Review Article

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Are persistent aircraft trails a threat to the environment and health?

https://doi.org/10.1515/reveh-2021-0060
Received May 4, 2021; accepted June 11, 2021;
published online July 7, 2021

Abstract: According to most scientific studies, media and governments, the white trails that can be seen behind aircraft in flight, corresponding to condensation mixed with engine particulate emissions, only persist under specific atmospheric conditions. They are called condensation trails, and cirrus contrails when they remain for hours to reach several kilometers wide. The fact that they have gradually filled the skies over the last twenty years would be due to the increase in air traffic. However, other official documents link these persistent trails to a weather modification technology called solar geoengineering by stratospheric aerosol injection (SAI). These sprays would be mainly composed of metallic particles (Al, Ba, Sr, Fe, nanoparticles) and sulfur, which would considerably increase air, soil and water pollution. Many of the current environmental and health problems are consistent with those described in the literature on solar geoengineering by SAI if this method was employed. For example, metal particles used are well known environmental contaminants, ozone layer depletion, cardiorespiratory diseases, neurodegenerative diseases, sunburn. The observations (whiter skies, less solar power) also correspond to the same risks as those described in the solar geoengineering works. Patents show that this weather modification technology has been known and mastered for a long time. In addition, some scientific papers as well as policy documents suggest that solar geoengineering by SAI has been used for many years. The amount of official information presented in this review is intended to open new ways of investigation, free of conflicts of interest, about the growing global pollution of persistent aircraft trails and their possible links with solar geoengineering by SAI.

Keywords: atmospheric pollution; climate; neurodegenerative diseases; radiofrequency; stratospheric aerosol injection; vitamin D.

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Introduction

What are those long white trails in the sky left by aircraft, which persist and spread out forming a cloudy veil to give a milky sky that strongly obscures the sunlight all day long?

The information given to the public stipulates that these are “Aircraft condensation trails” made up of water and combustion emissions, which form only under specific atmospheric conditions. The World Meteorological Organization (WMO), a specialized agency of the United Nations (UN), has named these new clouds: Cirrus homogenitus (Figure 1) [1].

Many scientists attribute the growing number of persistent aircraft trails to the mere increase in air traffic [2, 3]. Nevertheless, there are publications, political issues, patents and observations indicating that these persistent trails are sprays of chemical compounds, known as solar geoengineering by stratospheric aerosol injection (SAI), aimed at changing the climate. These chemicals would be mainly composed of metallic particles, nanoparticles, sulfur and black carbon, causing air, soil and water pollution and therefore having a strong impact on health [4–6]. Interest (especially by the military) in climate control is not recent. Indeed, an electromagnetic technology, with very strong environmental and health side effects, would seem to have been deployed and activated since the 1990s without the public being informed about it but to the official knowledge of governments [7]. In addition, one military document shows that this electromagnetic technology requires chemical spraying to manipulate weather [8]. Therefore, since stratospheric aerosols would clearly have an impact on health [9], it becomes important to analyze the persistent aircraft trails with a different perspective for several reasons: (1)/ Aviation emissions and persistent aircraft trails are known to increase air pollution and have climate and health impacts [10, 11]. Air pollution is an important factor in cardiorespiratory diseases, which are constantly rising [12, 13], and also induces an adverse effect on the central nervous system (CNS) [14]; (2)/ The metal particles (such as aluminum, barium) that would be contained in these aerosols are among the causes of neurodegenerative diseases such as Alzheimer’s, Parkinson’s, autism, transmissible spongiform encephalopathies, amyotrophic lateral

Figure 1: Aircraft condensation trails that have persisted for at least 10 min are named Cirrus homogenitus by WMO [1].

sclerosis, multiple sclerosis [15]. For example, aluminum is neurotoxic and is strongly associated with neurodegenerative diseases such as Alzheimer's. In addition, a burgeoning number of studies demonstrate the presence of aluminum in human brain tissue, and data support that high levels of aluminum in the brain are not a fatality of aging [16]; (3)/ Many diseases are linked to vitamin D deficiency, whose synthesis is impaired by reduced sun exposure due to air pollution [17]. It is important to note that this deficiency is global [18]. One of the known objectives of this meteorological modification program corresponds precisely to the reduction of solar radiation; (4)/ Several papers mention the negative environmental and health effects if solar geoengineering by SAI was employed [9, 19–21]. It can be noted that all these environmental and health impacts have been observed, measured, demonstrated and have been constantly increasing for many years.

The purpose of this article is to compare the official and mainstream media explanation of persistent aircraft trails with other documents (publications, patents, policies, legal) as well as with observations, in order to provide readers with new research directions on this growing global pollution.

Official explanation of persistent aircraft trails

Condensation trails (contrails) are short-lived when the ambient air is dry, with relative humidity below saturation over an ice surface so that the ice particles forming in the contrail evaporate. Contrails persist, evolve into more extended cirrus clouds if the ambient air is humid enough [22].

These trails consist of condensation of water vapor mixed with soot and sulfate particles from emissions resulting from fuel combustion. They depend on humidity, air temperature, altitude, abundance of ice nuclei, and can remain in the sky for several hours. When they persist and spread, these aircraft trails are called cirrus contrails and become indistinguishable from natural cirrus clouds [11, 23, 24].

Soot particles are mainly composed of carbon in which various metals are also mixed: chromium (Cr), iron (Fe), molybdenum (Mo), sodium (Na), calcium (Ca), aluminum (Al), vanadium (V), barium (Ba), cobalt (Co), copper (Cu), nickel (Ni), lead (Pb), magnesium (Mg), manganese (Mn), silicon (Si), titanium (Ti), zirconium (Zr) [25].

Emissions from aircraft engines can lead to an increase in the concentration of ice nucleating particles, affecting natural cirrus clouds, even in the absence of contrails, thus impacting the climate [25–27].

Persistent trails cause a change in the Earth's radiation balance, influence climate and contribute to global warming by inducing a positive radiative forcing (balance of solar energy received and re-emitted by the Earth to space. Positive, the Earth warms up; negative, it cools down). Indeed, these long trails reflect little of the incident solar radiation back to space but absorb the Earth's infrared radiation. They have an impact on the climate, air quality, on the environment and human health [11, 25, 28].

A recent study has shown that global contrails cirrus radiative forcing will triple by 2050. Improvements in fuel quality and propulsion efficiency, resulting in lower emissions of soot and water vapor, will not compensate for the increase in air traffic and new technologies that allow aircraft to reach higher cruising altitudes conducive to contrails [2]. This will contribute to global warming in the

regions concerned. The climatic impact due to contrails requires urgent research [29].

Persistent aircraft trails seem to be a "natural" and unavoidable consequence of aviation. However, other documents referring to a weather modification technology must be taken into account in order to better understand the problem as a whole.

Solar geoengineering by stratospheric aerosol injection

Definition and method

« There are several proposed solar geoengineering technologies. These include marine cloud brightening, cirrus cloud thinning, space-based techniques, and stratospheric aerosol scattering, amongst others. » Stratospheric aerosol scattering would introduce tiny reflective particles, into the upper atmosphere, where they could scatter a small fraction of sunlight back into space [30] (Figures 2 and 3).

In 2013, the Intergovernmental Panel on Climate Change (IPCC) presented solar geoengineering as a potentially usable, albeit highly controversial, method [31].

In 2016, the CIA Director's annual speech refers to geoengineering, and more specifically SAI, as a practically unavoidable, inexpensive, climate-altering technique that is totally devoid of standards [32].

The first official document showing the possibility of using geoengineering programs was presented in 1992 [33]. By adding dust to the stratosphere through the use of aircraft, a screen could be created to increase the reflection of sunlight (pp 59, 449). Such dust would have a visible effect, especially on sunsets and sunrises, and would warm the stratosphere causing a modification of the ozone layer at this altitude (pp 459–60). Decreased engine combustion efficiency would also allow a thin cloud of soot to persist in order to intercept sunlight (pp 59).

The stratospheric injection of sulfur compounds is a highly studied method of solar geoengineering [34]. These sulfur compounds are added directly to the aircraft's fuel [35]. However, other authors suggest that it would be preferable to attach a nozzle to release the sulfur from its own tank inside the aircraft rather than mixing it into the fuel. They advocate the use of military aircraft only (F-15C Eagles, KC-135 Stratotankers and KC-10 Extenders) because the military has already manufactured more planes than would be required for this geoengineering scenario, potentially reducing the costs of this method, and because climate change is an important national security issue [19]. Nevertheless, these sulfur aerosol sprays involve many risks: increasing the rates of stratospheric ozone destruction; more sunburn; less solar power; acidifying the oceans; causing drought; effects on electrical properties of atmosphere; changing the color of the sky from blue to white; degrade terrestrial optical astronomy; military use of technology [19–21].

Alumina (Al_2O_3) seems to be a better compound than sulfate for solar geoengineering. However, chemicals that are less common in nature than sulfate potentially present additional risks, both known and unknown [34]. In total, many substances can be used, such as: injection of either sulfate particles, or sulfuric acid (H_2SO_4), which condenses into particles, or precursor gases like sulfur dioxide (SO_2), hydrogen sulfide (H_2S) or carbonyl sulfide (COS), which

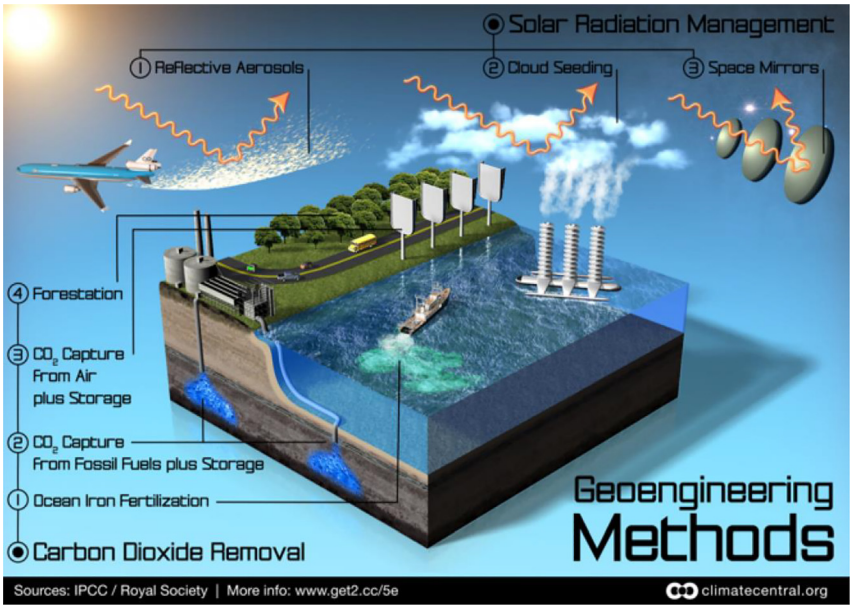

Figure 2: Geoengineering strategies, including the injection of reflective aerosols into the atmosphere. (https://www.climatecentral.org/news/geoengineering-could-cut-global-rainfall-study-finds-16699).

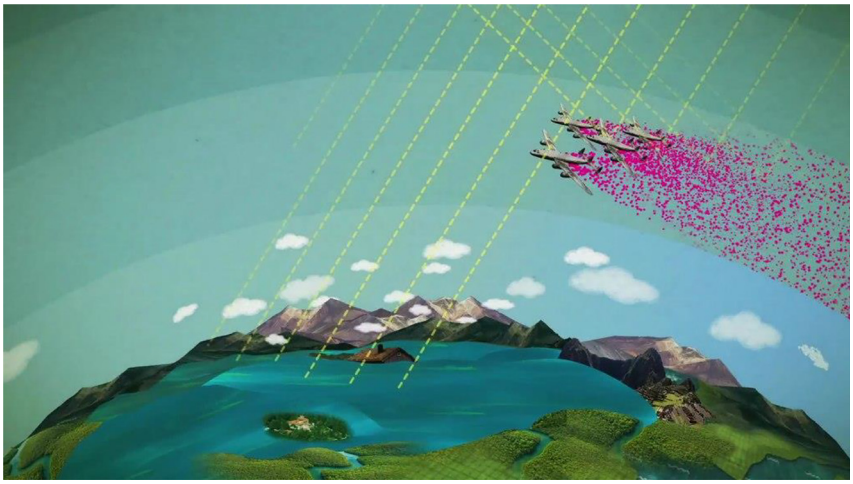

Figure 3: SAI (stratospheric aerosol injection): Injection of inorganic particles, such as sulfur dioxide, into the stratosphere to block incoming sunlight. (https://www.belfercenter.org/publication/world-needs-explore-solar-geoengineering-tool-fight-climate-change).

would then be oxidized to H_2SO_4; calcite ($CaCO_3$, the main component of limestone); crystal forms of titanium dioxide (TiO_2), zirconium dioxide (ZrO_2), and aluminum oxide (Al_2O_3); silicon carbide (SiC); synthetic diamond; soot; and self-lofting nanoparticles [36].

To reduce cirrus cloud cover, Mitchell and Finnegan [20] recommend using « a pressed composite mixture of Bismuth tri-iodide (BiI_3), potassium perchlorate ($KClO_4$), aluminum and gilsonite (a natural hydrocarbon) », and then release it into the atmosphere using the civil aviation industry. Although this method is not considered an SAI, the objective is still to spray aerosols at high altitude. « The seeding material could either be (1) dissolved or suspended in their jet fuel and later burned with the fuel to create seeding aerosol, or (2) injected into the hot engine exhaust, which should vaporize the seeding material, allowing it to condense as aerosol in the jet contrail ».

In the British newspaper "The Guardian", geoengineering is presented in a futuristic way. « Solar geoengineering is outlandish and unsettling. It invokes technologies that are redolent of science fiction – jets lacing the stratosphere with sunlight-blocking particles…» [37].

In spite of the papers that mention SAI as a technology only studied in the laboratory, the observations that can be made outside almost every day (Figures 1 and 5) correspond exactly to what is described by some previous authors if this solar geoengineering was used.

International authorities and solar geoengineering by SAI

Climate engineering, thus geoengineering by SAI, remains a largely ungoverned space with shared norms, institutional arrangements, and formal rules to regulate climate engineering that do not yet exist. However, *de facto* governance has emerged through authoritative assessments by the UK Royal Society and the US National Academy of Science (NAS). That means: "The steering entailed in *de facto* governance is not explicitly recognized as an act of governing by others, even as it steers a field of inquiry in specific directions, thereby also shaping the context for *de jure* governance." It is important to note that: "the NAS report rejects the position that any small-scale, outdoor experimentation would need to be regulated, and that societal concerns associated with this technology make self-governance by the scientific community inadequate" [38].

In 2013, in the European Parliament, solar geoengineering by SAI is described as a military science that has been active for several years. It is stated that the media, as well as governments, are not telling the truth about this technology, which is practiced outside of any national or international legal framework [4].

For several years, recurring questions have been raised by Members of the European Parliament about the illegal spraying of chemicals at high altitudes around the world. So much so that these persistent trails are called chemtrails (chemical trails) [39]. The following is a summary of the questions asked in the European Parliament Commission from 2007 to 2017:

In 2007, it is asked whether the Commission is aware that, since 1999, U.S. and Canadian citizens are complaining more and more about of persistent aircraft trails that can sometimes remain in suspension for several hours and spread out in milky veils called "aerial obscuration". In the United States, investigations conducted by complainants, observations by pilots and statements by government bodies are increasingly leading to the hypothesis that aircraft emit small particles composed of barium, aluminum and iron, known as chemical trails (E-2455/07).

In 2009, a member of parliament wanted to know whether the Commission has taken, or will take, steps to ensure that chemical trail emissions from certain aircraft and the resulting air pollution are banned (E-3730/09).

In 2011, it is being asked whether chemicals spread by aircraft for geoengineering in the United States can be present in European airspace (E-006621/2011).

In 2012, analyses of the chemical trails have verified the presence of radioactive barium, aluminum, radioactive thorium and cesium, copper, titanium, silicon, lithium, cobalt, lead, ethylene dibromide and several pathogens. The question was whether the Commission was aware of the health effects of these chemical sprays (E-002906/2012).

In 2013, the Commission is asked to explain how, from a scientific point of view, the continuous inhalation of heavy metals and the settling of these on the ground (contaminating water and food) do not adversely affect the efforts of Europe's 500 million citizens to maintain a high quality of life. Many in the international scientific community believe that the persistent aircraft trails disperse toxic substances such as aluminum, barium and iron into the air, and are therefore extremely dangerous. It is also asked why the Commission and most Member States withhold information on chemical trails and geoengineering instead of making it available to the public (E-008804/2013).

In 2014, it is asked whether NATO or the army is involved in geoengineering operations by spraying aerosols into the atmosphere, as more and more chemical trails have been spotted over a county in England (Bedfordshire) (E-003690/2014).

In 2015, the issue concerns the environmental and health risks of geoengineering, as four employees of the Spanish Meteorological Agency have confessed to airplanes spreading lead dioxide, silver iodide and diatomite in the atmosphere throughout the country, in order to keep rain away and allow temperatures to rise. The problem is that this geoengineering generates storms and respiratory diseases (E-007937-15).

In 2017, the Commission is asked whether measures have been taken to analyze and assess the effects of chemical trails on the environment and how it intends to protect the European population (E-005130-17).

The latest answer from the European Commission was: « As a consequence of the lack of the necessary evidence to initiate policy response, no action has been taken nor further analysis foreseen » [39].

For several years, Members of Parliament in different countries have also been asking their governments about chemical trails. From 2003 to 2011, 13 questions were submitted to the Italian government. Following complaints from many citizens and associations, the government has often been asked to provide information, and investigations, concerning metals (Al, Ba, Ti) measured in high concentrations in soil and water as a result of the passage of chemical trails, as well as about the very high number of cases of cancer in regions where persistent aircraft trails are regular. According to members of parliament, the government's responses are non-existent or unconvincing [40]. In France, persistent aircraft trails have been observed by thousands of people for years. Military geoengineering by spreading chemicals has been the subject of questions by members of the French parliament [41]. In UK, the question concerned research undertaken by the Department of the Environment on the polluting effects of chemical trails [42].

On each occasion, the European Parliament and the governments always give the same very brief style of reply: there is no information on releases of chemicals from aircraft; it is a condensation of water from normal aircraft emissions; there is no evidence of adverse effects on human health.

However, this would not be the first time a government has carried out military actions involving the spraying of chemicals on its citizens. Indeed, from 1955 to 1963, a report reveals that the British Ministry of Defense sprayed "zinc cadmium sulfide" on the UK population without its consent [43].

Patents

The patents do not prove in any way that solar geoengineering by SAI is used, but they show that the techniques for spraying particles into the atmosphere have been known for a very long time.

In 1971, aluminum was already the most suitable metal for climate change [44].

In 1975, a mechanism was invented in order to create powder trails (other than condensation trails) or reflective screens, for any desired purpose. The main compound is titanium dioxide, but the patent specifies that: « Other type powder compositions can also be used with the apparatus described herein. For example, various powder particles which reflect electromagnetic radiation can be dispensed as a chaff or the like from the contrail generator » [45].

In 1976, a device was developed to accurately deliver tiny amounts of biologically active chemicals over large areas, for example from an airplane [46].

In 1983, an improvement in the spraying of a liquid from the wing of an airplane was implemented [47].

In 1990, a liquid atomization device for aerial spraying, coupled with an electric control to regulate the liquid flow rate, was manufactured [48].

The most important patent was issued in 1991. In order to reduce global warming, this method consists of seeding the Earth's stratosphere with Welsbach-type materials in the part where greenhouse gases are trapped, which absorb strongly near infrared wavelength radiation. These materials are metallic particles, aluminum oxide and thorium oxide, having the characteristic of wavelength-dependent thermal emissivity (or reflectivity). « Particles are suspended within the greenhouse gases' layer and provide a means for converting radiative energy at near infrared wavelengths into radiation at the far infrared wavelengths, permitting some of the converted radiation to escape into space… The particle seeding should be done at an altitude on the order of 10 km (between 7 and 13 km). The particles may be seeded by dispersal from seeding aircraft; one exemplary technique may be via the jet fuel as suggested by prior work regarding the metallic particles » [49].

In 2008, a patent was granted for an aerial delivery system. Tanks, distributed in the plane, can spread products of different kinds: water, gel, powder, decontamination compound, weather modification compound, oil spill treatment compound, and a firefighting compound [50] (Figure 4). This system will be enhanced in 2010 [51].

Literature and observations

Some researchers, who have been interested in the links between persistent aircraft trails and solar geoengineering by SAI, mention coal fly ash (CFA), an industrial waste, among the particles used [6, 52–54]. Various elements are contained in CFA: silicon, aluminum, iron, barium, strontium (Sr), arsenic (As), mercury (Hg), manganese, nanoparticles, uranium (U), thorium (Th), and nanoparticles of magnetite (iron oxide) [55–59].

In general, publications showed that chemical trails would appear to be very rich in aluminum, barium and strontium, in the form of nanoparticles, with a strong predominance of aluminum [5, 60–63]. Note also that for enhancing/refracting radar and radio signal communications, military already uses atmospheric barium spraying [64, 65].

Persistent aircraft trails were analyzed using a spectral radiometer. The results indicate that they are not condensation trails but chemical trails [66]. Following the spraying of these aerosols, whitish lines appear without fading, then gradually extend, leaving the sky completely veiled (Figure 5).

Solar geoengineering particles spreading are heated by solar and terrestrial radiation, transferring this heat to the atmosphere through molecular collisions, thereby reducing atmospheric convection and thus heat loss. This results in local or global warming of the atmosphere [6].

Although these persistent trails are present everywhere in the sky when they occur, regular observation shows that they are very often more concentrated in the sun's direction. This reinforces the hypothesis of the use of solar geoengineering by SAI, since its purpose is to reflect sunlight.

According to a study, solar geoengineering based on the stratospheric spraying of sulfate aerosols at an altitude of 20 km could not be carried out in secret because of the large logistical volume to be managed [69]. However, the authors do not discuss U.S. military research on climate control since the 1960s. In addition, a patent has shown that solar geoengineering by SAI can be used at much lower altitudes than those mentioned [49]. Moreover, the chemical elements studied are not limited to the diffusion of sulfur [9, 20, 36].

Bills

In October 2001, a bill (which was rejected) was presented to the US Congress to control specific weapons, including so-called "exotic" weapons. Among these are "chemtrails". « The term 'exotic weapons systems' includes weapons designed to damage space or natural ecosystems (such as the ionosphere and upper atmosphere) or climate, weather, and tectonic systems with the purpose of inducing damage or destruction upon a target population or region on Earth or in space » [70].

In 2017, a bill to regulate geoengineering was proposed in the state of Rhodes Island. « "Geoengineering" means

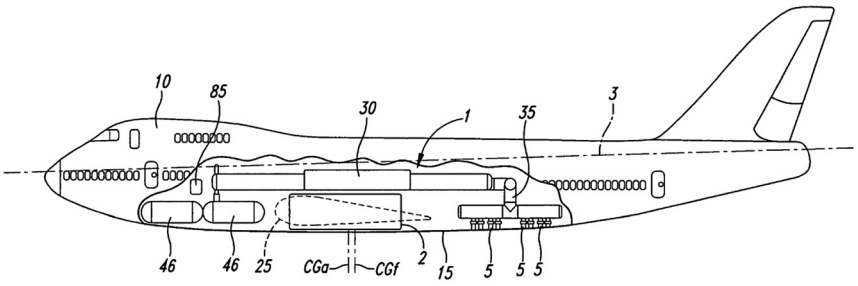

Figure 4: One embodiment of the aerial delivery system [50].

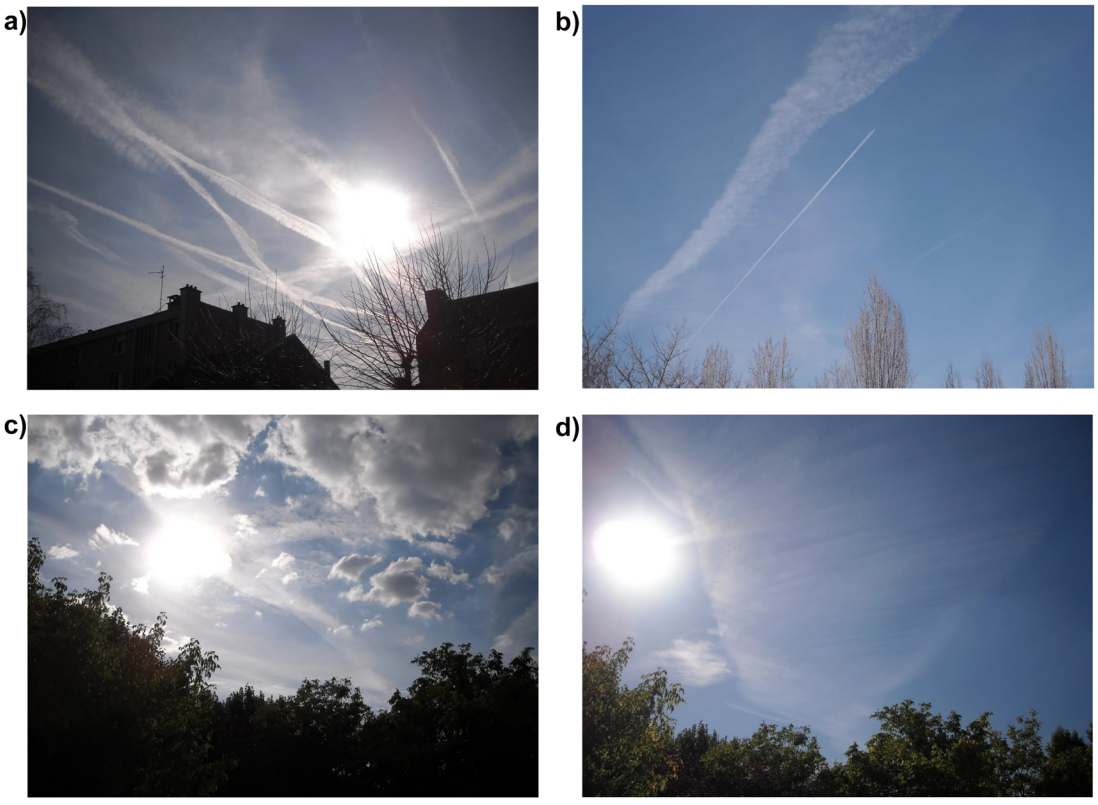

Figure 5: The photographs were taken by the author himself in the city of Lille located in northern France, with a Nikon Coolpix L16 camera, showing persistent aircraft trails of various shapes depending on the phase of their spread. (a) Feb 17, 2019, 13h45; (b) Feb 13, 2021, 14h51; (c) Aug 4, 2020, 18h02; (d) July 29, 2020, 17h40. Other photographs or testimonials reveal that persistent aircraft trails, giving a veiled sky, are found in many regions on earth [4, 5, 39, 53, 62, 66–68].

the intentional manipulation of the environment… The Rhode Island general assembly finds that geoengineering encompasses many technologies and methods involving hazardous activities that can harm human health and safety, the environment, and the economy…». Among all the geoengineering methods listed in this document, mention is made of the application of reflective particles such as aluminum oxide, sulfur dioxide, barium, which prevent sunlight from reaching the Earth's surface and then fall back as pollution. But also deliberate releases of black carbon into the atmosphere to produce artificial weather phenomena. In addition, the paper emphasizes the devastating effects of this geoengineering on the environment and human health [71].

This original bill has been replaced by an alternative bill to establish a commission to study and provide recommendations for state regulation and licensing of all geoengineering technologies [72].

Weather manipulation

Government archives show that there is a clear and long-standing desire to modify weather and climate [73–78]. This intention to control the climate remains mainly military [7]. In 1996, a research paper was presented to the US Air Force with the aim of outlining a strategy for using a future weather modification system to achieve military objectives in 2025 with national and international applications through NATO and the UN [8]: « In 2025, US aerospace forces can "own the weather" by capitalizing on emerging technologies and focusing development of those technologies to war-fighting applications… Current technologies that will mature over the next 30 years will offer anyone who has the necessary resources the ability to modify weather patterns and their corresponding effects, at least on the local scale… The number of specific intervention methodologies is limited only by the imagination,

but with few exceptions they involve infusing either energy or chemicals into the meteorological process in the right way, at the right place and time. The intervention could be designed to modify the weather in a number of ways, such as influencing clouds and precipitation, storm intensity, climate, space, or fog. » This paper presented a technique for dispersing black carbon into the atmosphere by injecting liquid hydrocarbon fuel into post-combustion exhaust gases [79]. It was suggested that this technology could be useful for dispersing other modifiers. Uninhabited aerospace vehicles (UAVs), with stealth technology, could be routinely used for weather-modification operation [8]. Nevertheless, as many planetary territories are concerned, aircraft would be specifically dedicated to this type of spraying [80].

The military manuscript also shows an intention to inexpensively create intelligent clouds using nanotechnology, thus generating the illusion of natural weather phenomena. « A cloud, or several clouds, of microscopic computer particles, all communicating with each other… designed to have a wide-range of properties… » [8].

The chemical part (CHEM), which would have started in the 1990s, is accompanied by an exponential growth of electromagnetic wave pulses in the ionosphere (AIM) (Figure 6). The electromagnetic wave device described in the paper presented to the US Air Force is very similar to the HAARP (High-frequency Active Auroral Research Program) system, which is strongly suspected of causing global weather disturbances and adverse health effects [7].

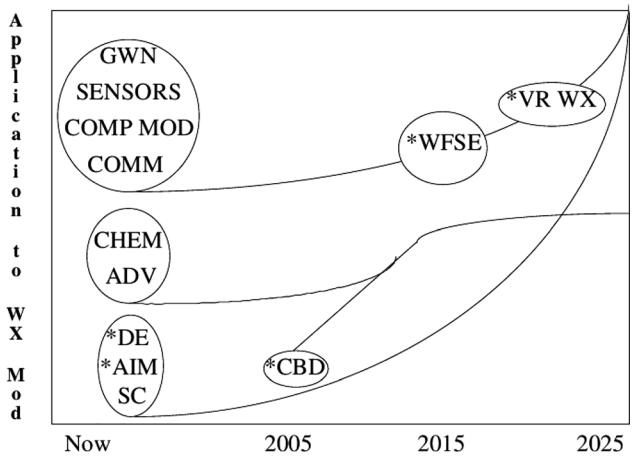

Figure 6: A road map to weather modification in 2025 [8]. ADV: Aerospace Delivery Vehicles; AIM: Artificial Ionospheric Mirrors; CHEM: chemicals; CBD: carbon black dust; COMM: communications; COMP MOD: computer modeling; DE: directed energy; GWN: Global Weather Network; SC: Smart Clouds (nanotechnology); SENSORS: sensors; VR WX: Virtual Weather; WFSE: Weather Force Support Element.

Environmental and health effects if solar geoengineering by SAI is effectively used

In 2016, a study assessed the risks to human health if solar geoengineering involving stratospheric aerosols was used. The most recommended materials have been analyzed: sulfur dioxide, hydrogen sulfide, carbonyl sulfide, black carbon, and specially engineered discs (nanoparticles) composed of metallic aluminum, aluminum oxide and barium titanate. The health effects of a potential exposure to these aerosols are: respiratory, cardiovascular, gastrointestinal, hematologic, musculoskeletal, hepatic, renal, endocrine, dermal, ocular, metabolic, immunologic, neurologic, reproductive, developmental, genotoxic, cancer, death. In addition, there is no knowledge of toxicity, and therefore no exposure standards, for barium titanate. For public exposures the Environmental Protection Agency, European Environmental Agency, and World Health Organization (WHO) specify regulatory standards for ambient air quality. There are currently no limits set by any of these agencies for most of the substances that may be used for SAI, and little infrastructure is in place to assess the potential public health impacts of stratospheric aerosol deployments [9].

Most of the toxic substances mentioned in solar geoengineering by SAI are surprisingly related to many current environmental and health problems.

The presence of large amounts of metal nanoparticles in atmosphere can contribute to an increased health risk. In the air, these nanoparticles may have strong magnetic, toxic, carcinogenic, oxidizing, and extensive adsorption surface properties. In addition, there are currently no ambient air quality standards for nanoparticle number concentrations. As a result, the air is becoming more and more polluted and therefore dangerous to living organisms [81].

Heavy metals and nanoparticles, present in solar geoengineering by SAI, would affect air, soil, water, and are indubitably found in agriculture, polluting a large part of the food supply [5, 6, 52, 53, 61, 62].

Environment

Local or global warming of the atmosphere would seem to be the most evident effect of SAI leading to local melting of snow and ice [6]. But also an ozone depletion when sulfur particles are released into the stratosphere [19].

The drought caused by sulfur [20] combined with the pyrophoric capacity of aluminum nanoparticles (less than

68 nm) increasing the risk of explosions or fire [81], could explain the severity of wildfires around the world in recent years [62, 82].

Magnetic pollution from magnetite found in CFA (from coal burning power plants or any other industrial use of coal to generate high temperatures) could disrupt the orientation of cetaceans and cause them to strand [59]. The same hypothesis has been put forward due to a military use of electromagnetic waves [7]. The higher the level of electromagnetic waves, the more the magnetite accumulated in cetaceans will be stimulated, obviously disturbing their orientation, which is true for any other animal dependent on magnetic navigation.

Aluminum is the most significant environmental contaminant of recent times. Bumblebee pupae have been found to be highly contaminated with aluminum. Since bees are strongly dependent on cognitive functions, the high aluminum content measured in bumblebee pupae could interfere with the development or functioning of cognitive performance of adult bees, playing a role in their population decline [83].

Pulmonary system

Particulate matter (PM) emissions from airliners, classified as ultrafine $PM_{0.1}$, penetrate deep into the respiratory tract and can reach the bloodstream [25]. Air pollution causes cardiovascular diseases, respiratory diseases, metabolic diseases, cancer, neurological, and oxidative effects, particularly due to fine particles, and is the leading environmental cause of global disease and premature death [14]. In children, exposure to air pollution composed of SO_2, Si, S, Ti and black carbon leads to respiratory diseases [84]. Note that these components are present in solar geoengineering by SAI. According to Kapadia et al. [35]: « the greatest reduction in aviation-induced mortality is simulated for complete desulfurization of aviation fuel ».

Coal fly ash is composed of $PM_{2.5}$, PM_1 and nanoparticles, causing mild neutrophilic inflammation in the lung tissue and blood, DNA damage, cytotoxic effects (apoptosis and necrosis) and oxidative stress [58, 85]. Coal fly ash, which would also be part of solar geoengineering by SAI, presents toxic substances such as aluminosilicates, iron oxide, silica, arsenic, cadmium, hexavalent chromium, radioactive elements, as well as very small particle size, which would significantly increase air pollution, leading to potential risks of lung cancer and severe respiratory disease [54]. Particles can enter the circulation via the lungs through breathing and reach the alveolar region. At this point, they can translocate to the systemic circulation and then across the blood-brain barrier (BBB), by reactive oxygen species (ROS) formation which alter the permeability of the BBB, to the brain parenchyma [14]. Particles with a size of 10–100 nm can reach the area of the bronchioles and alveoli with an efficiency of 20–60%. In addition, the slow elimination mechanisms of embedded nanoparticles promote their retention time and thus their penetration into epithelial cells of the airways, blood or lymphatic system [81].

Exposure to iron and other transition metals can result in generation of ROS on the lung cells surface, which may cause injury and lead to formation of scar tissue [86].

Major compound of stratospheric aerosol injection seems to be aluminum. The literature shows that the organs targeted by aluminum poisoning are the lungs, central nervous system and bone. Small inhaled aluminum particles can be transported from the alveoli to the bloodstream by dissolution, or by phagocytosis of macrophages [87]. Inhalation of aluminum may cause lung damage such as granulomatous pneumonia, pulmonary granulomatosis, pulmonary fibrosis, pulmonary alveolar proteinosis, desquamative interstitial pneumonia and asthma [88]. In Pakistan, 15% of the population suffers from asthma, with an increase in the number of cases due to aluminum oxides sprayed by SAI from solar geoengineering [5].

Cardiovascular system

Fine and ultrafine particles' passage into the blood can trigger a systemic inflammatory process via induction of ROS production and pro-inflammatory cytokine release [86]. Long-term exposure to air pollution can lead to atherosclerotic plaque formation and, over time, subsequently to various cerebro/cardiovascular disease phenotypes such as stroke, arterial hypertension, coronary heart disease, myocardial infarction, heart failure, and arrhythmia [14]. Nanoparticles of magnetite/maghemite have been found in the hearts of Mexico City residents, a risk factor for the development of cardiovascular disease [89].

Central nervous system

A clear relationship has been established between air pollution and neurodegenerative diseases [90, 91]. The magnetite fines and nanoparticles contained in coal fly ash have the ability to penetrate and damage the BBB, leading to an accumulation of these magnetic elements in the brain, which can trigger neurological disorders such as Alzheimer's disease [59].

According to Pakrashi et al. [60], because of the aluminum oxide nanoparticles they contain, chemical trails raise concerns about their role in increasing the incidence of Alzheimer's disease, but also autism [16, 92, 93]. In addition to the lungs, there is another way by which very small particles in the air can penetrate the central nervous system and reach the brain, the olfactory receptor neurons or the trigeminal nerve [14]. Absorption of Al is much easier in the respiratory than digestive tract. Hence, aluminum nanoparticles can be translocated along the olfactory nerves and deposited mainly in the brain and spinal cord [81].

Researchers have shown that air pollution composed of nanoparticles of aluminum, iron and titanium puts people at risk of potential neurological disorders such as Alzheimer's, Parkinson's and motor neurone disease. These nanoparticles are found in the brainstem, particularly in the substantia nigra and cerebellum. The titanium particles reach the brain after being swallowed and moving from the gut into the nerve cells which connect the brainstem to the digestive system. Metal-rich nanoparticles from pollution can therefore reach the brainstem by inhalation or swallowing. These particles can cause inflammation and act as a catalyst for the excessive formation of reactive oxygen species. The authors highlight that the control of nanoparticulate sources of air pollution becomes critical and urgent [94, 95].

Purdey's work has shown that an environment with high levels of aluminum, barium, strontium, iron and manganese cations, from natural geochemical and man-made (mainly military) pollutant sources, is conducive to the development of neurodegenerative diseases such as Alzheimer's, Parkinson's, transmissible spongiform encephalopathies, amyotrophic lateral sclerosis, multiple sclerosis, especially if chronically exposed individuals in these areas are depleted in Mg/Ca. Individuals can absorb theses metal nanoparticles directly into the brain via the nasal-olfactory route of inhalation, or by contaminated foodchains absorbing them across the gut–blood and blood–brain barriers. When the permeability of the blood–brain barrier is impaired, in the Mg/Ca depleted brain, the uptake of Al, Fe, Sr, Ba or Mn leads to rogue metal substitutions at the Mg/Ca binding domains released on various enzyme/proteoglycan groups, causing a broad ranging disruption in Mg/Ca dependent systems. In addition, these toxic metals chelate the free sulfate depriving the endogenous sulfated proteoglycan molecules (heparan sulfates) of their sulfate co-partner. These reactions allow the proliferation and accumulation of metal-protein crystalline arrays in the brain devoid of proteoglycans, which could represent, associated with a dietary deficiency in Mg/Ca, a common key feature to neurodegenerative diseases [15, 64, 65, 96].

These results should be related to the fact that radiofrequencies electromagnetic fields (RF-EMFs) induce an opening of the blood–brain barrier [97], which can increase the absorption of Al, Fe, Sr, Ba or Mn [15]. Consequently, there is a very high health threat when RF-EMFs and solar geoengineering by SAI are used simultaneously. Moreover, a high content of heavy metals in the body increases the risk of becoming hyperelectrosensitive, a new and growing pathology due to the constant rise in the level of electromagnetic waves [97, 98].

Vitamin D and UV-B

Ingestion of aluminum inhibits the biological function of vitamin D in the intestine related to calcium absorption, resulting in altered bone mineralization [88]. In addition, oral vitamin D supplementation appears to enhance aluminum absorption [87, 99]. Moreover, aluminum can bind to dietary phosphorus and decrease its absorption in the gastrointestinal tract, leading to osteomalacia and rickets [87]. Strontium also interferes with normal vitamin D metabolism by blocking renal synthesis of 1,25-dihydroxyvitamin D, the active form of vitamin D, and seems to be more readily absorbed by vitamin D supplement [100, 101].

The main source of vitamin D (90%) comes from the sun. Air pollution has been reported as one of the most significant factors that causes vitamin D deficiency by reducing sun exposure, especially UV-B radiation [17]. Bill 2017 states that if solar geoengineering aerosols are sprayed, solar radiation would decrease, implying a decline in vitamin D synthesis [71]. In the literature, a global vitamin D deficiency can be found at any latitude. It is a global public health problem, so much so that it is referred to as a "pandemic" mainly in Europe, except in some high latitude countries (e.g., Norway, Finland, Sweden, Denmark, and the Netherlands), which can possibly be attributed to high vitamin D supplementation [18, 102, 103]. In addition, 1,25-dihydroxyvitamin D enhances innate immune system (induces antimicrobial peptides, such as cathelicidin, which acts against bacteria, fungi and exhibits direct antiviral activities against many respiratory viruses; modulates the differentiation and functions of antigen-presenting cells; vitamin D and its metabolites modulate endothelial function and vascular permeability; plays a role in maintaining gut integrity and intestinal homeostasis between host and gut microbiota) and promotes the adaptive immune system by producing T and B cell responses. Vitamin D deficiency increases the risks of developed several immune-related diseases and disorders, including psoriasis, type 1 diabetes, multiple sclerosis, rheumatoid arthritis, tuberculosis, sepsis, respiratory

infection, influenza [104]. It should be noted that aluminum exposure also induces an increase in oxidative stress leading to immunosuppression (lymphocyte apoptosis) [88].

Atmospheric pollution decreases solar radiation, and thus UV-B radiation [17]. Furthermore, over time, geoengineering by SAI will cause depletion of the ozone layer [6, 19, 20, 21] thus increasing the risk of sunburn and skin cancer due to overexposure to UV-B radiation [21, 105, 106]. This UV rise will take place in locations less affected by air pollution (e.g. outside of cities and industrial areas), as well as in clear weather, i.e. without clouds or sprays. Consequently, if geoengineering by SAI is really linked to persistent aircraft trails, not only does it reduce exposure to solar radiation involving a drop in vitamin D synthesis, but it also degrades the quality of solar UV resulting in more aggressive radiation.

Although persistent aircraft trails exacerbate atmospheric pollution and thus impair public health, it should not be forgotten that various natural mechanisms also contribute largely to the increase in air pollution by raising the concentration of sulfur gases, particulate matter (carbon, ash), and aerosols in the atmosphere from volcanic eruptions [107], forest fires [108], sand and dust storms [109–111], and other natural disasters [112]. Therefore, a weather manipulation and control technique, such as solar geoengineering by SAI, only adds pollution to an already existing natural critical value.

Conclusion

Despite publications exposing the risks of solar geoengineering by SAI if it was used and that all these environmental and health effects have been noted for several years, no university is interested in the possible links between persistent aircraft trails and solar geoengineering by SAI. Only a few authors have conducted this work, but without directly measuring the consequences on health.

The relationship between the possible undisclosed use of this technology and the catastrophic increase in the level of environmental pollution (particularly metallic nanoparticles), having a direct impact on health, should be rigorously considered in subsequent studies. In particular, the hypothesis of a causal link with the strong growth of respiratory and neurodegenerative diseases.

Given the level of conflict of interest between the health sciences and the financial and political spheres [113–116], as well as the enormous military interests added to decades of research on weather modification techniques, could it be that solar geoengineering by SAI, able to change the weather and trigger serious environmental and health effects, is also tainted?

Research funding: This research did not receive any specific funding from public, commercial or non-profit funding agencies.

Competing interest: The author declares that he has no known competing financial interests or personal relationships that might appear to influence the work presented in this paper.

Informed consent: Not applicable.

Ethical approval: Not applicable.

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