strong risk for women, increasing their chance of the disease about 100%. [69] There is emerging evidence that air pollution aggravates symptoms of Parkinson's disease. [70]

Air pollution is associated with higher risk for developing and seeking treatment for mental disorders like anxiety and depression and a much higher mortality risk for those with mental health and behavioral disorders, including suicide. [71,72,73,74,75,76]

CHILDREN

Most of the increased mortality from air pollution occurs in adults. Far fewer studies have been done exploring possible increased rates of infant mortality. A new study adds significantly to the evidence that air pollution also contributes to infant mortality. Almost 500,000 infants were tracked for over 6 years. Researchers found a very strong association between small increases in PM2.5 and total infant deaths, respiratory deaths, and SIDS. Specifically, 1.3 ug/m3 increases in PM2.5 increased the rate of these outcomes between 200% and 300%. [77]

This distressing outcome might be furthered by what we learned about how inhalation of particles is different depending on the age of the person. Particle deposition is highest in an infant, less in an older child, and lowest in an adult. [78]

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PREGNANCY, FETAL DEVELOPMENT

Numerous studies added to the now overwhelming evidence that air pollution is a significant risk factor for just about every type of pregnancy complication and adverse outcome--premature birth, low birth weight, hypertension of pregnancy, intrauterine growth retardation, smaller placentas, reduction in the placental blood supply, still births and birth defects. [79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94] Even air pollution exposure of a mother prior to conception has been shown to cause an increase in certain types of birth defects, especially of the heart. [95]

Particulate pollution has been linked to 2.7 million preterm births per year, 18% of all pre-term births in the US.[96] This represents a substantial public health menace because it increases the risk of numerous adult onset diseases, impaired organ development, and an enormous economic liability.

Both chronic and acute ozone exposure during pregnancy increase the risk of still birth, as much as 39% even at levels below the EPA's standards. Even the ozone levels in the week prior to delivery increase the risk. Extrapolating from this research to Utah indicates about 100 still births a year occur in Utah due to our ozone, not counting the risk of PM2.5. [97]

There is growing evidence that the most potent toxin in urban air pollution, especially regarding pregnancy and fetal development, may be the chemicals attached to particulate matter, like PAHs (polycyclic aromatic hydrocarbons), rather than the particles themselves. [98] This is more evidence that not all air pollution is created equal, and we should be paying much more attention to those sources that create high levels of PAH pollution--i.e. wood smoke, and industrial pollution.

TOXICITY TO GENES

Because almost all organs are at critical and vulnerable stages of development during pregnancy, in addition to altering pregnancy outcomes, even brief air pollution exposure during pregnancy can have lifelong consequences to a baby in utero, setting the stage for chronic diseases later on during childhood and adulthood, and a shortened life expectancy. The biological mechanism centers on the alteration of genes, and gene expression or “epigenetics,” a term used to describe the microbiologic environment that surrounds the genes, and molecules that are attached to them, and can program their activity. Like genes, epigenetic changes can be passed on to subsequent generations. Numerous studies in 2017 added strong evidence for this phenomenon having real clinical significance.

Telomeres are repeating sequences of DNA at the ends of chromosomes that provide a marker of biological aging or life expectancy. Another new study showed that prenatal air pollution is associated with shorter telomere length in newborns, biologic evidence that their life expectancy has been shortened even before they are born. [99]

In utero exposure to air pollution, specifically diesel exhaust, has been shown in animals to lead to heart failure in adulthood, and the likely mechanism is the alteration of genes that play a role in the function of heart cells. [100] Air pollution exposure of a pregnant mother increases the likelihood of obesity later in childhood, [101] and can affect the function of the thyroid gland which is critical to normal growth and brain development. [102]

Exposure after birth can continue to alter gene and epigenetic function, providing a mechanism for impaired organ function and inflammation. [103, 104, 105, 106, 107, 108] The window of opportunity for air pollution to shorten telomere length and therefore life expectancy continues with exposure during childhood and adolescence [109 and] perhaps throughout adulthood.

MISCELLANEOUS EFFECTS

The most toxic type of particulate pollution is the ultrafine subset, i.e. less than 0.1 micron in size. Ultrafine pollution is associated with increased rates of inflammatory bowel disease, [110] and another study reveals at least one likely mechanism. When ingested, ultrafine pollution alters the microbial makeup of the bowel, and increased atherogenic lipid metabolites. [114]

In 2017 we saw the first study we know of to show that osteoporosis is associated with air pollution exposure, [111 and] we saw the beginning of research that shows air pollution impairs kidney function. [112] Given that inflammation is the biological pathway through which air pollution causes many diseases, for a new study to find an exacerbation of lupus with air pollution is not at all surprising. [113]

A NEW RECOMMENDATION FROM THE RESEARCH

We'd like to finish our report on a positive note. There is sufficient research to recommend anti-oxidants as part of a healthy diet to help offset the inflammation triggered by air pollution. A new study in mice shows that an anti-oxidant in grapefruit reduces the DNA damage and oxidative stress in heart cells, and the tendency for blood clot formation caused by diesel exhaust. [115 This] is just one study, but we don't see any down side to eating more grapefruit, and it just might help.

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