ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Sistema Nazionale per la Protezione dell'Ambiente

International Workshop on Offshore Geologic CO_2 Storage

The first Italian experience of carbon dioxide capture and storage in an offshore depleted natural gas field in Northern Adriatic Sea. Focus on environmental monitoring plan activities.

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ISPRA technical and scientific activities

ISPRA is a public research Institute, that operates under the supervision of the Italian Ministry of the Environment:

Main tasks and functions of the Institute:

- Technical and scientific activities aimed at environmental protection and the sustainable management of land and sea
- Control, monitoring and evaluation activities to guarantee the protection of the environment
- Promotes scientific and technical cooperation ensuring uniformity and quality in environmental protection activities throughout the national territory
- Scientific publications and Guidelines
- Environmental education and training activities, dissemination of environmental information to the public

ISPRA activities in support of *Carbon Capture and Storage (*CCS)

- **ISPRA** was involved in permitting process for the first experimental CO_2 geological storage project (Ravenna CCS - Phase1), providing technical and scientific support to the Ministry of Environment (ETS Committee and CCS Secretariat) with prescriptions and recommendations for the environmental control and monitoring activities

  The experimental project was authorized on **26 January 2023**

- **Regulatory framework**: **EU Directive n. 31 of 2009** on the geological storage of carbon dioxide

- Italian **Legislative Decree No. 162/2011** at the time of authorization (January 2023), Environmental Monitoring Plan (**EMP**) and Environmental Impact Assessment (**EIA**) were not mandatory in Italy for experimental project under 100,000 tons. Later, the Legislative **Decree No. 181 of 9 December 2023** modified the previous Decree introducing mandatory monitoring activities for all CCS storage project

Ravenna CCS Phase 1: Experimental Project Overview

- **Project:**
  First case in Italy of the integrated application of CO_2 capture, transport, and geological storage technologies (Carbon Capture and Storage - CCS).

  The project involves capturing CO_2 produced at an onshore plant, transporting it via a 9-km-long sealine to an offshore platform in the **Northern Adriatic Sea** (in front of Ravenna), and subsequently injecting and permanently storing CO_2 streams in a **depleted gas reservoir** located **3,000 meters** depth under seabed. This reservoir is characterized by suitable porosity and permeability for CO_2 storage and a secure caprock to prevent CO_2 migration.

- **Objective:**
  The Experimental Phase of the Ravenna CCS program aims to collect technical data on the entire CCS process chain, which will be useful for fine-tuning the development of the project on an industrial scale

- **Scale:**
  Authorization for the injection of a total volume of 50,000 t of CO_2 (25,000 t/year for two years)

Infrastructure and Injection Setup

- **CO_2 Capture:**
  - Located at a Gas Plant (Ravenna coast), capturing up to 25,000 t/year of CO_2

- **Transport System:**
  - Reuse of existing pipelines (20'' and 14'' pipelines) for offshore transport

- **Injection Well:**
  - Revamping of an existing well used for injection
  - Well equipped with downhole sensors for real-time data

CO_2 Leakage Risks and Environmental Concerns

Main Potential Risks:

- Anomalous CO_2 migration through geological faults and fractures systems reactivated by injection
- CO_2 accidental releases from pipeline
- Impact on marine ecosystems and water quality in case of leaks

Main Prescriptions of the Authorization Decree

- **Monitoring and continuous control of injection parameters** (composition of the injected fluid purity > 95%, control of pressure - threshold values for the project 240 bar, temperature, and flow rates for injection well monitoring)
- **Microseismic and Ground deformation monitoring plan**
- **Environmental monitoring and control of environmental impacts** (Offshore and Onshore Environmental Monitoring Plan)
- **Operational safety, risk prevention, and environmental protection management**
- **Closure and post-operational monitoring phase**

CO_2 Injection Operations

- **Injection period**: Aug 2024 - Aug 2025
- **Total injected:** approx. 11,000 t significantly below the authorized volume of 50,000 t
- **Injection flow rate:** approx. 50 t/day (during operation)
- **Injection pressure:** 150-160 bar
- **CO_2 purity >** 99%

Operations always within safety limits

Monitoring activities

A periodic and continuous monitoring system was implemented to test CO_2 injection in order to assess the selected storage site in terms of compliance (injectivity and reservoir quality) and containment, as well as its potential environmental impact:

- Well
- Microseismic
- Ground Deformation and geomechanical model
- Geodynamic reservoir model
- Onshore Environment
- Pipeline
- Offshore Environment

Well Monitoring

The injection well was re-drilled between December 2023 and April 2024.

<u>Purpose/Key Objectives</u>:

Acquisition of well measurements and parameters collected both at the injection well (e.g., injection monitoring and well integrity):

- Pressure and temperature sensors installed in the injection well
- Fluid sampling and analysis tools to track CO_2 behavior

Microseismic Monitoring

Purpose/Key Objectives:

- Provide real-time insights into reservoir stability and injection impacts
- Detect and analyze seismic activity related to CO_2 injection
- Microseismic network, according to Italian specific guidelines (MiSE, 2014), and sperimental use of DAS (Distributed Acoustic Sensing) technology

Ground Deformation Monitoring and Geomechanical Model

Purpose/ Key Objectives:

- Continuous monitoring of ground movements, through a CGPS network (onshore and offshore GPS permanent stations), geometric levelling campaigns and InSAR data (according to MiSE guidelines)
- Prevent potential infrastructure damage
- Prevent ground subsidence/uplifting on the coast
- Update the geomechanical model to calculate evolution over time of stress and strain, estimate subsidence/uplift, perform fault stability assessment

Geodynamic reservoir model

<u>Purpose/ Key Objectives</u>:

To predict pressure evolution as well as the movement and expansion of CO_2 plume within the storage site.

- Static and Dynamic Models
- 3D geological models to predict CO_2 behavior
- Continuous model updates based on monitoring data

Onshore Environmental Monitoring

Purpose/Key Objectives:

Monitoring of the Gas plant, involved in the carbon dioxide capture and compression process, was carried out (Before/During) to control:

Air Quality:

- Continuous measurement of atmospheric emissions, including CO_2 and other pollutants
- Noise monitoring to ensure compliance with acoustic standards
- PM10 monitoring during construction phase

Water Quality:

- Monitoring for chemical pollutants in waste water

Pipeline monitoring

Purpose/ Key Objectives:

- Pipeline integrity and potential environmental impacts

CO_2 Transport Safety:

- Continuous pressure and flow monitoring along the pipeline
- Automatic shutdown systems in case of anomalies

Standard and Inspection Protocols:

- Regular pipeline integrity assessments by independent entities
- Defined standards for CO_2 stream transport in pipeline and CO_2 stream composition

Offshore Environmental Monitoring

<u>Purpose/Key Objectives</u>:

- Characterize baseline marine environmental conditions before CO_2 injection (*ante operam*)
- Monitor potential leakage and detect anomalies in water column, sediment and marine biota (*ante operam*, *in opera* and *post operam*)
- Assess short- and long-term ecological impacts
- Develop models for CO_2 dispersion and ecosystem responses

Offshore Environmental Monitoring (Before/During/After)

- **Seafloor and water column geophysics** (MBES, SSS and SBP) to detect morphological and acoustic anomalies in the seabed and water column
- **Leakage quantification** to identify and quantify potential CO_2 released into the water column from the seabed prior to CO_2 storage in the reservoir
- **Physical, chemical, and biogeochemical water column analyses** to assess potential changes resulting from CO_2 leakage

Offshore Environmental Monitoring (Before/During/After)

- **Sediment physical, chemical, and ecotoxicological analyses** to evaluate the impact of CO_2 injection on sediment
- **Modeling** develops numerical models to simulate CO_2 dispersion, migration patterns, and potential ecological effects within the marine environment
- **Biota Investigations** to detect biological responses to CO_2 exposure
- **Environmental Risk Assessment** to evaluate environmental risks, ensuring compliance with regulatory standards and informing mitigation strategies

Main Monitoring Conclusions

- No evidence of CO_2 leakage
- Well integrity and injectivity confirmed
- No abnormal ground deformation detected
- No seismic events near reservoir

Main Monitoring Conclusions

- No marine environmental impacts observed:

-Baseline captures natural and seasonal variability of the Northern Adriatic marine environment

-Baseline dataset will support future monitoring during industrial-scale operations

-No anomalies in water chemistry or biology

-No sediment alterations detected

-Marine ecosystems within natural variability

-Observed environmental variability reflects natural background conditions

-Gas emissions consistent with natural seepage

Lessons Learned from the Pilot Monitoring Programme

- Storage depth approximately 3,000 meters and caprock provided strong natural containment to prevent CO_2 migration
- No significant anomalies detected during the operational phase
- The experimental Programme successfully tested a comprehensive monitoring model, confirming the effectiveness of the monitoring system
- Demonstrated feasibility of integrated offshore CCS monitoring under real conditions
- Multi-parameter approach ensured high sensitivity and early detection capability
- Experimental Programme will support future industrial-scale operations
- Experience provides a key reference for updating international guidelines and strengthening regulatory oversight

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Thanks for your attention

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