# ORGANIC MARICULTURE AND BIOSEQUESTRATION

## Executive Summary.

The concept is to use novel, buoyant, ultra-slow-release fertilizer flakes, made of low-cost, natural and waste materials, which are distributed over nutrient-deficient ocean areas to cause ecologically-balanced communities of phytoplankton (diatoms and microalgae) and marine organisms above them in the food chain to increase many-fold. Such an increase in marine biomass transforms acidifying carbon dioxide into neutral biomass. Furthermore, when marine organisms are consumed in the ocean or die, part of their carbonaceous material sinks to the seabed where, if conditions are propitious, portions are either biosequestered in deep ocean sediments for typically thousands of years or are otherwise removed from the terrestrial biosphere for long periods.

The de-acidifying effects of these processes are magnified whenever:

\* the ocean depths are cold enough to hinder bacterial degradation of the biomass;

\* the rate of descent of the sinking biomass is fast, as is the case with dense aggregates of diatoms and with the bodies and excrement of larger marine species; and

\* when the components of fertilizer used are tailored to match the specific nutrient deficiencies known to occur down-current or down-wind from the site of buoyant fertilizer dispersal.

The extra, typically turquoise-coloured biomass generated in the surface waters also significantly increases ocean reflectiveness (albedo) and cloud formation, both leading to ocean cooling.

The chosen fertilizer-carrier mix is designed to meet the strict requirements of international agreements on ocean fertilization research and usage, see <http://iospress.metapress.com/content/l3nrrdt64f6v0cb0/fulltext.pdf>. The carrier comprises rice husks with the triple benefit of being:

\* a plentiful, benign, and naturally-occurring waste product;

\* light yet durable; and

\* high in hydrated silica that diatoms require to make their dense yet porous skeletons (frustules). Ocean areas remote from land are typically deficient in phosphate, silica and iron – all of which are available as industrial tailings wastes and as otherwise commercially valueless low-grade mineral deposits.

Durable buoyant flakes containing the ultra-slow release nutrients are made by adhering the mineral dusts to rice husks using hot-melt lignin glue, which is a waste or co-product from removing the sugars from straw. Flakes are distributed pneumatically at sea from large, possibly otherwise obsolete, bulk ships.

## Introduction

Minerals are added to the oceans by coastal erosion, runoff, dust storms and volcanoes. However, most are lost to the biosphere because they sink rapidly. Moreover, massive amounts of iron and phosphorus in the form of fish catch have been and are being removed from the oceans by humans. This remedial concept has been developed to replace those lost minerals, thereby rendering the oceans more productive and enabling their sediments to be a more substantial carbon sink. Thus, people will benefit from healthier jurisdictional seas and biodiversity, from additional fish catch and royalties, from reversing ocean acidification, global warming and sea level rise, and possibly even from carbon credits.

The most suitable form of iron fertilizer may be the red mud waste product from bauxite refining. Not only does this have other useful mineral components but it is alkaline, cheap, already finely-divided, and readily-available in tailings stockpiles. Additional suitable, and otherwise uncommercial, sources of iron and other ocean-deficient minerals are ironstone, lateritic soil, and various low-grade ore deposits of iron or phosphate. The third flake component is lignin, a by-product of the extraction of cellulosic sugars from crop and forestry wastes. Lignin can be used as plentiful and durable thermo-adhesive to glue the fertilizer to the carrier. Moreover, when it eventually sinks, the lignin itself will form a carbonaceous sediment that is fortuitously resistant to conversion into soluble carbon dioxide or methane.

The fertilizer flakes are simply and economically made by heating the three components differentially, typically using concentrated solar or other heating. The turbulent mix of husks, glue, and minerals combine to form fertilizer flakes in successive stages. As they fall in a wedge-shaped tower, successive layers of powdered glue and mineral accrete onto all surfaces of each rice husk. The flakes are then compressed flat before ship transference and later pneumatic dissemination to the ocean surface. About 2% of any nutrient-poor sea surface should be covered in flakes.

Even in rough, ice-strewn polar waters, the slightly buoyant flakes will last on the surface for a year or so, whilst their nutrients are slowly released, extracted and absorbed by special, concentrating proteins (ligands) in phytoplankton’s cell walls. Each tonne of iron in the flakes can theoretically produce around 1,000 tonnes of algae or 29,000 tonnes of harvestable, dry weight fish. In practice, carbon sequestration and other losses might reduce this last figure some fivefold.

Under colonisation by phytoplankton and their predators, each sunlit flake will form a miniature green habitat, farm or nursery that anchors or shelters eggs, larvae and organisms, feeds and provides mates for its resident ecology, as well as providing a rich hunting ground for larger species. Undesirable eutrophication is inhibited by the ultra-slow release of the fertilizer and by the predation this allows.

For jurisdictional seas and exclusive economic zones, the leasing out of fishing and carbon credit rights for areas of moving and effectively-managed, fertilized plumes of water ought to be achievable. Plumes in the high seas are another matter. One solution might be for the UN to take stewardship of these, thereby providing for equitable access to corporations from all nations, whilst the UN polices them, ensures adequate scientific monitoring and research, and obtains a secure revenue base from a resulting share of royalties. Fish catch from unmanaged areas would remain royalty-free, though still subject to limits.

In addition to the benefits discussed above, multi-component fertilizer released from buoyant flakes produces several other desirable results. First, and unlike the highly-soluble commercial fertilizer already trialled, it means that little is wasted to the dark depths; virtually all is released in the top several centimetres of best-illuminated, and hence most productive, water. Second, because of the high illumination and partial interruption of sunlight to the depths caused by the presence of sunlight-absorbing flakes and extra plankton in the surface waters, the growing season is extended in polar waters, more CO2 is converted into biomass, and there are more fish stocks than otherwise. Third, the increased albedo of the plankton-rich green ocean, combined with the consequent reduction in atmospheric CO2 and the increase in cloud-seeding emissions caused by the phytoplankton, means that both global warming and sea-level rise would substantially be reduced, then reversed by essentially natural means, over business-as-usual.

After about fifteen years of full operation, the reductive effect of this on global temperatures is estimated to be able substantially to offset global warming and extreme weather events exacerbated by anthropogenic greenhouse gas emissions, whilst the concomitant biosequestration of carbon progressively reverses ocean acidification in surface, then deeper waters.

Fertilizer flakes and nutriated plumes are readily tracked and managed. Once the science has been validated and licences for trials approved under international scientific surveillance, industry will do the rest. No other method of reversing ocean acidification is as: achievable, rapidly effective, sure, safe, sustainable, beneficial, politically-acceptable, and indeed profitable, as this. Documents sent to The Oceanography Society provide additional support for these claims.

**Expected Impact**

* Laboratory research to confirm the flake’s effect on plankton and marine life in nutrient-deficient seawater, flake durability, and the comparative suitability of the flake compositions proposed;
* Pilot flake production, approved field trials, and techno-economic analyses to establish safety and viability, leading to social licensing;
* Commercial agreements and rollouts with outcome monitoring to establish effectiveness and profitability.

OVERALL IMPACT: progressive ocean de-acidification.

*Expected duration of work to make progress:*

Some of these durations can be overlapped. No time has been allowed for negotiation, agreement, collaboration delays, write-up, publication, discourse, peer confirmation, approvals, or contingency. Each activity is assumed to be performed by the organization with the most applicable facilities, resources, and capabilities. Variation from this will increase both the duration and cost.

* Laboratory testing & refinement: **9 months & $150k**
* Design/construct/commission pilot flake facilities: **15 months & $12m**
* Field trials and analyses: **22 months & $160m**
* Global rollout: **Progressive. Could achieve the reversal of ocean acidification and global warming by 2027** unless dire positive feedbacks occur to delay achievement**.** **Self-funding,** given some negotiated agreements**.**

*Expected total cost:*

**USD $172m in June 2013 dollars.**

Investments by, and profits and other benefits to, commercial organizations, institutions, governments, peoples, international bodies and biodiversity should prove the unparalleled value of this seminal philanthropic investment by 2020.

*Author biography 3000 char max for each author bio*:

Nurtured by a warm, extended family, I grew up in Australia, a city boy with country experience. From an early age I can remember conceptualizing ways to solve problems, mainly those solvable by science or technology. This focus strengthened through work and political participation; reading science fiction contributed to expanding my ideas of what is possible.

Following my interests, I took two bachelor degrees concurrently, one in science and one that mixed history with economics, both at the University of Melbourne. After twelve years in industry, I earned an MBA from Stanford. My interests and skills in emerging technologies and ideas culminated in my appointment as the inaugural Director of Knowledge Management with the Australian Defence Organization.

My early industrial experience had begun in Sales with an international merchant house, then through IT, Finance, and Corporate planning in a mid-sized food and packaging company, and yet later to the pharmaceutical industry, where I was a senior executive at the Commonwealth Serum Laboratories (CSL).

Whilst at CSL, I had my first experience of the effects of global warming. After a ten-year drought, the Ash Wednesday Bushfires (1983) destroyed my family home, despite the efforts made by my comrades in the local fire service. Nothing effective could be done to stop the inferno. All we could do was to try and save the people. Hundreds were saved, but not all. Nor did much of our wildlife survive, though our magnificent eucalypt forests are now back.

As a consultant and independent researcher for the past nine years, I have been researching and developing solutions to the environmental challenges we are all facing. My technology suites in algaculture and biorefinery technology are currently under patent examination.

Not having the pressures and constraints that most academic and corporate researchers operate under, whilst taking advantage of their publications, I have been able to develop my solutions holistically. This has also enabled me to develop systems of analysis to predict which concepts and combinations of technologies are technically, commercially, or politically non-viable. The same analysis has worked to make mine viable, subject to expert validation.

As my land-based solutions to climate change are incremental, they are likely to have substantial global effect only after the oceans have disastrously expanded, become acidic, depleted, and tumultuous. A simpler, faster-acting solution is required, one where corporations take up the load, thereby doing well by doing good. This is what is offered here to the judges of the Ocean Challenge competition. Properly supported, the innovations can act both in time and at the necessary scale for our oceans, atmosphere and biodiversity to recover.