



## Role of Aerosolized Coal Fly Ash in the Global Plankton Imbalance: Case of Florida's Toxic Algae Crisis

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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 geophysical and mineralogical considerations. Both authors read and approved the final manuscript.*

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### ABSTRACT

Red tide is the term used in Florida (USA) and elsewhere to describe a type of marine harmful algal bloom (HAB) that grows out of control and produces neurotoxins that adversely affect humans, birds, fish, shellfish, and marine mammals. HABs are becoming more abundant, extensive, and closer to shore, and longer in duration than any time in recorded history. Our objective is to review the effects the multifold components of aerosolized coal fly ash as they relate to the increasing occurrences of HABs. Aerosolized coal fly ash (CFA) pollutants from non-sequestered coal-fired power plant emissions and from undisclosed, although "hidden in plain sight," tropospheric particulate geoengineering operations are inflicting irreparable damage to the world's surface water-bodies and causing great harm to human health (including lung cancer, respiratory and neurodegenerative diseases) and environmental health (including major die-offs of insects, birds

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and trees). Florida's ever-growing toxic nightmare of red tides and blue-green algae is a microcosm of similar activity globally. Atmospheric deposition of aerosol particulates, most importantly bioavailable iron, has drastically shifted the global plankton community balance in the direction of harmful algae and cyanobacterial blooms in fresh and salt water. Proposed geoengineering schemes of iron fertilization of the ocean would only make a bad situation unimaginably worse. Based on the evidence presented here, the global spread of harmful algae blooms will only be contained by rapidly reducing particulate air pollution both by implementation of universal industrial particulate-trapping and by the immediate halting of jet-sprayed particulate aerosols. Corrective actions depend not only on international cooperation, but on ending the deadly code of silence throughout government, academe, and media on the subject of ongoing tropospheric aerosol geoengineering. Long-standing weather control, climate intervention, and geoengineering operations have come to threaten not only all humans but the entire web of life on Earth.

**Keywords:** *Karenia brevis*; aerosol particulates; harmful algal blooms; red tide; blue-green algae; coal fly ash; particulate pollution; geoengineering.

## 1. INTRODUCTION

Red tides were a scourge during 2017-18, coloring the water, closing beaches, creating foul odors, killing innumerable fish and producing die-offs of birds and marine mammals. Red tide is the term used to describe a type of marine harmful algal bloom (HAB) that grows out of control and can produce toxic effects on humans, birds, fish, shellfish and marine mammals [1] (Fig. 1). In Florida (USA) red tides have become a toxic nightmare for the state, generating red alerts among fisherman, residents and coastal property owners, the tourist industry, and health officials [2].

Florida red tides are caused by the toxic dinoflagellate *Karenia brevis*, formerly known as *Gymnodinium brevis*. Red tides have been documented in Florida since the 1800's but have now spread to both Florida coasts, Mexico, and the Southeast U.S. coast [1]. *Karenia brevis* blooms have been shown to be several times more abundant, extensive, closer to shore, and longer in duration in Florida in the years 1994-2012 compared to 1954-1963 [3].

Related red tide dinoflagellates cause toxic blooms throughout the world, including red tides and other toxic species expanding into the Arctic [4]. *Karenia brevis* produces brevetoxins, neurotoxins that open up the sodium channels of nerve cell membranes, causing the cells to depolarize. Fish, birds, and mammals are all susceptible to these neurotoxins. Human health effects from red tide result from ingestion (neurotoxic shellfish poisoning) and inhalation of brevetoxin aerosols [5].

*K. brevis* is adept at utilizing both organic and inorganic nutrients. There is an ongoing

controversy concerning sources and contributing factors to blooms of *K. brevis*. The relative importance of nutrients from coastal rivers, non-point sources, and atmospheric deposition to these blooms is currently an intense area of research [6].

Historically, periodic blooms of red tide were stimulated by iron-containing "African dust" [7-9]. Here we review the evidence that the exponential growth of atmospheric pollution, especially of iron-containing coal fly ash (CFA) released into the atmosphere from coal-burning utilities and jet-sprayed into the atmosphere to geoengineer Earth [10-14], is the primary factor in the explosive growth of red tides and other HABs in Florida and elsewhere.

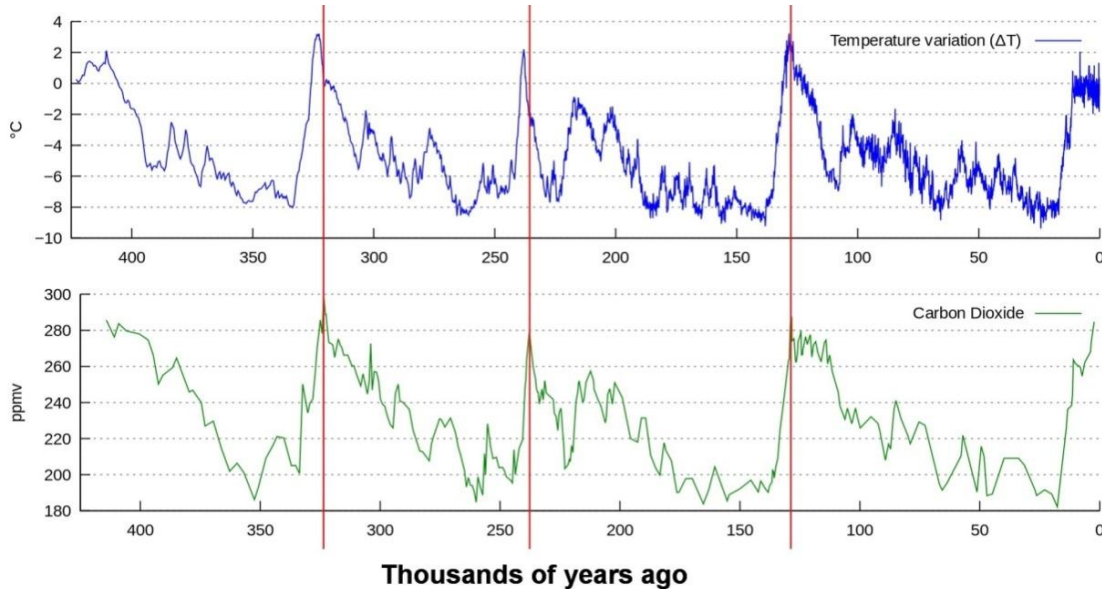
## 2. EXPLOSIVE GROWTH OF PARTICULATE POLLUTION

For the past three decades, the scientific community, without a sound scientific basis, has promoted the idea that anthropogenic carbon dioxide (CO<sub>2</sub>) and other greenhouse gases are causing global warming. Moreover and to the contrary, Antarctic ice-core data [15-17], shows that increases in temperature generally precede increases in CO<sub>2</sub>, not the reverse (Fig. 2).

For all ranges of salinity and temperature observed in ocean water, increases in temperature always lead to decreases in CO<sub>2</sub> solubility [11]. With increases in ocean water temperature, not only is less CO<sub>2</sub> absorbed by the ocean, but additional CO<sub>2</sub> is forced out of the ocean into the atmosphere by reduced CO<sub>2</sub> solubility. This indisputable behavior of CO<sub>2</sub> solubility in ocean water provides a powerful argument against the assertion that global warming is caused by atmospheric CO<sub>2</sub> [11].



**Fig. 1. *Karenia brevis* and *Trichodesmium erythraeum* Bloom, Offshore Lee County, Florida (USA), October 22, 2007. Photo courtesy of Florida Fish and Wildlife Conservation Commission**



**Fig. 2. From [11]. Temperature and carbon dioxide data from the Vostok ice-core [15-17]. Note that temperature rises before carbon dioxide, not vice versa. This figure shows compelling evidence that temperature rise results in a subsequent increase in atmospheric carbon dioxide content, in striking contradiction to the IPCC model-driven assumption that CO<sub>2</sub> causes global temperature increases. The rise or fall of CO<sub>2</sub> follows the increase or decline of Earth's variable heat, absorbed from above and produced from below**

If, hypothetically (and falsely), atmospheric CO<sub>2</sub> were the main cause of global warming, ocean heating would result, liberating more CO<sub>2</sub> into the atmosphere, causing further global warming and additional ocean heating, liberating yet more CO<sub>2</sub> into the atmosphere, causing still further ocean heating and CO<sub>2</sub> liberation, and so forth, in an endless chain reaction that would have occurred in the geological past, presumably only once with catastrophic consequences for virtually all biota, possibly excepting some species of bacteria. Instead, the paleoclimatic record shows a different cycle in which planetary heat rises and falls, followed by the rise and fall of CO<sub>2</sub>. Were CO<sub>2</sub> the driver of global warming and ocean heating, the proliferation of plants and ice-age events would only slow the inevitable runaway global warming and concomitant planetary destruction [11].

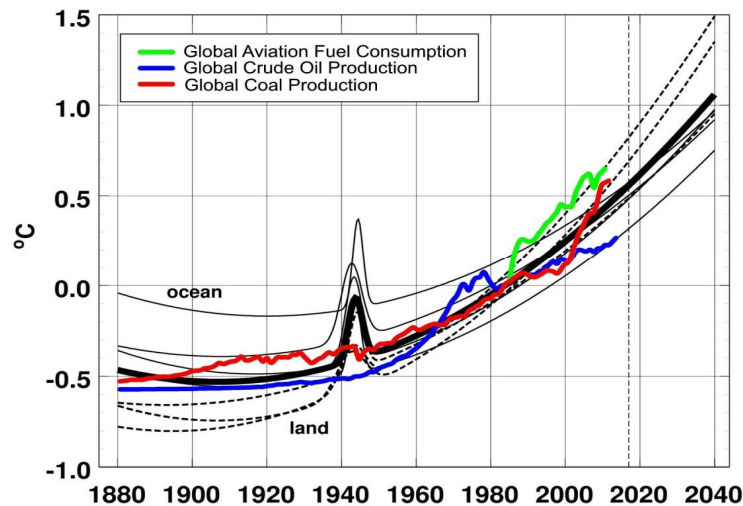
In a series of publications beginning in September 2018, evidence was presented to support the contention that global warming is caused principally by particulate pollution, not CO<sub>2</sub> [10-14]. The climate science community, not only failed to recognize particulate pollution as the prime-driver in global warming, but falsely claimed that particulate pollution cools the Earth and thus compensates for presumed CO<sub>2</sub>-caused global warming [18].

Harvard University physicist Bernard Gottschalk was inspired by an image on the front page of the January 19, 2017 New York Times showing a

“bump” coincident with World War II (WW2) in a thermal profile of relative Earth temperatures over time. By sophisticated curve-fitting techniques he demonstrated that the “bump” was a robust feature in eight NOAA data-sets, four land and four ocean, and concluded that the thermal peak “is a consequence of human activity during WW2” [19,20].

Inspired by Gottschalk’s work, one of us (JMH) showed that the WW2 peak could not have resulted from CO<sub>2</sub>, which has a decades-long lifetime in the atmosphere [21] and which Antarctic ice-core data showed to be of constant level during the period 1936-1952 [22]. Instead, warfare-generated aerosol particulates appeared to be involved in producing the observed WW2 thermal peak [10], which is understandable as warfare-produced aerosol particulates would fall to ground in days to weeks just like tropospheric pollution-particulates [23].

Support for the idea that particulate pollution is the primary cause of global warming came first by demonstrating that proxies for post-WW2 particulate pollution tracked well with the increases in global warming [10] (Fig. 3). Later, as the Mt. St. Helens’ volcanic plume passed overhead, daily high-temperatures decreased and nighttime low-temperatures increased, indicating that particulate heating of the atmosphere reduced the efficiency of atmospheric convective heat-loss from Earth’s surface [13,14].



**Fig. 3. Copy of Gottschalk’s fitted curves for eight NOAA data sets showing relative temperature profiles over time [19] to which are added proxies for particulate pollution. Dashed line: land; light line: ocean; bold line: weighted average. From [10]**



Accelerated post-WW2 industrial growth, initially in Europe and Japan, and later in China, India, and the rest of Asia dramatically increased worldwide aerosol particulate pollution, and concomitant global warming [24]. Currently, the main source of industrial particulate pollution is coal fly ash (CFA) that is exhausted unfiltered into the atmosphere by coal-burning utilities in India and China [25,26]. There is, however, another, more pervasive, covert, deliberate, CFA particulate contamination taking place to geoengineer Earth, wrongly justified in part by the false belief that pollution particles cool the Earth [14].

### 3. DELIBERATE GEOENGINEERING POLLUTION

Life is possible because of the myriad interactions by and between biological creatures and the variable and complex natural physical processes of Earth. Consequently, no one has the ability to geoengineer our planet that we depend upon for a healthy environment without

causing wholesale and irreversible devastation. However, geoengineering is in fact taking place on a near-daily, near-global basis with devastating consequences. One of the adverse consequences, as shown in this review, is disrupting the natural balance in aquatic systems giving advantage to harmful algal blooms (HABs) over “good phytoplankton.”

Fig. 4 shows jet-emplaced particulate-pollution trails in the sky above the Kennedy Space Center in Florida. Such deliberately placed tropospheric aerial particulate-pollution is now a common occurrence across North America, Europe, and other places.

In a time span of a few minutes to hours the trails spread out, for a time resembling cirrus clouds, before further spreading-out to become a white haze in the sky [27]. The fine-grained particles mix with and contaminate the air we breathe and settle to earth, slowly poisoning the soil and bodies of water [28].



**Fig. 4. Exterior view of NASA's Launch Control Center at Kennedy Space Center, Cape Canaveral, Merritt Island, Florida against a sky filled with jet-emplaced particulate geoengineering trails**

Forensic scientific investigations of the consequences of the undisclosed aerial spraying are consistent with their main aerosolized component being coal fly ash (CFA), a waste product of coal-burning utilities that is considered too toxic to be allowed to exit smokestacks in Western nations [27,29].

When coal is industrially burned, the heavy ash settles, while coal fly ash (CFA) forms in the gases above the burner and would exit the smokestacks if not trapped and collected as required in Western nations [30]. Coal fly ash is one of the world's most abundant waste products, and its disposal is problematic, although a significant portion of it is "recycled" into products including structural fill, concrete, soil additives, and fertilizer [31,32].

The primary elements in CFA are oxides of silicon (Si), aluminum (Al), iron (Fe) and calcium (Ca), with lesser amounts of magnesium (Mg), sulfur (S), sodium (Na), chlorine (Cl), and potassium (K). The many trace elements in CFA include arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), phosphorus (P), selenium (Se), strontium (Sr), thallium (Tl), titanium (Ti), vanadium (V), and zinc (Zn) [33] as well as radioactive elements uranium (U), thorium (Th) and their daughter products [34]. Concentrations of these trace elements in CFA are typically higher than those found in the Earth's crust, soil, or even solid coal [35].

Coal fly ash consists of particles that formed by the cooling of molten droplets of fused material contained within the exhaust gases leaving the combustion furnace, producing the characteristic spherical morphology of CFA particles by the surface tension of the melt. The most volatile elements, which are last to condense, are more strongly enriched on surfaces of the smallest particles [35].

#### **4. HUMAN AND ENVIRONMENTAL ADVERSE HEALTH CONSEQUENCES**

Fine pollution particles penetrate deep into lungs and systemic circulation and contribute to stroke, heart disease, lung cancer, COPD, respiratory infections, and asthma [36]. Cumulative exposure to particulate pollution in the U.S. is associated with all-cause lung cancer and cardiopulmonary mortality [37]. Excessive or insufficient combustion of fossil fuels is the

dominant source of particulate air pollution on a worldwide basis [38]. Air pollution is a major contributor to both stroke, neurodegenerative disease [39], and is a risk factor for cognitive decline at all ages and for Alzheimer's Dementia later in life [40].

Determination of exogenous magnetite pollution particles in brain tissue of persons with advanced dementia is like a "smoking gun," indicating the relationship between particulate air pollution from coal combustion and neurodegenerative disease [41]. We have shown that the size and morphology of these pollution particles is most consistent with their origin in coal fly ash [42], and we have shown that coal fly ash is consistent with the main particulate being jet-sprayed into the troposphere to geoengineer our planet [27,29,43-47].

Aerosolized coal fly ash, unfiltered from industrial smokestacks as well as deliberately jet-emplaced in the troposphere, is a significant risk factor for COPD and respiratory disease [48], lung cancer [49], and neurodegenerative disease [42], and is potentially a major agent in the globally catastrophic demise of insects [50], birds [51], and forests [28].

With such serious and adverse human and environmental health consequences, it is not surprising that coal fly ash particulate air pollution is the prime-driver of the devastating increase in red tide proliferation, as reviewed below.

#### **5. EXPLOSION OF HARMFUL ALGAL BLOOMS**

Photosynthesis combines solar energy, carbon dioxide, and nutrients to form carbon-rich plant material and to oxygenate the atmosphere. In the ocean, photosynthetic phytoplankton forms the basis of the marine food chain, accounting for approximately one-half or more of the biosphere's primary production, oxygen, and carbon fixation [52]. Anthropogenic factors have already caused major changes in ocean water temperature, light, acidification, atmospheric deposition, nutrient upwelling, and stratification [53], and have been blamed for a staggering 40% decline (presently approximately 1% per year) in the ocean's phytoplankton population [54]. The rapidly changing ocean environment affects both diversity and productivity of marine phytoplankton, often giving advantage to the fast-growing opportunistic species [55]. This radically

shifting milieu favors harmful algal blooms at expense of the “good phytoplankton” that are essential to primary production and healthy marine ecosystems [56].

Harmful algal blooms (HABs) are a global problem in coastal environments, with major adverse effects on ecosystems and regional economies. HABs have one feature in common – they cause harm – by their production of toxins and/or by their proliferation and subsequent decomposition, resulting in bottom layer hypoxia (“low oxygen”) and subsurface acidification in marginal seas [57]. The spread of HABs is a result of complex interactions among physical, chemical, and biological factors that are still poorly understood.

Most HABs are dinoflagellates or cyanobacteria, but other classes of algae, e.g. diatoms, can include species that form HABs under certain conditions [58]. Harmful algal blooms are almost certainly symptomatic of a major ecosystem imbalance related to anthropogenic factors and climate change. HABs are a major problem in marine, brackish, and freshwater systems worldwide. Cyanobacteria invade inland waters, while eukaryotic phytoplankton (e.g. dinoflagellates like red tide) are rapidly increasing in the marine environment, and

benthic mats of chlorophytes, cyanobacteria, and other HABs plague the shorelines [59].

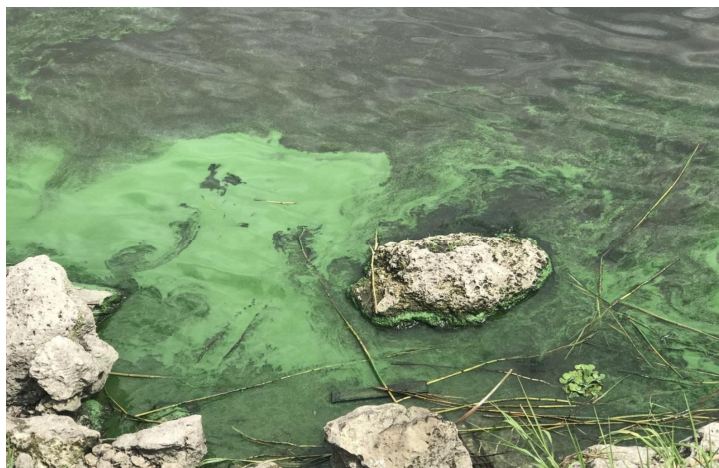
## 6. HARMFUL ALGAL BLOOMS ADVANTAGES UNDER STRESS

Florida, as with most of the U.S. and the rest of the world, is grappling with ever-worsening harmful algal blooms (HABs) of inland lakes, waterways, and estuaries. Most of these HABs are caused by cyanobacteria, the so-called cyano-HABs, and they have become one of the most important global threats to aquatic ecosystems and public health. Cyano-HABs degrade water quality more than most chemicals and other pollutants, and yet formal surveillance and monitoring of these HABs is very limited [60].

Cyanobacteria are often called “blue-green algae,” but they are actually photosynthetic prokaryotes with no direct relationship to higher algae (Figs. 5 and 6). Throughout their long evolutionary history, cyanobacteria have diversified into a great many species with various morphologies and niche habitats. They occur as unicellular, surface attached, filamentous, colonial, and mat-forming species, and they inhabit diverse freshwater and marine systems across a wide range of eutrophic and oligotrophic conditions [61].



**Fig. 5. Blue-green algae along shore of residential canal – Port Charlotte, Southwest Florida. May 20, 2019**



**Fig. 6. Blue-green (cyanobacteria) bloom – Eastern shore of Lake Okeechobee near Pahokee, Florida. May 17, 2019**

High nutrient loading, rising temperatures, enhanced stratification, increased residence time, and increased salinity all favor cyanobacterial dominance in many of these aquatic ecosystems [62]. Cyanobacteria resist pollution and are even used in so-called “photoremediation,” or bioleaching of heavy metals from coal fly ash [63]. Cyano-HABs have serious adverse effects on human and environmental health that are projected to expand and worsen with demographic and climate changes [64] and increased aerial particulate pollution.

The Earth and oceans have warmed significantly over the past five decades [65] and the oxygen content of the oceans has declined [66]. Cyanobacteria evolved under anoxic conditions, dominating the oceans during past extinction events, and they are adapted to higher temperatures, high levels of ultraviolet radiation, and fluctuating nutrient supplies [67]. Warming oceans favor smaller phytoplankton, with implications for the decline of photosynthesized organic carbon and carbon fixation [68]. Ocean warming since 1982 has expanded the niche of toxic algal blooms in both the North Atlantic and North Pacific Oceans [69].

Increased acidification of oceans inhibits the growth of phytoplankton with shells of calcium carbonate, which dissolve in acidic conditions. More acidic oceans therefore favor organisms, which do not have calcium carbonate shells, including the harmful dinoflagellates [70]. The ocean surface has become more stratified with increased temperature, glacier melt, and

precipitation runoff. This stratification gives advantage to smaller phytoplankton/algae and motile organisms like dinoflagellates capable of vertical migration [71].

The increasing penetration of deadly ultraviolet (UV-B) to Earth’s surface, associated with stratospheric ozone depletion due to anthropogenic aerosols, poses a threat to all biotic communities including plankton [72-75]. Penetration of UV-B into the water column depends on a number of factors including solar zenith angle, elevation, atmospheric aerosols, water vapor height, and the presence of dissolved particulate and organic material in the water [76].

UV-B’s deleterious effects on phytoplankton and thus primary production include breakage of proteins and cell membranes, interference with enzymatic reactions, decreased photosynthesis, impaired motility and orientation, and DNA damage resulting from the production of cyclobutane pyrimidine dimers [77]. Changes in ultraviolet radiation have significant effects on aquatic carbon cycling, nutrient cycling, and water-air trace gas exchange [78]. Photochemical reduction reactions between UV-B and organic or inorganic ferric iron complexes release iron into the medium in the more bioavailable ferrous Fe(II) form [79]. Enhanced UV-B decreases chlorophyll by both direct (effect on photosystem) and indirect (pigment formation) mechanisms. Reduction in chlorophyll pigments and photosynthesis typically result in lower biomass [80].



Enhanced Ultraviolet B decreases overall photosynthesis by phytoplankton, but certain algae and cyanobacteria have evolved avoidance, shielding, and repair mechanisms to protect these organisms against damaging UV radiation [80]. Adaptive strategies to mitigate UVB (280-315 nm) include vertical migration, mat formation, UV-absorbing substances, repair strategies, and enzymatic and non-enzymatic quenching of reactive oxygen species (ROS) [81]. Continued ozone depletion with enhanced UV radiation is unlikely to cause abrupt collapse of photosynthetic production, but rather result in species/community level changes that impact higher trophic levels [81,82].

## 7. NUTRIENT EFFECTS ON HARMFUL ALGAL BLOOMS

Anthropogenic nutrient sources from agriculture, land use, fossil fuel emissions, and climate events correlate with the global increase in frequency, size, and duration of algal blooms. In warmer waters, these nutrients fuel high organic production, or eutrophication [83]. This enhanced primary production results in the accumulation of particulate organic material, which in turn induces microbial breakdown and consumption of dissolved oxygen in bottom waters, which later turn into "dead zones" [84].

Estuaries and coastal seas are particularly vulnerable to the dual threats of warming waters and dead zones [85]. The most widespread and costly pollution problem along the world's coastlines is excessive nutrient deposition resulting in hypoxic or anoxic dead zones [86]. Over the past 50 years the amount of ocean water with insufficient or zero oxygen has quadrupled [87]. The forecast for hypoxic seas and dead zones is for worsening occurrence, frequency, severity, and duration [88]. Oxygen is not only essential to life on earth, but it also regulates major nutrient and carbon cycles. Great extinction events are associated with global warming and oxygen-deficient oceans [87].

The ocean cycles of life's essential elements, carbon (C), nitrogen (N), phosphorus (P), and iron (Fe), are closely coupled through the metabolic requirements of phytoplankton, whose average proportion of these elements is C106:N16:P1:Fe.0075 (Redfield Ratio) [89]. Growth rates, crop size, and photosynthetic activity are often governed by nutrient availability. Liebig's Law of the Minimum

suggests that growth of phytoplankton/algae should be limited by the most deficient nutrient [90]. Nitrogen and phosphorus are primary constituents of biomass, and iron is essential for a variety of enzymes and electron transfer proteins, including those needed for photosynthesis. The vast majority of oceans waters are severely limited in inorganic nitrogen, phosphorus, iron, and silica, nutrients necessary for primary production. In high nutrient-low chlorophyll regions (Southern Ocean, Eastern Equatorial Pacific, and Subarctic North Pacific), iron is a limiting nutrient, while outside these areas productivity is often limited by inorganic nitrogen [91].

Anthropogenic sources of nutrients to phytoplankton include agricultural runoff, sewage, groundwater flow, and atmospheric deposition. These nonpoint inputs of nutrients are difficult to measure and regulate since they originate and disperse from activities over wide areas [92]. Across the globe, there is a strong correlation between phosphorus input into fresh water, nitrogen input into estuaries, and biodiversity of marine life. The overall effect of nutrient over-enrichment is often species specific among phytoplankton and algae [93].

Harmful algal blooms have become a global phenomenon affecting every continent and coastal nation. Nutrient availability, along with temperature and light conditions, are primary determinants of harmful algal growth and biomass accumulation [94]. The expansion of HABs throughout the world is linked to biotic and abiotic environmental conditions, the physiological adaptations of harmful algae, and a change in the supply of "the right nutrients at the right time" [95].

There is a general understanding that: (1) Degraded water quality from nutrient pollution promotes development and persistence of HABs; (2) The composition – not just the total quantity of this nutrient pool affects HABs; (3) Both chronic and episodic nutrient delivery promotes HAB development; and, (4) That management of nutrient inputs to the watershed can lead to significant reduction of HABs. Further, there is general agreement that high biomass blooms must have exogenous nutrients to be sustained [96]. For nutrients like phosphorus, iron, and silica, this external supply is limited to atmospheric deposition or coastal runoff, whereas their main sink is the sedimentation of particulate matter. Nitrogen has an additional

source, the fixation of  $N_2$  gas, and the biological sink of de-nitrification [91].

Phytoplankton growth is supported by recycling of nutrients and re-introduction of nutrients from deeper waters by upwelling and mixing. New or external sources of nutrients including phosphorus, nitrogen, iron, and silicon are supplied mainly by coastal/riverine input or atmospheric deposition [91]. Natural aerosols include dust, sea spray, and bio-aerosols, while anthropogenic pollution aerosols are produced primarily by industrial combustion energy sources, and geoengineering-emplaced coal fly ash [27,46,97].

Human-driven contributions to atmospheric deposition of nutrients have the potential to change the marine environment, favoring certain phytoplankton/algal species over others, thus affecting overall ecosystem health and balance [98]. On a global scale atmospheric nutrient inputs are equal to or greater than riverine inputs, and for most species of phytoplankton this contribution is greater in the Northern vs. the Southern Hemisphere [99]. The atmosphere is an important transport path for essential nutrients like nitrogen and iron. Reactive nitrogen from atmospheric deposition in the ocean derived from anthropogenic emissions on land is now equal in magnitude to nitrogen input from coastal (fluvial) sources and nitrogen fixation by living organisms [100]. There is a high content of another key element, phosphorus (P), from biomass, coal combustion, and geoengineering-emplaced coal fly ash [101]. It is estimated that combustion sources (not including geoengineering) may contribute more than half of the total emissions of P to the atmosphere [102].

## 8. CATASTROPHIC EFFECTS OF COAL FLY ASH IN AQUATIC ENVIRONMENT

The intentional or accidental release of coal fly ash (CFA) into aquatic systems is associated with a host of harmful environmental effects [103]. The disposal of CFA directly into ocean waters leads to a profound impoverishment of benthic life near the dumping site [104,105].

There is a growing body of evidence that catastrophic dispersion of coal fly ash into the world's oceans played a key role in previous Great Extinction Events. The Permian (or "Great Dying") Extinction coincided with epic volcanic activity in the Siberian Traps, resulting in mixing of underground magma with thick coal seams

and producing widespread plumes of pyroclastic fly ash ascending to the upper atmosphere [106]. This theory is strongly supported by char deposits in Permian-aged rocks that are remarkably similar to modern CFA [107].

The Permian Extinction period was characterized by oxygen-depleted oceans, high levels of carbon dioxide, methane gas, hydrogen sulfide, and rapid global warming to levels lethal to most living organisms [108]. During the Permian extinction, eukaryotic plankton/algae would have greatly declined at the expense of prokaryotic photoautotrophs and primary producers capable of nitrogen fixation. Biomarkers from this era show expansion of planktonic (photosynthetic) cyanobacteria and obligate anaerobic bacteria like *Chlorobiaceae* - which use sulfates for respiration rather than oxygen, producing hydrogen sulfide as a byproduct [109,110]. Life did not totally die out by the end of the Permian, but it is estimated that at least 80% of all marine species became extinct during this time [111].

## 9. COAL FLY ASH IRON INPUTS INTO AQUATIC SYSTEMS

Iron (Fe) is a primary element in coal fly ash and it is contained in both the aluminosilicate glass phase and found in mineral phase including magnetite ( $Fe_3O_4$ ) and hematite ( $Fe_2O_3$ ) [35]. Soluble iron Fe(II) is vanishingly scarce in oxic (oxygenated) ocean water due to its rapid oxidation to insoluble Fe(III) forms (iron oxyhydroxide). There is accumulating evidence to suggest that "ferruginous", or high dissolved iron conditions, were a major feature of anoxic ocean like the Permian throughout Earth's history [112].

Dissolved iron in the water column comes from sources including hydrothermal vents, shelf sediments via anoxic diagenesis, and from atmospheric deposition [112]. Iron in CFA can be partially converted to a water-soluble form in laboratory leach-experiments [101,113]. Rain collected following aerosolized particulate geoengineering activity contains ratios of elements similar in proportion to those in CFA-leach experiments, including iron [27,29].

External iron supply exerts controls on the dynamics of plankton blooms, which in turn affects the biogeochemical cycles of carbon, nitrogen, silicon, sulfur, and other elements, thereby influencing Earth's climate system [114]. Bioavailable iron can derive from atmospheric processing of relatively insoluble mineral dust

and from direct emissions of more soluble iron from combustion sources [115]. Increased deposition of iron from pollution-type aerosols leads to increased regional productivity, respiration, and subsurface oxygen depletion [116]. Although there are still gaps in our understanding, it has become clear that humans substantially impact iron availability to the world's oceans, through industrial pollution and geoengineered pollution [27,29,46,97] and that anthropogenic iron plays a key role in the Earth biogeochemical system [117].

Investigations indicate that there has been a dramatic increase of atmospheric soluble iron to the world's oceans over the past 100-150 years [118]. Acids formed from anthropogenic gaseous pollutants such as sulfur dioxide dissolve iron in aerosolized particles, greatly increasing the bioavailable form of iron to the ocean [119]. Single particle analysis of atmospheric particles over the East China Sea showed that iron-rich particles were coated with sulfate after just 1 or 2 days residence in the atmosphere. Scanning transmission electron microscopy (STEM) of these pollution particles revealed that most of them occur in the characteristic spherical morphology of coal fly ash particles [120].

Current iron emission inventories, not including geoengineering utilization, indicate that soluble iron deposition to the ocean from coal fly ash alone may be 50% greater than that from natural dust [120]. Variation in iron speciation produces systemic differences in iron solubility; less than 1% of iron in arid soil was soluble, compared to 2-3% in glacial particles, and up to 80% in oil combustion products [121]. Simulated atmospheric processing also elevates iron solubility due to significant changes in the morphology of aluminosilicate glass, a dominant component of coal fly ash. Iron is continuously released into the aqueous environment as fly ash particles break into smaller fragments [122]. Together, these findings suggest that coal fly ash, of industrial and geoengineering origins, is a primary source of oceanic soluble iron, with a significant impacts on ocean productivity, carbon export, and oxygen depletion [120].

## **10. COAL FLY ASH IRON EFFECTS ON AQUATIC SYSTEMS**

Particle acidity affects aerosol concentration, chemical composition, and toxicity. Sulfates and nitrates are the primary components that determine the acidity of particulate particles that

are  $\leq 2.5$   $\mu\text{m}$  across. Sulfate-coated pollution aerosol particles have maintained high acidity despite declining levels of  $\text{SO}_2$  in the atmosphere [123]. Iron-rich coal fly ash particles rapidly develop a sulfate coating through gas-to-particle conversion after just 1 or 2 days of atmospheric weathering effect on both fresh and saltwater surfaces, an effect which is enhanced in coastal areas [124].

A recent study showed that sulfate and nitrate aerosol loading in winter and spring in the coastal Bay of Bengal increased acidity to the point of transforming this region from a sink of atmospheric  $\text{CO}_2$  to a source of  $\text{CO}_2$  [125]. Many trace elements and metals in coal fly ash show increasing tendency toward dissolution or "mobilization," with decreasing pH [126].

Ocean acidity can drastically impact the structure and function of marine food webs, ultimately decreasing ocean productivity. Warming and acidifying oceans enhance cyanobacterial biomass and reduce energy flow to higher trophic levels, thus lowering energy transfer efficiency between producers and consumers [127].

Aluminum and silica are primary components of coal fly ash. Aluminum is normally locked up as oxides in Earth's crust and has no biological function. However, aluminum and many trace elements in coal fly ash can be leached into chemically mobile or bioavailable forms by exposure to moisture and increased acidity. Iron and aluminum in coal fly ash follow an amphoteric pattern with increased leaching in very acid and very basic conditions [128]. There have been few studies of the effects of aluminum on phytoplankton, but some evidence suggests that aluminum facilitates iron utilization, both enhancing plankton/algae biomass and carbon fixation in the upper oceans and reducing decay of biogenic matter at lower depths [129].

Marine diatoms are sensitive to aluminum levels in seawater with toxic mechanisms related to both dissolved and precipitated aluminum [130]. On the other hand, increased aluminum concentrations leads to higher biomass and increased decay products among cyanobacteria [131]. The majority of particulate trace metals associated with phytoplankton originates from anthropogenic aerosols, not mineral dust. [132]. A study of multiple elements (P, Si, Al, V, Cr, Mn, Fe, Co, Ni, Cu, and Zn) in size-fractionated plankton and suspended particulate matter in the

surface waters of the South China Sea observed the following: the majority of the metals were extracellular and concentrated in algae, and the elements associated with phytoplankton were derived from anthropogenic aerosols containing an abundance of dissolvable metals [133].

Many of the trace elements in coal fly ash, from industrial and geoengineering sources, which become bioavailable as ions from atmospheric deposition are toxic to marine life and phytoplankton. Mechanisms of metal toxicity are diverse and species specific, but include: (1) Binding to sulfhydryl groups and disrupting protein function; (2) Displacement of essential ions from binding sites; and, (3) Generation of reactive oxygen species [134]. Most exogenous metal ions have a negative effect on photosynthesis. At sub-lethal levels non-essential elements including Cd, Pb, and Hb inhibit photosynthetic enzymes, while others like hexavalent chromium ( $\text{Cr}^{6+}$ ) cause damage by bleaching due to production of reactive oxygen species [135].

Mercury contamination of the environment is one of the adverse consequences of geoengineering using aerosolized coal fly ash [27]. The ocean's burden of divalent mercury ( $\text{Hg}^{2+}$ ) from atmospheric deposition has increased by a factor of 5 over the past 150 years and it is one of the most toxic non-essential elements to plankton and other marine life [136].

Essential elements at supra-optimal levels also affect phytoplankton. Copper deposition has increased sharply and has been shown to alter marine primary production and plankton community structure in high aerosol, low chlorophyll areas [137]. A study of a mixture of ten metal pollutants at high concentration showed inhibition of growth of phytoplankton in both laboratory and natural settings, with an enhanced effect of both copper and mercury [138]; both elements are components of coal fly ash [101].

Cyanobacteria are the only prokaryotes capable of oxygenic photosynthesis, and they have spread out to many highly polluted, metal-contaminated areas. Cyanobacteria have mechanisms to protect themselves from metal excess including production of metallothioneins, induction of metal transporters, and excretion by siderophores [139]. In highly polluted, metal contaminated areas, harmful algal blooms are greatly advantaged.

## 11. COAL FLY ASH IRON EFFECTS ON HARMFUL ALGAL BLOOMS

Iron from atmospheric sources is thought to be the trigger for both "brown" tide (*Trichodesmium*) and "red" tide (*K. brevis*) blooms [6,7]. Atmospheric sources predominately consist of industrially-released and geoengineering-dispersed coal fly ash.

Large *K. brevis* blooms frequently occur in association with blooms of the nitrogen-fixing cyanobacterium *Trichodesmium* in the otherwise nitrogen deficient waters of the eastern Gulf of Mexico [140]. Significant levels of iron are needed for nitrogen fixation by the enzyme nitrogenase, and therefore soluble/bioavailable iron levels restrict the biomass of *Trichodesmium* spp [141].

Blooms of *K. brevis* from seed populations (usually cystic forms) originating 20-75 kilometers offshore later intermingle with *Trichodesmium* due to both species with initial positioning on the bottom Ekman layers, their similar vertical migration patterns on the middle shelf, and later upwelling and marine flows to coastal waters [142]. A multi-decade analysis of *K. brevis* blooms supports the following sequence of events: (1) Summer "dust" and precipitation events increase offshore soluble iron levels; (2) Iron deposition fuels seed stocks of *K. brevis* and *Trichodesmium*; (3) Release of dissolved organic nitrogen stimulates not only *K. brevis*, but also its planktonic competitors; (4) Rapidly reproducing *K. brevis* competitors are selectively grazed upon (*K. brevis* is considered unpalatable by zooplankton), and; (5) Large bloom masses are able to proliferate in nutrient-rich water closer to the coast [7].

Proximate nutrient sources for *K. brevis* include other species of plankton and their decay products, land-based fluxes of nutrients from anthropogenic sources (industrial and geoengineering), benthic (sea bottom fluxes), and even fish kills and decaying wildlife [6].

The iron in combustion aerosols from industrial and geoengineering sources is much more water-soluble than in mineral dust, and accounts for the large majority of the bioavailable iron deposition to the world's oceans [120,122]. However, due to scavenging of soluble/gaseous species by mineral dust when mixed with pollution aerosols, dissolved iron fractions in dust are augmented.



In the presence of pollution, acidic gaseous substances condense on mineral dust, converting particles from hydrophobic to hydrophilic. Dust transport from the Gobi desert in Asia into the Pacific Ocean results in phytoplankton blooms only if the dust is accompanied by a high SO<sub>2</sub>-to-dust ratio, suggesting that sulfuric acid coatings on the dust particles are able to mobilize the embedded iron and make it available for phytoplankton uptake [143] in a manner similar to "acid rain" [144].

Both types of coal fly ash aerosols, industrial and geoengineering, and (atmospherically aged) mineral dust provide cloud condensation nuclei [145,146], and reduce heat loss from the Earth's surface [10-14]. Redox cycling of iron occurs in atmospheric water droplets, and the concentration of dissolved Fe (II) in those droplets increases with exposure to light and decreasing pH [147]. Rainwater, especially post-geoengineered rainwater, is a major source of soluble Fe in the North Atlantic [147], and red tides usually develop after heavy summer rains. Thus the combination of toxic elements and potential macro and micronutrients in both types of coal fly ash aerosols and mixed dust/pollution air masses play a significant role in the complex changes of phytoplankton/algae populations on a global basis.

Cyano-HABs have great socioeconomic and ecological costs, which include problems associated with drinking water, fisheries, agriculture, tourism, real estate, food web disruption, bottom layer anoxia, and fish kills. Cyanobacterial toxin poisoning (CTP) occurs in fresh and brackish water throughout the world. CTP biotoxins include neurotoxins, like anatoxins and saxitoxins, and hepatotoxins, like microcystins and cylindrospermopsins [148].

It has been shown that atmospheric deposition of coal fly ash type aerosols are not only sources of nitrogen and phosphorus but a primary source of soluble/bioavailable iron. While nitrogen and phosphorus are important, bioavailable iron is likely the critical limiting factor that regulates cyanobacterial growth in freshwater eutrophic lakes [149]. In addition to atmospheric deposition, fluvial inputs, internal recycling, and seepage of iron-rich groundwater are sources of iron to inland lakes and waterways [150]. Phosphorus can regulate biomass and productivity in fresh waters until excessive loading renders a system N-limited or light limited, but it is ferrous iron ions, which enhance

the ability of cyanobacteria to dominate their eukaryotic competitors.

Cyanobacteria acquire iron by migrating down to acquire Fe(II) in anoxic waters and by the production of siderophores that provide Fe(III) for reduction at the cyanobacterial cell membrane [151]. Many "new" cyanobacterial blooms occur in oligotrophic (nutrient poor) freshwater lakes with no prior history of cyano-HABs. Findings suggest that cyanobacteria are able to employ similar Fe-scavenging systems to overcome Fe limitation in lakes of all trophic states [152].

*Lyngbya majuscula* is a toxic marine cyano-HAB of increasing importance in coastal Florida and elsewhere around the world. Co-occurrence of *K. brevis* red tide and *Lyngbya* (blue-green algae) blooms have now been documented in South Florida coastal waters [152]. Nutrients stimulating the growth of the nitrogen-fixing *Lyngbya* are as follows: Fe > P > N [153]. This kind of accumulating evidence suggests that limiting soluble iron release from atmospheric pollution aerosols is essential to controlling HABs on a worldwide basis.

## 12. FOLLY OF OCEAN IRON FERTILIZATION

There is still much discussion about geoengineering techniques for "iron fertilization" of the world's oceans [154]. The quote, "Give me half a tanker of iron and I'll give you a new ice age," by the late oceanographer John Martin (author of the "iron hypothesis") in 1988 was the starting point for these talks. The idea is that in high nitrate/low chlorophyll (HNLC) Southern Oceans, added iron would stimulate both phytoplankton and photosynthesis, with increased drawdown of atmospheric CO<sub>2</sub> [155].

Thus far, iron fertilization has been limited to a dozen or so scientific experiments. Over the past two decades, these experiments have shown that iron can indeed increase drawdown of nutrients with a corresponding increase in primary production and dissolved inorganic carbon. However, the majority of these studies document potentially harmful effects of iron fertilization including shifts of plankton populations, surface oxygen decline, and greater release of potentially adverse substances such as nitrogen oxides, dimethyl sulfide, and volatile halogenated organic compounds [156].

It has been shown that iron enrichment causes blooms of the toxic diatom *Pseudonitzschia* and

its production of the neurotoxin domoic acid, producing deadly effects on marine ecosystems [157]. The evidence to date indicates that large-scale iron fertilization is potentially deleterious to global climate and ocean systems, and unlikely to have positive consequences [158,159].

Recently published data strongly indicates that pyrogenic iron-containing aerosols, industrial and geoengineering, represent the primary sources of bioavailable iron to the open oceans [160]. Furthermore, high iron solubility, especially over the Southern Oceans, suggests that there is a missing source of pyrogenic iron and its dissolution products [161]. We have published firm evidence that this “missing source” of bioavailable iron is amply supplied by undisclosed tropospheric aerosol geoengineering operations utilizing coal fly ash that are taking place around the world [27-29,44-46,162]. The resultant atmospheric deposition of nutrients, most importantly soluble iron, has tilted the global plankton population away from the “good phytoplankton” responsible for primary production and toward harmful blooms of algae and cyanobacteria.

In addition to nutrient flux, plankton balance and productivity are controlled by other factors undergoing major shifts due to anthropogenic climate change caused by industrial pollution and coal fly ash geoengineering pollution [10-14,28]. Pollution, ocean warming and surface acidification, stratification, terrestrial run-off, and excessive ultraviolet radiation all interact to disrupt and alter the global population of prokaryotic and eukaryotic phytoplankton [163]. Despite the importance of microbes in the process of recycling anthropogenic pollutants, the interactions of ocean acidification, ultraviolet radiation, man-made pollutants, and marine microbial communities has been largely neglected [164]. The evidence we present in this review clearly indicates that atmospheric deposition originating from coal fly ash aerosol pollution, industrial and geoengineering, is a major factor contributing significantly to all of these environmental/ecosystem factors and is as well the major factor causing global warming.

### 13. EMERGING THREATS

Sargassum seaweed, a tropical macroalgae, is the most recent threat to ecosystems in Florida, the Southeast U.S., and the Caribbean. Sargassum, traditionally an important nursery for marine life in the Western Atlantic, has shown

such explosive growth in the last decade that it now threatens coastal areas from Mexico to West Africa. The seaweed piles up on beaches, creating a putrid barrier threatening plants and animals, and its decomposition is associated with hydrogen sulfide emissions and regional anoxia [165]. The underlying causes of this transformation of Sargassum from beneficial to extremely harmful algae are unknown, but warming oceans, disturbances in liquid boundaries, and changing currents have been implicated [166]. Nutrient input from the Amazon and Mississippi Rivers likely contributes to the expanding Sargassum biomass [167]. However, it is already known that iron from atmospheric deposition (“eolian dust”) is the most important regulator of primary production in the Sargasso Sea [168], which suggests that aerosolized coal fly ash is a prime factor in its explosive growth. Clearly, further research is warranted to investigate this relationship in order to control the rapid spread of this recently emerged harmful algae.

### 14. RECOMMENDATIONS FOR FURTHER STUDY

Further research is needed to understand the most appropriate ways to predict, monitor, minimize, and suppress HAB outbreaks, including whether and how to regulate algal toxins. Multiple agencies need to be involved in carrying out HAB-related activities including conducting HAB research, forecasting HABs, supporting projects to improve water quality, and community outreach programs [169]. The U. S. Environmental Protection Agency (EPA) supports quantitative criteria for nutrients targeted at different categories of water bodies based on the scientific understanding of nutrient loading and water quality [170]. However, there has been a striking lack of research emphasis and thus progress in area of HAB prevention, control, and mitigation (PCM). Reasons for this deficiency include lack of funding for bloom control and the sheer complexity of the dynamic, three-dimensional marine ecosystems in which these blooms occur. The global reach of HABs, including the expanding impact of HABs in developing countries, and the critical role of nonpoint pollution (that does not respect borders) means that international cooperation is vital for both research and prevention/control purposes [171].

Research should focus on iron as the key nutrient in regulating primary production and

affecting the balance between beneficial and harmful algae. It has now been shown that high iron solubility in aerosols is mainly attributable to labile iron release from pyrogenic iron oxides. Further investigation of processes enhancing iron solubility are needed in aerosols, rain (rain clouds), and snow (snow clouds) over the oceans. Standard analytic methods for assessing aerosol solubility for polluted and clean environments should be a high priority [161]. World-wide browning of surface waters including coastal areas, so-called "brownification," is associated with increased amounts of dissolved organic matter and soluble iron. Research is necessary to address this global issue since this environment is likely a fertile environment for new HABs [172]. Since iron is a critical growth factor for HABs, the development of HABs in early phases can be halted by measures to reduce bioavailable iron, e.g. methods to reduce Fe(II) to insoluble sulfides (FeS/FeS<sub>2</sub>) [173]. However, the source of bioavailable iron must still be stopped at its sources in both combustion emissions and coal fly ash utilized in tropospheric aerosol geoengineering.

The primary understanding stemming from the research described here is that the key to reducing harmful algal blooms (HABs) in Florida and elsewhere is reducing particulate pollution, especially pyrogenic iron-bearing pollution. Prompt cessation of coal-fly-ash tropospheric geoengineering should substantially reduce HABs. Further reduction in HABs may be expected by reducing pollution from the unfiltered exhaust of coal-burning utilities. Already in Western nations, most of the particulate-matter from the exhaust of coal-burning utilities is electrostatically trapped [174], and the sulfur and nitrogen oxides are also sequestered [175]. That technology should be applied universally where no or inadequate trapping currently exists. More effective methods are needed to further reduce gaseous pollutants (SO<sub>2</sub> and NO<sub>x</sub>) that acidify pollution particles, thereby mobilizing iron and other harmful elements.

## 15. CONCLUSIONS

Life on Earth is possible because of the myriad interactions by and between biological creatures and the variable and complex natural physical processes that are a crucial part of our planet. Consequently, no one has the ability to geoengineer Earth without causing wholesale

and irreversible devastation to the environment that we depend upon for a healthy existence.

Geoengineering, however, is in fact taking place on a near-daily, near-global basis without public disclosure, without informed consent, but with devastating consequences. As described in this review, coal fly ash from geoengineering and industrial sources is forcing a rampant shift of global aquatic environments to favor harmful algae and cyanobacterial blooms over the "good phytoplankton".

Aerosolized coal fly ash (CFA) pollutants from uncontrolled coal-fired power plant emissions and from undisclosed, although "hidden in plain sight," tropospheric geoengineering operations are inflicting irreparable damage to the world's surface water-bodies and causing great harm to human health (including lung cancer, respiratory and neurodegenerative diseases) and environmental health (including major die-offs of insects, birds and trees).

New evidence indicates that particulate pollution, not carbon dioxide, is the primary cause of global warming. Air pollution and its associated climate change are now global public health and environmental emergencies, the consequences of which, as described in this review, are responsible for dramatically shifting both salt water and fresh water environments to benefit harmful algae and cyanobacterial blooms at the expense of "good phytoplankton".

Key conclusions are summarized as follows:

- Aerosolized coal fly ash from non-sequestered coal-fired power plant emissions and from undisclosed tropospheric geoengineering operations has inflicted great damage to human health, the natural environment, and surface waters throughout the world.
- Coal fly ash from spontaneous coal combustion played a significant role in previous Great Extinctions, and coal fly ash pollution is greatly accelerating the current anthropogenic Sixth Great Extinction.
- The proliferation of harmful algae and cyanobacteria blooms threatens not only all marine and freshwater ecosystems but human and environmental health as well.
- Atmospheric pollution-type aerosols make significant contributions to ocean warming,

- acidification, stratification, and the level of ultraviolet irradiance.
- Atmospheric deposition of CFA-type pollution particles, most importantly bioavailable iron, has drastically shifted the balance of phytoplankton in the direction of harmful algae and cyanobacteria.
  - Coal fly ash is the primary source of soluble iron to surface waters and, moreover, iron is the key nutrient governing the balance between beneficial plankton and harmful algae and cyanobacteria.
  - Multiple toxic elements in CFA can affect plankton balance.
  - Through mixing and atmospheric weathering, CFA-type pollution also “corrupts” mineral dust, increasing its amount of bioavailable iron.
  - Proposed geoengineering schemes involving iron fertilization of oceans will make a bad situation much worse as shown by both scientific studies and ongoing covert geoengineering operations utilizing CFA.
  - The global spread of harmful algae and cyanobacteria blooms can only be contained by rapidly reducing particulate air pollution and immediately halting jet-sprayed aerosols.
  - Since particulate pollution is a major cause of global warming, controlling emissions and ending deliberate jet-emplaced aerosols should help alleviate runaway warming in the short term.
  - Corrective actions hinge on not only on international cooperation at all levels of authority, but upon finally ending the deadly silence on the subject of undisclosed tropospheric aerosol geoengineering.
  - The global imbalance of beneficial phytoplankton and harmful algae blooms is directly related to atmospheric aerosol contamination and manipulation.
  - Continuing geoengineering operations by multiple nation states is a threat to all life.

Florida’s ever-growing toxic nightmare of red tides and blue-green algae is a microcosm of similar activity being played out throughout the world. Atmospheric deposition of nutrients and pollution particles is a critical factor that must be contained at its sources. The good news is that global warming and air pollution can both be rapidly reduced with universal particulate

emission controls and the immediate halting of jet-sprayed particulate aerosols. We present evidence here that the global spread of harmful algae blooms will only be contained by these kinds of measures. However, these corrective actions hinge not only on international cooperation, but on finally ending the smog of complacency, and the associated deadly code of silence on the subject of ongoing tropospheric aerosol geoengineering that is so pervasive throughout government, academe, and media. The long-term, behind-the-scenes push for weather control, “climate intervention,” and geoengineering has come to threaten not only all humans but the entire web of life on Earth.

## ETHICAL APPROVAL

The authors hold that technical, scientific, medical, and public health representations made in the scientific literature in general, including this particular journal, should be and are truthful and accurate to the greatest extent possible, and should serve to the highest degree possible to protect the health and well-being of humanity and Earth’s natural environment.

## COMPETING INTERESTS

Authors have declared that no competing interests exist, neither institutional nor commercial. The research was funded by personal efforts of the authors.

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