Absorption of flue gases by water

SIR — Flue gas desulphurization by means of seawater scrubbing is an effective technique for reducing industrial emissions of sulphur dioxide (SO_2) with reported efficiencies as high as 99% (refs 1,2). Conventional scrubbers, however, require relatively large volumes of sea water to maintain the necessary liquid-to-gas ratios. We have carried out preliminary studies of SO_2 absorption in sea water to assess the potential of injecting flue gases directly into the sea.

A known volume of sea water (300 cm^3) was placed in a 500-cm^3 Dreschell bottle with a sintered frit. A stream of SO_2 in nitrogen (4,000 p.p.m.v.) was bubbled through the water at a set flow rate, and the concentration of SO_2 at the exit of the bubbler was monitored continuously using an infrared analyser (ADC model RF2A) and chart recorder. The pH of water was measured at the beginning and end of each run.

Typical absorption efficiency–time profiles are shown in Fig. 1. Initially all the SO_2 was absorbed, but after about 10 min the absorption efficiency began to fall off, reaching almost zero after 2 hours. Absorbed SO_2 is rapidly oxidized to sulphate in sea water[3] resulting in acidification of the reacting solutions. It was possible to evaluate the SO_2 absorption capacity of sea water as 1.3 ($\pm$ 0.1) g SO_2 l^{-1} from absorption curves in five experiments. Increasing the flow rate from 0.8 to 3 l min^{-1} had no significant effect on the absorption of SO_2.

The final pH in all experiments was about 2, indicating that the decrease in absorption efficiency was due to the lowering in pH as a result of SO_2 absorption. That SO_2 solubility decreases with decreasing pH is well established[2], but sea water can accommodate significant quantities of acid without a significant change in pH. Bicarbonate was the main buffer. The buffer capacity was studied by adding increasing quantities of a standard sulphuric acid solution and monitoring the resultant pH. A typical curve is shown in Fig. 2. The buffer capacity begins to break down at around 10^{-3} mol H^+ l^{-1}, and at 10^{-2} mol H^+ l^{-1} any advantage of using sea water over pure water is lost.

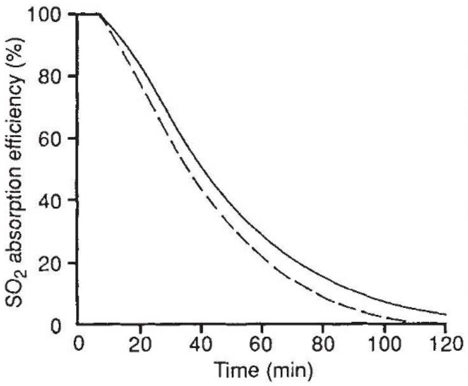

FIG. 1 Sulphur dioxide absorption efficiency in sea water versus time. Solid line, instant ocean sea water; dotted line, Mersey brine.

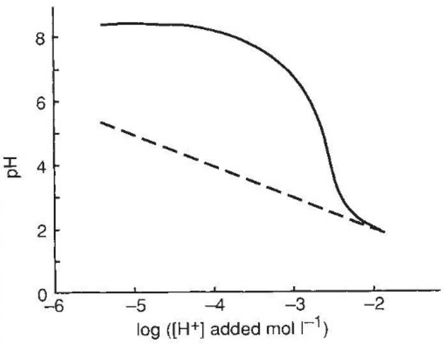

FIG. 2 Decrease in seawater pH as a function of added sulphuric acid. Similar curves were obtained with natural seawater samples. Solid line, instant ocean sea water; dotted line, pure water.

Sea water is a concentrated electrolyte solution containing high levels of chloride, sulphate and bicarbonate ions. Flue gases from a 2,000-MW power plant emitting 4×10^3 g SO_2 s^{-1} and 2×10^3 g NO_x s^{-1} could be discharged directly into an ocean current with no perceptible effect on seawater pH or composition. Emissions of toxic metals associated with particulate matter may be minimized by passing the flue gases through suitable dust collection equipment, whereas NO_x species could be reduced by using NO_x abatement technologies, before piping the flue gases out to sea. In any case these would be diluted to background levels given the high transport rates of ocean currents (10^7–10^8 m^3 s^{-1}).

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Density-dependent populations

SIR — The apparently chaotic dynamics generated by a deterministic but nonlinear relation between successive population densities have cast doubts on the efficacy of the standard methods of detecting population density-dependence[1]. We believe that these doubts are unfounded.

We applied the conventional standard method of detecting density-dependence[2] to the deterministic relation between successive population densities $N_{t+1}=N_t\exp[r(1-N_t/K)]$, where N_t denotes population density at time t, r is the intrinsic relative growth rate and K is the equilibrium density. Chaotic dynamics are generated by values of $r>2.6294$. The analysis used 1,000 successive series of 10 values generated by the model with K=1,000 and for each r=2.7, (0.1), 3.1. The test was also applied to a stochastic version of the model in which N_{t+1} is assumed to be a Poisson variate with mean $N_t\exp[r(1-N_t/K)]$. The results are presented in the table. Even for a series as short as 10 observations, density-dependence is detected in more than 99% of the cases at the 5% level.

Clearly, chaos induced in this instance by a first-order difference equation does not prevent the detection of density-dependence by the standard method. Similarly, in the case of chaos induced by second or higher-order difference equations it is confidently expected that the underlying signal will be detected by the standard tests for stationarity of autoregressive schemes. Thus chaos does not in any way invalidate the conventional tests of detecting density-dependence.

NUMBER OF CASES IN WHICH BULMER'S TEST DETECTED DENSITY-DEPENDENCE

	Deterministic model		Stochastic model	
r	5%	1%	5%	1%
2.7	1,000	1,000	999	999
2.8	1,000	1,000	990	983
2.9	993	957	992	974
3.0	996	990	996	974
3.1	997	988	993	976

We used 1,000 sets of 10 observations at the 5% and 1% levels of significance in the model $N_{t+1}=N_t\exp[r(1-N_t/1{,}000)$.

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MAY REPLIES — My News and Views article[1] referred mainly to population models built up from assumptions about the behaviour of the constituent individuals (as distinct from those with phenomenological, population-level parameters, as above). I discussed how some kinds of noise in some behavioural parameters can, if nonlinearities in the