Chemical risk assessment on photovoltaic (PV) panel

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Outline

A.	What is risk? What is risk management?
B.	Risk assessment (RA) processes of chemical substances
C.	RA of PV module – a case study on CdTe PV panel
D.	Summary

What is risk ?

Risk:

the probability of that a person (or an environment) will be harmed or experience an adverse effect if exposed to a hazard.

On chemical substances:

Risk =f (Hazard, Exposure)

Hazard: potential to cause harm or adverse effect from a chemical

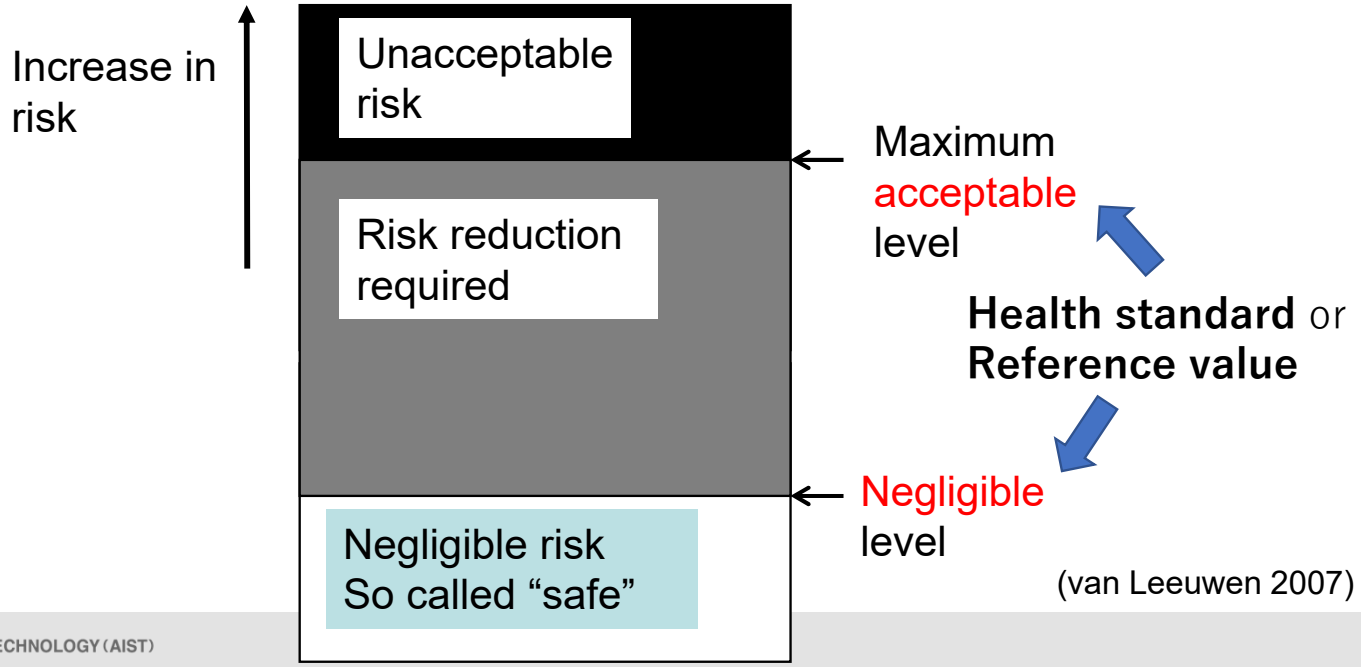
Exposure: dose of a chemical to which a person or an environment is (or will be) exposed.

What is risk management?

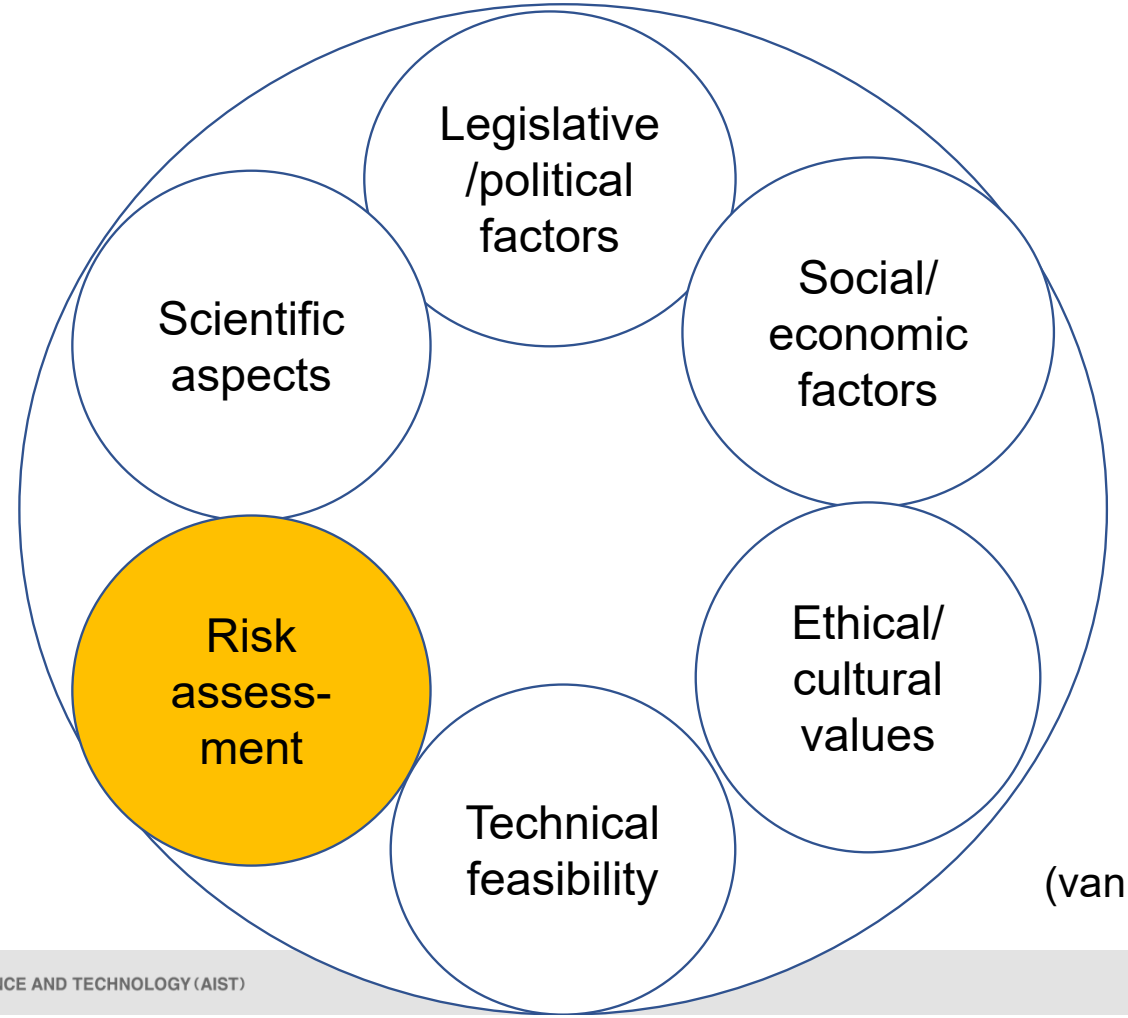
Risk management：

(1) To estimate the magnitude of the risk, then to determine whether the risk will be acceptable or not.

(2) To decide how we reduce the risk if the risk will be unacceptable.

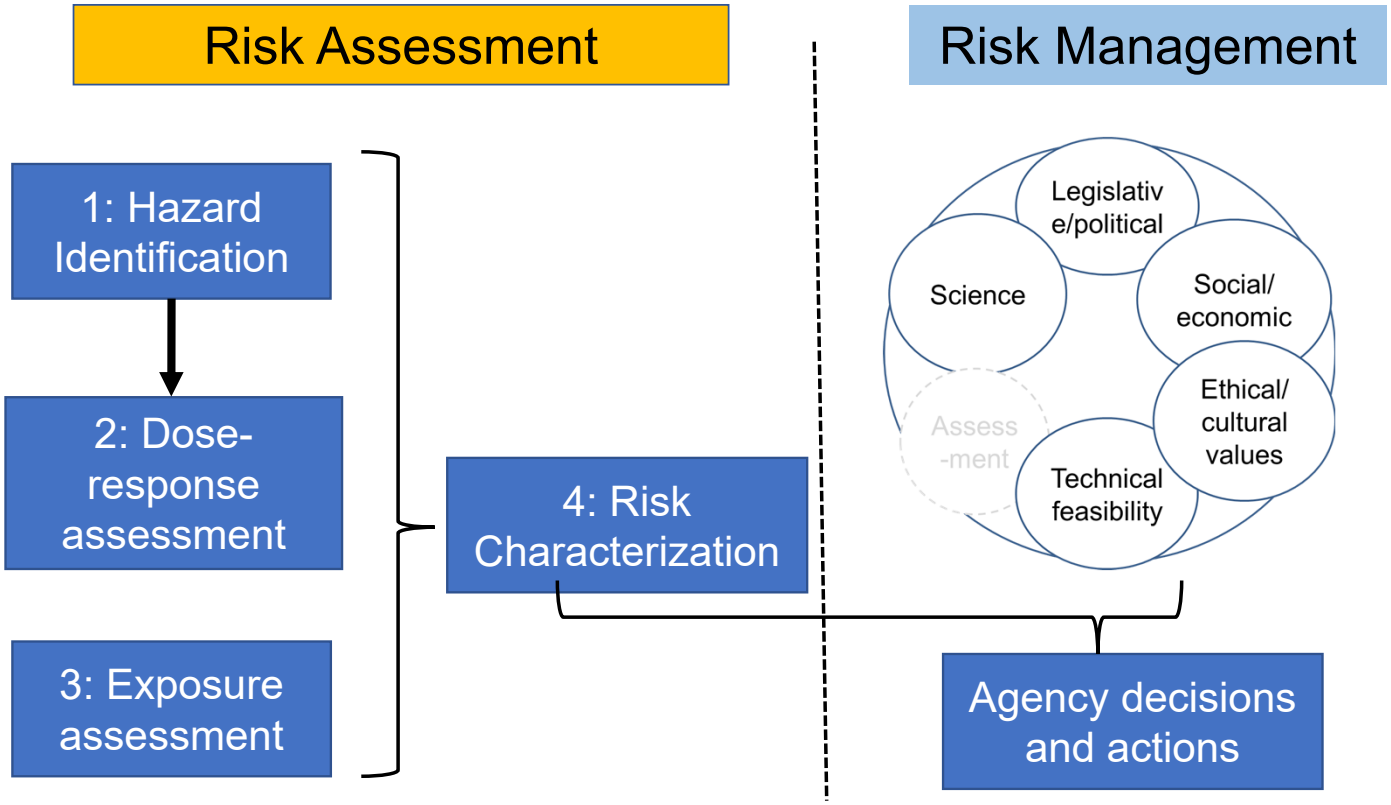


Risk management: Regulatory decisions



(van Leeuwen 2007)

Risk assessment processes of chemical substances



Risk =f (Hazard, Exposure) NAS 1983

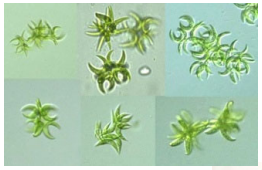
Hazard Identification

- To Identify adverse effect of the chemical
- **Endpoint** = adverse effect of interest
  - Death, pain, irritating, or environmental destruction.
- Based on human data or laboratory animals or other test systems

Epidemiology (Human)

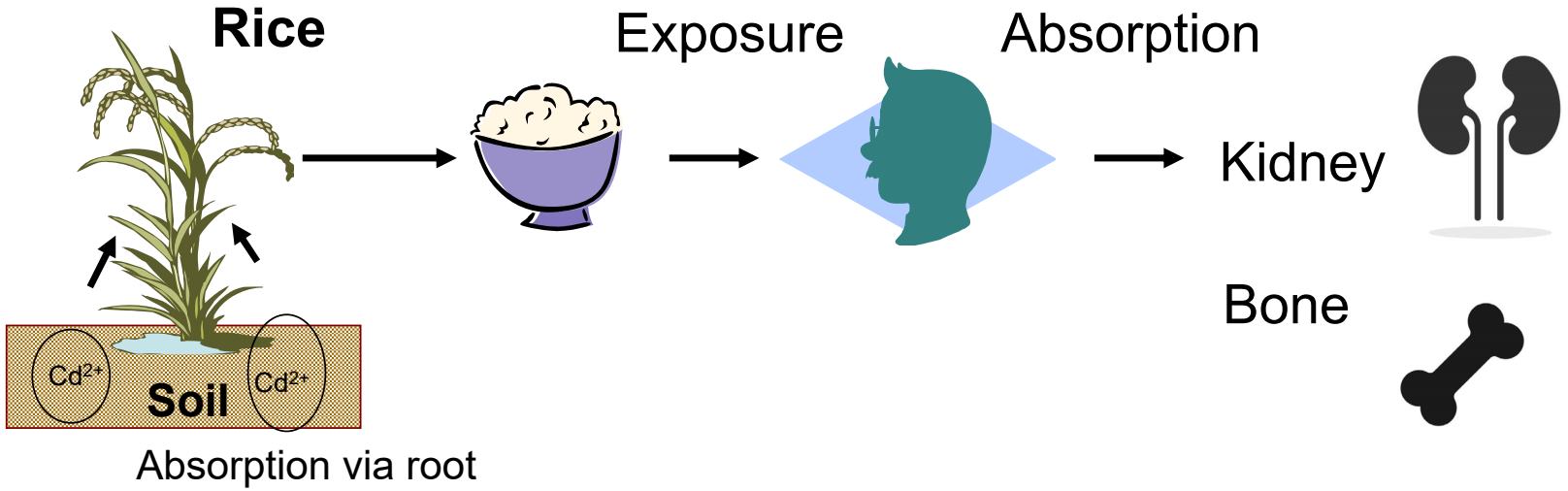
Itai-itai disease:
Too much cadmium exposure causes damage on bone with severe pain. “Itai” (means “Ouch!” in Japanese)

Animal test



Ecotoxicology test

Identification of exposure route (cadmium; Cd)



Endpoint: Damage on kidney and bone system
Standard for cadmium intake control (Japan): 0.4 mg/kg in brown rice
Environmental standard (Japan): 0.003 mg/L in drinking water etc.

Identification of Exposure route (mercury)

Food

Exposure

absorption

Blood

distribution

Nerve system

Drinking water

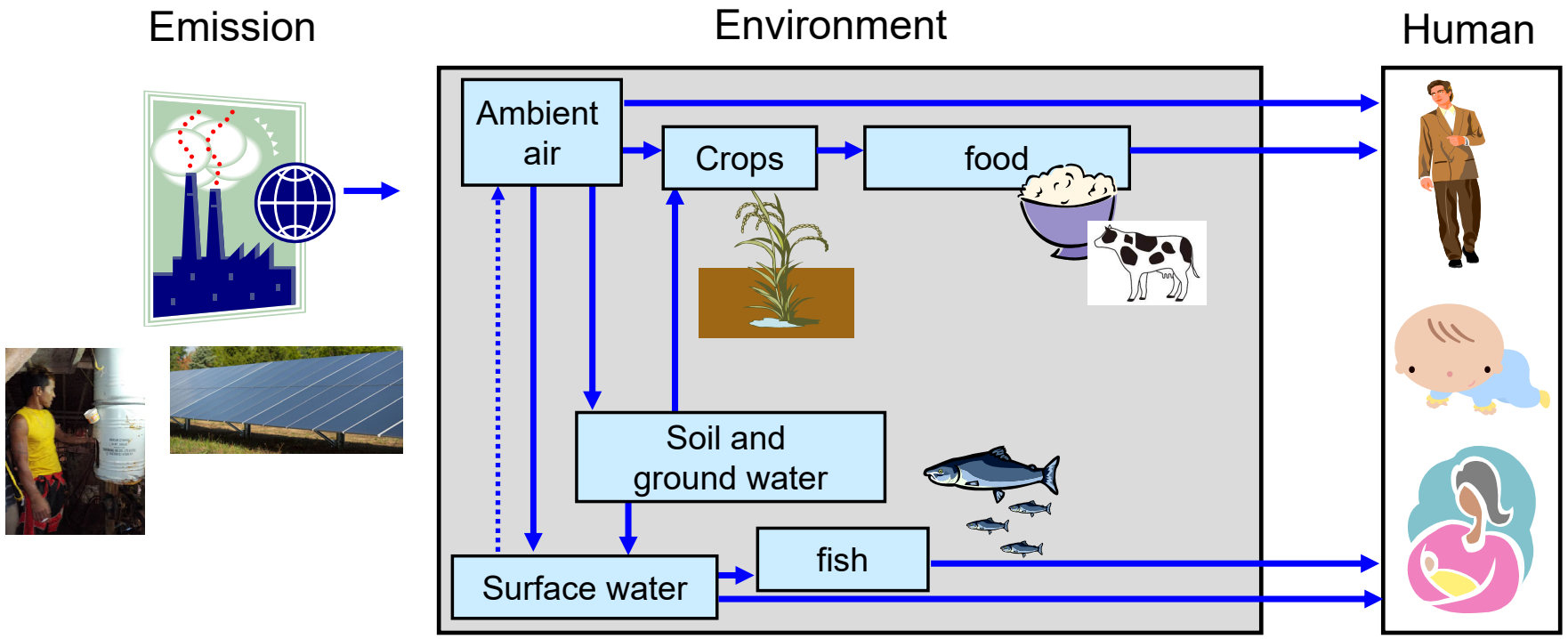
- Endpoint: damage the central nervous system (pain, shaking…)
- Guidance for mercury intake control (Japan): 0.4 ppm in fish (upper limit, for pregnant women)
- Environmental standard (Japan): 0.0005 mg/L in drinking water

Exposure assessment

Exposure assessment：the process of characterizing

✓ the magnitude, frequency and duration of contact with the chemical

✓ the number and characteristics of the population exposed.



Risk assessment of PV module

– a case study on cadmium telluride (CdTe) PV panel –

Research questions:

- ✓ Are soil and water pollution likely by on site disposal of PV module?
- ✓ If yes, how severe the pollution will be?

Hazard Identification

- To Identify adverse effect of the chemical is the first step of RA.

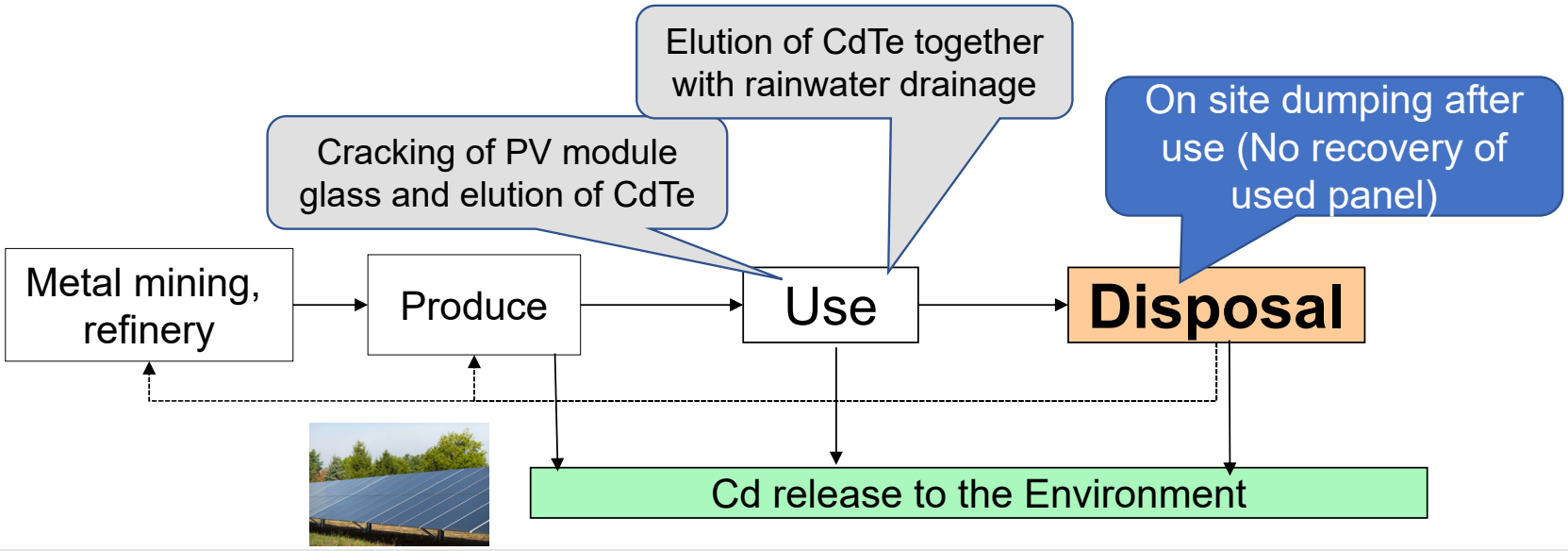
Properties and hazard information of Cd and CdTe

		Cd	CdTe
Physico-chemical properties	Density (@25℃) [g/cm^3]	8.6	6.2
	Melting point [℃]	321	1041
	Boiling point [℃]	765	-
	Water solubility	Insoluble in water. Easily soluble in dilute nitric acid. Slowly soluble in hot hydrochloric acid.	Dissolve in the form of Cd and Te ions when in contact with water and oxygen.
Hazard	Median Lethal Dose (LD50): acute, oral (rat)	107–327 mg/kg (Patty 5th, 2001)	>2,000 mg/kg (Zayed & Philippe, 2009)
Env. Criteria (Japan)	Water	0.003mg/L	-
	Soil	0.003mg/L (elution) 45 mg/kg (content)	-

Exposure Assessment
Risk scenarios considered for CdTe PV module

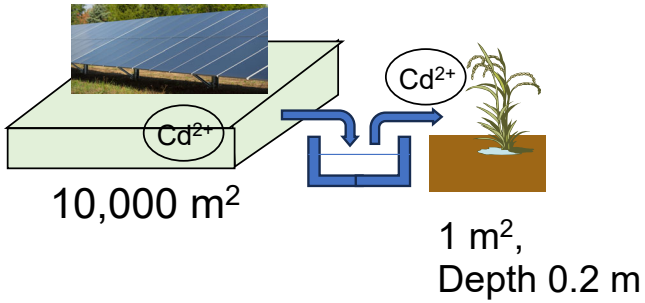
- "On site PV module dumping after use" (No recovery of used panel) scenario should be focused as a worst-case scenario.
- Risks during use process and after disposal into solid waste damping site were likely, but were negligible.

Life cycle of PV module and material flow of Cd



Risk characterization
Soil contamination (1)
Total Cd load to soil after dumping of a PV panel

- Assumptions:
  - A scrapped PV module (containing 60 kg of Cd) was dumped in a 1-hectare (=10,000 m^2) dumping site



  - The elution was collected at a basin. The Cd contaminated water percolates into a 1 m^2 area (Depth: 0.2 m) of land.
  - The assumed contaminated area was limited (worst case)

- Predicted maximum concentration at the site of dumping site: 0.8 mg/kg-dry soil
  - Background level of Cd in Japan: 0.2 mg/kg-dry soil

Risk characterization
Soil contamination (2)
Consideration of bioavailability

Relationship between the form and bioavailability of metals in soil

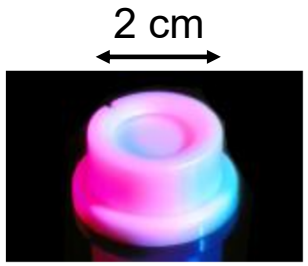
Metal form	Solubility in soil pore water	Bioavailability (Ability for absorption into organisms)
Free ion	+	+
Chelate compound	+	-
Sulfide	-	-
Compound with mineral	-	-
Organic Carbon Complex	+	NS

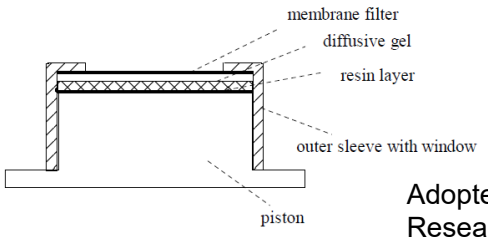
+: Generally high, -: Generally low, NS: not to be specified

Risk characterization
Soil contamination (2)
Measurement of bioavailability

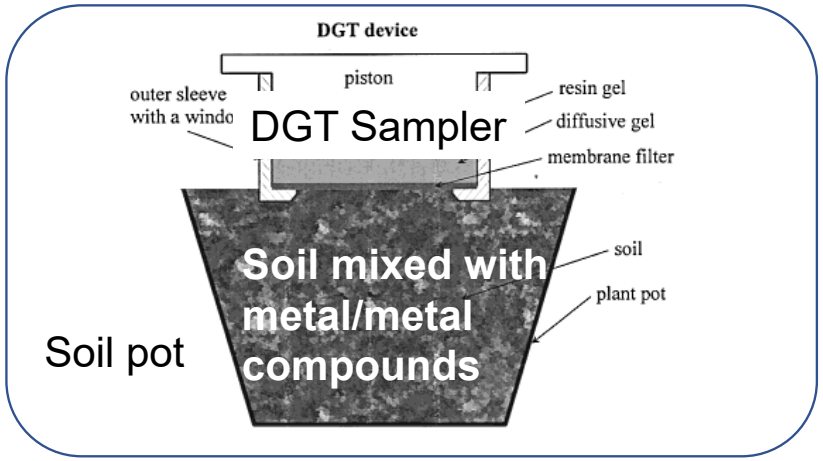
- ✓ Cd as free ion (i.e. bioavailable form) derived from CdTe compound is detected by diffusive gradient in thin film (DGT) method.

DGT Sampler





Adopted from DGT Research



Zhang et al. (2001)

Cd nitrate

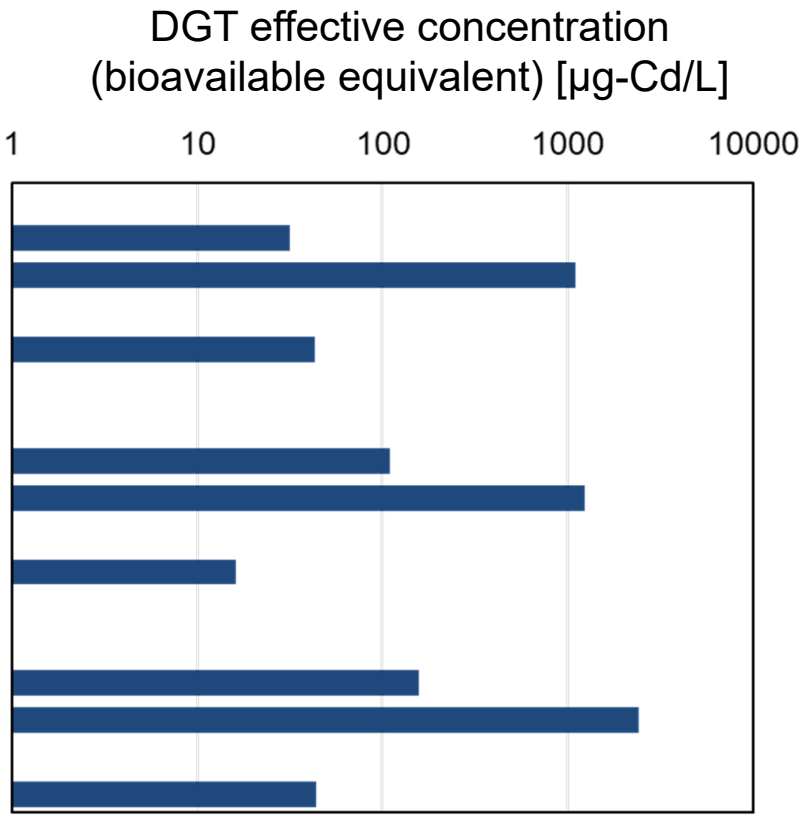
CdTe

Soil

Risk characterization
Soil contamination (2)
Measurement of bioavailability — Results on CdTe

		Total Cd content in test soil (mg/kg-dry)
Soil 1	Control	< 0.1
	Cd*_Low	0.8
	Cd_High	9.9
	CdTe_Low	0.4
	CdTe_High	6.5
Soil 2	Control	0.1
	Cd_L	0.9
	Cd_H	8.1
	CdTe_L	0.7
	CdTe_H	4.3
Soil 3	Control	0.3
	Cd_L	1.1
	Cd_H	8.3
	CdTe_L	0.7
	CdTe_H	6.9

*: Cd nitrate; Cd(NO3)2



Ono (2011) Unpublished

- ✓ Bioavailability varies with soil type.
- ✓ Bioavailability of CdTe compounds is less than one-tenth of Cd compounds.
- ✓ Environmental impact by CdTe seems lower than that of Cd.

Summary

- ✓ Risk = Hazard × Exposure
- ✓ It is important to know exposure route and to identify vulnerable organisms or environmental medium.
- ✓ As for risk assessment of CdTe PV module, we focused “on site PV module dumping” scenario as a worst-case, and we assessed soil contamination risk.
- ✓ Elevation of Cd concentration in soil was estimated for total Cd, and bioavailability of CdTe was measured using 3 soil samples.
- ✓ CdTe compound had smaller bioavailability (less than one-tenth) than that of Cd compounds.

Thank you for attention !

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