

Biomimicry -
Sequestering Carbon Dioxide as
Calcium Bicarbonate

Ken Green and Graham Thoms

Introduction

We are going to show you a technology for the sequestration of carbon dioxide in aqueous solution as

calcium bicarbonate

- Natural
- Safe
- Effective
- Enough capacity
- Permanent sequestration
- Practical to apply
- Non polluting
- Minimal carbon footprint
- Economic

The Problem

The two dangerous forms of carbon dioxide are CO₂ gas in the atmosphere and dissolved carbon dioxide/carbonic acid in the oceans

- Anthropogenic carbon dioxide, CO₂, emissions
70 million tonnes per day
- 100ppm+ increase in the atmosphere since about 1850s
Greenhouse effect/Climate change
- Ocean acidification (pH down 0.075pH)
25 million tonnes CO₂ absorbed per day
- Conservation and reducing emissions will not prevent the problem, only delay
- Renewable energy limited application
- Need to permanently sequester CO₂ emissions from fossil fuels in large quantities to make a significant difference

Ocean Acidification Problem

- Most dissolved CO₂ is in surface to shallow waters
- Largest impact on seawater acidification
- Largest impact on marine life
- Largest impact on coral reefs

Bicarbonate

- a safe form of carbon dioxide

- Bicarbonate is a safe form of carbon dioxide
- It is found in baking soda as sodium bicarbonate
- It is the temporary hardness of water as calcium bicarbonate
- There is a huge amount of bicarbonate in the oceans already (203 trillion tonnes) which has been stable at the pH of seawater for millions of years. The atmospheric CO₂ was at 280ppm all of this time

The Solution

- Capture carbon dioxide emissions in water
- Convert captured carbon dioxide gas emissions in water and already captured carbon dioxide/carbonic acid in seawater to bicarbonate
- Sequester in the oceans as calcium bicarbonate

So how do we do it?

- Think of it as a simple acid-alkali or acid-base neutralisation reaction



Atmosphere - Acid gas

Earth - Alkali Minerals in the earth/magma

Oceans - Salt by neutralisation in water

Atmosphere – Acid gas

Oceans - Salt

Earth -
Alkaline
mineral

Atmosphere – Acid gas
carbon dioxide/carbonic acid

Oceans – Salt
calcium bicarbonate

Earth -
Alkaline mineral
Calcium carbonate

How do we convert carbon dioxide CO₂ to bicarbonate HCO₃⁻ ?

- Arrange CO₂ gas to be introduced to basic or alkaline conditions



- We use calcium carbonate as a preferential alkali/base



One molecule of carbonic acid/dissolved carbon dioxide will react with **one** carbonate anion to form **two** anions of bicarbonate.

The products of the reaction are soluble and are able to be discharged as effluent. There is no solid residue.

Carbon Dioxide in Water

In nature carbon dioxide CO₂ forms the following:

- 1 **Carbon dioxide gas in the atmosphere**
CO₂
- 2 **Dissolved carbon dioxide or carbonic acid in water**
H₂O.CO₂ or H₂CO₃ **Acidic pH <6**
- 3 **Bicarbonate anions in fresh and seawater**
HCO₃⁻ **Intermediate pH 6.5-10**
- 4 **Carbonate anions in water**
CO₃⁻⁻ **Alkaline high pH >10.5**

Carbon dioxide/carbonic acid is stable under acidic, low pH conditions
Bicarbonate anions are stable under intermediate pH conditions
Carbonate anions are stable under alkaline, high pH condition

Carbon Dioxide Cycle in Water

High pH
pH 10.5+

Carbonate anion
(CO₃)²⁻

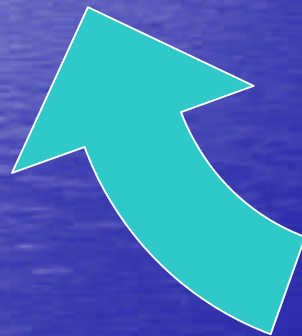
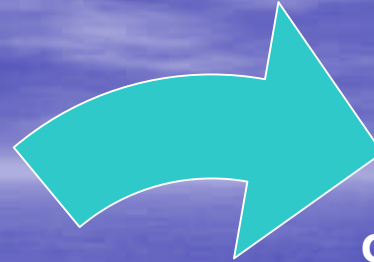
Low pH
pH 4-6

Dissolved
Carbon dioxide
H₂O.CO₂

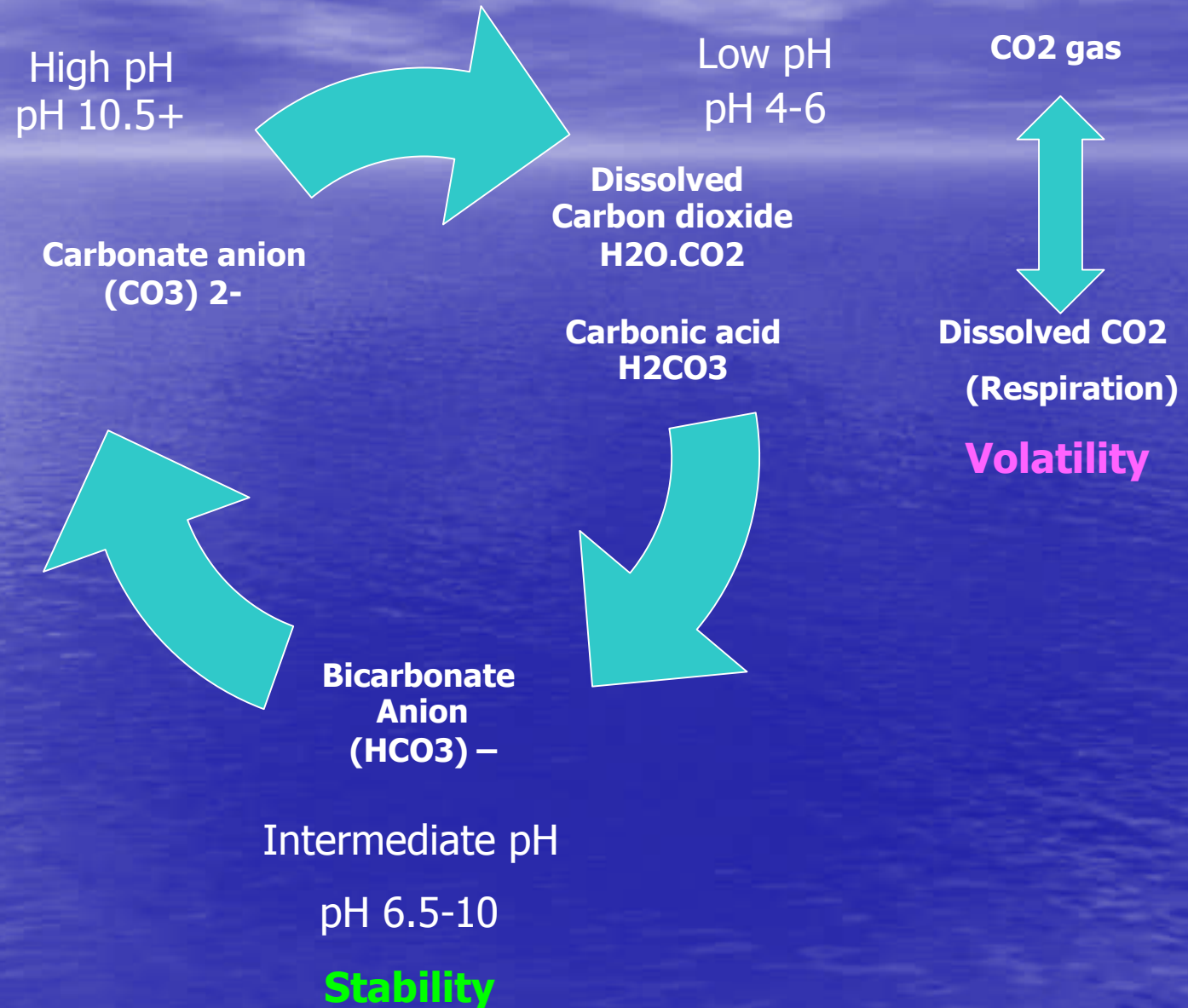
Carbonic acid
H₂CO₃

Bicarbonate
Anion
(HCO₃)⁻

Intermediate pH
pH 6.5-10



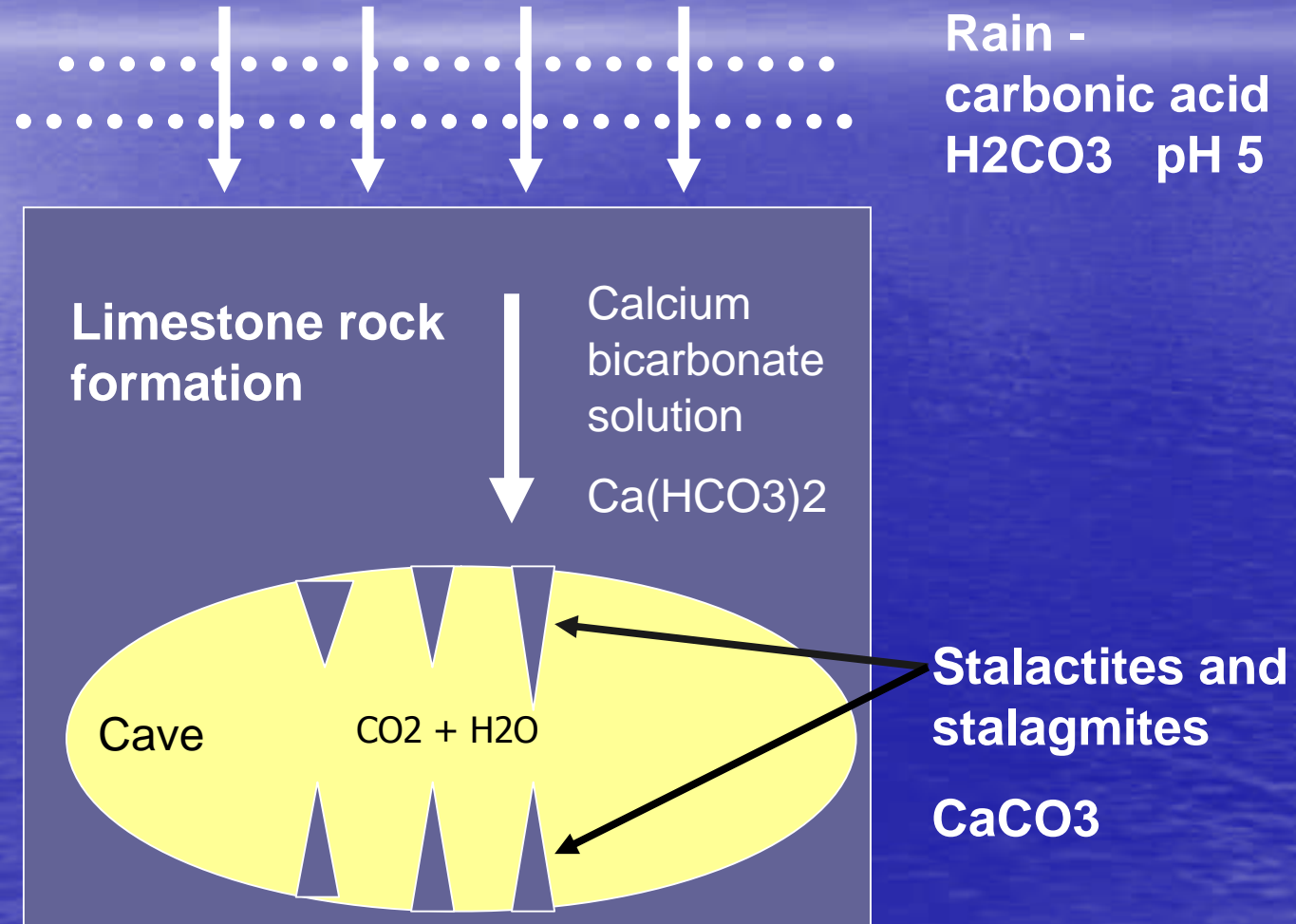
Carbon Dioxide Cycle in Water



Mimicking Nature

Nature is doing it already during the process of formation of limestone caves!!!!

Process of formation of limestone caves, stalactites and stalagmites



Temporary hardness of water

- Mountain streams form temporary hardness (dissolved calcium bicarbonate) as the fresh water containing carbon dioxide (weak carbonic acid) flows over calcium carbonate containing limestone rocks.
- 1 tonne of carbon dioxide will be absorbed by 2.27 tonnes of calcium carbonate to form 3.68 tonnes of calcium bicarbonate which gives the temporary hardness of water.

Composition/Quantities

- Composition of Seawater

Chemical ions		ppm
Sodium	Na	10752
Chlorine	Cl	19345
Magnesium	Mg	1295
Calcium	Ca	411
Sulphate	SO ₄	2701
Bicarbonate	HCO₃	145
Carbonate	CO ₃	trace

- Occurrence of materials

	Tonnes	
Mass of atmosphere	5.1 X 10 ¹⁵	
Mass of oceans (272 X atmosphere)	1.4 X 10 ¹⁸	
Mass CO ₂ in Atmosphere 380ppm	1.9 X 10 ¹²	
Mass Increase in CO ₂ 100ppm	0.5 X 10 ¹²	(500 billion tonnes)
Mass estimated CO ₂ absorbed by oceans)	0.25 X 10 ¹²	(250 billion tonnes)
Bicarbonate in oceans 145ppm	203 X 10¹²	(203 trillion tonnes)
Calcium carbonate in the earth's crust	2.4 X 10¹⁸	(2.4 million trillion tonnes)

203 trillion tonnes of bicarbonate anions in the ocean waters represents safe sequestration of carbon dioxide probably from the ancient atmosphere (3% or 30,000ppm of CO₂) by neutralisation with alkalinity from minerals from the magma.

If all of the anthropogenic carbon dioxide increase in the atmosphere and the oceans were converted to bicarbonate the increase in bicarbonate would be about 1ppm only.

Huge quantities of limestone in the earth's crust provide more than enough calcium carbonate to convert all of the anthropogenic carbon dioxide to bicarbonate.

Summary

- Carbon dioxide can be converted to bicarbonate using a simple natural process of dissolving CO₂ into water and then neutralising the resultant carbonic acid with limestone. This is happening now in nature.
- The bicarbonate is safely sequestered since the bicarbonate anion is stable under the pH conditions of the oceans pH 8-8.5.
- Absorption of ALL the anthropogenic increase of atmospheric CO₂ (100ppm) plus the anthropogenic CO₂ already absorbed by the oceans since the start of industrial revolution using calcium carbonate would increase the bicarbonate levels (145ppm) by about 1ppm
- There is more than enough calcium carbonate available in limestone rock deposits to convert the excess anthropogenic carbon dioxide to bicarbonate.

PROJECT OBJECTIVES

- To develop a system to sequester carbon dioxide, CO₂, based on observations of the natural processes used by nature.
- Grid electrical power was to be avoided as much as possible due to the large carbon footprint
- The system needed to utilise the unlimited storage capacity of the ocean
- Apply the technology where the carbon dioxide concentrations are highest
- To be of use in the transition from fossil fuels to renewables
- To make a safe, practical, usable difference

Application of the Technology

Process 1

Capture the CO₂ in the emissions of industrial plants and convert to bicarbonate anions as calcium bicarbonate.

Process 2

A Use the CO₂ already captured in rain which drains into rivers and convert to bicarbonate anions as calcium bicarbonate.

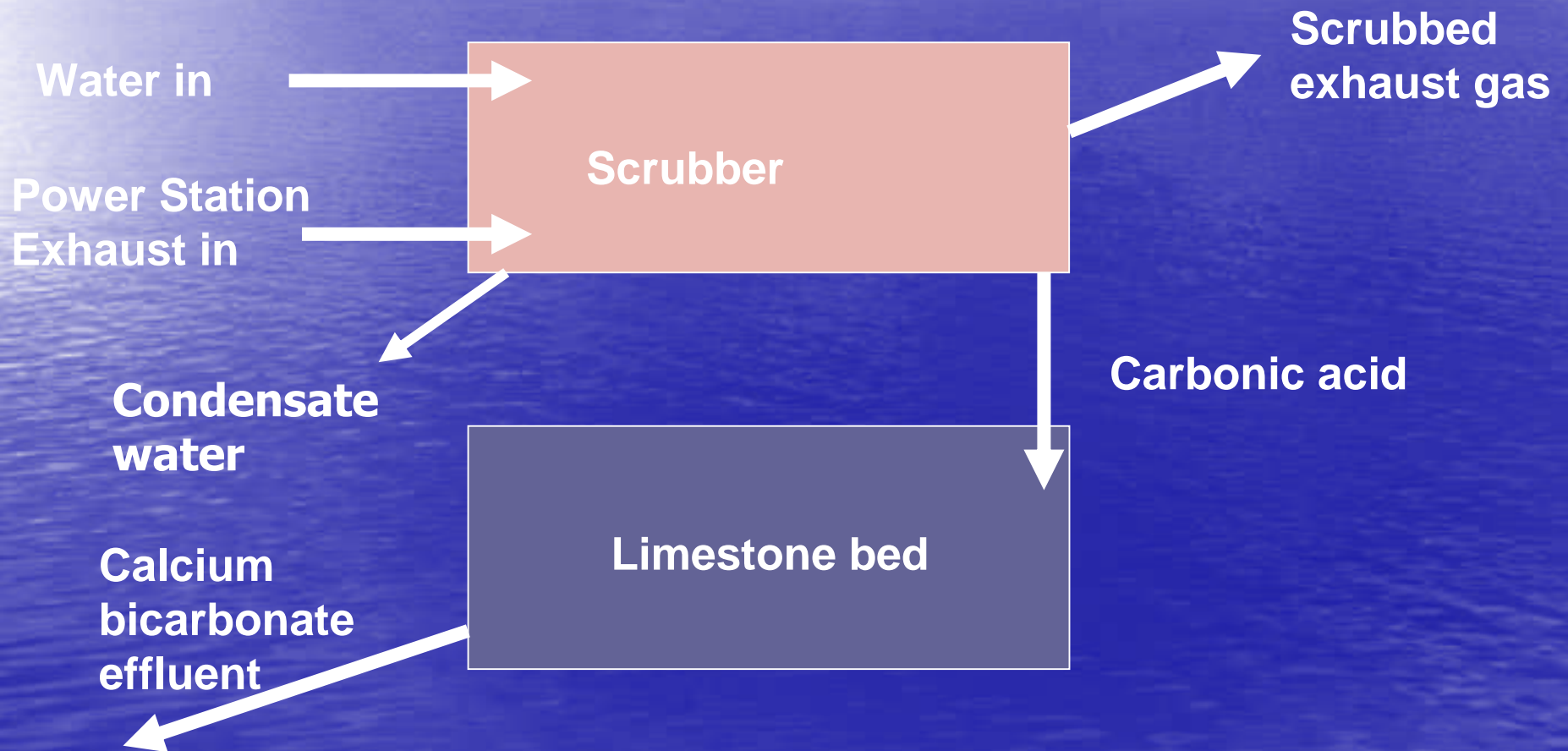
B Use the CO₂ which absorbs directly into the oceans and convert to bicarbonate anions as calcium bicarbonate

Process 1

Sequestering CO₂ as Calcium Bicarbonate

- The carbon dioxide from the emissions of a power station or industrial plant can be captured in water to form dissolved carbon dioxide/carbonic acid solution.
- The carbonic acid will react with calcium carbonate which will dissolve to form calcium bicarbonate.
- The dissolved calcium bicarbonate can be allowed to flow into sea water where the bicarbonate anions will be stable under the aqueous and suitable pH range conditions.
- The first stage of cooling the emission gases produces condensate water as a useful by-product

Application to a Power station exhaust



Regional Applications

- Diesel generators
- Regional Power stations
- Other industrial fuel burning plant
- Condensate from cooling stage

Process 2

Sequestering CO₂ as Calcium Bicarbonate

- Some of the global carbon dioxide emissions (70 million tonnes per day) are captured in rain/river water and seawater (25 million tonnes per day)
- Most of the absorbed carbon dioxide is near the surface of the seawater where it has the greatest effect on ocean acidification.
- The carbonic acid will react with limestone placements which will dissolve to form calcium bicarbonate.
- The resultant calcium bicarbonate will disperse in the seawater where the bicarbonate will be stable under the aqueous and suitable pH conditions.

Applications

- Breakwaters
- Estuaries
- Shallows
- Coastal seawaters
- Coral reefs

Design Features of Process 2

Placement of the limestone is in areas where the CO₂ is at the highest concentration

Rivers - Estuaries - Shallows – Coastal – Reef

Water containing CO₂ is exposed to LARGE quantities of limestone. The dilute carbonic acid is exposed to an alkaline rock world.

The Benefits

This amazingly simple process met ALL the desired objectives:

- Natural
- Safe
- Economic
- Effective – one step sequestration
- Unlimited storage capacity of sequestered carbon dioxide as bicarbonate
- Permanent
- Practical
- Non polluting
- Minimum carbon footprint

The Next Steps

- Invitation to form an organisation
- Equity to be shared with stakeholders