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Air and Fire – the Roles of Two of the Ancient 'Elements' in Keeping our Skies Blue

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International Day of Clean Air for blue skies, 7 September 2020:[1] The resolution[2] adopted by the UN in deciding to observe this annual International Day for the first time in 2020 stresses the urgent need to raise public awareness at all levels and to promote and facilitate actions to improve air quality, bearing in mind that clean air is important for the health and livelihood of people. It is mindful that air pollution is the single greatest environmental risk to human health and one of the main avoidable causes of death and disease globally, recognizing also that air pollution disproportionately affects women, children and older persons, and concerned also by the negative impact of air pollution on ecosystems.

Much of the atmospheric pollution that the world experiences is caused by combustion – and chemistry has played a central role in understanding the nature of air and fire, the relationship between them and the consequences for the composition and properties of the atmosphere. In ancient times, Air and Fire were widely considered by philosophers in different cultures to be among a handful of 'Elements' – 'Platonic solids' in ancient Greece – (others included Earth and Water, and sometimes the Void) that combined to made up all the substances in the world. Fire was made use of for heat, light, cooking and, as technology advanced, increasingly for the manipulation of materials such as clays and metals and to create pressure in steam and internal combustion engines to drive motive power. Air remained mysterious, its roles in atmospheric wind, respiration and combustion only starting to emerge with the development of science from around the 16th Century. The advancement of chemistry knowledge in the 18th Century was closely connected with the discovery of oxygen and its role in combustion, while later studies have explained the chemical processes that take place during partial or complete combustion and the complex nature of the materials produced.

Throughout history, people have behaved as if the atmosphere is an infinite sink, with an unlimited capacity to absorb wastes emitted by combustion, as well as by other agricultural and industrial processes. But we now know that this view is wrong. The substances emitted into the air, including many gigatons per year of oxides of carbon, nitrogen and sulphur, as well as micro- to nano-sized particles of soot and other materials from combustion, do not simply disappear. They circulate in the atmosphere for long periods of time, filtering out sunlight, absorbing heat, warming the atmosphere, acidifying rain and oceans.

This has changed conditions on the planet in the last two centuries, raising global temperatures and impacting on weather patterns, making extreme weather events more frequent and more damaging. Climates have shifted, making agriculture more difficult or impossible in some areas and melting glaciers to raise sea levels and cause inundation of many low-lying coastal areas and islands. Forest fires have become more frequent due to higher temperatures, dryer conditions and increases in lightning strikes – the massive damage to natural habitats, lives and property in Australia and California being among recent, dramatic examples. Air pollution has affected the health of many people, with illness and death caused by lung and cardiovascular diseases and cancer resulting from inhalation of fumes from poorly ventilated indoor fires, from the build-up in urban centres of complex mixtures of toxic gases and particulates emitted from petrol and diesel engines, and from the toxic smogs and aerosols formed by the products from urban, industrial and agricultural combustion of fuels and waste materials. According to the World Health Organization, 9 out of 10 people in the world breathe air containing high levels of pollutants and around 7 million people die every year from this exposure.[3]

The urgency of dealing with the problem of air pollution has now become extreme. The evidence[4] is clear that atmospheric emissions caused by human activities are causing global warming and profound changes to the Earth's climate, contributing to the mass extinction of species and damaging human health, wellbeing and economic progress. Countries have dragged their feet in implementing the 2015 Paris Agreement[5] which was designed to slow the greenhouse gas emissions and limit the rise in global average temperature to below 2°C.The pace of climate change is accelerating[6] and it is feared that safe planetary boundaries[7] will be greatly exceeded and some critical tipping points will be reaching in coming decades that will result in massive, catastrophic changes to the planetary environment.

The overall solution to the challenge of planetary air pollution requires more than incremental reductions within a business-as-usual approach. It is essential that the disposal of unwanted matter from combustion and other polluting industrial and agricultural processes by discharge into the atmosphere is brought to an end as quickly as possible. Chemistry must be central to developing better approaches.

The IOCD Action Group, *Chemists for Sustainability* (C4S)[8] has emphasised the need for the 'waste' culture is replaced by a 'post-trash' culture.[9] A comprehensive approach is urgently needed to tackle historic problems created by previous failures to manage waste and to institute better policies and practices now and for the future. Action is needed to *clean up* the pollution that has already been created, *catch up* by improving inadequate current approaches to waste generation and management, and *smarten up* by developing ways to design out waste and innovate for clean technologies and products designed to be more readily returned and recycled into valuable uses. As an example, C4S has presented detailed case studies of the production, use and disposal of aluminium, plastics and textiles, highlighting successes and remaining challenges in working towards maximum circularity and sustainability of each of these materials.[10]

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