The use of multiple lines of evidences to conduct risk assessment in sediments affected by CO₂ acidification

Manoela R. de Orte, Ángel DelValls, Augusto Cesar and Inmaculada Riba
Concentration of atmospheric CO$_2$: 402.68 ppm (Mauna Loa, July 2014)

“Unprecedented concentration in the recent planet history (human)”

Related to fossil fuel use

Urgent need to reduce emissions
Options to reduce emissions

- Change of combustibles (other than fuels)
- Improve energy efficiency
- Use of renewable and nuclear energy
- Increase of biological sinks of CO$_2$
- Capture and storage of CO$_2$

Until 2100, it can contribute among 15 and 55% of the world mitigative effort (IPCC 2005).
**CO₂ Capture and storage (CCS)**

- **Ocean storage**: direct dumping of CO₂ in the water column or on the deep sediment

- **Mineral carbonation**: industrial fixation of CO₂ to inorganic carbonates

- **Industrial uses**: instead of fuel use of CO₂ in chemical processes

- **Biological sequestration**: by primary production using microalgae

- **Geological storage**: e.g. deplete oil and gas reservoirs, deep saline formations, etc.
• Deplete oil and gas reservoirs
• Deep Saline formations
Several ongoing projects

Need to be regulated

The worldwide capacity of potential CO2 storage reservoirs

Ocean and land-based sites together contain an enormous capacity for storage of CO2\textsuperscript{a}. The world’s oceans have by far the largest capacity for carbon storage.

- **Worldwide Sequestration option capacity\textsuperscript{b}**
  - Ocean: 1000s GtC
  - Deep saline formations: 100s–1000s GtC
  - Depleted oil and gas reservoirs: 100s GtC
  - Coal seams: 10s–100s GtC
  - Terrestrial: 10s GtC
  - Utilization: <1 GtC/yr

\textsuperscript{a} Worldwide total anthropogenic carbon emissions are ~7 GtC per year (1 GtC = 1 billion metric tons of carbon equivalent).

\textsuperscript{b} Orders of magnitude estimates.

Herzog, 2001

Global CCS MAP, October 2014

http://www.sccs.org.uk/expertise/global-ccs-map
Conventions for the Protection of the Marine Environment

**LONDON CONVENTION AND PROTOCOL**
In November 2006 the text of the convention was amended to allow the storage of CO$_2$ in marine geological structures. Framework and waste assessment guidelines for CO$_2$ sequestration developed.

**OSPAR CONVENTION**
In June 2007, the text of the convention was amended to allow the storage of CO$_2$ in marine geological structures, and obliges the contract countries to apply the risk assessment and management guidelines formulated by the convention.

**EUROPEAN COMMISSION**
A new EU Directive on CCS has been adopted in Dec. 2008.
CO$_2$ geological storage

**LEAKAGE FROM THE STORAGE**

- **Short term:** mainly during operation
  Risk of leakage of what fills the pore space in the formation: *natural gas* (mainly methane) and *formation waters* (mainly seawater) (Wallman, 2008)

- **Long term:** mainly post operation
  Risk of leakage of CO$_2$ and associated substances
CO$_2$ geological storage

MAIN IMPACTS IN THE ENVIRONMENT

$$\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{CO}_3^{2-} + 2\text{H}^+$$

$$\text{CO}_2 + \text{H}_2\text{O} + \text{CO}_3^{2-} \leftrightarrow 2\text{HCO}_3^-$$

OCEAN ACIDIFICATION

CO$_2$ LEAKAGE: \(\approx 5.1\) 
(EL Hierro- CANARY ISLAND)
CO₂ geological storage

MAIN IMPACTS IN THE ENVIRONMENT

DIRECT EFFECTS

Acidosis
Hypercapnia
Asphyxiation

INDIRECT EFFECTS

MOBILITY OF METALS

➢ BIOAVAILABILITY
➢ TOXICITY
Basic steps for Risk Assessment for geological storage

1. PROBLEM FORMULATION
2. SITE SELECTION AND CHARACTERISATION
3. EXPOSURE ASSESSMENT
4. EFFECTS ASSESSMENT
5. RISK CHARACTERISATION
6. RISK MANAGEMENT

- Determine the sensibility of species and communities
- Determine the scale of exposure
- Significant adverse consequences in the marine environment and human health
WEIGHT OF EVIDENCE APPROACH

What contaminants?
What levels?
What biological effects?

ECOSYSTEM HEALTH
Quantification of pollution
Quality values
Bioaccumulation/Biomagnification of contaminants?

HUMAN HEALTH
-Tissue quality values

Acidification of the environment

pH variation in LOEs
Designed CO$_2$ injection system: patented #201200753 (9/2013)
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Simulation of the potential effects of CO₂ leakage from carbon capture and storage activities on the mobilization and speciation of metals

Manoela Romanó de Orte a,*, Aguasanta M. Sarmiento b, T. Ángel DelValls a, Inmaculada Riba a
Effects on the mobility of metals from acidification caused by possible CO₂ leakage from sub-seabed geological formations

Manoela Romanó de Orte a, Aguasanta M. Sarmiento b, c, Maria Dolores Basallote a, Araceli Rodríguez-Romero a, Inmaculada Riba a, Angel delValls a
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Studying the Effect of CO₂-Induced Acidification on Sediment Toxicity Using Acute Amphipod Toxicity Test

M. Dolores Basallote,⁎† Manoela R. De Orte, †‡ T. Ángel DelValls, † and Inmaculada Riba †

†Cátedra UNESCO/UNITWIN WiCop. Departamento de Química-Física, Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Polígono Río San Pedro s/n, Puerto Real, Cádiz 11510, Spain

Ampelisca brevicornis

[ ] Metals in sediments
Predicting the Impacts of CO₂ Leakage from Subseabed Storage: Effects of Metal Accumulation and Toxicity on the Model Benthic Organism *Ruditapes philippinarum*

Araceli Rodríguez-Romero, Natalia Jiménez-Tenorio, M. Dolores Basallote, Manuela R. De Orte, Julián Blasco, and Inmaculada Riba

Survival (%) and Burrowing activity (%) of *Ruditapes philippinarum* at different pH levels and control conditions.
HISTOLOGICAL DAMAGE

Gills

Digestive gland
Simulation of CO₂ leakages during injection and storage in sub-seabed geological formations: Metal mobilization and biota effects

Polychaeta

*H. Diversiculor*
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<table>
<thead>
<tr>
<th>Variables</th>
<th>Factor 1</th>
<th>Factor 2</th>
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<tbody>
<tr>
<td>pH</td>
<td>-0.95</td>
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<tr>
<td>Sand</td>
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<td>Organic carbon</td>
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<td>Cu in sediment</td>
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<tr>
<td>Zn in sediment</td>
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<tr>
<td>As in sediment</td>
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<tr>
<td>Hg in sediment</td>
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<td>H. diversicolor mortality</td>
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<td>Cu in seawater</td>
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<td>Zn in seawater</td>
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<td>As in seawater</td>
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<td>Variance (%)</td>
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<tr>
<td>Cumulative %</td>
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<td>78.18</td>
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BENTHIC MACROFAUNA

**ABUNDANCE**

- Notomastus latericuas
- Capitella capitata
- Hediste diversicolor
- Tanacidae
- Carcinus maenas
- Cirratulus cirratus
- Jassa marmorata

**BIOMASS**

- Notomastus latericuas
- Capitella capitata
- Hediste diversicolor
- Tanacidae
- Carcinus maenas
- Cirratulus cirratus
- Jassa marmorata

**Conditions:**

- D0
- Control
- pH 7.0
- pH 6.5
- pH 6.0

**Notes:**

- * indicates significant difference from D0
- ** indicates significant difference from Control
- +++ indicates highly significant difference
“The effects of CO₂ acidification on the bioavailability of contaminants in marine sediments associated with petroleum reservoirs leaks (ECO2Mar)”

Study Area- Santos Estuarine System

Sediment sampling in contaminated areas

CCS

Ocean Acidification
MUSSELS

Perna perna

pHs (control) 7.6 - 6.0
Experiment with Amphipod: *Hyale yongi*

Sediment sampling in Santos Estuarine System
Acknowledgments

Project

➢ “The effects of CO$_2$ acidification on the bioavailability of contaminants in marine sediments associated with petroleum reservoir leaks (ECO2Mar)”

Ph.D. Scholarship

Postdoctoral Scholarship

Congress scholarship