

# Drafting Guidelines on Environmental Risk Assessment procedure for the CO<sub>2</sub> capture process

7<sup>th</sup> September, 2017



Toshiba Mikawa post combustion capture pilot plant  
(at Omuta, Fukuoka Prefecture)

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# Sustainable CCS Project by Japan's Ministry of the Environment

- [Toshiba Corporation](#), the representative of this project, demonstrates the technology of capturing CO<sub>2</sub>, and the participating parties ([Mizuho Information & Research Institute](#) and 11 other organizations) addresses issues on the introduction of CCS in Japan.
- This 5-year project (FY2016-2020) is funded by [the Japanese government, Ministry of the Environment \(MOE\)](#).

## Demonstration of CO<sub>2</sub> capture technology integrated with coal-fired power plant

- The facility that separates and captures CO<sub>2</sub> from emissions of the coal-fired power plant (Mikawa Power Plant, 50MW) using amine-based solvents is constructed and demonstrated [while assessing environmental impacts](#).

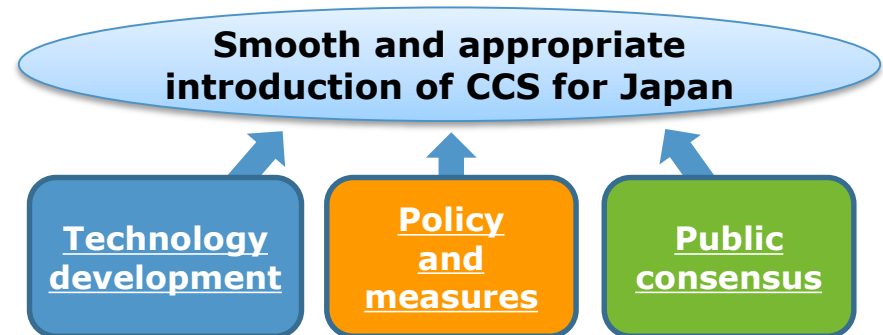


(Source:  
[http://www.toshiba.co.jp/about/press/2016\\_07/pr\\_j2602.htm](http://www.toshiba.co.jp/about/press/2016_07/pr_j2602.htm))

**CO<sub>2</sub> capture facility (image)**

## Investigation of strategies to introduce CCS in Japan

- The strategies for enabling CCS in Japan are developed by investigation the following:
  - Methods for mitigation of CO<sub>2</sub> leakage and remediation on offshore storage
  - Regulations and measures
  - communication strategy and knowledge sharing platform



# Project members (consortium involving 13 parties)

## Project leader

Dr. Makoto Akai

Ministry of the  
Environment

## Representative party

**TOSHIBA**

## Collaborative parties

**MIZUHO** (Head of the collaborators)

**MITSUBISHI**  
MITSUBISHI MATERIALS CORPORATION



**電力中央研究所**  
Central Research Institute of Electric Power Industry

**JANUS**  
JAPAN NUS CO., LTD.



 **THE UNIVERSITY OF TOKYO**

 **DIA CONSULTANTS**



**JGC** **JGC CORPORATION**

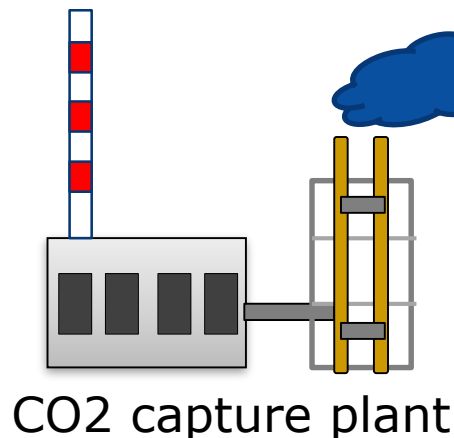


 **QJ Science**

# Overview of “Drafting Guidelines on Environmental Risk Assessment procedure”

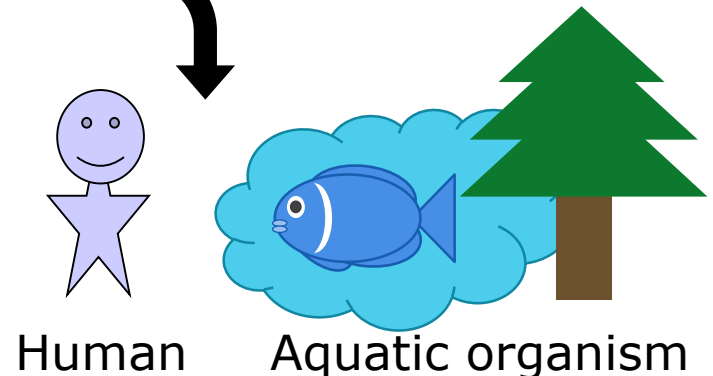
- Based on Toshiba’s emission data from 10 ton-CO<sub>2</sub>/day scale pilot plant using MEA solution at Mikawa coal fired thermal power plant.
- Mizuho
  - conducted a trial of environmental risk assessment for the CO<sub>2</sub> capture process,
  - examined the risk assessment procedure,
  - drafted technical guidelines.

**TOSHIBA**



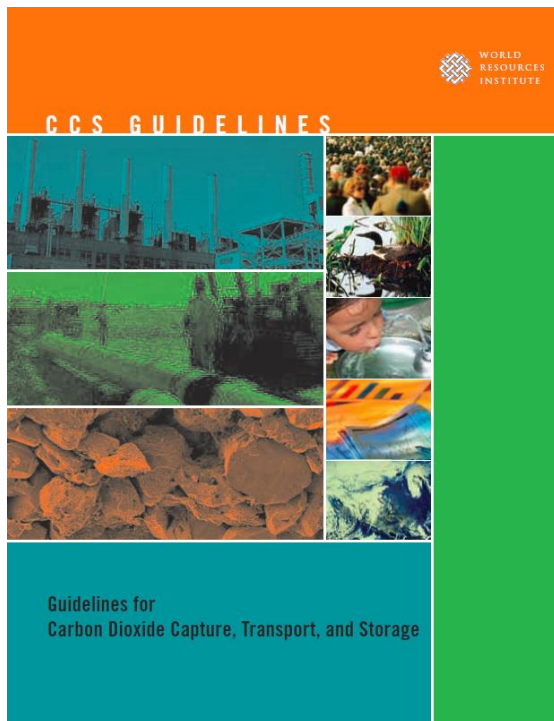
Amines and degradation products

**MIZUHO**

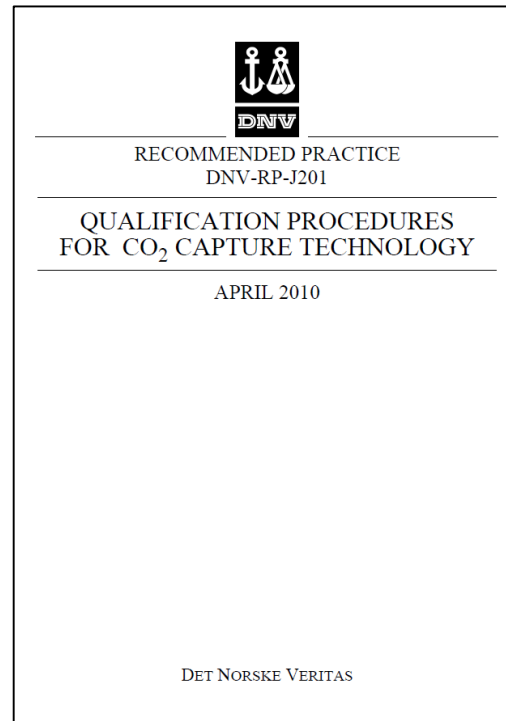


# The status of publication of “Guidelines on CCS”

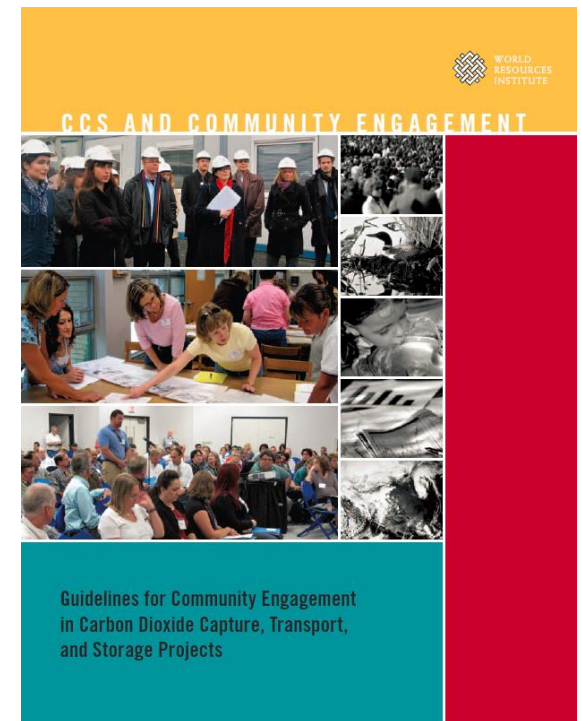
- Several technical guidelines on other aspects of CCS have been already published.
- However, there are no guidelines on environmental risk assessment method for the CO<sub>2</sub> capture process.



CCS Guidelines: Guidelines for Carbon Dioxide Capture, Transport, and Storage (WRI)



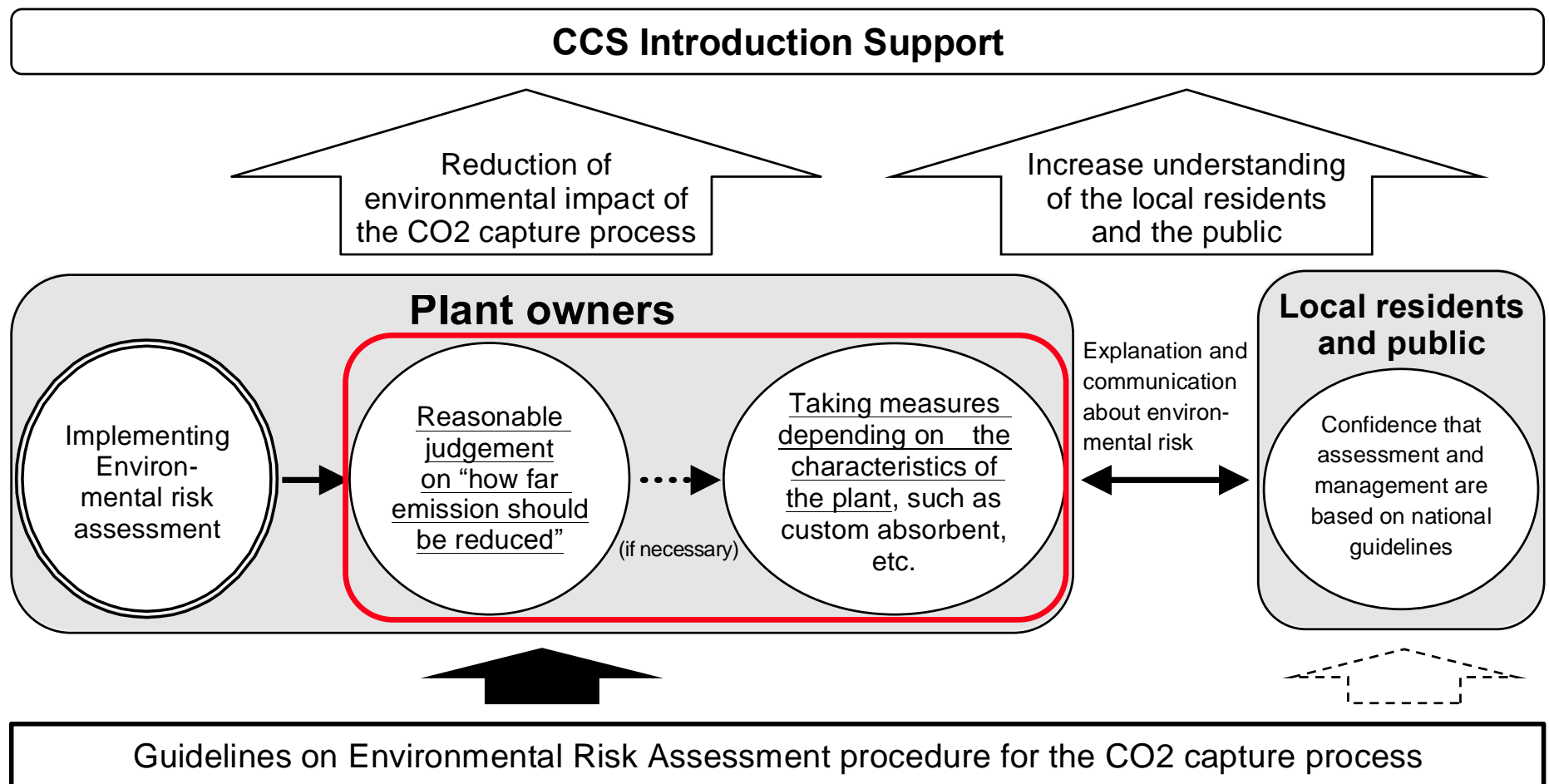
Qualification Procedures for CO<sub>2</sub> Capture Technology (DET NORSKE VERITAS)



Guidelines for Community Engagement in Carbon Dioxide Capture, Transport, and Storage Projects (WRI)

# Purpose of the drafted "Guidelines on Environmental Risk Assessment procedure"

- The drafted guidelines present the basic principles (methods, basic points)
  - to reduce the environmental impact of the process
  - to increase local residents and public understanding
  - to promote the introduction of CCS



# Overview of implementation items for "Drafting Guidelines on Environmental Risk Assessment procedure"

## Drafting technical guidelines

### Component-based approach

#### Exposure assessment

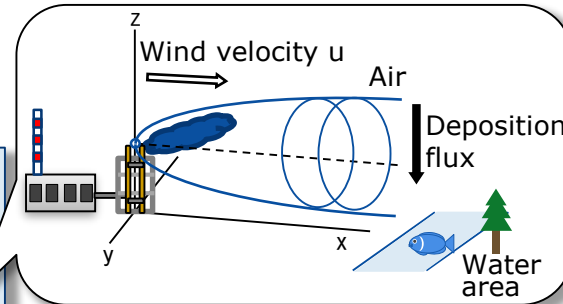
##### Environmental monitoring

1. Atmospheric concentration
2. Deposition flux
3. Water area concentration

Comparison and confirmation of the validity  
↔  
(Improvement of mathematical models)

##### Environmental concentration prediction

1. Atmospheric concentration
2. Deposition flux
3. Water area concentration



Verification operations of large-scale facilities (500 tons-CO<sub>2</sub>/day~) (FY2020)

Suggesting the criteria of "how far emission should be reduced" based on the environmental risk

#### Identification and quantification of emitted substances

Formulating of measures to mitigate environmental impact and verification of these measures

Identification and quantification of emitted substances

#### Toxicity assessment

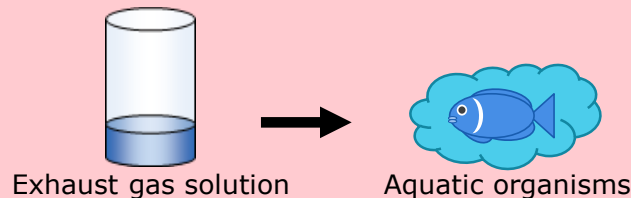
Examination of the category approach

Toxicity test for components of CO<sub>2</sub> absorbent

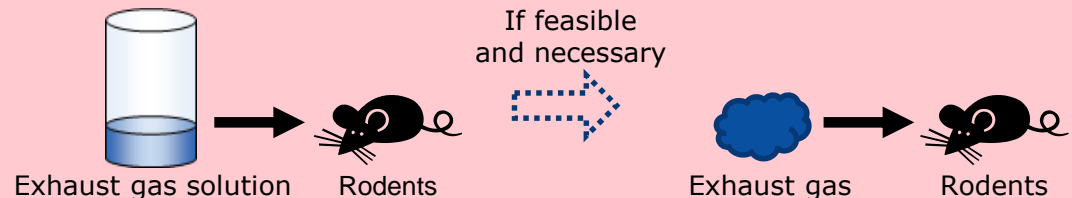
Correlating exhaust gas and environmental concentration using mathematical models

### Whole-mixture approach

#### Bioassay targeting "exhaust gas solution" (assessment of the effect to aquatic organisms)



#### Bioassay targeting "exhaust gas" (assessment of impact on human health)





# The provisional framework of Environmental Risk Assessment and Management for CO2 capture process

- The framework is composed of two approaches:
  - “Component-based approach” (conventional approach)
  - “Whole-mixture approach” (to deal with the challenges for CO2 capture process)

## Substances requiring risk assessment and management

Components of CO2 absorbent (including additives), by-products

### Component-based approach

#### Identification and quantitative determination of emitted substances

- Components of CO2 absorbent : quantitative determination of all components
- by-products : **identification and quantitative determination within a technically and economically proper range based on “previous experimental data,” etc.**

(concerning the identified substances)

#### Toxicity assessment

Performed in stages using the following methods

- assessment using **toxicity values for each individual substance**
- assessment using the **category approach** for assumed emission substances

#### Exposure assessment

Performed in stages using the following methods

- estimation using **Plume Model** regarding the vicinity of the source of emission and Estimation Formula for deposition
- estimation using **Multimedia environmental model**

Risk  
characterization

No concern

Continue inspection of emitted substances

Concern

Toxicity test

Environmental monitoring

Risk  
characterization

No concern

Continue inspection of emitted substances

Concern

Examination of additional emission reduction controlling measures and/or operating conditions

performed as per requirement

### Whole-mixture approach

#### Assessment employing bioassay

- [Impact assessment on human health]
  - bioassay with “emission gas” as the subject
- [Impact assessment on aquatic organisms]
  - bioassay with “emission gas solution” as the subject

Bioassay

no impact

Continue inspection employing bioassay

impact

#### Specification of causative substances

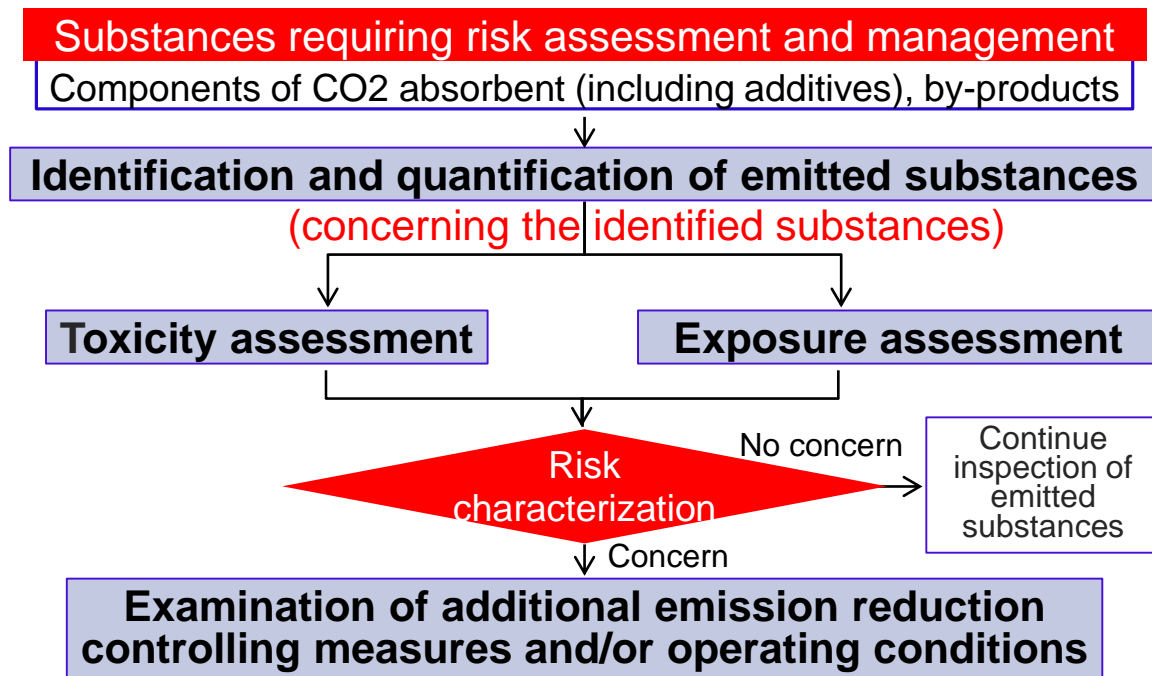
On the basis of the results obtained in component-based approach implemented following the procedure described on the left, specify the causative substance

(concerning causative substances)



# Component-based approach

- A general risk assessment is conducted through the “component-based approach”.
- In addition to the component(s) of the CO<sub>2</sub> absorbent (all purposely used substances including the main agent), every chemical substance generated as degradation products in the CO<sub>2</sub> capture process are individually subjected to
  - toxicity assessment (collection of toxicity data, implementation of toxicity tests),
  - exposure assessment (estimation of environmental concentrations using a mathematical model, and if necessary, conducting environmental monitoring),
  - risk characterization.



It is necessary to identify the degradation products within technically and economically appropriate limits

and measure their amount of emission to the environment.

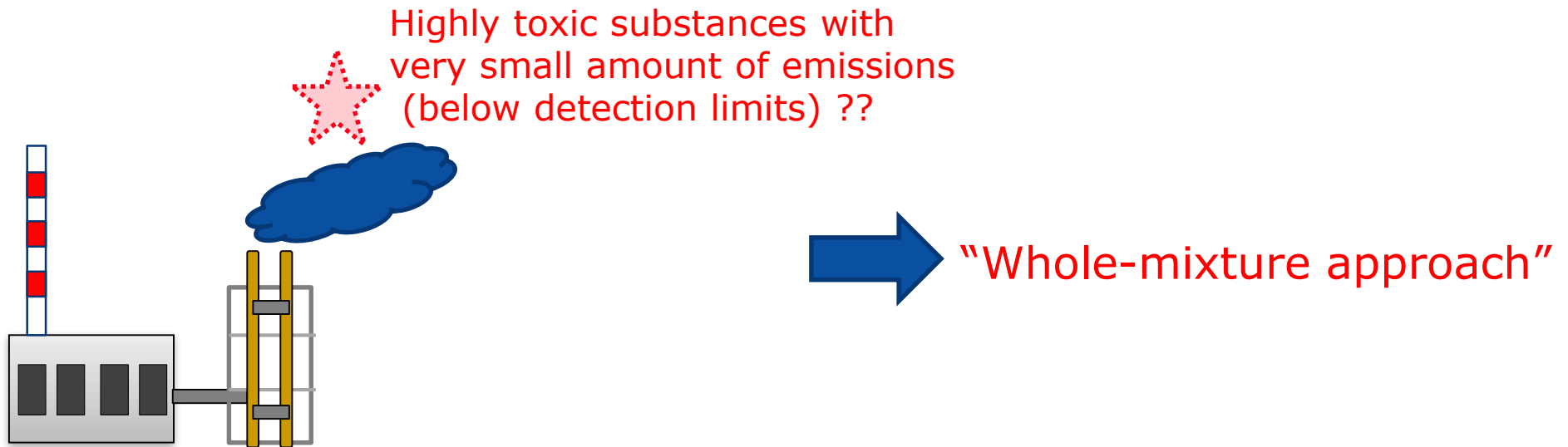
# The characteristics of the CO<sub>2</sub> capture process using amine solvents

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- Acid gas separation and recovery using amine solvents based on the chemical absorption method is conventionally used in natural gas purification, the hydrogen–ammonia industry, and the likes.
- Meanwhile, the CO<sub>2</sub> separation and recovery process intended for the combustion exhaust gas of fossil fuels mainly differs from the existing processes in the following points:
  - Because the exhaust gas from thermal power plants includes oxygen, oxidative decomposition of the amines is likely to occur in the CO<sub>2</sub> capture system.
  - In addition to oxygen, impurities contained in the exhaust gas from thermal power plants exert an impact on the degree of degradation of the amines (and thus on the amount of emission) and the type of degradation products.
  - With the future commercial development, the scale of the CO<sub>2</sub> capture system will increase.

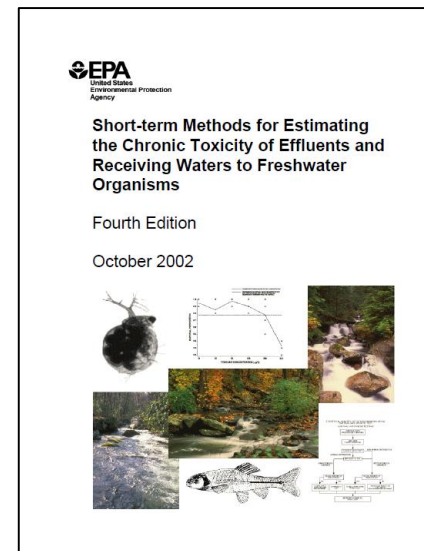
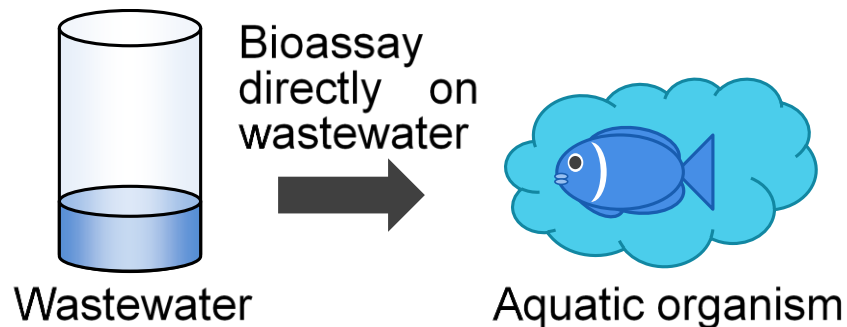
# The challenges for environmental risk management for the CO<sub>2</sub> capture process

- Numerous substances are generated secondarily and it is economically and technically not feasible to identify "all" these degradation products.
- From the perspective of environmental risk assessment, there are concerns that highly toxic substances with very small amount of emissions (below detection limits) might be emitted into environment.
- Thus, conventional methods of risk assessment and management (component-based approach) may not sufficiently ensure safety.



# Whole-mixture approach

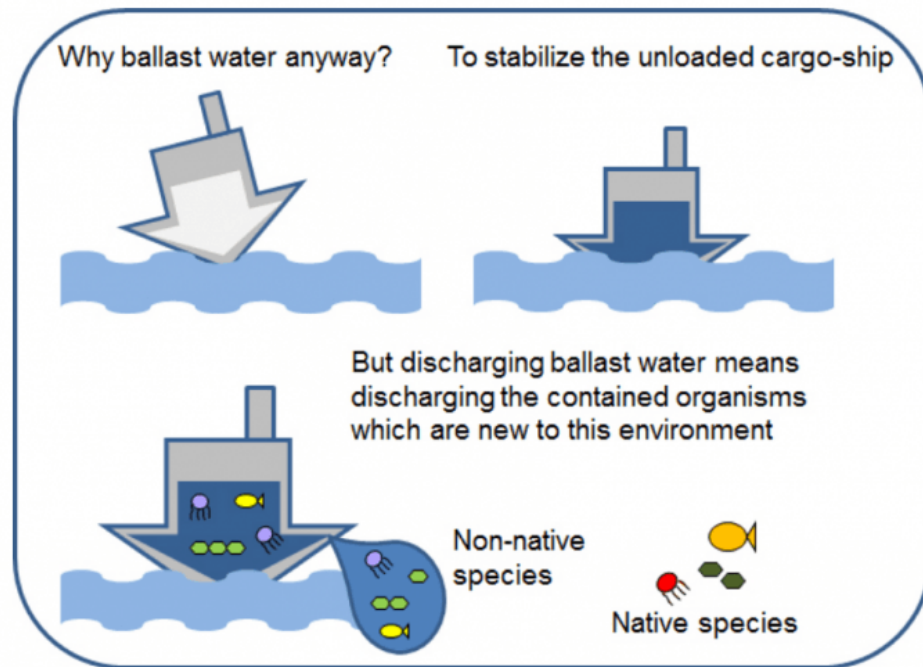
- “Whole-mixture approach” is needed to complement “Component-based approach” (conventional approach).
- Whole-mixture approach
  - uses bioassay (biological response test) conducted “directly” on wastewater etc.
  - known as Whole Effluent Toxicity (WET) test.
  - efficient to evaluate the impact of small amounts of degradation products as well as their additive effect and/or synergistic effect.
  - already introduced in the United States and other countries as a wastewater management technique.



Short-term Methods for  
Estimating the Chronic  
Toxicity of Effluents and  
Receiving Waters to  
Freshwater Organisms;  
4th ed (EPA)

# Whole-mixture approach in “Ship’s ballast water”

- The component-based approach and the whole-mixture approach are combined in the guidelines, also in the context of management of “ship’s ballast water”.
  - A WET test is prescribed on the ballast wastewater itself, in the guidelines formulated for “the International Convention for the Control and Management of Ship’s Ballast Water and Sediments”, adopted by the International Maritime Organization (IMO) at Feb 2004, and going to effect Sep 2017.



Ballast water and oceanic ecosystems

(Source: <https://www.greenoptimistic.com/ballast-water-management>)

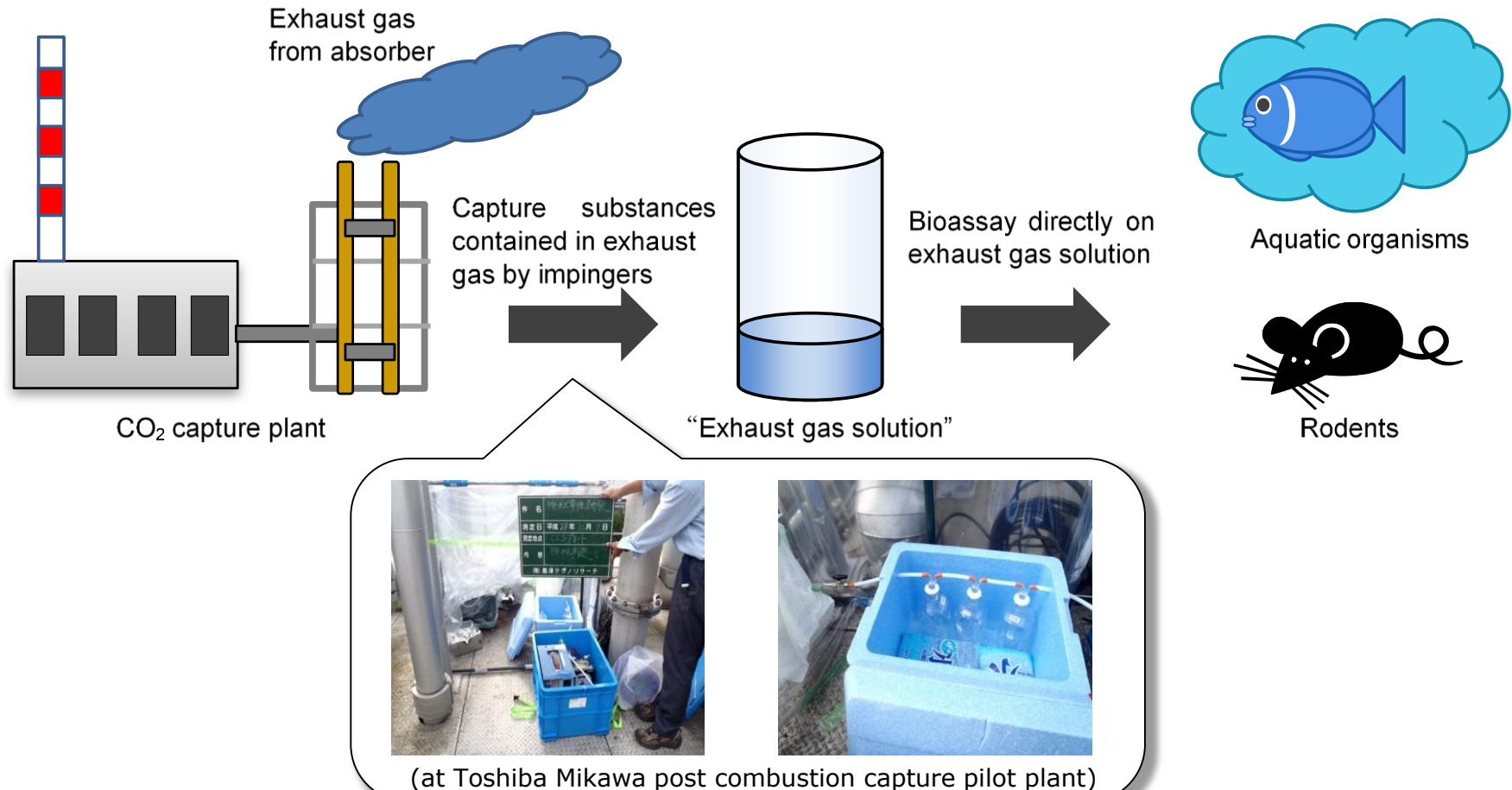
“Chemically treated ballast water”  
(which contain numerous  
secondarily generated chemical  
substances) needs WET tests,  
to protect oceanic ecosystems.



In the sense of “new” technology,  
“ballast water treating facility” is  
in a similar context with CO<sub>2</sub>  
capture technology.

# The concept of bioassay targeting “exhaust gas (solution)”

- To conduct a risk assessment of the impact on human health and/or aquatic organism from the viewpoint of the whole-mixture approach, “exhaust gas solution” will be used for bioassay.



# Comparison of two approaches in risk assessment and management

- Two approaches are complementary.

	Component-based approach	Whole-mixture approach
Assessment feasible without substance identification?	No	Yes
Ease of “publishing” the results	Inconclusive	Positive
Ease of “understanding” the results	Inconclusive	Positive
Ease of establishing emission reduction measures targeted to specific causative substances	Positive	Inconclusive

- “Whole-mixture approach” not only helps to overcome the issues typical of the CO<sub>2</sub> capture process, but also is easy to understand and thus familiar to local residents and public.
  - like “a canary in a coal mine”.

Source:  
<http://coachellavalleyweekly.com/canary-in-a-coal-mine/>





# Whole-mixture approach is also cost-effective

- An issue is that there is poor hazard information for substances emitted from the CO<sub>2</sub> capture process.
  - For example, in the test result of environmental risk assessment using Toshiba's emission data from 10 ton-CO<sub>2</sub>/day scale pilot plant using MEA solution at Mikawa coal fired thermal power plant, 13 substances were identified as emitted substances.

Hazard information availability  
of MEA and its degradation products

Name of substance	Abbreviation	Hazard information available?	
		Human health	Aquatic organism
Monoethanolamine	MEA	Yes	Yes
Diethanolamine	DEA	Yes	Yes
N-(2-hydroxyethyl)imidazolidone	HEIA	Yes	Yes
N-Nitrosodiethanolamine	NDELA	Yes	No
Pyrazine	PY	Yes	No
Methylpyrazine	MePY	Yes	No
N-(2-hydroxyethyl)imidazole	HEI	No	No
2-Oxazolidinone	OZD	No	No
N-(2-hydroxyethyl)acetamide	HEA	No	No
N-(2-hydroxyethyl)lactamide	HELA	No	No
N-(2-hydroxyethyl)glycine	HEGly	No	No
1-hydroxyethyl-2-piperazinone	HEPO	No	No
N-(2-hydroxyethyl)formamide	HEF	No	No

No hazard information

Of the 13 substances identified, there are hazard information for only 6 substances on human health and only 3 substances on aquatic organisms, respectively.



Instead of toxicity testing of each substance, assessment of the impact "all at once" by using the whole-mixture approach

# Conclusion

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- We are drafting “guidelines on environmental risk assessment method for the CO<sub>2</sub> capture process”,
  - to reduce the environmental impact of the process
  - to increase local residents and public understanding
  - to promote the introduction of CCS
  
- Now, in order to complete the framework of environmental risk assessment and management, we are trying to overcome the issues, through the demonstration using post-combustion CO<sub>2</sub> capture pilot plant and so on.
  
- “Whole-mixture approach” not only overcomes the issues typical of the CO<sub>2</sub> capture process, but also is easy to understand and thus familiar to local residents and public, and cost-effective.

# Acknowledgements

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- This study was carried out as a part of the project funded by Ministry of the Environment, Government of Japan.
- The authors would like to acknowledge the subcommittee for environmental impact of CO<sub>2</sub> separation and capture absorbent.