Title: Atmosphere carbon dioxide sequestration through fertilization of a high-nutrients-low chlorophyll (HNLC) oceanic region with iron

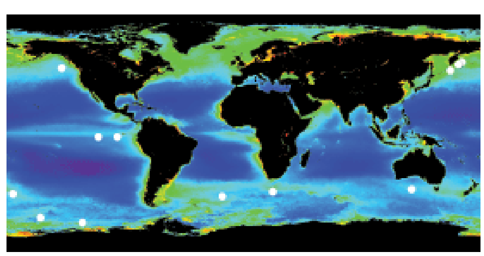
Project Leader: Narvekar, P.V..

Latest News

BACKGROUND

As far back as 1930s, scientists suggested that iron deficiency could account for scarce phytoplankton production in some areas of the Antarctic Ocean. **Decades later,** John H. Martin, oceanographer of Moss Landing Marine Laboratories, California, pointed out the larger role of iron in controlling the biogeochemistry of oceans and possibility that iron concentration in the ocean was higher during glacial periods when atmospheric CO_2 levels were lower. In late 1980s, he proposed the "iron hypothesis", that adding iron to the ocean would basically activate the biological pump by fueling phytoplankton blooms to remove CO_2 from the air.

National Research Council's report estimated that phytoplankton blooms could annually sequester extremely large quantities (2 GT) of carbon for less than $1 billion. Recommendations from two NRC workshops in the late 1980s called for an international iron enrichment experiment. By 2005, ocean scientists had conducted a dozen small-scale field experiments (white dots in the world map) in various parts of the ocean between 1993 and 2005 to test the iron hypothesis. Each study was conducted in the open ocean, and required between 1 and 3 metric tons of iron dispersed in 100-km^2 patches.



Data from NASA SeaWIFS Project

These experiments have verified the iron hypothesis

MECHANISM OF IRON FERTILISATION

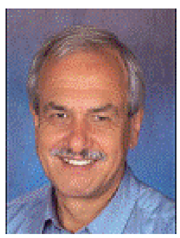
Phytoplankton can grow naturally when iron-containing aerosol dust falls over the ocean surface. Phytoplankton can fix 50 billion tons of carbon per year. However the Iron available for their growth is scarce because of its low solubility in oxygenated seawater. When the iron is available to them in abundant quantity, the phytoplankton develops in sporadic blooms. Larger species of phytoplankton, such as diatoms make the bloom bigger. The smaller phytoplankton is eaten by zooplankton. Their fecal material, sometimes aggregating with organic matter, sinks thereby carrying carbon into the deep ocean.

LOHAFEX (ANT XXV/3) PROGRAM

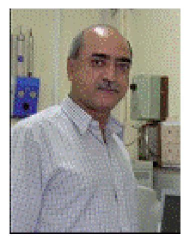
A team of Indian and German scientists will be conducting the iron fertilisation experiment LOHAFEX (Loha is Hindi for iron, FEX stands for Fertilisation EXperiment) from the German research vessel “Polarstern”. The experiment will be carried out in January 2009 in the ocean surrounding Antarctica.

RATIONALE

LOHAFEX will stimulate rapid growth of oceanic plant life – the minute, unicellular algae known as phytoplankton – over an area of 300 square kilometres by fertilizing it with 20 tonnes of dissolved iron sulphate. The spreading of tonnes of iron over the southern ocean is expected to trigger oversized blooms of phytoplankton. The team of physicists, chemists, biologists and geochemists will then study for seven weeks the effects of the algal bloom on the exchange of carbon dioxide (CO_2) between ocean and atmosphere as well as on the planktonic food chain and the organisms of the underlying sea floor.



Victor Smetacek is is a Professor for Bio-Oceanography at the University of Bremen, and at the Alfred Wegener Institute in Bremerhaven



Wajih Naqvi heads the Chemistry Department at National Institute of Oceanography, Goa of the Council of Scientific and Industrial Research, India

LOHAFEX CRUISE

The Indo-German team, comprising 32 scientists from India, 11 from Germany and 10 from Italy, Spain, Chile, France, UK and USA, will board “Polarstern” in Cape Town, S. Africa on January 7, 2009, and proceed on a mission to the experimental site in the southwest Atlantic at about 50°S latitude and 37°W longitude. They will disembark 70 days later in Punta Arenas, Chile, after spending an arduous two months in a desolate strip of cold, stormy ocean between the notorious “Roaring Forties” and “Furious Fifties”. But the scientists will be immersed in a fascinating experiment on board a sturdy ship, so they will be able to work at wind speeds that would rock and roll an average research vessel. If successful, LOHAFEX will set a landmark in the upcoming struggle to mitigate the worst effects of dangerous climate change.

The list of participants, participating Institutes and investigations planned by them are given at the end

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Polarstern

The undertaking is part of the Memorandum of Understanding between the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven of the Helmholtz Association and the National Institute of Oceanography, Goa of the Council of Scientific and Industrial Research (CSIR) that was signed in the presence of the Prime Minister of India and the Chancellor of Germany during her visit to India in October 2007. The costs of running the ship are being shared by Germany and India.

The results of the experiment will be of great interest to both ocean ecologists and geochemists because phytoplankton not only provide the food sustaining all oceanic life but also play a key role in regulating concentrations of the greenhouse gas CO_2 in the atmosphere. Indeed, there is reason to believe that fertilising the Southern Ocean with trace amounts of iron could help in transferring some of the CO_2 currently accumulating at an alarming rate in the atmosphere, to the deep ocean for a few centuries.

Testing this hypothesis is one of the goals of LOHAFEX. Another goal is to study the effects of iron fertilisation on the zooplankton, in particular the shrimp-like krill,which is the main food of Antarctic penguins, seals and whales. Stocks of krill have declined by over 80% during the past decades and their response to the iron-fertilised bloom will indicate whether the decline is due to declining productivity of the region for which there is evidence. Thus, large-scale iron fertilisation of the krill habitat could well help in boosting their stocks to their former high densities and facilitate recovery of the decimated great whale populations.

Earlier experiments have shown that fertilising a patch of sea surface in the Southern Ocean results in rapid growth of phytoplankton, which convert substantial amounts of CO_2 dissolved in the water into biomass. Such dense aggregations of algal cells are known as phytoplankton blooms. The CO_2 deficit in the surface layer caused by conversion to bloom biomass is compensated by uptake from the atmosphere until equilibrium is re-attained. The carbon in biomass consumed and respired by zooplankton and microbes in the surface layer refluxes back to the atmosphere within weeks or months but the carbon in organic particles in the form of dead algal cells and zooplankton faecal pellets that sink from the decaying bloom to the underlying deep ocean is sequestered from exchange with the atmosphere for centuries.

The fate of carbon from the bloom could not be adequately determined in earlier experiments. LOHAFEX will now study the entire range of processes determining the partitioning of carbon between atmosphere and deep ocean in the experimental bloom. Such a mechanistic understanding of the complex network of cause and effect gained from studying the same bloom under natural conditions over relevant time scales is required to parameterise mathematical models predicting the out-come of larger scale fertilisation.

How much carbon could this method transfer from the atmosphere to the deep ocean, and for how long? The area covered by the nutrient-rich, iron-limited Southern Ocean, the only part of the ocean where this technique would have a measurable effect, is vast: 50 million square kilometres, 15 times the area of India and 140 times that of Germany. If the entire Southern

Ocean were fertilised and a sizeable fraction of the bloom, equivalent to 20 grams carbon per square metre, sank well below 1,000 m, then about 1 billion tonnes of carbon (1 Gigatonne, Gt) would be sequestered annually for centuries.

The carbon footprint (additional carbon emitted by the technique) would be minor: only a few million tonnes of freely available iron sulphate are needed annually and a very small percentage of ships, currently transporting 7 Gt of goods every year, including oil and coal, would be required for transport.

However, 1 Gt is not much compared to the annual atmospheric CO_2 increase of 3.5 Gt and the current carbon emissions of 7 Gt. However, other proposed techniques to capture and dispose of CO_2 are much more energy-intensive and faced with the problem of disposal which can be visualised the following way:

If all the carbon in the excess CO2 in the atmosphere released by humans in the last century (200 Gt) were converted to its elemental state (e.g. graphite) in the form of a rod of one square metre base (1 cubic metre of pure carbon weighs 2 tonnes), then this rod would extend for 100 million kilometres into space and, at today's rate of emissions, reach the sun within 20 years! Alternatively, a plate of carbon 1 m thick would cover an area of approximately 330,000 km2, equivalent to that of Germany and represent about a third of the entire carbon contained in global terrestrial vegetation.

Clearly even extensive reforestation could sequester only a small portion of the excess carbon., The ocean, however, already contains 38,000 Gt of dissolved inorganic carbon (in the form of bicarbonate, carbonate and dissolved CO_2), so adding a few hundred Gt, if adequately diluted, is not going to make much of a difference. One Gt a year will add up to 100 Gt in a century of persevered fertilisation. Clearly, there is an urgent need to investigate the feasibility of this method and to assess its effect on the ocean biota.

So far only one experiment (EIFEX, the results of which have not yet been published) carried out on board Polarstern, on which the senior author served as Chief Scientist, was able to follow the rain of organic particles sinking from the bloom because it was carried out in a stationary ocean eddy which LOHAFEX will repeat. The difference is that LOHAFEX will be carried out in a more promising region of the Southern Ocean, will last 10 days longer and is better prepared to monitor the particle rain from the bloom than was EIFEX.

The scientific community is sceptical about the efficacy of ocean iron fertilisation (OIF) because published results have not convincingly demonstrated that carbon was actually sequestered for relevant time scales. They are also apprehensive of possible negative side effects that could result from commercialisation of OIF in the carbon credit market specified in the Kyoto Protocol. We feel that the issue is too important to be left to market forces, particularly in view of the uncontrollable, ongoing over-exploitation of marine living resources.

Recently, various scientific and international organizations have issued cautionary statements on OIF and called for more experiments before embarking on large-scale operations.

We feel that an international agency manned by scientists and operating under the UN umbrella should be established to supervise and monitor OIF implementation. LOHAFEX is the first of the new generation of iron fertilisation experiments and the beginning of close cooperation between India and Germany in the field of ocean research to ameliorate the dangerous effects of ongoing climate change.
Ocean scientists have been thinking about iron's role in oceans, plankton growth, and climate for a long time. The success of sequestration via iron fertilization of the ocean ultimately depends on whether that carbon stays sunk in the deep ocean.

Other reading material

- Should Oceanographers Pump Iron?
- Ocean Iron Fertilization—Moving Forward in a Sea of Uncertainty
- The next generation of iron fertilization experiments in the Southern Oceans
- A changing climate of opinion?
- Marine Ecosystem : Pumping Iron
- Fertilizing The Ocean With Iron Large-scale experiments will determine whether plankton
  can battle climate change
- LOHAFEX: Deutsch-indisches Forschungsexperiment zur Eisendüngung des Meeres