Regulatory Framework for Carbon Dioxide Sub-seabed Storage - Safety and Potential Environmental Impact

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Office of Marine Environment
Water Environment Division
Environmental Management Bureau
Ministry of Environment

Contents

Carbon dioxide sub-seabed storage:

1. The regulatory framework of CO_2 sub-seabed storage under the London Protocol

2. The regulatory framework of CO_2 sub-seabed storage under the *Marine Pollution Prevention Law*

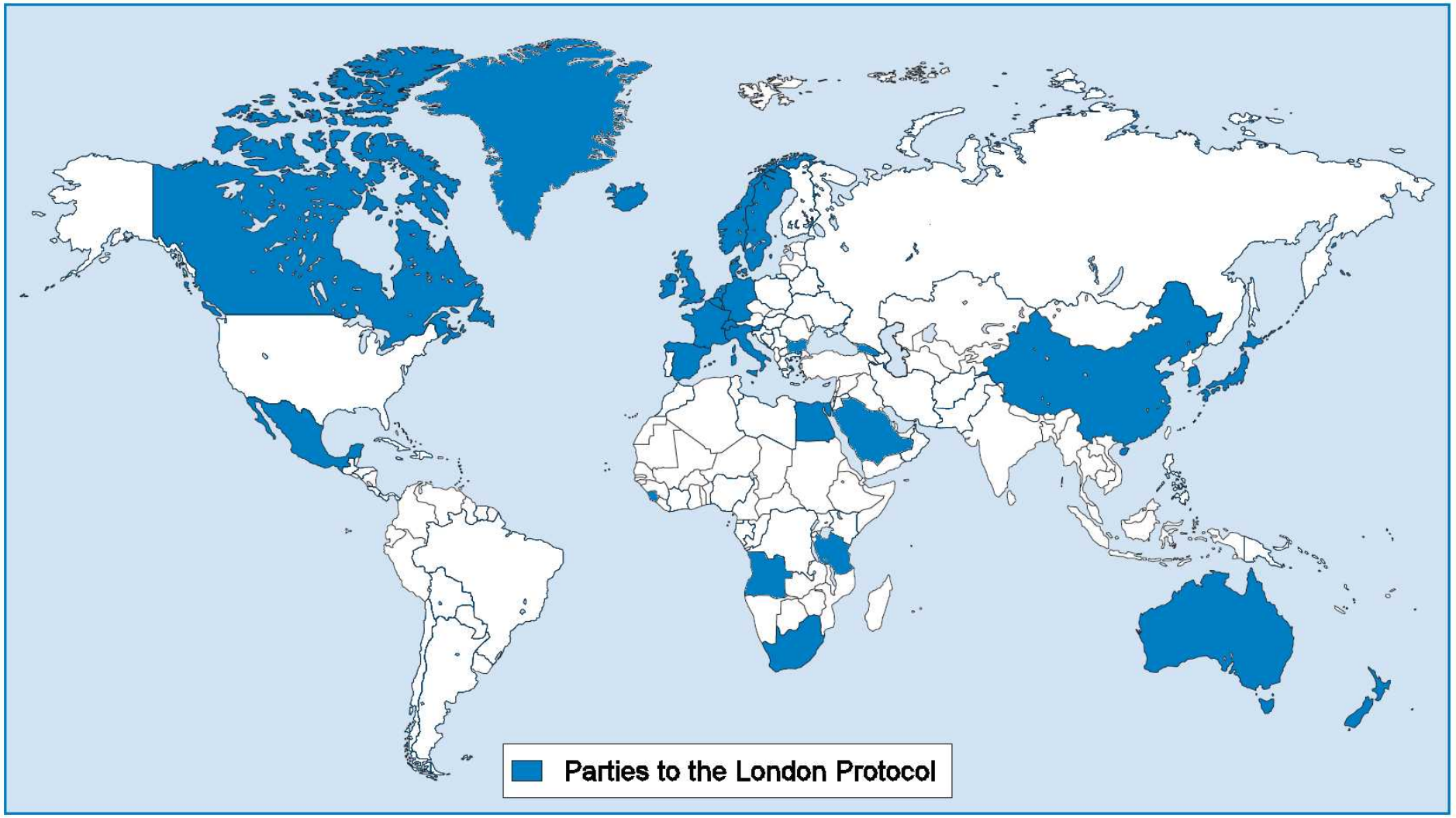
3. Methodology of “Monitoring Plan” and “Potential Environmental Impact Assessment”

1. The regulatory framework of CO_2 sub-seabed storage under the London Protocol

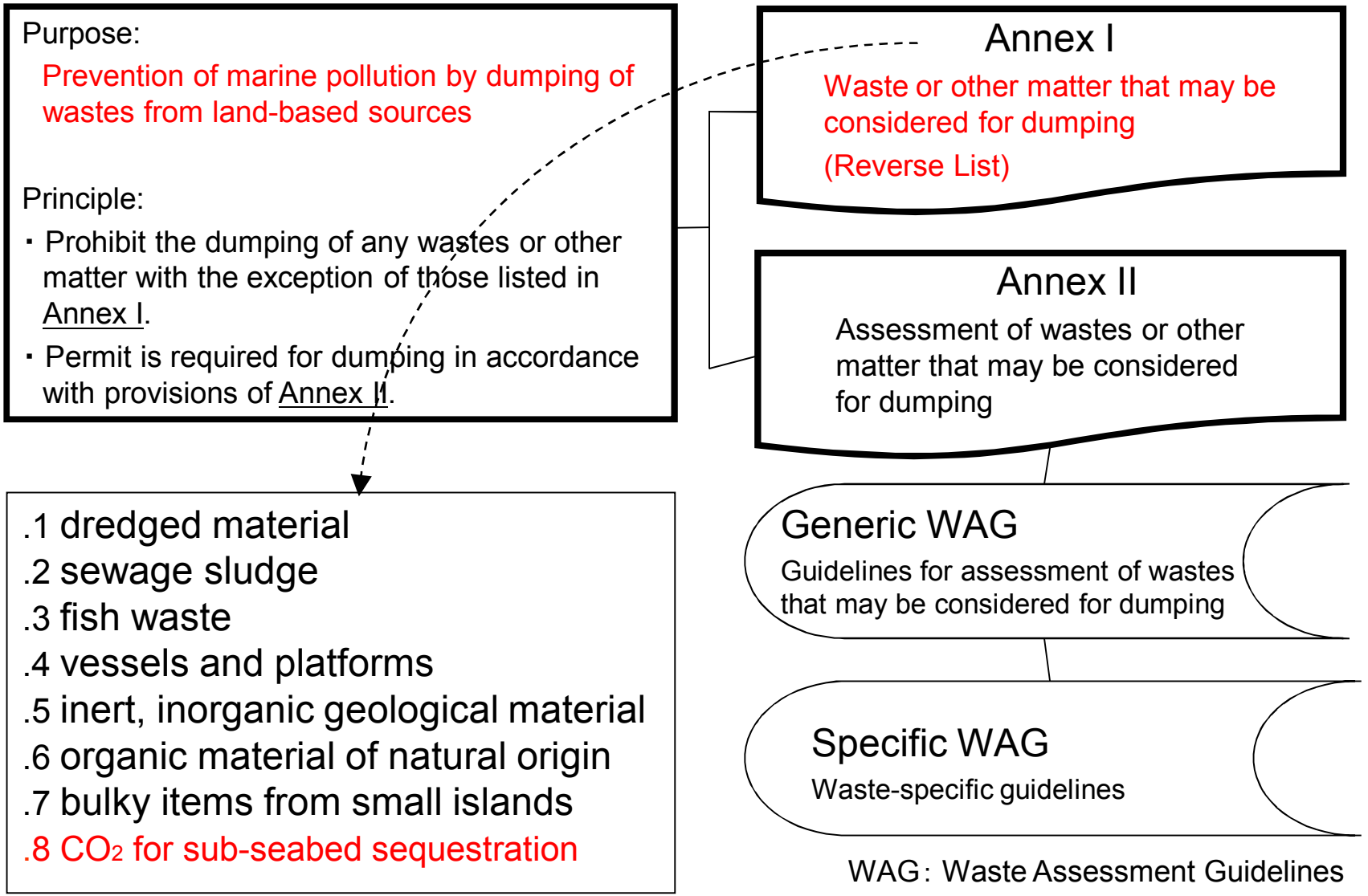
The 1996 London Protocol

The 1996 London Protocol to the London Convention 1972 - 40 contracting parties

(as of July 5, 2011)



Structure of the 1996 Protocol



WAG: Waste Assessment Guidelines

Annex I amendments (2006.11)

"Carbon dioxide streams from carbon dioxide capture processes for sequestration"

may only be considered for dumping, if

(1) disposal is into a sub-seabed geological formations

(2) wastes consist overwhelmingly of CO_2 (may contain incidental associated substances derived from the source material, and the capture and sequestration processes used)

(3) no wastes or other matter are added for the purpose of disposing of those wastes or other matter.

2. The regulatory framework of CO_2 sub-seabed storage under the *Marine Pollution Prevention Law*

LP Annex I Amendment

Implementation of LP within country

Marine Pollution Prevention Law Amendment

- Regulatory framework aimed to “protect marine environment”
- Does NOT intend to “promote CCS”

Objective of Marine Pollution Prevention Law

➢Objective（Article 1）

- Regulating discharge of oil, hazardous liquid substances and waste from vessels, platforms and aircrafts into ocean
- Regulating disposal of oil, hazardous liquid substances and waste under seabed
- Regulating emission of exhaust gas from vessels into air
- Regulating incineration of oil, hazardous liquid substances and waste on vessels and platforms
- Ensuring appropriate treatment of waste oil
- Removing any discharged oil, hazardous liquid substances, waste and others
- Preventing offshore fire and its spread
- Taking measures to prevent hazard to vessel traffics caused by offshore fire and others.

Control, treatment, prevention, measures

Protection of marine environment
Protection of people's lives, bodies and property

Outline of amendment (1)

(1) Prohibition of disposal of oil, hazardous liquid substances, and wastes under the seabed

No one shall dispose oil, hazardous liquid substances, and wastes under the seabed, except for CO_2 stream storage under the seabed with permit from Minister of the Environment (Article 18.7)

(2) Provisions for the permit for CO_2 stream storage under the seabed

1) Anyone intending to dispose CO_2 stream under the seabed must obtain a permit from Minister of the Environment (Article 18.8.1)

2) Minister of the Environment shall not issue a permit for the CO_2 stream storage under the seabed unless it meets all conditions required such as "the storage site under the seabed and the method taken for the storage will not harm marine environmental protection at the storage site" and "there is no other appropriate disposal is available other than storage under the seabed" (Article 18.9)

3) A person holding a permit for CO_2 stream storage under the seabed must monitor status of the pollution at the storage site and report monitoring results to Minister of the Environment (Article 18.12)

Outline of amendment (2)

(3) Designation of a registered area

1) Minister of the Environment designates a CO_2 storage site under the seabed as a registered area, in order to prevent potential impact on marine environment from CO_2 leakage by altering the seabed and the sub-seabed features (Article 18.15.1)

2) Notification to Minister of the Environment is required for activities which alter the seabed and the sub-seabed features within a registered area. If the method of altering the seabed and the sub-seabed features does not comply with the standards, Minister of the Environment has competence to order a change of project plan (Article 19.2.4).

(4) Collection of reports

Minister of the Environment has competence to order submission of a report on CO_2 storage under the seabed and conduct inspection for the purpose of implementation of the Law (Article 48.2)

Documentation for application of permits

- Application for a Permit (Ordinance of the MOE: Article 1)

  Consists of “Project Plan” and “Monitoring Plan”

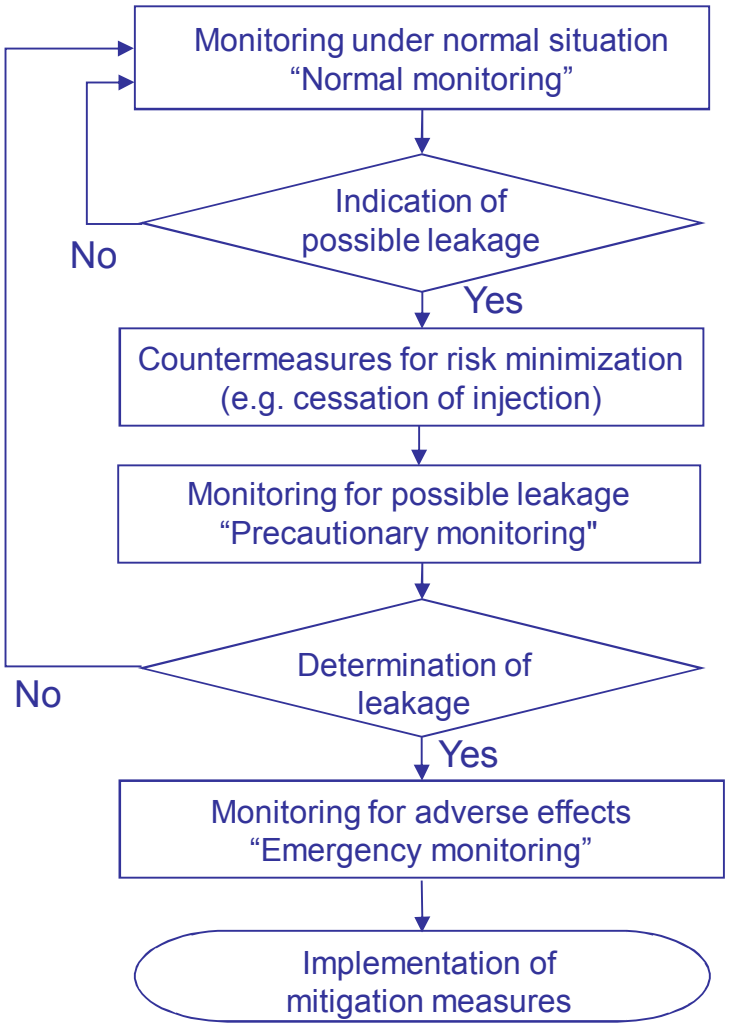
- Attachments (Ordinance of the MOE: Article 4 and 5)

  1. Site selection report
  2. Potential Environmental Impact Assessment Report (hypothetical case of CO_2 leakage and predicted potential impact on marine environment)
  3. Explanation for no appropriate disposal is available other than sub-seabed storage
  4. Financial capability of applicant
  5. Technical capability of the applicant
  6. Outline of the entire project (beyond permitting period)

3. Methodology of “Monitoring Plan” and “Potential Environmental Impact Assessment”

Concept of monitoring

Monitoring Plan



More than once a year, report to Minister of the Environment (injection amount, pressure, disposal area etc.)

Report to Minister of the Environment

Monitor status and report to Minister of the Environment

Monitor as long as the impacts continue.
Improve leakage prevention measure.

Monitoring area delineation

Key aspect of monitoring plan - example of area delineation

"Injection point"

"Storage area" : area which CO_2 exists underneath

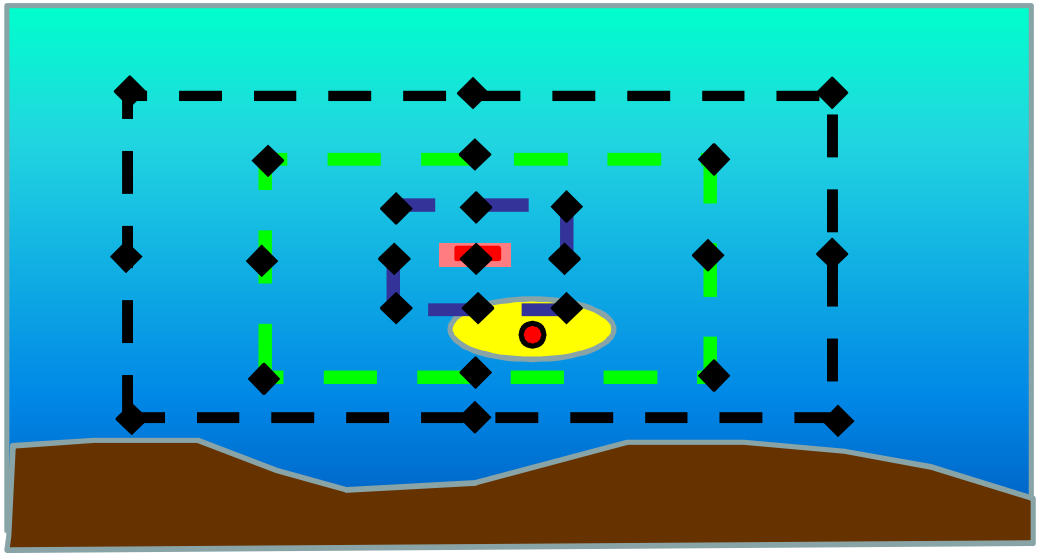
"Baseline survey area" : area in which seawater and marine organisms are surveyed before CO_2 injection

"Predicted leaking point" : leaking point based on leak hypothesis

"Predicted area of impact" : area in which biological impact is predicted with high pCO_2, based on leak simulation

"Peripheral area" : elevated pCO_2 area surrounding the predicted area of impact

"Monitoring area"



	Injection point
	Storage area
	Baseline survey area
	Predicted leaking point
	Predicted area of impact
	Peripheral area
	Monitoring area
	Survey point

Monitoring under normal situation (Normal monitoring) - purpose and methods

Purpose

- Ensure that CO_2 is stored in accordance with project plan
- Confirm that no sign of CO_2 leakage is observed

Methods

- The same methods as in baseline survey in order to compare the data - before and after CO_2 storage

(1) Seawater and bottom sediment

Seawater: analysis of CO_2 indices by seawater sampling from ship. Combination with continuous measurements such as pH sensor and pCO_2 buoy is preferable.

Bottom sediment: bottom sediment sampling from ship.

(2) Marine organisms and ecosystems

Benthos must be surveyed, using bottom sampler.

Monitoring under normal situation (Normal monitoring) - timing and frequency

(1) Seawater and bottom sediment

- Understand seasonal changes of CO_2 indices by seawater sampling
- For continuous measurements, establish appropriate sampling and maintenance period, considering instrument specifications and field characteristics such as tidal cycle
- Frequency

  Seawater sampling – 4 times a year or more

  Bottom sediment sampling – once a year or more

(2) Marine organisms and ecosystems

- Frequency

  Field survey – once a year or more

Monitoring for possible leakage (Precautionary monitoring) - purpose

- Determine the existence of CO_2 leakage, when there are possibilities of leakage
- Report the monitoring results immediately to Minister of the Environment. Injection can be re-started when it is determined that there is no leakage, or no possibilities of leakage.

Monitoring plan need to includes:

- Conditions of status shift from “normal” to “precautionary” monitoring
- Conditions of status shift back from “precautionary” to “normal” monitoring, as well as steps to be taken between the operator and the ministry
- Survey plan for shifting back to “normal monitoring”

etc.

Monitoring for possible leakage
- from “normal” to “precautionary” monitoring

- Shift to “precautionary monitoring” is required when there are possibilities of CO_2 leakage from the seabed, for example,

- when pH and pCO_2, measured by seawater sampling and continuous measurements under “normal monitoring”, are out of natural fluctuation range derived from the baseline survey.

- when biological data from “normal monitoring” indicates possibilities of impact such as population change.

- when unusual phenomenon in marine environment such as bubbles from the seabed are observed.

- when strong seismic movement is observed around the storage area.

- when inconsistency with data, such as significant difference between planned injection pressure and actual observed data, indicates CO_2 migration out of the storage reservoir during injection.

Monitoring for possible leakage (Precautionary monitoring) - monitoring items

- In combination with CO_2 indices of seawater and bottom sediment, additional monitoring items are required to determine whether changes in seawater quality are caused by leaked CO_2 or other factors.

Examples:

- Temperature, salinity, dissolved oxygen, and nutrient salts of seawater to determine whether the change in pH or other parameters is caused by water mass movement.
- Existence of bubbles can be a useful parameter to understand the marine environment.

Monitoring for possible leakage (Precautionary monitoring) - timing and frequency

- Seawater and bottom sediment sampling should be conducted at higher frequency, immediately after the possibilities of leakage are observed.

- Continuous pH and pCO_2 measurements should be conducted at higher frequency than in “normal monitoring”.

Monitoring for adverse effects (Emergency monitoring) - purpose

- Understand extent and degree of impact and contribute to take concrete leak prevention measures.
- “Emergency monitoring” need to be more intensive to understand the extent of the leakage and to identify effective countermeasures, and to identify degree of the impact.

Monitoring plan need to include:

- Conditions of status shift from “precautionary” to “emergency” monitoring
- Conditions of status shift back from “emergency” to “precautionary” monitoring, as well as steps to be taken between the operator and the ministry
- Survey plan for shifting back to “normal monitoring”.

etc.

Monitoring for adverse effects

- from “precautionary” to “emergency” monitoring

- Shift to “emergency monitoring” is required when the leak is assured, for example,

  - when a leak is determined from pH and pCO_2 data collected with water sampling and/or continuous measurements under “precautionary monitoring”.

  - when bubbles are determined to be originated from the stored CO_2

Monitoring for adverse effects (Emergency monitoring) - methods

(1) Seawater and bottom sediment

1) Conduct an intensive seawater and bottom sediment survey centering around leak point.

As well, place pH sensors and pCO_2 buoys intensively for continuous measurements around the leak point.

2) Monitor bubbles by utilizing equipments such as side scan sonar and ROV.

3) Estimate area of impact and leak amount from surveys 1) and 2).

(2) Marine organisms and ecosystems

Conduct bottom sediment sampling or other surveys required to assess biological impact particularly on benthos.

Monitoring for adverse effects (Emergency monitoring) - timing and frequency

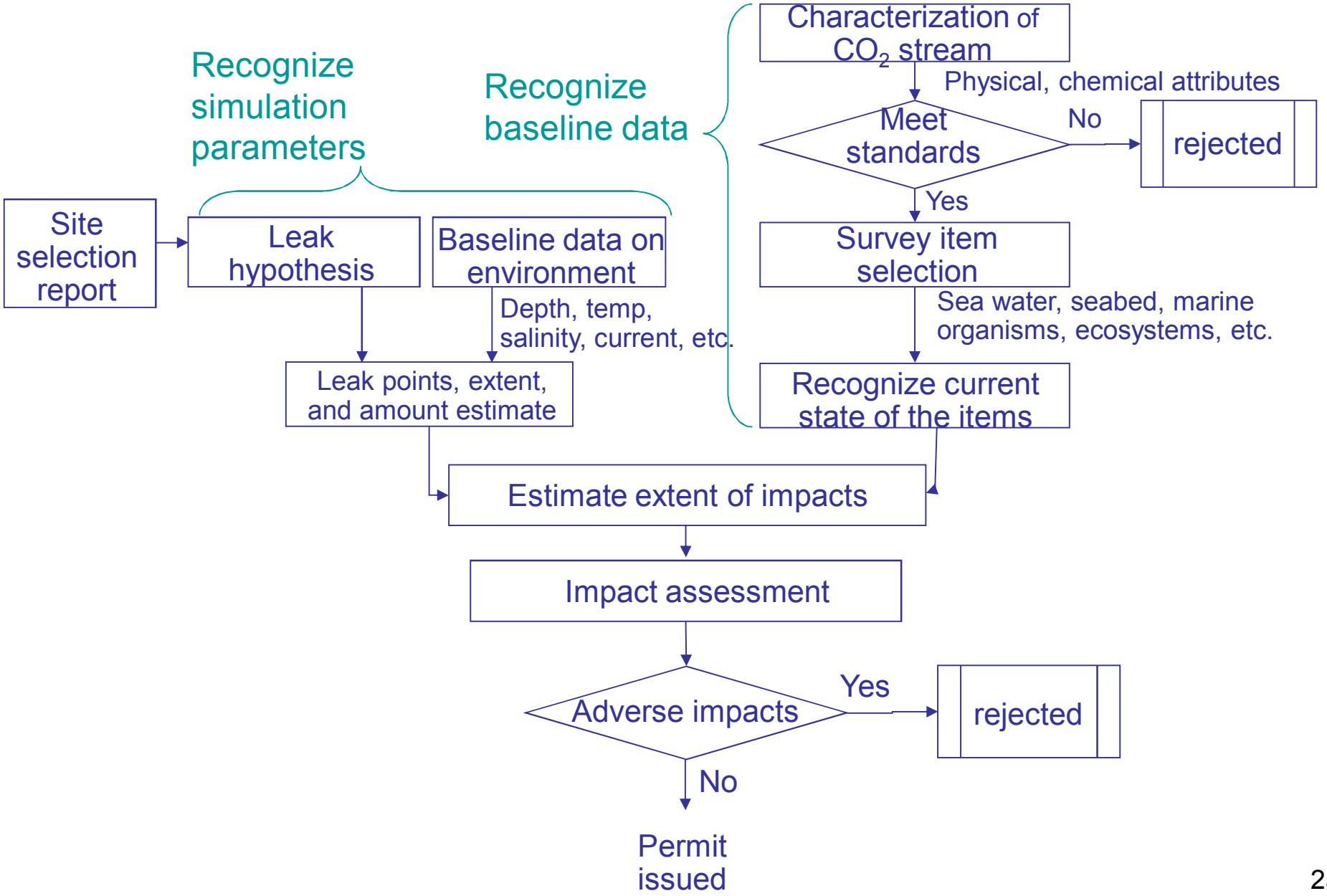
- Monitoring should be conducted at appropriate frequency to understand the situation of CO_2 leakage

  - Seawater and bottom sediment sampling should be conducted at higher frequency than in "precautionary monitoring", immediately after "emergency monitoring" is initiated.

  - Continuous pH and pCO_2 measurements should be conducted at higher frequency than in "precautionary monitoring".

- With understanding of the location and extent of the leakage, appropriate countermeasures should be taken. The monitoring should be continued until the situation is improved – until there are no longer possibilities of leakage observed.

PEIA and permit procedure



PEIA - baseline data on environment

- Measurements to Baseline data to predict the adverse effect.

  Measurements of parameters required for ocean simulations of leaked CO_2 dispersion.

Examples:

- Depth
- Temperature, salinity, existence of thermocline and/or pycnocline, and their seasonal changes
- Current regime and its seasonal changes

etc.

PEIA - leak hypothesis and leak estimation

- Form a leak hypothesis based on the site's situation and the surrounding environment

- Estimate leaked CO_2 flux over time

Example:

Configure a possible leak path based on the field conditions and run a leak simulation to estimate leaked CO_2 flux over time. Then, Estimate possible leaked CO_2 amount from case studies and literatures, and verify the simulated results.

PEIA - survey items and methods

(1) Seawater and seabed

For CO_2 index, a field survey is required. Although it is one of the most important indices for a PEIA, it is difficult to obtain data from current literature.

(2) Marine organisms

Overall understandings of inhabiting marine organisms around the site. *Inter alia,* benthic survey is crucial, because CO_2 leaks from the seabed, and requires a field survey.

(3) Ecosystems

Basic information may be obtained from literature.

A field survey may be conducted as required.

PEIA - evaluation of biological impact

（1）Determine indicative level of ΔpCO_2 for biological impact: identify organisms around the storage area, choose target species based on the methodology for determining target species, then refer to available information on biological impact of CO_2 to determine ΔpCO_2.

（2）Evaluate biological impact by considering both simulated CO_2 leakage and the ΔpCO_2 determined above, as well as other items such as natural fluctuation of CO_2 indices.

Database on biological impact by CO_2 exposure

- Extracted from the Ministry of the Environment Japan -

Target species	NOEC/ LOEC/ EC_{50}	ΔpCO_2 (ppm)	Effect	Endpoint	Notes	Reference
Hemicentrotus pulcherrimus (Japanese green sea urchin)	LOEC	200	Reduced	Survival rate	・Life stage: Juvenile ・Exposure period: 6 months ・Control pCO_2: 360ppm	Shirayama and Thornton, 2005
	LOEC		Reduced	Growth rate		
Mytilus edulis (Blue mussel)	NOEC	1,535	None	Regeneration (Tissues of a reproductive organ)	・Life stage: Adult ・Exposure period: 60 days ・Control pCO_2: 340ppm	Beesley et al., 2008

http://www.env.go.jp/earth/kaiyo/ccs/eikyo_db.pdf

Summary

- It is important, from the safety management viewpoint, the ensure the steady implementation of monitoring plan and to take prompt measures in response to the possible leakage or adverse effects.

- With respect to potential environmental impact, it is important to improve the methodology of PEIA based on the latest findings in order to reduce risks.

- Additionally, it is also necessary to collect related information on regulatory frameworks and projects around the world.