ecofluidics

Unpublished Letter to Nature

John Reid

26 July 2008

ecofluidics pty ltd, acn 091 770 339
12 view street, sandy bay, tasmania, 7005, australia
613 6295 0468 (o/s), 03 6295 0468 (aust)
info@www.ecofluidics.com

Unpublished Letter to Nature

Contents

Covering Letter

3 July 2008

The Editor
Nature

Dear Sir

Please find attached my Letter for submission to *Nature*. The Letter contains 1500 words, 3 tables and 1 diagram.

I am a retired physicist and former employee of CSIRO. A friend and myself thought of the method of carbon sequestration by using the energy from sub-sea hydrothermal vents to mix the ocean15 months ago and decided to form Ecofluidics and take out a patent. Complete specifications were filed today. We took this course because we believe it increases the likelihood of our idea becoming a physical reality.

In developing this idea, when talking to former colleagues who are oceanographers, I repeatedly encountered the objection that upwelling would "always" bring up excess CO_2 which would then be exhaled into the atmosphere. None of them could refer me to papers in the published literature where this is spelled out. When I used observational data and did the calculations I found that it was certainly not the case for significant areas of the ocean. It seems to be something of an "urban myth" among oceanographers. There also appears to be an unspoken ideological objection to geo-engineering. If so, then well and good, but it should not be allowed to distort the facts.

Geo-engineering is about to become a hot topic. There is a looming battle between those who believe the earth should be restored to a pristine pre-industrial state by the exercise of commercial restraint and those who believe the best practical course is to use whatever means are available to maintain the health of the environment and of human society. Whatever the rights and wrongs of these points of view, let us at least make decisions based on good science and not on myths and false preconceptions.

It is in this spirit that I submit the attached Letter.

Yours sincerely

John Reid PhD

Letter to Nature as Submitted

Lovelockian pipes can be made to work

SIR - James E. Lovelock and Chris G. Rapley proposed bringing nutrients, nitrate and phosphorus, found at depth, to the surface of the ocean in order to remove CO_2 from the atmosphere by the ensuing photosynthesis ('Ocean pipes could help the Earth to cure itself', *Nature*, **449**, 403; 2007). Their proposal was criticized on a number of grounds by John Shepherd, Debora Iglesias-Rodriguez and Andrew Yool ('Geo-engineering might cause, not cure, problems' *Nature*, **449**,781;2007). One criticism was that the scheme would bring water with high natural p_{CO2} levels (associated with the nutrients) back to the surface, potentially causing exhalation of CO_2.

We show that this is not always the case and depends on the location. Their other criticisms were based on experiments with intermittent iron fertilization and do not apply to the continuous upwelling case. The difficulty with Lovelock and Rapley's proposal is physical rather than chemical: where is the energy to be found to lift the colder denser water to the surface?

The physical chemistry of the interaction of carbon dioxide with seawater is complex but well understood, (see W. S. Broecker and T.-H. Peng *Tracers in the Sea*, Lamont Doherty Geophysical Observatory, 1982). Temperatures, salinities and concentrations of all of the major chemical components needed in the calculations can be downloaded from the WOCE Pacific Ocean Atlas (http://www-pord.ucsd.edu/whp_atlas/pacific/sections.htm)

Four widely separated locations in the Pacific Ocean were chosen and are listed in Table 1. We calculated what would happen to alkalinity and total carbon content when a parcel of water from intermediate depth is brought to the surface at each of these locations. Graphs of the various quantities were downloaded in *pdf* form and values to be used were read from the graphs. These values are shown in Table 2, which shows the salinity in p.s.u. (practical salinity units) and concentrations of the other components, phosphorus, silicon, total alkalinity, A_i, total dissolved inorganic carbon, C_i, and nitrate, N_i, at the locations listed in Table 1.

We assume that when the parcel of water reaches the surface phytoplankton will bloom and photosynthesis will remove all of the nitrate. This will bring about changes to the total alkalinity, and the total carbon concentration to yield new values A_o, and C_o, according to the following formulae:

$$A_o = A_i + N_i \qquad (1)$$

and

$$C_o = C_i - 6.8N_i \qquad (2)$$

Equation (1) describes the increase in alkalinity brought about by photosynthesis and is derived from equation (2 - 25) of Broecker and Peng (*loc. cit.*); alkalinity increases according to the number of nitrate ions removed from solution. Equation (2) above describes the decrease in carbon brought about by photosynthesis. The factor of 6.8 is the Redfield ratio for carbon and nitrogen. Resulting values of A_o and C_o are listed in Table 3.

The total dissolved inorganic carbon, C_{380} , that can be held by the water mass at atmospheric partial pressure (380) depends on temperature and alkalinity and to a lesser extent on the other parameters listed in Table 1. This was calculated using the *CO2sys* program (see Lewis, E., and D. W. R. Wallace. 1998. *Program Developed for CO2 System Calculations.* ORNL/CDIAC-105. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee). The sequestration rate, i.e. the rate at which carbon is absorbed from the atmosphere by the water mass per kilogram of upwelled water, is given by

$$\Delta C = C_{380} - C_o \qquad (3)$$

where negative values of ΔC imply that CO_2 is exhaled to the atmosphere

We assume that the upwelled water mass soon acquires the local sea surface temperature (SST) and that its alkalinity will remain unchanged once the initial phytoplankton bloom has occurred. Using the WOCE values of SST and the computed alkalinity, values of C_{380} and ΔC were found and are listed in Table 1. Comparison of values of the sequestration rate, ΔC , for locations A, B and C indicate that it is positive and a strong function of local SST at the upwelling location. However comparison of ΔC between locations A and D, which have the same local SST, indicates that alkalinity is also a factor. C_{380} at location D is negative because the lower alkalinity and lower nitrate concentration of the upwelled water mass leads to net exhalation of CO_2 to the atmosphere.

Thus upwelling can lead to carbon sequestration but only at locations where the nutrient concentration and alkalinity of the upwelled water are relatively high. Such locations can be found in most of the Pacific ocean north of the equator and as far south as latitude 30^o S in the Western Pacific, an area of the earth's surface larger than the continent of Asia.

The importance of alkalinity and nitrate concentration in these calculations implies that conclusions drawn from iron fertilization experiments do not apply to fertilization by upwelling as discussed here. High alkalinity and high nitrate concentration are both important in bringing about positive sequestration in regions where iron is not the limiting factor.

Another distinction from the iron fertilization experiments is that those experiments all involved a single one-off event which could not be tracked

continuously for long periods of time owing to limitations on cruise time and ship availability. Artificial upwelling as discussed here involves an ongoing process which continues unabated until such time as the mechanism fails. In this way a large carbon-containing biomass will be built up until the export of carbon to the deep ocean in the form of faecal pellets and other detritus is equal to the total carbon input from the atmosphere and the upwelled water. Much of this carbon will be remineralized in the deep ocean where it will remain for a millennium or so. Even when it resurfaces the ratio of carbon to nitrate and phosphorus should remain in the Redfield ration and renewed photosynthesis would ensure that there would be no net exhalation to the atmosphere.

A more cogent criticism of Lovelock and Rapley's proposal is based on physical rather than chemical grounds. The peak in nutrient concentration occurs at depths of 1000m or so, rather than the 200m suggested by them. It seems unlikely that any scheme based on wave power alone could generate enough energy to raise water from these depths in sufficient quantity to be useful.

However a supply of carbon-neutral energy is available in the deep ocean in the form of superheated water released by hydrothermal vents found along volcanic arcs and mid-oceanic ridges. When such superheated water (typically at 360^{o} C) is brought up to shallower depths (1100m), it is capable of moving much larger quantities of nutrient-rich water by entrainment into the plume of steam bubbles which will form when it boils (Figure 1). The density ratio of steam to the surrounding water mass is orders of magnitude larger than the density ratios within the water mass itself so that the flux "gain" in moving water upwards by this means is similarly large.

Only 20 percent of the world's mid-oceanic ridges have been explored and wherever they have been explored vents have been found. It has been estimated that the total power released from mid-oceanic ridges is of the order of tens of terawatts, roughly equal to the total power consumption of mankind.

There is likely to be both sufficient hydrothermal power and sufficient nutrient available in the North Pacific alone to halt the present upward trends in atmospheric carbon and ocean acidification.

Acknowledgement: I would like to thank Ass. Prof Tom Trull of the Institute of Antarctic and Southern Ocean Studies, University of Tasmania for his helpful guidance about carbon chemistry.

John Reid
Ecofluidics Pty Ltd
12 View Street
Sandy Bay
Tasmania 7005
Australia

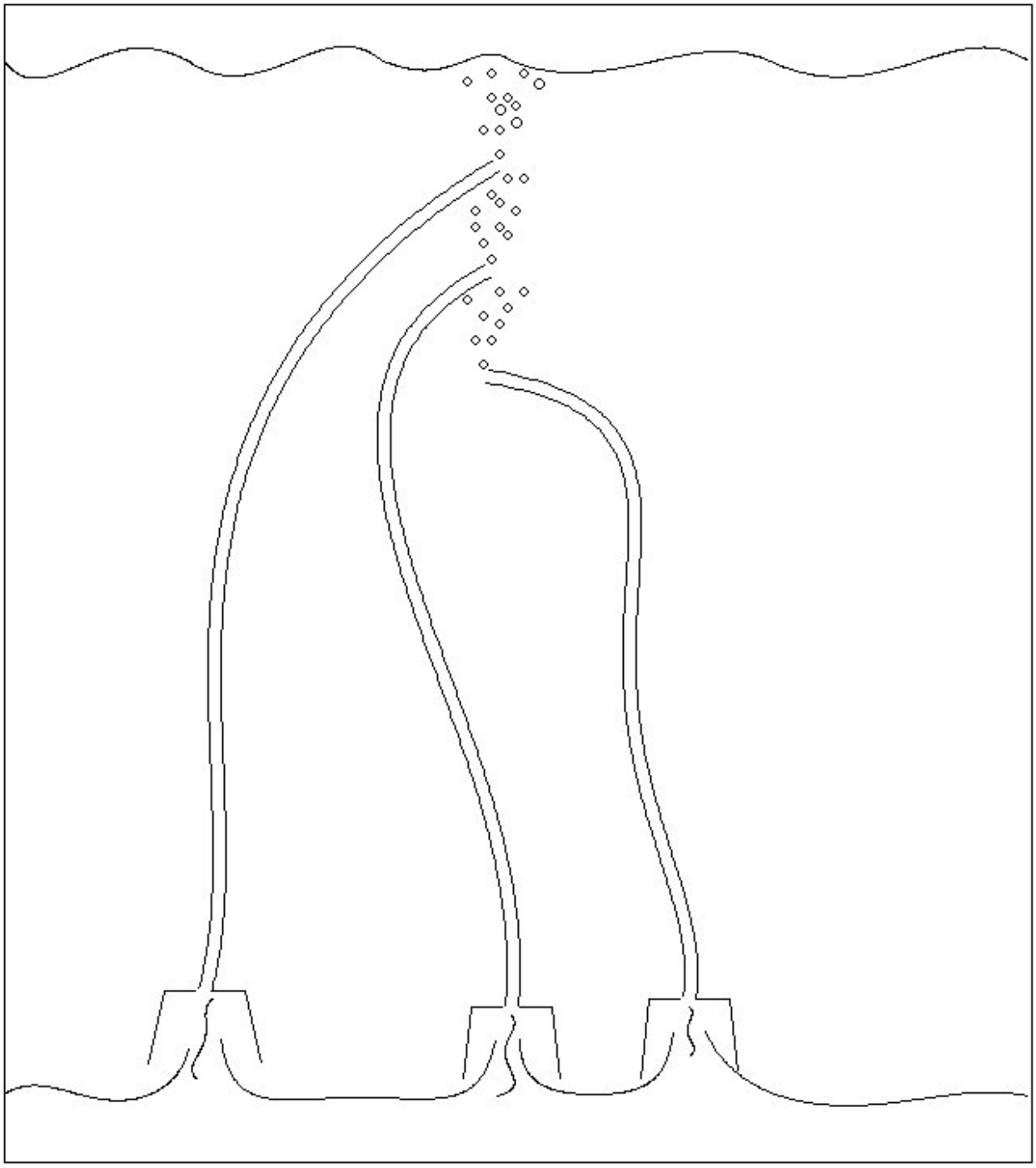

Figure 1. A schematic diagram showing how hydrothermal vents in the ocean floor may be used to mix the upper layers of the ocean by conducting their superheated effluent through insulated pipes, to depths at which it boils.

Location	Latitude	Longitude	Depth	WOCE Section
A	15^o S	105^o W	800m	P18
B	40^o S	105^o W	1000m	P18
C	54^o N	165^o W	400m	P15
D	30^o S	165^o W	500m	P15

Table 1. Sample locations in the Pacific Ocean.

Location	Salinity	P	Si	A_i	C_i	N_i
A	34.5	3.0	60	2320	2300	43
B	34.3	2.2	30	2295	2200	31
C	34.0	3.0	98	2320	2330	42
D	34.6	1.3	7	2290	2127	19

Table 2. Salinity (in p.s.u.), concentrations of phosphorus, P, silicon, Si, alkalinity, A_i, dissolved inorganic carbon, C_i, and nitrate, N_i, at each of the locations shown in
Table 1. All concentrations are given in μmol / kg.

Location	A_o	C_o	SST	C_{380}	ΔC
A	2363	2008	24^o C	2031	23
B	2326	1989	15^o C	2082	93
C	2362	2044	8^o C	2171	127
D	2309	1998	24^o C	1990	-8

Table 3. Alkalinity, A_0, and the dissolved inorganic carbon concentration, C_0, which result when the parcels of water described in Table 2 are brought to the surface. The saturation concentration of atmospheric carbon in the surface layer of the ocean, C_{380} at the given sea surface temperature, "SST", is also shown. The difference between the two carbon concentrations, ΔC ,indicates how many micromoles of carbon will be taken up (positive values) or exhaled (negative value) per kilogram of upwelled water.

Rejection eMail

Subject: NATURE: Thank you for your submission to Nature
From: Decisions@nature.com
Date: Sat, July 5, 2008 0:53
To: jsr@ecofluidics.com

4th July 2008

Dear Dr Reid

Thank you for submitting your manuscript, which we are regretfully unable to offer to publish.

It is Nature's policy to return a substantial proportion of manuscripts without sending them to referees, so that they may be sent elsewhere without delay. Decisions of this kind are made by the editorial staff when it appears that papers are unlikely to succeed in the competition for limited space.

In the present case, while your findings may well prove stimulating to others' thinking about such questions, I regret that we are unable to conclude that the work provides the sort of firm advance in general understanding that would warrant publication in Nature. We therefore feel that the paper would find a more suitable outlet in a specialist journal.

I am sorry that we cannot respond more positively on this occasion, but I hope that you will rapidly receive a more favourable response elsewhere.

Yours sincerely

Manuscript Administration, Nature

This email has been sent through the NPG Manuscript Tracking System
NY-610A-NPG&MTS