With 80% of the world’s population living in regions that exceed World Health Organization (WHO) air quality guidelines (AQG), air pollution is a serious global health concern. Scientific evidence shows that air pollution can have a negative impact on cardiovascular health and can lead to other serious health issues for people worldwide. Air pollution is expected to become a central focus of government regulation and environmental reform. To control and reduce emissions at their source is ideal, but very challenging to practically implement. However, new science suggests that nutrition-associated solutions, in particular micronutrients and long-chain poly-unsaturated fatty acids (PUFA, i.e. fish oil), can play a role in tackling the detrimental cardiovascular effects that people can suffer having been exposed to polluted air.
Inhaling polluted air, especially air containing particulate matter of a diameter smaller than 2.5 µm (PM2.5), constitutes an environmental risk that has a proven impact on the quality and duration of human life. In a recent study, global exposure to ambient PM2.5 mass was estimated using data collected from several satellite instruments. The analysis concluded that global population-weighted ambient PM2.5 concentrations increased by 0.55 µg/m³ per year from 1998 until 2012. The WHO Interim Target-1 for PM2.5 concentration is 35 µg/m³. Of the population in East Asia, 70% lived in areas above this level between 2010 and 2012.3

Reduction of PM2.5 emissions requires many coordinated efforts and resources including education, novel and affordable technology, legislation and law enforcement and, most importantly, precious time. In the United States, according to the Environment Protection Agency, it took over 12 years to achieve a 37% reduction in PM2.5 concentration.4 Meanwhile, in countries, such as China, even the most aggressive plan to lower PM2.5 would only achieve a 25% reduction by 2017.5 Therefore, a significant proportion of populations worldwide will remain exposed to levels of PM2.5 well above the WHO recommendations for the coming years.
Negative long-term effects of air pollution on cardiovascular health

Air pollution is made up of a complex mixture of gases and particles, which among others include ozone, nitrogen dioxide, particulate matter, carbon dioxide, lead and sulfur dioxide. Of these, ozone, nitrogen dioxide and particulate matter are the main pollutants which constitute health problems.

Particulate matter, also known as particle pollution or PM, is a mixture of extremely small particles and liquid droplets. These particles are mainly emitted when fossil fuels (especially coal and petroleum) and biomass are combusted and some are so small they can only be detected using an electron microscope. PM2.5 consists of a complex mixture of solid and liquid components, with organic and inorganic substances including sulfate, nitrates, ammonia, sodium chloride, carbon, mineral dust and water. According to the 2005 WHO Air Quality Guidelines, exposure to PM2.5 at the 35 µm/m³ level is associated with an approximately 15% increase in mortality risk, relative to the AQG of 10 µm/m³.7

In sensitive populations, such as people with diabetes or the elderly, exposure to PM2.5 for even a few hours or days can trigger cardiovascular-disease (CVD)-related deaths from heart attack, stroke, arrhythmia, sudden cardiac arrest and heart failure. For example, air pollution has recently emerged as a leading risk factor for strokes worldwide, being associated with about a third of global strokes in 2013.8

Carrying many toxic substances, PM2.5 can evoke a series of responses locally and systemically when inhaled. These can include exacerbation of asthma, chronic obstructive pulmonary disease (COPD), decreased lung function and increased risk of heart attacks. At the cellular and molecular level, exposure to PM2.5 causes an increased inflammatory response and a decreased anti-oxidative capability which would normally counteract free radicals (reactive oxygen species, ROS), leading to oxidative stress.9,10 Acceleration of the inflammatory processes in response to the formation of, and increase in, ROS can cause additional cell damage, which may lead to non-communicable diseases, such as CVD.11

The long-term effects of air pollution on the human body are considerable. Both short- and long term exposure to pollutants is associated with increased respiratory afflictions, cardiovascular mortality and the risk of several chronic diseases, including diabetes and cancer, via oxidative stress and inflammatory mechanisms. WHO reported that around 7 million people died in 2012 as a result of air pollution exposure, which equated to one in eight of the total number of global deaths.12 Also, it is widely recognized that some population groups, such as older adults, children and those already suffering from illnesses like asthma and diabetes, are especially vulnerable to the harmful effects of air pollution. Air pollution is also a serious issue for expectant mothers; for example, increased exposure to air pollution has been linked to a reduction in the size of babies delivered.13
Air pollution and cardiovascular health: new evidence on nutritional solutions

Specific nutrients help reduce the risk of cardiovascular damage resulting from pollutants

Cardiovascular health is one of the biggest consumer health concerns, with many people turning to dietary supplements as a safe and effective way of looking after their hearts. There are specific nutrients available to help maintain cardiovascular health, but many heart health products available today only address blood pressure or cholesterol. A European Food Safety Authority-approved, natural, functional ingredient is now commercially available that supports healthy blood circulation, thereby helping to reduce the risk of blood clots. The product is backed by human volunteer studies that have demonstrated the potency and bioavailability of active compounds in a water-soluble tomato extract in significantly inhibiting platelet aggregation.

IN THE BRAIN
• May constrict blood flow to the brain, stopping it from meeting metabolic demand

IN THE HEART
• May create irregular heartbeat
• May lower blood flow to the heart muscle via the coronary arteries
• May increase the risk of non-fatal heart attacks

IN THE LUNGS
• May induce inflammation and oxidative stress

IN THE BLOOD
• May alter flow of blood through to the heart and blood vessels
• May increase the risk of forming blood clots
• May reduce oxygen saturation

IN THE VASCULATURE
• May harden arteries
• May hinder arteries and arterioles from widening fully in response to an appropriate stimulus
• May constrict blood vessels and create hypertension

VITAMIN C
Acts together with vitamin E as an antioxidant system.

OMEGA-3s PUFA
Helps improve cardiovascular health.

VITAMIN E
Helps protect against free radical damage and has an important role in anti-inflammatory processes.

The activation of blood platelets leads to hemostasis and major arterial disorders.
The solution can smooth blood platelets, reducing the risk of blood clots and other cardiovascular events.

Nutrition profiles to counter the negative health impact of air pollution

The reduction of air pollution plays the most substantial role in disease prevention, however, there are additional ways to counteract its negative effects on human health. Nowadays, people’s eating behavior, including the consumption of more prepackaged foods, results in a nutrient profile that is deficient or inadequate in beneficial nutrients, such as antioxidants and omega-3 EPA and DHA. Despite the prevalence of diets high in energy in more developed countries, people seem to find it difficult to meet adequate intakes of essential micronutrients. For example, typical Western diets are low in fruit and vegetables, wholegrains and fish, but are high in saturated fats and refined carbohydrates. Without proper nutrition, people are more susceptible to the damaging effects of pollutants, which can trigger the development of chronic diseases. Optimizing the intake of micronutrients, antioxidants and omega-3 EPA and DHA may reduce inflammation, and therefore reduce the risk of developing the associated diseases.

Several scientific studies have highlighted that some micronutrients, such as omega-3 EPA and DHA, B vitamins and vitamins C and E, may reduce oxidative stress. In addition, various combinations of micronutrients may prevent the impact of PM2.5 exposure on different aspects of health. For example, omega-3 EPA and DHA alone may reduce oxidative stress, improve heart function and HRV decline induced by PM2.5 exposure. B vitamins may prevent the decline of HRV and vitamin E and C may also reduce PM2.5 induced oxidative stress.

Disclaimer: claims made above are valid only for the EU. 14,15
Air pollution and cardiovascular health: new evidence on nutritional solutions

**Did you know?**

- **Fish oil may prevent HRV reduction associated with PM2.5.**
  In a double-blind clinical trial, 50 subjects over 60 years old were randomized to receive 2g of fish oil or 2g of soy oil (the placebo) for a period of six months. For every 8 µg/m3 increase in PM2.5, the corresponding reduction of HRV-HF (heart rate variability-high frequency) before supplementation was 54%. After five months of fish oil supplementation, the reduction was only 7%. In other words, a 47% reduction of HRV-HF was prevented by fish oil, compared to 31% by the placebo.16

- **Vitamin E and omega-3 EPA and DHA may protect against PM2.5-induced oxidative stress in vascular endothelial cells.**
  In an in-vitro experiment in China, supported by DSM, it was found that vitamin E and omega-3 EPA and DHA may block the inflammation and oxidative stress caused by ambient PM2.5. This inflammatory response and oxidative stress can be associated with PM2.5-induced vascular endothelial dysfunction.17

- **Air pollution and biomarkers of nutrient availability may have an effect on CVD indicators.**
  There is ongoing research to understand the effects of air pollution and biomarkers of nutrient availability on chronic inflammation and CVD indicators. For example, a human cohort sample analysis using air pollution data from prior air monitoring campaigns in Pittsburgh – combined with regulatory pollution data – has shown that the level of air pollution exposure may be associated with systemic inflammation and the incidence of CVD. Further, there is early evidence that circulating levels of omega-3 fatty acids, vitamin E and carotenoids have the potential to improve this relationship.18

- **Gene expression levels may be linked to air pollution exposure in elderly people with CVD.**
  In an exploratory analysis, gene expression was measured in 43 elderly subjects with CVD living in the Los Angeles air basin for a period of 12 weeks. This provides preliminary evidence of a positive association between traffic-related pollutants and the Nrf2-mediated oxidative stress response pathway.19

The potential health and economic benefits of establishing nutritional approaches (e.g. dietary supplementation) to air pollution management are high.

**Szabolcs Péter**
Senior Scientist, DSM

The findings of a number of human studies are encouraging and a good basis for further work to determine optimal combinations of nutrients to prevent or reduce the impact of PM on different aspects of health.

**Lisa Wood**
A leading expert on asthma and respiratory diseases at the University of Newcastle (UoN), Australia

**Conclusion**

With scientific evidence demonstrating the promising health benefits provided by desirable micronutrient and antioxidant intake to combat the global health threat of air pollution, it is essential that investment into research on nutritional solutions and collaborations by scientific communities, industry bodies and governments is continued. These findings do not reduce the responsibility of polluters or remove the pressure from authorities that legislate and enforce environmental protection policies and regulations. However, nutritional supplementation is simple and inexpensive, and may help in minimizing some of the harm caused by PM2.5 exposure in the interim prior to reaching compliance with the WHO AQG.

DSM offers a number of nutritional solutions that may help to counter the harmful effects of air pollution on the human body, including a broad portfolio of nutritional lipids, vitamins and natural extracts.

**KEY TAKE-AWAY MESSAGES**

- Air pollution is a global challenge
- There are specific nutrients to help reduce the risk of cardiovascular conditions
- There are diet profiles rich in beneficial nutrients, such as vitamin E with antioxidant properties and omega-3 EPA and DHA, that help counter the negative health impacts induced by air pollution
Air pollution and cardiovascular health: new evidence on nutritional solutions

TalkingNutrition provides news, views and insights to the global food industry on real-time science, technical breakthroughs and consumer trends, as well as event updates. As DSM’s ‘voice’, it includes contributions from both DSM and external experts. It is also a resource hub, directing readers to the latest webinars, whitepapers, infographics and videos as well as market surveys and relevant product information.

For more information please visit: www.talkingnutrition.dsm.com, or the dedicated social media platforms on LinkedIn, Facebook and Twitter (@DMSNutrition).

References

1. van Donkelaar A, Martin RV, Spurr RB, Burnett RT. High-resolution satellite-derived PM2.5 from optimal estimation and geographically weighted regression over North America. Environ Sci Technol. 2015 Sep 1;49(17):10482-91.
18. Client to provide reference

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