ENVIRONMENTAL SIGNIFICANCE OF TOXIC TRACE ELEMENTS FROM FOSSIL FUEL COMBUSTION

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Keywords: Toxic trace elements, fossil fuel combustion, environment, pollution, air quality, emissions, metal pollutants, aerosol particles, methylation.

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Summary

Toxic trace elements from fossil fuel combustion impact on the environment almost exclusively as suspended particulate matter (SPM). Metal pollutants from coal and crude oil, transported in the air, contaminate soils and water producing metal ions in solution that can be absorbed by plants and animals.

Humic and clay colloids in soils have strong adsorption of metal ions and the duration of contamination may be for hundreds or thousands of years. Fortunately, the major impact of these contaminants are geographically limited by the dispersion of SPM and so offer the possibility of treatment of this region like a “closed environmental system” for modeling approaches with epidemiological methods in the case studied.

1. Basic Concepts

Combustion processes are the main source of anthropogenic air pollution. They are used for generating energy in industrial and power plant furnaces, in vehicular combustion engines, in airplane engines and in domestic heaters.

Although combustion of fossil fuels can generate liquid and solid pollutants, the environmental significance of air pollution is higher since, once the pollutants are in the air, exposure cannot be easily avoided.

It has been known for a long time that people with certain occupations, like miners, contract diseases of the lungs and respiratory system. Looking back, today we know that many of these effects were not only induced by fine particles and toxic metals, but also by carbon monoxide. It appears that radon gas was one of the components of the miners' lung disease in the Erzgebirge Mountains in Central and Eastern Germany, between the fifteenth and twentieth centuries.

With the rise of industrialization in the late eighteenth and nineteenth centuries, the effects of air pollutant emissions were noticed in greater portions of the population; however, air quality management options, in other words, controls and prohibitions, generally lagged behind societal concerns for sanitation, water supply, and solid waste. We know that odors from the Thames River in the late 1850s were reported to make life in London almost intolerable. Industrial centers like the Ruhr Valley in Germany were known to cause significant impact on life in general, and health and local appearance in particular.

1.1. Air Pollution

Air pollution is a general term that describes the admixture of potentially harmful substances within the air we breathe. The most well-documented of these substances (and those usually monitored on a routine basis) include sulfur dioxide (SO_2), nitrogen oxides (NO_x, including NO and NO_2), carbon monoxide (CO), ozone (O_3), lead (Pb), and total suspended particles (TSP, also known as suspended particulate matter, or SPM, of which the respirable particles are of most concern, e.g. particulates of up to 10 μm in size, or PM_{10}). The major sources of these pollutants are the combustion of fossil fuels for energy generation, industrial processes and transportation, and solid fuels, such as coal and wood, used for domestic purposes.

1.2. Criteria and Non-Criteria

Today, in the public health field, the six contaminants above are named "criteria" air pollutants. The criteria pollutants have been studied in some cases for over 100 years and their human health and vegetation effects are fairly well documented.

The "non-criteria" pollutants are those other contaminants designated as toxic or hazardous by legislation or regulation. They fall into two further categories depending upon the legislation, which defines them. In general, the hazardous air pollutants (HAPs) may pose a variety of health effects (irritation, asphyxia, etc.), whereas the "toxic aspect" focuses on one physiological response (i.e. toxicity).

These non-criteria air pollutants have been studied in industrial hygiene settings. In the ambient air, non-criteria pollutants tend to be several orders of magnitude lower in concentration than the criteria pollutants. For instance, it would be uncommon to find ambient carbon monoxide in the range of parts per million, whereas ambient concentrations of hazardous air pollutants, as benzene, would be in the range of parts per billion.

Criteria Pollutants	**Noncriteria**
Few (6)	Potentially numerous
Not bioaccumulated	Some may bioaccumulate
Lung is primary target organ (except CO)	Many target organs
Human health effects readily available	Human dose-response data rarely available
Effects generally occur from minutes to months after exposure	Effects generally occur after long latent period (years)
Presents global effects	Geographically restricted

Table 1. Criteria and hazardous air pollutant comparisons

There are differences between how criteria pollutants and non-criteria pollutants act. Prior to an evaluation of specific pollutant effects, it would be instructive to differentiate between these two types of air pollutants. Table 1 summarizes these differences. Lead, a criteria pollutant, is the exception to this discussion, since it is obviously toxic.

In general, criteria pollutants have a known threshold dose, below which no adverse health effects are known to remain after cessation of exposure. With respect to carcinogens, there is no known threshold to which we can point with confidence.

In comparison to the non-criteria or hazardous air pollutants (HAPs), which are potentially numerous, there are only six criteria air pollutants. Other significant differences are that the gaseous criteria pollutants occur in the ambient air at the parts per million level, whereas the others tend to be in the parts per billion level. Indeed, it has only been with the advent of modern technology that we have been able to regularly and routinely monitor these trace contaminants in the ambient air.

The criteria pollutants are not bioaccumulated in tissues, whereas some of the others have the tendency to bioaccumulate. This may have significant impacts on long-term health with respect to air toxic particles.

The lung is the primary target organ for criteria pollutants (with the exception of carbon monoxide). The non-criteria or hazardous air pollutants, on the other hand, have potentially many target organs.

Human health effects data have been available for the criteria pollutants since they have been studied not only in the ambient air (in some cases for over 100 years), but also in occupational exposures. With respect to the HAPs, there are much fewer human health data available, particularly for dose-response relationships of carcinogens, mutagens, and teratogens.

The effects of the criteria pollutants tend to last a period from minutes to months, whereas the HAPs tend to have long-term effects.

1.3. Emissions

Emissions are air contaminant mass releases into the atmosphere from a source. They may be from a tail pipe, vent, or stack, though some may be airborne, such as those from aircraft. Emission regulations are expressed in one of two ways; the first is by a mass emission rate, such as pounds per hour, tons per year, or milligrams per second. Or they may be expressed in terms of a concentration, such as parts per million or grains per standard dry cubic foot (g / SDCF).

Constituent	Chemical Formula	Percent by Volume	Parts Per Million by Volume
PERMANENT GASES			
Nitrogen	$\mathbf{N_2}$	78.084	
Oxygen	O_2	20.946	
Argon	Ar	0.934	
Neon	Ne		18.2
Helium	He		5.2
Krypton	Kr		1.1
Hydrogen	H_2		0.5
Nitrous Oxide	N_2O		0.3
Xenon	Xe		0.09
VARIABLE GASES			
Water vapor	$\mathbf{H_2O}$	0.01 – 7	
Carbon dioxide	CO_2	0.035	
Methane	CH_4		1.5
Carbon monoxide	CO		0.1
Ozone	O_3		0.02
Ammonia	NH_3		0.01
Nitrogen dioxide	NO_2		0.001
Sulfur dioxide	$\mathbf{SO_2}$		0.0002
Hydrogen sulfide	H_2S		0.0002

Table 2. Composition of the clean atmosphere near sea level

Standards for either expression are set by regulation, depending upon the air contaminant, the source and the regulatory jurisdiction. Mass emission rates are calculated from a measured concentration and calculations of total gas flow per unit time. Emission standards expressed in concentration units were derived from early measurements of air pollutants at sources. In these early efforts to control air pollution, this was the quickest method to determine compliance at a source without having to quantify the mass emission rates.The reference clean atmosphere is indicated in Table 2.

2. The Epidemiological Model

Mass emission rates and ambient air quality concentrations are related according to the source/transport/receptor model. In the public health field, this is termed “the epidemiological model,” and relates a source through a mode of transmission to the receptor.Modeling of the transport phenomenon during which diffusion and dispersion occur yields a calculated downwind ambient pollutant gas concentration. Recent air quality management approaches for hazardous air pollutants and air toxic particles have used the epidemiological model to relate health effects to emissions by using various dispersion models.

Human exposure to pollutants in the air, water, soil, and food—whether in the form of short-term, high level episodes, or long-term low level exposures—is a major contributor to increased morbidity and mortality. The disease burden attributable to these exposures is not known with any degree of certainty, however, because levels of general environmental pollution fluctuate greatly. Methods for analyzing the relationships are incompletely developed, and the quality of available data is generally poor. Precise measures of the association between pollution levels and health outcomes are therefore rare.The ability to link health and environment data, and thereby to understand the relationship between the levels of exposure and health outcome, is clearly vital in attempts to control exposure and protect health. This capability is particularly important to countries in which issues of environmental pollution have traditionally taken second place to demands for economic development.

Standards and guidelines against which to assess levels of environmental pollution are now widely available. WHO (World Health Organization, Geneva) has developed environmental quality guidelines for different pollutants in the air (WHO, 1987), water (WHO, 1993), food (FAO/WHO, 1989), and the workplace (WHO, 1980, 1981, 1982, 1983, 1984, 1986). These guidelines are based on epidemiological and toxicological studies and indicate the maximum environmental levels, or the levels of human exposure, considered acceptable in order to protect human health.Many epidemiological studies have been undertaken to analyze the relationships between specific forms of environmental pollution and health outcome. Most of these have been in developed countries, and the methods used are not always easily applicable to other settings, especially if high quality data is unavailable.

The analysis of data on health and environment, as a basis for estimating the health impact of pollution and setting priorities for action, thus remains an urgent need in many parts of the world. To develop methods in the linkage of environmental and health data, using relevant epidemiological models as well as tools of environmental analysis, WHO started the HEADLAMP project (The Health and Environment Analysis for Decision-Making) in 1993.

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Biographical Sketches

Wanderley de Lima, born in 1937, physicist, has been working for twelve years as a researcher in the Physics Department of Universidade de São Paulo in the field of nuclear parts accelerator and solar energy. Since 1981, after joining the Nuclear and Energy Research Institute–IPEN-CNEN/SP, has been working in laser spectroscopy and nuclear techniques applications. Head of the Industrial Applications Department at IPEN, is in charge of research and development in the following areas:
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Dora de Castro Rubio Poli, born in 1949, physicist, PhD Doctor in Radioisotope Specializing in hydrology, has been working for 2 years as a researcher in the Physics Department of Universidade de São Paulo in the nuclear field. Since 1974, after joining IPEN-CNEN/SP (Nuclear and Energy Research Institute), has been working as researcher of the Industrial Applications Department, in the field of industrial and environmental applications of radioisotope and radiation. Technically responsible for projects in the radioactive tracer application for determination of groundwater recharge, dosimetry and application of radiation for flue gas treatment with electron beam accelerators. Lectures in industries and in Post-graduation courses at Universidade de São Paulo.