Iron Salt Aerosol

Frequently Asked Questions

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What is Iron Salt Aerosol (ISA)?

Iron Salt Aerosols are naturally occurring iron compounds, mainly iron chloride, that are main cooling agents in the earth's atmosphere. Iron chloride removes carbon dioxide and other greenhouse gasses from the air, while also bringing extensive benefits for marine biology. Expanding ISA could be the single most economic, safe, easy and rapid contribution to reversing climate change.

What scientific information has been published on ISA?

Climate engineering by mimicking natural dust climate control: the iron salt aerosol method is a scientific article written by Franz Dietrich Oeste, Renaud de Richter and other scientific colleagues. This article was published in 2017 by the European Geosciences Union in their peer reviewed journal Earth System Dynamics, and is available for free at https://www.earth-syst-dynam.net/8/1/2017/. The article explains the ISA method in scientific detail, and has an extensive list of references to other related scientific articles.

How does ISA cool the atmosphere?

ISA was one of the main natural cooling agents that expanded earth's glaciers in the Ice Ages. During the ice ages the continents dried out, causing iron-rich dust to blow onto the oceans. This dust formed into aerosols and generated immense plankton production, due to the fact that iron is a key limiting nutrient for plankton growth. The iron in ice age dust removed about 50 parts per million of CO2 and other greenhouse gasses from the atmosphere, a natural feedback process that amplified global cooling.

By copying this natural process from the ice ages, production of ISA can become a safe, rapid and low-cost way to help reverse global warming. Natural and man-made sources now add about 100,000 tonnes of iron to the ocean each year. Doubling this existing rate using ISA would have a range of cooling benefits, while only adding a few grams of iron per square kilometer each day.

ISA firstly helps produce clouds as it reacts with moisture in the air. Creating more cloud means less light and heat gets through to the earth surface, cooling the land and sea through increased reflection and increasing rainfall. Sunlight acting on the ISA then releases chlorine, which depletes atmospheric methane and other greenhouse gasses. The ISA falls with the rain to provide a safe productive micronutrient, increasing growth of plankton, continental plants and microbes. By enhancing ocean biological productivity, the ISA method sucks CO_2 out of the air and sea as a safe and inexpensive way to slow global warming and acidification. This removed carbon will either become part of the sediment at the ocean floor or recycle as biological material.

More than sixty million square kilometres of the world ocean is anaemic, with very low iron levels, and will benefit from added iron. In these regions ISA can enable photosynthesis using up to 100,000 carbon atoms for each added iron atom. Other regions also benefit from ISA through its various cooling effects.

How can ISA be delivered?

ISA plumes can be generated by burning soluble iron compounds such as ferrocene in ships and power stations or on purpose-built platforms. Tiny particles of iron oxide will rise in hot combustion gases to a height of about one kilometer. The iron compounds stay in the air for a few days, where they react with naturally occurring hydrogen chloride, mainly from sea-spray, forming iron chloride, a salt aerosol with many cooling impacts.

What are the global benefits of ISA?

ISA could remove up to twelve gigatons of CO_2 equivalent per year at an estimated cost below one dollar a tonne. This is double the CO_2 reduction rate expected under the Paris Accord over the next decade, at a tiny fraction of the planned Paris cost, making ISA potentially the single most cost-effective climate change response available.

Scientific modelling indicates that ISA could safely begin to reverse global warming within a decade, while delivering essential local ecosystem protection, by global addition of 150,000 tonnes of iron to the atmosphere each year. Global use of the ISA method could provide a rapid, safe, low cost way to reverse climate change and protect biodiversity.

ISA can be implemented rapidly at scale in cooperation between commercial, government and scientific partners. Cooling benefits from ISA come equally from removing CO_2 and from other effects including methane removal and cloud formation. The methane removal is particularly beneficial since methane has global warming potential 28 times worse than CO_2.

At global level, doubling the current natural addition of 150,000 tonnes of iron per year onto the ocean surface would have major immediate impact to cool the climate, using about one kilogram of iron per square kilometer per year in the large ocean regions with high nutrient and low chlorophyll.

ISA could increase krill and fish populations, reduce cyclone intensity, break down marine plastic and lower acidity.

What benefits would ISA have for Australia?

ISA could help save the Great Barrier Reef and other threatened marine ecosystems, and could enable Australia to fully meet commitments under the Paris Accord at low outlay with major economic and ecological benefits.

By cooling the ocean water, ISA can protect coral reefs from bleaching and reduce warming risk to other threatened ecosystems.

Release of ISA from locations such as Macquarie Island or southern Australia could meet Australia’s emission reduction targets at a small fraction of current planned cost, while boosting Southern Ocean fish yields.

How does new biomass help the oceans?

Humans are causing the sixth planetary extinction. Creating new ocean biomass aims to help stop the collapse of biodiversity. To return our planet to the stable climate our ancestors enjoyed for the last ten thousand years of the Holocene era, about a trillion tonnes of carbon must eventually be converted from CO_2 and methane into biological or other stable form. Increasing ocean biomass by accelerating natural photosynthesis is a primary effective strategy to achieve this climate restoration goal, replicating natural planetary cooling mechanisms. ISA is a significant and easily deployed starting point on this long road, with annual potential to remove more than ten gigatons of CO_2 equivalent.

Is ISA safe?

In replicating how the earth cooled down in the ice ages, ISA mimics an entirely safe natural process, with rewards expected to far outweigh risks. Environmental safety of ISA can only be determined through small scale scientific field trials.

A stepped process of testing ISA for atmospheric, marine ecosystem and continental impacts, including through field monitoring, measurement and computer modelling, can ensure the safest approach to ensuring ISA effects are well understood. The impacts of ISA should be thoroughly measured and tested in small scale coastal scientific field trials and subjected to computer modelling before any larger deployment, in accordance with

United Nations protocols. ISA trials must be rigorously committed to the highest levels of safety at each stage of development, through application of best practices to safeguard the environment, the health and safety of the public and those at work on the project.

Desktop analysis indicates very low risk of adverse events from ISA. Hypothetical risks from the related process of adding iron sulphate to the ocean include growth of unwanted algae and jellyfish species, change to ocean oxygen levels, shifts in the location of plankton in the ocean, and rapid return of captured carbon to the air. ISA field trials will assess these and other identified issues. Safety factors reducing any risk include the miniscule level of ISA addition in any location, planned adherence to strict scientific process, and the fact that ISA replicates beneficial natural cooling processes.

Research and development of ISA can reduce the dangers resulting from failure to control global warming. Investing in research and development to create knowledge is a far safer path than just banning ISA because of hypothetical untested risks.

Assuring safety during field trials should be a major focus. All ISA activities use products that are now in widespread commercial use. Technical use is carefully regulated, for example with ferrocene now widely used as an automotive fuel additive. The ISA production process involves protocols for chemical handling of iron additives, in storage, transport and combustion, including in combination with fuel, compliant with Material Safety Data Sheet requirements.

How much does ISA cost?

Our models indicate ISA can remove carbon for less than a dollar a tonne of CO2 equivalent, and possibly much less than that.

The low ISA cost would bring many times its value in economic and environmental benefits for industries including shipping, fishing, tourism, insurance, energy and plastics, making investment in ISA very attractive as a least cost carbon abatement strategy.

A recently published literature review of carbon removal options from The University of Michigan found typical prices in the order of $10-$60 per tonne of CO2. The ISA costings are around 1% of these benchmark figures.

A tonne of the main ISA input ferrocene costs about USD $10,000. A tonne of ferrocene could remove ten thousand tonnes of carbon dioxide equivalent, at cost of one dollar per tonne of abatement or less. That cost is orders of magnitude below other carbon removal methods under discussion. In the large regions of the world ocean that have high nutrients and low chlorophyll (HNLC), ISA could be many times more efficient than this dollar a tonne estimate.

Cost of ISA generation at the ferrocene market price of US$ 10,000 per tonne produces annual ISA costs of US$ 1.5 billion to finance the burial rate of up to six gigatons of CO2 per year. This is twenty five US cents for each tonne of CO2 removal alone, not including other cooling effects. Adding the likely equal cooling impact of removing CO2 equivalents, plus the albedo cooling effect, halves this cost estimate to US twelve cents per tonne of CO2e. Locating ISA in areas of lower uptake could increase the overall estimated unit price to about one dollar per tonne of CO2e.

What is the plan to test ISA?

Since publication of the Oeste et al journal article in 2017, supporters of the proposal to test ISA in the field have been discussing how to do a thirty-day scientific field trial in coastal waters to measure ISA effects. We are now seeking scientific, commercial and political support and funding for an Australian field trial in Bass Strait, between Victoria and

Tasmania, and have developed a detailed initial test proposal to discuss with investors, scientists, regulators and the public.

Why Bass Strait?

After evaluating a range of possible initial trial locations, Bass Strait appears the best place in the world for a first small ISA trial in terms of logistics, cost, safety and regulation. Bass Strait could be an entry point that can generate scientific and public understanding and interest, preparing for more comprehensive later trials, with easy management by scientists based in Victoria and Tasmania. Bass Strait location options include offshore oil platforms or the Spirit of Tasmania vessels that cross Bass Strait every day between Melbourne and Devonport. Tests in the Southern Ocean and the Coral Sea could follow an initial proof of concept in Bass Strait, given that these deep marine locations are logistically more challenging.

Who will manage the ISA field trials?

Iron Salt Aerosol Australia Pty Ltd has been established to coordinate government and scientific and commercial partner involvement in the Australian field trials. Our team includes Franz Dietrich Oeste and Renaud de Richter, co-authors of the ISA journal article, and Robert Tulip and John Macdonald, the Australian contacts working to arrange scientific field trials and analysis. Franz and Renaud are chemical engineers, Robert is a former official in AusAID and the Department of Foreign Affairs and Trade, and John was a leading Australian architect. We are passionate about practical ways to stop global warming, and see ISA as the single best way that Australia can contribute to local and global action to limit climate change.

The primary research on ISA has been managed by Franz Dietrich Oeste over the last twenty years, detailed in his 2017 journal article published with co-authors including Dr Renaud de Richter. Australia’s Deakin University plans to support PhD research on ISA, mainly addressing how ISA can remove marine pollution, as a main academic engagement with the field trial. We hope to employ a Post-Doctoral Fellow through Deakin University to provide technical management of the field trial planning, implementation and reporting. The involvement of Deakin University has potential to include work in legal aspects, engineering, chemical science and environmental monitoring.

What approvals will be required for the field trial?

Initial approvals to proceed with project design from responsible government authorities are a precondition for further project commitment and expenditure of funds. Activities in Bass Strait are controlled by State and Federal regulation, involving a range of authorities with approval jurisdictions, ensuring compliance with relevant expectations. Overall project approval will be sought in stages, beginning with a broad project plan, discussing any concerns and refining detailed operational plans. Our initial field trials proposed under this project will fully comply with the United Nations London Protocol requirement that testing of iron fertilisation should be limited to scientific trials in coastal waters. We initially propose mainly to measure atmospheric effects, rather than the marine effects observable in the deep ocean.

How would ISA field trials be governed?

Recognising the potential strong public interest in the field trials, governance standards for the project will include clear processes for decisions, public access to information about planned activities and demonstrated compliance with Australia’s environmental laws. The project is rigorously committed to transparent and accountable standards of governance. We commit to the application of best practices for project planning and delivery, involving high levels of professional expertise and consultation, including in work with partner organisations and stakeholders and in project communications.

How would ISA field trials be monitored?

The new European Sentinel 5P Satellite is expected to be the primary monitoring system, measuring atmospheric and ocean effects, working together with scientific institutions including universities and government instrumentalities. The project is rigorously committed to effective, detailed, accurate and transparent monitoring of activities and impacts at each stage of development. We commit to the application of best practices for modelling, gathering and analysis of data for our project, monitoring all environmental effects and operational processes.

What technology is required to monitor the trial?

The European Space Agency launched the Sentinel 5P satellite in October 2017 to map and measure gas concentrations such as ozone, methane and aerosols. This satellite can help to observe ISA plumes with high precision and quantify their depletion effects on methane, ozone and numerous other chemicals in the atmosphere. Satellite location data will then be correlated to sea surface temperature reduction and increased chlorophyll A production by phytoplankton. Other satellites and ground based activities could also assist with monitoring.

What specific aspects need to be tested in the trial?

For the first trial planned in Bass Strait, we aim to gather data about the atmospheric cooling effects of ISA by measuring depletion of chemicals including methane (CH_4), volatile organic compounds (VOCs), ozone (O_3), nitrous oxide (NO_2), hydrochlorofluorocarbons (HCFC) and soot aerosol, as well as cloud formation and cloud brightness. Bass Strait has no iron deficiency, but the influence on phytoplankton can be measured to indicate possible results in subsequent tests in iron deficient waters. The temperature effects within the ISA plume and beyond will indicate expected cooling effects. We plan to test a range of precursor iron chemicals including ferrocene, at different fuel mixes, temperatures and concentrations. This Bass Strait trial will indicate ISA potential to cool sensitive locations such as the Great Barrier Reef, where later tests aim to prove a cost-effective method to prevent coral bleaching.

How does ISA compare with other climate change responses?

ISA appears to be far better value as a climate change response than reducing emissions, burying CO_2 or reflecting sunlight. The key theme emerging from our work is that ISA could be orders of magnitude superior to other proposed climate protection methods. This superiority is across primary criteria of cost, safety, speed, ease of implementation, natural precedent and effectiveness. These modelled effects require field tests to confirm or adjust the predictions.

How does ISA relate to ocean iron fertilisation?

ISA improves upon previously proposed methods of ocean iron fertilization in areas of cost, risk, effectiveness and ease of deployment at scale. ISA is suited to both local and global use, providing iron in extremely low and even concentration with cooling benefits both in the air and in the water. Previously studied methods of ocean iron fertilization spread liquid iron sulphate onto smaller regions of the ocean's surface, and did not bring ISA co-benefits such as methane removal and cloud formation. A key benefit of ISA is that it does not require any local concentration of iron, but operates systemically, reducing the anaemia of the world ocean. Spreading iron through the air as a salt aerosol enhances the concept of ocean iron fertilization and is likely to prove the safest single contribution to cooling the climate.

Who owns the Intellectual Property for ISA?

Franz Dietrich Oeste and Ernst Ries are owners of

International Application Number: PCT / DE02/02766

Title: Tropospheric volume elements enriched with vital elements and/or protective substances

This Patent is protected in Australia, Austria*, Canada, China, France, Germany*, Great Britain*, India, Japan, Poland*, Russia, USA

*Protected parts of the European patent. The patent protection period of this Patent will end during 2019

International Application Number: PCT / DE2010/000002

Title: Method for cooling the troposphere

This Patent is protected in Australia, Brazil, Canada, China, France, Germany*, Great Britain*, India, Italy*, Japan, Netherlands*, Poland*, Russia, Spain*, Turkey*, USA

Which industries would benefit most from ISA?

ISA could provide major commercial benefits for industries such as insurance, shipping, tourism, energy, fishing, mining, chemicals and agriculture, through reducing the business impact of climate change and reducing the damage these industries cause to the climate.

Could ISA cause harmful algal blooms?

No. A range of hypothetical risks could arise from adding iron to the ocean, relating to plankton blooms, oxygen levels and permanence of carbon removal, but our calculation, to be validated by field testing, is that ISA will not cause any harm. The low iron concentration of ISA is expected to generate phytoplankton growth that will increase biological activity up the entire food chain, delivering major benefits for biodiversity and cooling. The field trials will measure phytoplankton properties to provide clear information on actual effects.

Could ISA affect jellyfish population?

Jellyfish booms result from human impacts including overfishing and warmer seas. ISA can counteract these problems by increasing the overall biomass in the ocean food chain, benefiting predators and competitors of jellyfish such as tuna and sardines. ISA could further reduce jellyfish numbers by cooling the ocean surface.

Could ISA change the downstream marine ecosystem?

Positive effects would far outweigh any localized adverse changes. ISA will increase primary productivity at the base of the ocean food chain, increasing quantity and diversity of all kinds of fish and ocean life. As a result, the location where some nitrate, silicate and phosphate nutrients in surface water are consumed by plankton will change, mainly increasing but possibly also decreasing in some locations. The scale and effect of these changes are expected to have major benefits for biodiversity, and will require monitoring and modeling as part of the ISA field test process, with scientific confirmation of benefits an important factor in decision to scale up ISA.

How will ISA affect ocean nutrient levels?

The world oceans have abundant phosphate and nitrate nutrients in deep water, but at the surface, the nutrient level is mostly less. In large regions, more than sixty million square kilometres or 20% of the world ocean surface, lack of iron creates ocean deserts with low biological activity – High Nutrient Low Chlorophyll or HNLC regions. ISA will result in mixing water from different ocean levels, increasing total biomass and primary productivity.

Contributing factors to ocean mixing include activation of brine production by enhanced winter ice freezing, less stratification of ocean water by reduced ice cap melting, and increased krill swarms due to greater volume of phytoplankton.

Huge swarms of krill move up and down hundreds of meters every day, eating plankton on the surface at night and resting in the deep water in the day. The krill move through a barrier called the thermocline, in and out of the higher nutrient deep ocean water. This daily movement helps to fertilize the surface water. By increasing plankton growth, ISA will increase krill population, thereby increasing the daily transport of deep water into the top layer. This will help replace nutrient removed by phytoplankton growth, reducing change to downstream nutrient levels.

How does ISA affect oxygen level?

ISA is the only available way to fertilize oceanic plankton at low and even dosage. By cooling the ocean surface through multiple effects, ISA enables the ocean to absorb more oxygen. Further, ISA protects against low oxygen (anoxia) by promoting increased vertical cycling of the ocean water.

Is there an upper limit for iron uptake by ocean life?

The main issues for upper limits are theorised with far higher iron concentration than delivered by ISA, and include downstream depletion and anoxia. Using all the available nutrients in one region with added iron would constitute the upper limit, but ISA is well below these levels, and ISA nutrient uptake is counteracted by causing krill to bring up deep ocean water nutrients. While adding to the total productivity and biodiversity, specific impacts of iron limits in sensitive locations indicate the need for careful measurement. Similarly, depletion of ocean oxygen levels from concentrated plankton blooms constitute a limiting factor, as seen in dead zones caused by agricultural runoff from rivers. The concentrations of iron from ISA are well below the level where these effects occur. At ISA level these factors are outweighed by the broad benefit for biodiversity of increasing overall uptake of otherwise unused nutrients.

Could ISA help clean up marine plastic?

Research is planned to determine how iron delivered with ISA can activate microbes that consume and degrade marine micro plastics, helping to remove a significant source of ocean pollution.

Can ISA affect the ozone layer?

No. The ISA plume only acts within the first kilometre above the ocean, where its chlorine is expected to deplete ozone that causes warming, as well as chlorofluorocarbons. The ozone layer that stops UV radiation is twenty kilometres high, in the stratosphere. ISA chlorine will be completely removed in the lower atmosphere by reaction with methane and other gasses, and will never rise to the stratosphere.

What political issues does ISA face?

A primary blockage for ISA is the widespread false belief among advocates of action on climate change that reducing emissions is the only way to stop global warming. This belief ignores the potential low cost and high impact of carbon dioxide removal technologies such as ISA, seeing research on carbon removal as detracting from the political focus on emission reduction.

Another widespread false assumption is that the settled science of climate change means political strategies to restore the climate are equally settled. This is wrong, because the Paris Accord plans to only remove 10% of planned emissions, and has no effective strategy to hold warming below four degrees. Achieving climate restoration must remove embedded warming from past emissions, through carbon dioxide removal methods such as ISA.

Relevant UN-system climate forums including the London Protocol on Dumping of Waste at Sea and the Convention on Biological Diversity. ISA will seek to ensure compliance with their guidelines to gain support for full deployment in the deep ocean in the event that our coastal trials are successful.