ID 54519
P86

Title: Solar-radiation management scheme by using aluminium oxide poses a severe risk to global mental health.

Introduction. The climate crisis is a highly complex and urgent challenge of our time, primarily caused by human activities. Unfortunately, the consequences of these activities on the planet's climate are irreversible and have led to a series of concerning environmental impacts. Therefore, it is essential to act swiftly to mitigate the effects of global warming (1). However, it is paradoxical that the G20 nations, including the world's leading economies, are providing significant financial support to fossil fuel industries, which hinders the transition to a green economy (2). Given this scenario, it becomes increasingly critical to explore and invest in potential tools such as geoengineering (GE) research (3). GE could offer innovative ways to counteract the consequences of human-caused temperature rises and help mitigate the impacts of global warming (4). However, it is crucial to exercise caution, as the ethical and environmental implications of such large-scale interventions require thorough investigation. One GE technique that could be effective is solar radiation management (SRM). It aims to reflect a small portion of the Sun's energy back into space, counteracting the temperature rise caused by increased levels of greenhouse gases. Stratospheric aerosol injection (SAI) is a specific SRM technique involving the injection of aerosols into the stratosphere (3). These particles reflect sunlight before it reaches the Earth's surface, effectively reducing the atmospheric heat accumulation. SAI is considered affordable and highly effective compared to other suggested GE methods for mitigating global warming. While sulfate aerosols are the most extensively studied, recent research indicates that aerosols with aluminium oxide (Al_2O_3) could dramatically increase light scatter, namely the reflection and refraction of light per unit mass, thereby increasing SAI's efficiency; moreover, Al_2O_3 may have less severe technology-specific risks than sulfates (5).
Nevertheless, **the use of Al_2O_3 comes with potential mental health hazards because releasing Al_2O_3 aerosols into the lower stratosphere could lead to global dispersal via precipitation, significantly increasing human exposure to aluminium** (Al) (6). **These concerns motivate our study, which seeks to investigate the potential mental health risks associated with increased Al exposure following its proposed use in SAI**. This research will contribute to understanding the human health implications of GE strategies, a crucial aspect often overlooked.

Methods. MEDLINE and EMBASE were searched for key terms related to aluminium, mental health, geoengineering, solar radiation management, and stratospheric aerosol injection. **Our criteria focused on relevant studies directly investigating possible links within these areas**.

Results. Several epidemiological investigations suggest Al may not be as innocuous as previously thought. **The literature clearly suggests that Alzheimer's disease (AD), multiple sclerosis (MS), and Parkinson's disease (PD) patients experience excessive accumulation of Al in the CNS, and epidemiological links between higher exposure to Al and their increased incidence have been observed in AD and PD. In PD, the potential use of Al as a disease marker has been noted** (7). In particular, a 2016 meta-analysis showed that **individuals chronically exposed to Al were 71% more likely to develop Alzheimer's disease (AD) (8), and 2021 data support the intricate associations of Al in the neuropathology of familiar AD (9). Furthermore, prolonged exposure even to low levels of Al, leads to changes associated with brain aging and neurodegeneration** (10). **These findings suggest that an increased risk of developing AD can follow chronic Al exposure**. The latter is the most common form of dementia and may contribute to 60 –70 % of cases. Approximately 55.2 million people have dementia worldwide, over 60% of whom live in low and middle-income countries. The number of people living with dementia is expected to rise to 78 million by 2030 (11). **The possible increased risk of dementia from Al exposure is further compounded by exposure to engineered PM2.5 particles designed to transport Al_2O_3**. A recent systematic review and meta-analysis, the first to use the new Risk of Bias In Non-Randomized Studies of Exposure (ROBINS-E) tool, **found consistent evidence of an association between PM2.5 exposure and dementia**. This association was present even when annual exposure was less than the current EPA annual standard of 12 µg /m^3, and among the studies using active case ascertainment, the researchers found a 17% increase in risk for developing dementia for every 2 µg/m^3 increase in average annual exposure to PM2.5 (12).
The injection amount of aerosol particles needed in SAI would depend on the desired radiative forcing and the particle composition, size distribution, optical properties, and the vertical and horizontal injection location (13). At the time of this study, the exact volume of PM2.5 Al_2O_3 aerosol particles necessary on an annual basis in SAI is yet to be determined, but **the injected mass necessary to achieve a 2 W/m^2 radiative forcing is roughly equivalent whether employing Al_2O_3 or sulfate aerosol**. SAI primarily utilizes sulfates, but the choice is less about their optimal nature and more due to the extensive record of past analyses regarding their efficacy and risks. This understanding minimizes the uncertainties associated with an initial partial deployment in a hypothetical scenario. Studies based on models and data from previous volcanic eruptions propose a potential maximum cooling (negative radiative forcing) by sulphate aerosol ranging from 2 W/m^2 to over 5 W/m^2. (14). **The latter, however, would necessitate extremely high volumes of injection - comparable to the current worldwide anthropogenic sulfur pollutant emissions of roughly 100 Tg (SO_2/yr). In this contest, the volume of Al_2O_3 necessary in a worst-case scenario could be more than significant, warranting intense further research into the potential impacts on human health**.

Conclusions. When considering using SAI to mitigate the global warming component of climate change, the recent report by the White House proposes a 'risk versus risk' scenario. In this framework, GE, including SAI methodologies, needs further study to accurately quantify the risks involved in its deployment compared to not implementing it (15). **If SAI strategies involve the use of Al_2O_3, after the eventual transport of aerosol particles into the troposphere, they undergo relatively rapid mixing processes by weather events, turbulence, and cloudscale overturning. Particles are then mostly removed from the atmosphere by dry deposition, sedimentation, or scavenging by clouds, finally polluting the environment (16). Worldwide terrestrial precipitations generally after 1-2 years following sprays of this element into the lower stratosphere could increase widespread aluminium human body exposure. This raises concerns about potential global mental health implications, notably an increased risk of incident dementia**. According to an extensive, globally coordinated research effort encompassing over 150,000 direct interviews across 29 nations with divergent economic statuses, it is projected that a significant epidemiological milestone will be reached wherein **one in every two individuals all across the world will experience a mental health affliction during their lifespan** (17). **In this perspective, the world's populace is not in a position to withstand additional burdens on mental health on a global scale by using Al in SAI**. A "small window" of opportunity to address the climate crisis is still open, and humanity possesses all the necessary tools. **However, solar geoengineering without concurrent comprehensive reductions in global fossil fuel usage could close this window**.

References

1. Intergovernmental Panel on Climate Change. Climate change 2023: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC; 2023.
2. International Institute for Sustainable Development. Fossil Fuel Subsidies and Sustainable Development (https://www.iisd.org/gsi/what-we-do/focus-areas/fossil-fuel-subsidies-sustainable-development) accessed on October 7, 2023.
3. National Academies of Science, Engineering, and Medicine. Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance. The National Academies Press; 2021.
4. Harvard's Solar Geoengineering Research Program. Harvard University (https://geoengineering.environment.harvard.edu/) accessed on October 7, 2023
5. Weisenstein DK, Keith DW, Dykema JA. Solar geoengineering using solid aerosol in the stratosphere. Atmospheric Chemistry and Physics. 2015;15(20):11835-11859.
6. Tracy SM, Moch JM, Eastham SD, Buonocore JJ. Stratospheric aerosol injection may impact global systems and human health outcomes. Elementa. 2022;10(1):47. doi:10.1525/elementa.2022.00047
7. Bryliński Ł, Kostelecka K, Woliński F, et al. Aluminium in the Human Brain: Routes of Penetration, Toxicity, and Resulting Complications. Int J Mol Sci. 2023;24(8):7228. doi:10.3390/ijms24087228
8. Wang Z, Wei X, Yang J, Suo J, Chen J, Liu X, Zhao X. Chronic exposure to aluminum and risk of Alzheimer's disease: A meta-analysis. Neurosci Lett. 2016 Jan 1;610:200-6. doi:10.1016/j.neulet.2015.11.014
9. Mold MJ, O'Farrell A, Morris B, Exley C. Aluminum and Tau in Neurofibrillary Tangles in Familial Alzheimer's Disease. J Alzheimers Dis Rep. 2021 Apr 9;5(1):283-294. doi:10.3233/ADR-210011
10. Bondy SC. Prolonged exposure to low levels of aluminum leads to changes associated with brain aging and neurodegeneration. Toxicology. 2014;315:1-7.
11. World Health Organization. Global action plan on the public health response to dementia. 2017-2025.
12. Elissa H Wilker, Marwa Osman, Marc G Weisskopf. Ambient air pollution and clinical dementia: systematic review and meta-analysis. BMJ. 2023;e071620. doi:10.1136/bmj-2022-071620
13. Niemeier U, Timmreck C. What is the limit of stratospheric sulfur climate engineering. Atmos Chem Phys. 2015;15:10939-10955. doi:10.5194/acpd-15-10939-2015
14. Kleinschmitt C, Boucher O, Platt U. Sensitivity of the radiative forcing by stratospheric sulfur geoengineering to the amount and strategy of the SO2 injection studied with the LMDZ-S3A model. Atmos Chem Phys. 2018;18:2769–2786. doi:10.5194/acp-18-2769-2018
15. OSTP. (2023). Congressionally Mandated Research Plan and an Initial Research Governance Framework Related to Solar Radiation Modification. Office of Science and Technology Policy, Washington, DC, USA.
16. Shepherd J. Geoengineering the Climate: Science, Governance and Uncertainty. The Royal Society; 2009.
17. John J McGrath, Ali Al-Hamzawi, Jordi Alonso, Yasmin Altwaijri, et al. Age of onset and cumulative risk of mental disorders: a cross-national analysis of population surveys from 29 countries. The Lancet Psychiatry. 2023. ISSN 2215-0366.

Conference on Connecting Health and Climate Change, Stockholm, Sweden, October 11-12, 2023

Giovanni Ghirga, MD, International Society of Doctors for the Environment (ISDE – Italy)