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Aerosolized Coal Fly Ash: Risk Factor for COPD and Respiratory Disease

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Authors' contributions

This work was a joint effort between the authors that is part of an ongoing collaboration aimed at providing scientific, medical, public health implications and evidence related to aerosolized coal fly ash including its use in the near-daily, near-global covert geoengineering activity. Author MW was primarily responsible for medical and public health considerations. Author JMH was primary responsible for mineralogical and geophysical considerations. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: Coal fly ash (CFA) is a significant contributor to ambient air pollution in India and China, but regulations require its trapping and sequestering in Western nations. Members of the public chronically exposed to aerosolized CFA are likely to have an increased incidence of respiratory disease, including chronic obstructive pulmonary disease (COPD). Our objective is to review the multiple chemical constituents of aerosolized CFA in connection with their potentiality to cause COPD and respiratory disease.
Methods: We review the interdisciplinary medical, public health, and scientific literature.
Results: Tropospheric geoengineering is and has been undertaken since the beginning of the 21st century, with increasing frequency and duration, without public discussion and without disclosure of the particulate matter composition being placed into the air we breathe, or its effects on biota including humans. Published data is consistent with the primary constituent being CFA, the toxic

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waste-product of coal-burning. We review and to bring together evidence spread throughout the medical/scientific literature that bears on the health risks posed by particulate matter, and especially CFA, aerosolized in industrial settings and in the troposphere during geoengineering activities and to consider in particular the potential consequences on chronic obstructive pulmonary disease (COPD) and respiratory disease.

Conclusion: Aerosolized CFA is a particularly hazardous form of deliberate air pollution. Ultrafine particles and nanoparticles found in coal fly ash can be inhaled into the lungs and produce many toxic effects including decreased host defenses, tissue inflammation, altered cellular redox balance toward oxidation, and genotoxicity. Oxidative stress and chronic inflammation can predispose to chronic lung disease. Recognition and public disclosure of the adverse health effects of geoengineering projects taking place in our skies, and their concomitant cessation will be necessary to prevent an ever-widening epidemic of COPD and other respiratory illnesses.

Keywords: Aerosols; coal fly ash; climate intervention; particulate air pollution; oncology; geoengineering; nanoparticles.

1. INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is now the third leading cause of death in the United States and the fifth leading cause of death world-wide [1,2]. Both prevalence and mortality rates of COPD continue to rise [3] despite increasing awareness of the importance of healthy lifestyles and implementation of regulations aimed at reducing toxic pollutants in the environment and in the workplace. Public health programs that focus on reducing total personal exposure to tobacco smoke, occupational dusts and chemicals, and air pollution are critically important [4]. So too are scientific investigations that identify previously unrecognized, but potentially causal agents for COPD; that is the purpose of this investigation.

Geoengineering is defined here as "the deliberate large-scale manipulation of the planetary environment," or more simply as "deliberate planetary intervention" [5]. To be more precise and meaningful, the definition of geoengineering should be broadened to include "weather and climate modification." Geoengineering is currently discussed in the scientific literature as some potential future activity that might involve spraying substances, such as sulfuric acid, high into the upper atmosphere (stratosphere) to reduce incident solar radiation [6]. The reality, however, is that geoengineering has been practiced covertly since the late 1990s, with ever increasing intensity and duration, not high in the upper atmosphere, but in the lower atmosphere (troposphere), which mixes with the air we breathe [7-9].

Seeding clouds with silver iodide or solid carbon dioxide (dry ice) to *enhance* nucleation of rain or snow is commercially employed in watershed enhancement [10], in agriculture [11] and recreational skiing [12], and was used during the Vietnam War to increase the monsoon rains so as to inhibit movement of troops and supplies [13]. Subsequently, the military developed the technology to *hinder* nucleation of rain or snow by blanketing the region where clouds form with pollution particles to keep water droplets from being able to coalesce, to grow massive enough to fall to Earth. Millions of people throughout the world have consequently witnessed ongoing geoengineering, i.e., jet-laid trails of particulate matter in the sky. Unlike aircraft contrails, which are engine-exhaust ice-crystals that rapidly disappear by evaporation, geoengineering particulate trails disperse, sometimes temporarily forming artificial cirrus-like clouds that further disperse to form a white haze in the sky [9]. Heavy spraying can cause a sky devoid of natural clouds to become overcast, sometimes with a brownish hue.

There is ample documentation of long-term and ongoing weather modification and geoengineering projects available to anyone who wants to review this evidence. Examples of such documents include "A Recommended National Program in Weather Modification [14], "Weather Modification: Programs, Problems, Policy, and Potential," (U.S. Senate) [15], "Weather as a Force Multiplier: Owning the Weather in 2025" (U.S. Air Force) [16], and "Executive Summary of the World Meteorological Organization Statement on Weather Modification [17]." Moreover, there are numerous U. S. Patents [18-20] and scholarly publications [13,21-23] pertaining to weather modification.

Although tropospheric geoengineering began as a strictly nationalistic military activity, for reasons not disclosed to the public, it has become a persistent and pervasive operation over much of the world. Officials provide no credible explanations for the aerial spraying, the reason it is being done, or the potential dangers to human and environmental health. The mainstream media and the scientific community are silent.

Not only is there no reliable information from officials, but there is deliberate misrepresentation [24]. One common deception ploy is to insist that the jet-sprayed aerial trails are jet-exhaust “contrails” consisting of harmless ice crystals. Aircraft exhaust contains water vapor which can form ice crystals provided the temperature is sufficiently low, the humidity is sufficiently high, and there is abundant water vapor in the exhaust. Under most conditions, especially with modern fan-jet engines, ice-crystal contrails, if they form, evaporate in seconds becoming invisible gaseous water.

Although the main particulate-pollutant substance used for geoengineering has been a closely guarded secret, there is cause for concern even without knowing its compositions. In order for particulate matter to remain suspended in the troposphere for reasonable periods of time, the particles must be in the micron or submicron size range. Pollution particles ≤ 2.5 µm across, i.e., $PM_{2.5}$, are adversely implicated in COPD and other disorders [25]. In recent years, the frequency and duration of the aerial spraying ramped-up to near-daily, near-global proportions, which caused us to have serious public health concerns.

One of the essential public health functions is the proper diagnosis and investigation of health hazards in the community [26]. The Precautionary Principle in Public Health asserts that the public should be protected from preventable health risks even before the full extent and level of exposure is known. Essential elements of the Precautionary Principle include taking preventive action in the face of uncertainty, shifting the burden of proof of safety to proponents of the activity, and exploring alternatives to the harmful action [27]. However, such health risks must first be recognized and characterized before warning the public that an activity may not be safe.

Aerial spraying witnessed as particulate trails across the sky has been of concern to millions of citizens since the beginning of the 21st century. In the absence of reliable information on the chemical composition and potential health-risks of the aerosol substance being sprayed, concerned citizens took post-spraying rainwater samples and had them analyzed at commercial laboratories. In most cases, only aluminum analysis was requested; occasionally barium was also requested and, rarely, strontium as well. As the aerial spraying became a near-daily activity in San Diego (USA), one of us (JMH) began a series of investigations aimed at ascertaining the composition of the aerosolized particles. Because the standard protocols for certified laboratory water analyses require filtration to remove particulate matter before measurements, it was evident that the rainwater had leached those three elements from some readily leachable particulate matter before falling to the ground. Comparing as ratios these Internet-posted 3-element analyses to corresponding experimental water-leach analyses of a likely aerosolize-substance provided the first scientific evidence that coal combustion fly ash is the main particulate-pollutant substance used for ongoing tropospheric geoengineering [7].

To understand by analogy the chemical process involved, consider the hypothetical example of finely powdered tea leaves being sprayed into the troposphere. Atmospheric moisture would “brew” the tea, extract tannin and other chemicals, which would come down as rain, with chemical signatures of tea; the rain would be tea, albeit very weak tea. Coal fly ash (CFA) forms principally by condensation in the hot combustion gases in the flue above the combustion chamber of coal-powered electric utilities and consists of a disequilibrium assemblage of typically anhydrous matter [28-30]. Water is capable of quickly extracting numerous toxic elements from CFA [31]. When CFA is sprayed into the troposphere, atmospheric water extracts numerous elements by leaching, which are brought down dissolved in rainwater and provide a chemical signature of the CFA. The more elements measured in rainwater, the more precise and unique the signature becomes. This is a significant signature as common windblown sands and soils are not readily and quickly leached by rainwater.

Every measurements made is necessarily related to some other measurement. Expressing a measurement as weight percent, for example, relates the specific measurement to the total sample weight. In laboratory water-leach experiments, the amount of water dilution is known as is the exposure time for lixiviation. But for aerosolized particulates leached by rainwater, relative aqueous dilution and exposure time are unknown variables. If one were to compare elements dissolved in rainwater with elements water-leached from coal fly ash in the laboratory, using weight percent or weight per volume as the reference, it would lead to variability caused by potentially different amounts of rainwater leach exposure-time and dilution. Expressing the same data as ratios relative to a common measured element in each sample, thought to be an unlikely contaminant of rainwater such as Ba, puts the measurements on a common basis for comparison. Ratio comparisons are also useful for solid samples, especially in instances where, because of sample rarity, hence minimal sample size, not all elements are able to be determined, or because the samples might have undergone reactions, such as oxidation, which might change their relative weight. Although ratios are useful for making comparisons to identify substances in the aerosolized particulate matter used for geoengineering, ratios are not useful in calculating human exposure dosage.

Ratio comparisons of post-spraying San Diego (USA) rainwater 8-element analyses provide further evidence of CFA geoengineering utilization by showing that the aerosolized particulate matter and CFA have similar water-leach characteristics [8,9].

Ideally, one should collect geoengineering particulate samples as the material is discharged from the aircraft. There are laboratories capable of such sampling; however, as government contractors/grantees their scientists do not seem to take notice of the aerial spraying. Nevertheless, there are ways to obtain samples of the material, either that which has directly fallen to Earth or which is brought down by some other material.

One “directly fallen” line of evidence that coal fly ash is the particulate-pollutant substance used for geoengineering is derived by comparing element-ratios measured in air-suspended dust collected outdoors on high efficiency air filters with corresponding element-ratios measured in a variety of European and American coal fly ash samples [8,9].

The idea that aerosolized geoengineering particulates can be “brought down” to Earth by some other material has its roots in the well-known chemical technique called co-precipitation. Co-precipitation is a well-established chemical/ physical separation technique useful for bringing down a trace substance whose relative abundance is too low to drop on its own or to be separated efficiently. Traces of plutonium, for example, can be separated from seawater by co-precipitation with much larger amounts of ferrous hydroxide [32]. Similarly, in water treatment [33] and dewatering [34] technologies, substances are added to cause coagulation and flocculation which permit separation by sedimentation/flotation. Recently, we demonstrated that snow-fall following aerial particulate spraying traps and brings down geoengineering particulates identified as coal fly ash which are released upon partial melting of the snow [35]. The generalization of this concept is that any material with a relatively high surface to volume ratio floating through the air where particulate-geoengineering is taking place can in principle trap and retain geoengineering particulates.

When coal is burned by utilities, it produces two types of ash, heavy ash that settles and fly ash that formally exited smokestacks in Western nations, but now, because of its toxic nature, must be trapped by electrostatic precipitators and sequestered. Cyclone-classifiers can be used to separate an ultra-fine component from the micron and submicron size CFA grains initially formed [36]. As one of the largest industrial waste streams, this substance is readily available throughout the world at low cost. Coal fly ash ranges from tan to dark gray in color and may be mixed with propriety additives to inhibit clumping caused by van der Waals forces [37,38].

When sprayed into the troposphere, convection currents mix the aerosolized CFA with the air we breathe [39]. Coal fly ash contains many toxic elements [29]. As discussed below, $PM_{2.5}$ coal fly ash, when inhaled, settles deep in terminal airways and alveoli and remains trapped there for long periods of time in which carcinogens, including radioactive elements, hexavalent chromium, and other leachable toxins potentially pose risk factors for COPD and respiratory disease, including lung cancer [40]. Here we report and provide evidence of the specific nature of the COPD threat arising from the use of aerosolized coal fly ash for tropospheric geoengineering.

2. METHODS

We review the interdisciplinary medical, public health, and scientific literature.

3. RESULTS AND DISCUSSION

Coal fly ash is a coal combustion product composed of fine particles driven out of the boiler with flue gases. In the modern coal power plant, CFA is collected by electrostatic precipitation. Under the microscope coal fly ash appears mostly as tiny spherical particles [41]. The main components of CFA are oxides of silicon, aluminum, iron, and calcium, with lesser amounts of magnesium, sulfur, sodium and potassium [3,29]. Mineral categories of fly ash can be divided into the following: (1) amorphous glass; (2) mullite ($3Al_2O_3$-$2SiO_2$) and quartz (SiO_2); and, (3) a magnetic fraction containing mainly magnetite (Fe_3O_4). The second and third category are crystalline phases and account for 25-30% of the total [42].

Among the trace elements are the following: arsenic, barium, beryllium, cadmium, chromium, lead, manganese, nickel, phosphorus, selenium, thallium, uranium, and zinc [3,29]. In addition, harmful polycyclic organic molecules, such as benzopyrene, are found in CFA in small amounts [43].

3.1 Coal Fly Ash Inhalation – Harmful Effects

Aerosolized CFA for geoengineering constitutes one form of deliberate air pollution. Exposure to ambient air pollution most certainly contributes to the growing global burden of COPD. Although smoking cigarettes is the most important cause of COPD overall, a substantial burden of disease is due to other risk factors. Occupational exposure to inorganic dusts increases mortality due to COPD even among never-smokers [44]. An Official Public Policy Statement by the American Thoracic Society concludes that specific genetic syndromes and occupations are associated with COPD prevalence, traffic emissions, and other outdoor pollution [45].

Air pollution world-wide is increasing at an alarming rate, accounting for one out of every nine deaths (the fourth leading cause of death), with 90% of deaths occurring in low-income countries where this type of pollution is becoming a public health emergency [46]. Even in the U.S., where air pollution levels are lower than the world average, ambient air pollution accounts for an estimated 200,000 premature deaths per year [47]. Short-term exposure to air pollution often leads to exacerbation of COPD and long-term exposure contributes to the development of COPD [48]. Outdoor air pollution contributes to the high incidence and prevalence of COPD in both the United States and Europe [49]. Long-term, cumulative exposure to fine particulate and sulfur oxide-related pollution in the U.S. is associated with all-cause, lung cancer, and cardiopulmonary mortality [50].

Some inferences on the consequences of CFA may be inferred from investigations of inhaled oil ash. Inhalation of residual oil fly ash (ROFA) has been shown to increase pulmonary morbidity and impair lung defense mechanisms in exposed workers. Animal studies show oil fly ash increases the susceptibility to infection and severely damages the lungs after pulmonary challenges with a bacterial pathogens [51]. Coal fly ash impairs immune mechanisms of bacterial clearance, specifically alveolar macrophage activity. Oxidant stress of lung cells is one of the primary mechanisms of particulate pollution-induced exacerbation of lung disease. Oxidant activation by particulate matter is cell-specific, with a particularly strong oxidant response of alveolar macrophages to oil fly ash [52]. Rat tracheal epithelial cells exposed to ROFA showed cytotoxicity mediated by reactive oxygen species with associated depletion of antioxidants like glutathione [53]. Deposition of particles in the lung from ROFA can produce pro-inflammatory cytokines leading to a systemic response that includes stimulation of bone marrow [54].

Recent in-vivo studies conducted in experimental animals document the pulmonary and systemic effects of coal fly ash. Inflammation with increased neutrophils (reactive white blood cells) in lung tissue and blood was induced in rats following short-term exposure to coal fly ash consisting of particulate matter PM_1 and $PM_{2.5}$. Histological examination of the exposed lung tissue revealed focal alveolar septal thickening and increased cellularity in alveoli beyond the terminal bronchioles [55]. Mice exposed to coal fly ash via the tracheal route showed increased lung mechanical impedance, inflammatory changes, and damaged DNA. These effects were associated with composition of the particles. Components of coal fly ash including chromium (Cr), iron (Fe), and nickel (Ni) were detected in liver, spleen, and brain of exposed mice, showing efficient transfer of these metals from the bloodstream to extrapulmonary organs [56].

Coal fly ash is known to contain iron [29], an important nutrient for bacteria. The successful functioning of antibacterial systems depends upon an extremely low level of free ionic iron in normal tissue fluids. Bacterial virulence is greatly enhanced by freely available iron, such as that in fully-saturated transferrin or free hemoglobin [57]. Coal fly ash reduces or delays bacterial clearance in vivo and in vitro, decreases antimicrobial peptides, and provides a source of iron for bacterial growth [58]. The toxic effects of CFA particles on alveolar macrophages and the ability of these particles to increase bacterial infectivity are associated with small size and the presence of metal in the particles [59].

Use of ultrafine grain sizes of aerosolized particulates for geoengineering is advantageous for increasing residence time in the convecting troposphere, but poses additional pulmonary health concerns. Ultrafine (0.1-1 μm) particles and nanometer-sized particles (<100 nm) are both found in CFA. Characterization of these particles by energy-filtered transmission electron microscopy has shown spherules embedded in a silica matrix with metals including aluminum, iron, and titanium [28]. A study of fractionated CFA revealed that nanoparticles have a greater ability to cause pulmonary inflammation and kill macrophages in cell culture compared to fine and coarse fractions [60]. The key to understanding the toxicity of nanoparticles is that their minute size, smaller than cells and cellular organelles, allows them to penetrate these biological structures, disrupting their normal function. Examples of toxic effects include tissue inflammation, and altered cellular redox balance toward oxidation, causing abnormal function or cell death [61]. Coal fly ash nanoparticles with surface adsorbed toxic heavy metal can act as cellular and DNA toxicant, capable of inducing inflammation, oxidative stress, DNA damage and cell death [62].

3.2 Mechanism of Particle Toxicity

Exposures to particles and fibers are associated with many lung diseases including COPD (chronic bronchitis and emphysema), pneumonitis, pneumoconiosis, mesothelioma, and lung cancers. All particles and fibers have the capacity to present an oxidative stress to the lung [63]. Among the characteristics shared by all of the particles introduced into the lung is the creation of a solid-liquid interface into the lower respiratory tract. Free radical production by fibers and particles in coordination with transition metals with two stable valence states can be observed at this solid-liquid interface [63-65]. For example, the same divalent character of iron that plays an important biologic role may also cause toxicity by sustaining oxidative conditions [66]. Radical generation catalyzed by metals associated with fibers and particles can result in a cascade of cell signaling, transcription factor activation, and mediator release [67-69]. Clinical manifestations of this process can present as inflammatory, fibrotic, and neoplastic disease.

3.3 Inhaled Particulate Matter and Lung Disease

Particulate matter (PM) is the generic term for the major portion of air pollution consisting of particles of chemicals, metals, soils, dusts, aerosols and acids. Quartz or crystalline silica, asbestos, and coal are the three major particle types historically linked to the majority of occupational and particle-induced diseases [70]. Inhaled durable particles and fibers have been of concern for over a century due to countless publications reporting lung diseases in trade workers and miners prior to the enforcement of permissible exposure levels in the workplace. It is now known that inhaled ambient particles are associated with adverse health effects, and their compositional components and biologic effects are undergoing intense investigation [71]. Man-made vitreous fibers (MMVFs) a large subset of man-made mineral fibers (MMMFs) are synthetic vitreous silicate fibers widely used in present-day insulation and the construction industry. The capacity for asbestos to induce pulmonary and pleural fibrosis is indisputable, whereas the evidence for this for MMVF's is limited. Adverse health effects from particles and fibers have focused on biochemical processes and alterations of host defense mechanisms [72].

Ultrafine particles and nanoparticles are small enough to pass through lung tissue directly into the bloodstream [71,73]. Beyond shape and size, increasing attention is be paid to particle/fiber chemistry as a determinant of variables such as dissolution behavior, ion exchange, sorption properties and surface reactivity [72,74].

As noted above, magnetite (Fe_3O_4) is a common constituent of coal fly ash. Transmission electron microscopy investigations revealed an abundance of magnetite nanoparticles among ultrafine coal fly ash particles [36]. There are a growing number of reports of pulmonary toxicity from inhalation of magnetite, including nano-particulate magnetite. Four different size fractions of magnetite on human alveolar epithelial cells showed effects including cytotoxicity, genotoxicity, and increased production of reactive oxygen species [75]. In another study lung epithelial cells were treated with various concentrations of magnetic nanoparticles. These results showed magnetite-treated cells vs. controls induced oxidative stress, depleted antioxidant levels, and affected the apoptotic pathway [76]. Long-term intermittent intratracheal spray of magnetite nanoparticles in rats revealed chronic inflammatory changes which occurred in a dose-dependent manner [77]. Subchronic inhalation toxicity of iron oxide in rats showed that pulmonary toxicity is determined by the particle kinetics typical of poorly soluble particles [78].

Further implications of the pulmonary toxicity of aerosolized coal fly are suggested by studies of asbestos, a fibrous silicate. Asbestos was widely used for more than 100 years and is still used in many countries despite alarming reports about its toxicity and carcinogenicity [79]. The presence of transition metals like iron in asbestos fibers and the ability of these fibers to attract iron from the surrounding environment may be key factors for asbestos toxicity and for the formation in the lung of the asbestos (ferruginous) bodies that characterize lung disease caused by asbestosis. Synchrotron-based scanning x-ray microscopy has demonstrated that long-lasting asbestos fibers and bodies cause a large mobilization of iron into the surrounding cells (mainly alveolar macrophages) and in tissue, partially a consequence of continuous iron adsorption onto the fibers and/or asbestos body degradation and metal release [66]. Iron (including magnetite) is an integral component of pathogenic amphibole (crocidolite, amosite) asbestos fibers and it occurs as a mineral contaminant of chrysotile (serpentine) asbestos [71,80]. Studies suggest that chrysotile is not toxic by simply acting as a carrier of iron into the cell, but rather the redox activity of iron is potentiated when organized at the fiber’s surface into specific crystallographic sites having coordination states able to generate free radical generation [81].

The respiratory tract is the system most commonly affected after exposure to PM, and particles increase the risk of human respiratory infections. One of the important mechanisms for particle-related infection is the accumulation of iron (Fe) by surface functional groups of PM, since the availability of this metal increases host susceptibility to pathogenic organisms [82]. Particulate matter in air pollution alters anti-mycobacterial respiratory epithelium innate immunity, possibly resulting in higher rates of active tuberculosis [83]. In vivo short-term exposure to residual oil fly ash (ROFA) impairs the immune response to non-tuberculous (or environmental) mycobacteria (NTM) [84]. When CFA arrives in the airway, it rapidly absorbs antimicrobial proteins and peptides (AMP's), thereby decreasing the functional amount of AMP's required to kill invading pathogenic bacteria [85].

Human health risk assessment for exposure to environmental toxins includes these steps [86]: 1) Hazard identification, 2) Dose-response assessment, 3) Exposure assessment, and 4) Risk characterization. This study identifies CFA, a known environmental hazard, as a secret and previously undisclosed material used in tropospheric aerosol geoengineering operations. This study is currently limited by the inability to quantify human exposure to this particular form of air pollution or to separate it from other forms of air pollution caused by human activity. A person’s level of exposure to air pollution depends on a variety of factors including physical condition, age, individual susceptibility, exposure concentration and duration, as well as on many complex interactions among host factors and the environment over time. Newer bio-monitoring techniques should enable more accurate measurements of exposure to specific air pollutants [87]. However, useful information concerning dose-response, exposure assessment, and risk characterization can be extrapolated from published data on the known toxic component-elements of CFA.

Forecasting public health disasters usually entails taking action in advance of strong proof of harm, particularly in the case of delayed and potentially irreversible harm, and especially in the case where healthcare costs might become excessive for society as a whole. The recognized approach toward such forecasting, now called the precautionary principle, places the burden of proof on the perpetrator of any environmentally questionable activity to show that it is in fact harmless [27]. Some of the major healthcare crises in the past might have been less severe had the precautionary principle existed and been exercised. Examples include poisonings by benzene, radium, and PCBs, cancer from asbestos, and mad cow disease, etc. [27]. Table 1 presents a brief instructional overview.

Table 1. Brief instructional overview

Risk Factors for COPD:	Occupational exposure to inorganic dusts, cigarette smoke, fumes/gases, and airborne pollutants including particulate matter (PM) and aerosolized coal fly ash (CFA)
Exposure to Aerosolized CFA:	CFA workers, persons living downwind of CFA dumps and boiler flue gases, populations exposed to covert CFA aerial geoengineering activities
COPD Harmful Components of CFA:	Radioactive elements, heavy metals, toxic and carcinogenic elements, nano-particulates, and iron compounds
Examples of CFA Interactions Affecting COPD:	Pulmonary inflammation, altered cellular redox balance, depletion of anti-oxidants, cellular toxicant causing abnormal functioning or cell death, alveolar macrophage dysfunction, bone marrow activation, DNA damage, cytotoxity, genotoxity, increased susceptibility to infection including altered anti-mycobacterial immunity, translocation of metals from lungs to other organ systems
Action Indicated:	Stricter emission standards, especially in developing nations Enact Precautionary Principle and halt aerosol geoengineering

The perpetrator of the aerosolized particulates, which evidence indicates is consistent with mainly CFA [35,88], has not only failed to show that this activity is harmless, but has misled the public about its dangers [89]. It is therefore incumbent upon the healthcare community to discuss the potential of delayed and irreversible harm arising from that activity.

It is highly likely that the perpetrators of the CFA aerial spraying are aware of the public health risks as virtually all Western nations require CFA to be trapped and sequestered, prohibited from exiting the smokestacks of coal-burning utilities, because of its toxic nature. Studies of the public health consequences of CFA now mainly focus on worker exposure and its accidental release from holding ponds and contamination of groundwater [90]. As noted above, a multitude of air pollution studies provide useful healthcare guidelines for aerosolized spraying of coal fly ash. Air pollution studies have shown that particles with the same range of diameters as aerosolized CFA, ≤ 2.5 µm, have been found to be associated with increased hospital admissions [91], morbidity and premature mortality [92-94], risk for cardiovascular disease [95], lung inflammation and diabetes [96], low birth weight [97], and reduced male fertility [98]. Moreover, CFA contains numerous carcinogens, including, for example, radioactive elements, arsenic, and chromium VI [99].

In most developed countries, healthcare personnel have become accustomed to rely on government notifications of impending health crises. In the case of tropospheric geoengineering with CFA, however, an ethical inversion exists, epitomized by hiding a potential danger from the health-care community rather than alerting it to the danger. Discussions among healthcare personnel might focus on ways to share observations and data, such as respiratory emergencies that might be related to aerosolized CFA, and to correlate such emergencies with air quality data. Public health organizations should consider ways to collate, analyze, and make public such information. It is unreasonable to expect candor and veracity from official sources directly or indirectly responsible for covert operations and their consequences, as 'national security' is an infallible trump card over all others.

Here we have investigated some of the potential public health hazards of aerosolized CFA, in the industrial context as well as its use in covert tropospheric geoengineering, focusing on the special risks for respiratory disease. Certainly there are many other serious medical concerns, including risk for lung cancer [40] and neurodegenerative disease [41]. Arsenic leached from coal fly ash can cross the placenta. There are possible consequences about which one can only speculate, e.g., spraying coal fly ash into the region where clouds form on a near-daily, near-global basis year after year will undoubtedly upset the complex and delicate equilibrium between and among Earth's biotas and their physical environments. Clearly, the only safe and healthy level for tropospheric geoengineering operations, like that for aerial nuclear detonations, is for none at all to take place.

4. CONCLUSION

The toxic mixture of substances in CFA poisons the air we breathe and grossly contaminates the rain that falls to earth. While geoengineering activities pose grave risks to Earth's biota and to human health in general, the impact upon respiratory disease is even greater due to the pathological processes described in this work. There has been a concerted, world-wide effort to conceal the full scope and danger of weather/climate modification projects from the public, but the effects of geoengineering have become an "undeniable reality" to those attuned to the natural environment. Considering the well-established and manifold toxicities of coal fly ash, there is an urgent need to enact the Precautionary Principle and call for an immediate halt on tropospheric and stratospheric aerosol geoengineering. The public must be made aware of the great potential danger to our health and to environment posed by covert geoengineering projects.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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