Challenge for Sustainable remediation of large-scale terrestrial contamination by the Fukushima Daiichi NPP accident

Tetsuo Yasutaka
t.yasutaka@aist.go.jp
Group leader,
National Institute of Advanced Industrial Science and Technology(AIST)
Visiting Professor,
Hokkaido University.

Co-author
Momo Takada, Kosuke Shirai(AIST),
Michio Murakami(Osaka University),
Susumu Ohnuma, Yukihide Shibata(Hokkaido University),

This research was performed by the Environment Research and Technology Development Fund (JPMEERF22S20930) of the Environmental Restoration and Conservation Agency Provided by the Ministry of Environment of Japan.

1. Introduction

Sustainable Remediation and Fukushima accident and decontamination work

2. Research

A) Assessment of public attitude and acceptance of FDS

1) Important factors for public acceptance of the FDS
2) Factors influencing acceptability of FDS
3) Public's Pros and Cons of Policy for the FDS
4) Citizen participation workshop

B) Stakeholder engagement in Fukushima

5) Evaluation of the Nagadoro case study

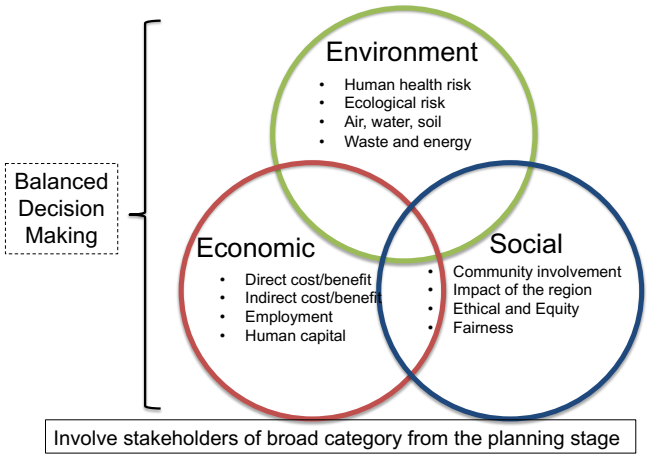
Ref.) Co-expertize process of former residents ISF near NPP.

Our recent approach of Sustainable Remediation

SuRF-JAPAN focused
Contaminated land

Sustainable Remediation Approach

SuRF-UK defined Sustainable Remediation as "The practice of demonstrating, in terms of **environmental, economic and social indicators**, that the benefit of undertaking remediation is greater than its impact and that the optimum remediation solution is selected through the use of a balanced decision-making process.



Nuclear disaster

- Recycle/limited reuse of the removed soil
- Selection of a final disposal site outside of Fukushima Prefecture
- Social acceptance
- Consensus building
- Stake holder involvment

Legacy Mine drainage management

- Water Use Point Risk Management
- Biological Impact Assessment
- Passive treatment
- Stakeholder involvement
- Publish the related guidance with government

COVID19 risk assessment

- Collaboration with Japan professional league, etc
- Develop the risk assessment model and evaluate the countermeasure.
- Stakeholder involvement

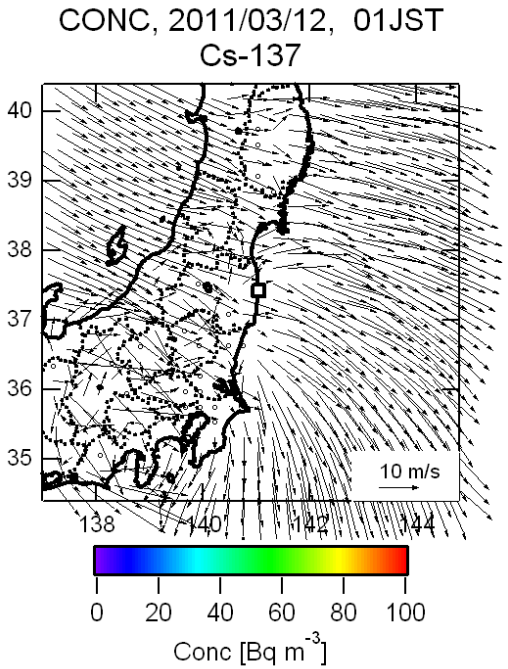
Accident of TEPCO Fukushima Daiichi Nuclear Power Station（1FNPP）

- On 11 March 2011, large earthquake struck the Tohoku region.
- A tsunami (15.7 meter high) struck the 1FNPP.
- The hydrogen explosion then occurred.
- Large quantities of radioactive Cs have been released into the atmosphere.

東京電力福島第一原子力発電所3号機（空撮）
（平成23年３月16日撮影、東京電力提供）

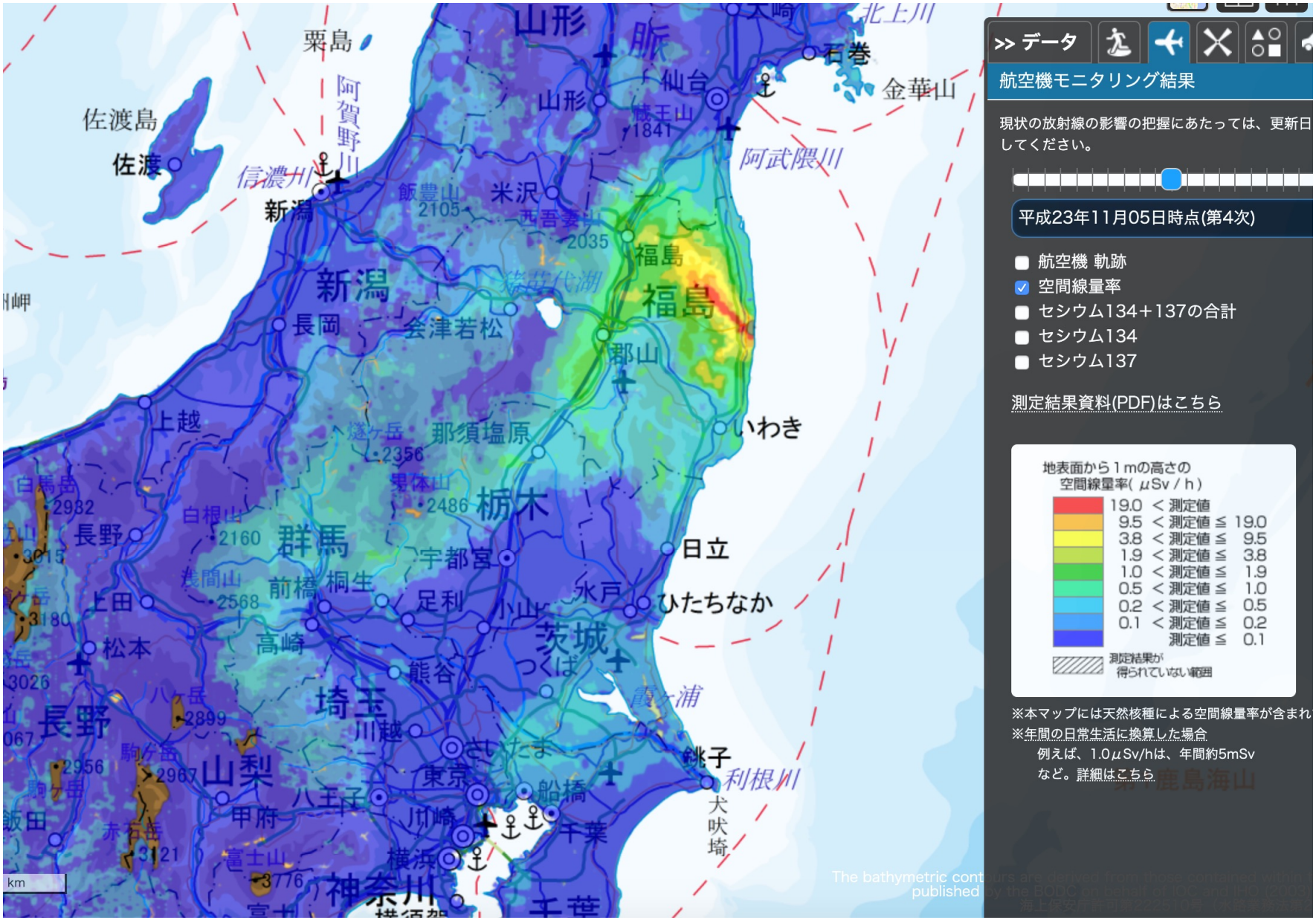
TEPCO Fukushima Daiichi Nuclear Power Station Unit 3
https://www.env.go.jp/chemi/rhm/h29kisoshiryo/h29kiso-06-01-02.html

^{137}Cs concentration in air



12th - 23th March, 2011
National institute of Environmental Studies,
https://www.nies.go.jp/fukushima/act-pg1-02.html

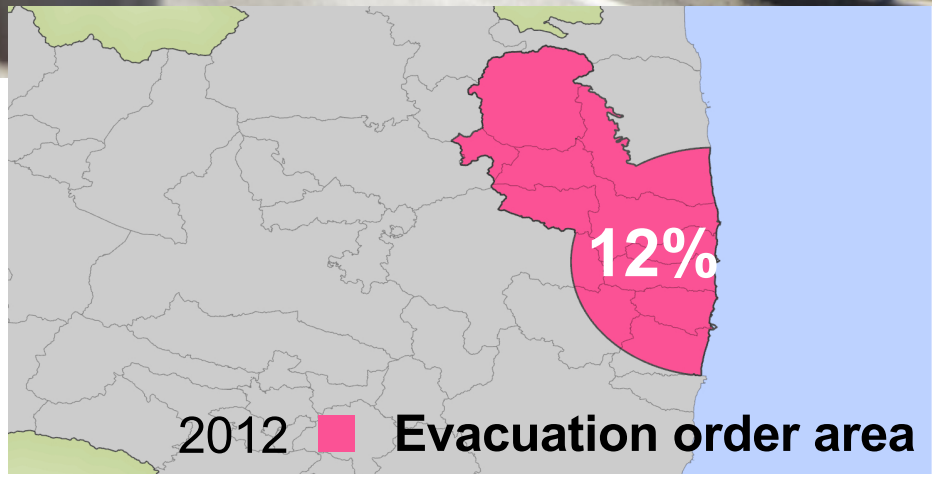
Air dose rate and soil contamination



放射線量等分布マップ拡大サイト
https://ramap.jmc.or.jp/map/#lat=36.975833237251486&lon=140.82343692361948&z=8&b=std&t=air&s=16,0,0,0&c=20111105_dr

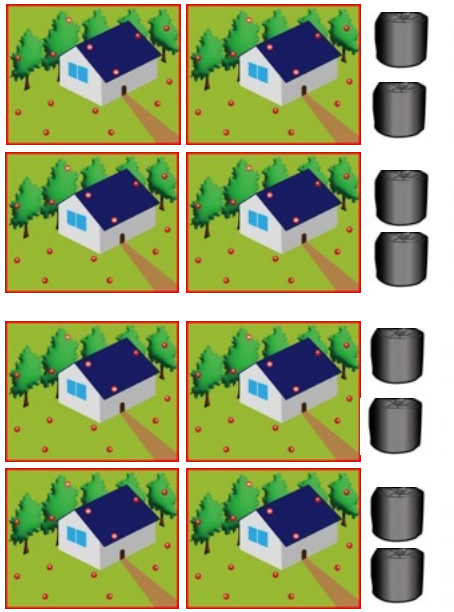
Social and Economical problem

- 12 % of area of the prefecture were under evacuation orders
- More than 165,000 people had been evacuated.



Decontamination process

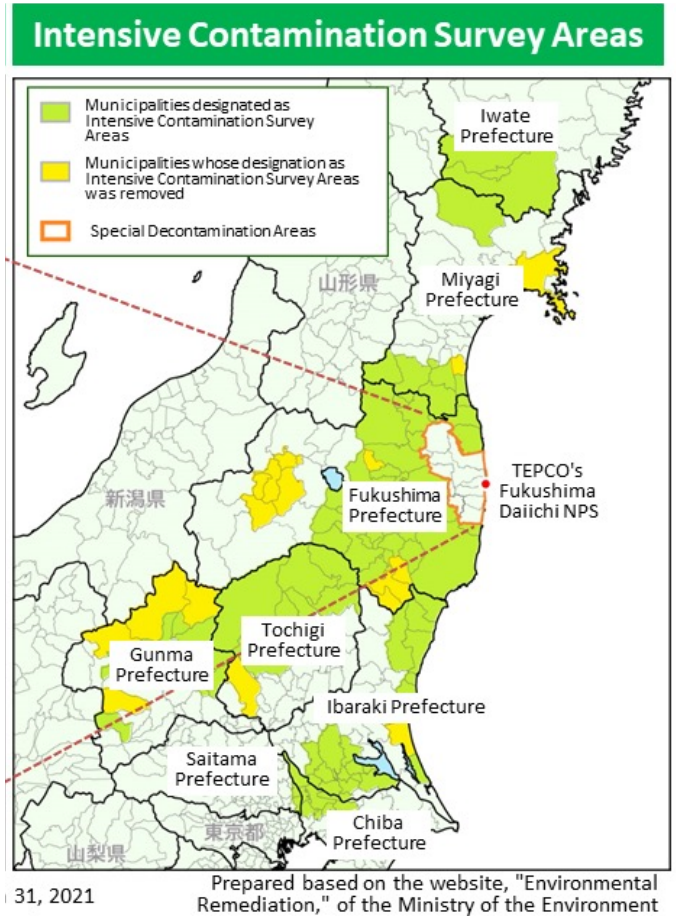
2012-2018(mainly)
Decontamination



Generate over 13 million m^3 “removed soil” and “waste”

Farmland

Residential area

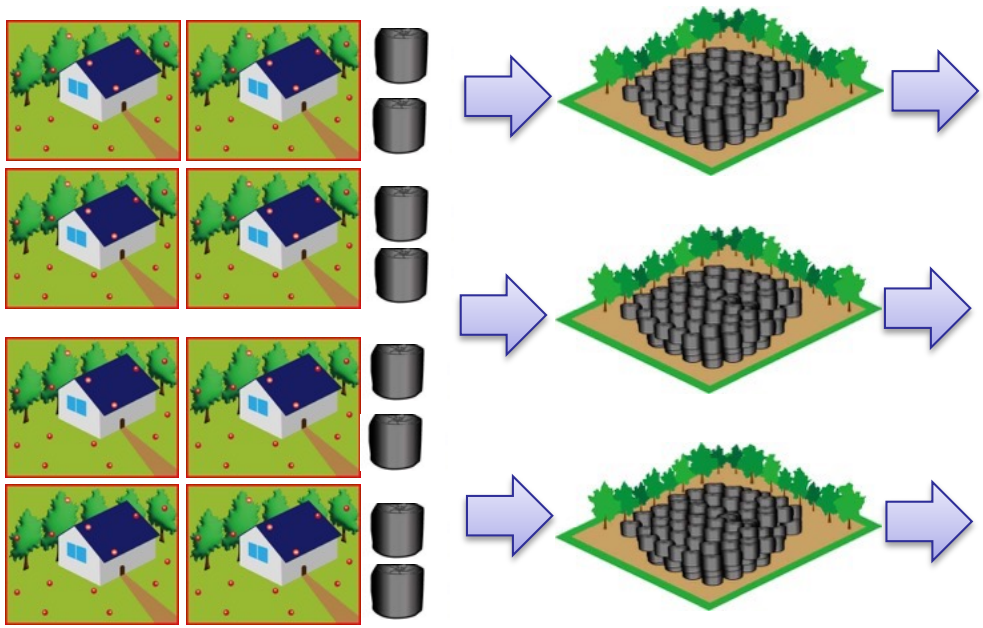


Decontamination process

2012-2017(mainly) Decontamination

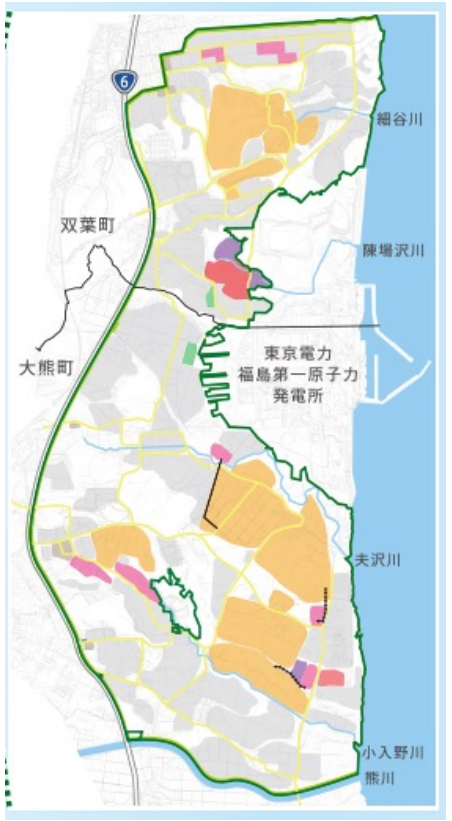
2012- Temporary Storage Site

2015-2045 The Interim Storage Facility (ISF)



Generate over 13 million m^3 “removed soil” and “waste”

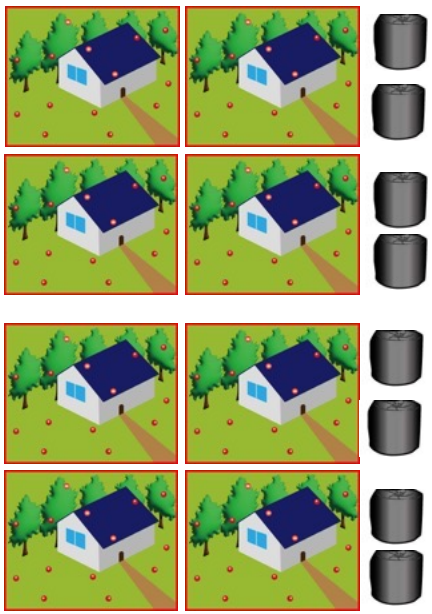
The concentration of radioactive Cs in about 80% of the soils is below 8000 Bq/kg.



http://josen.env.go.jp/chukanchozou/

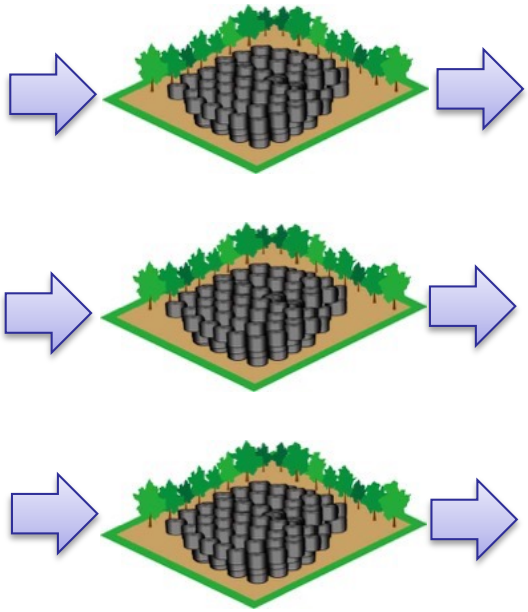
Decontamination process

2012-2017(mainly) Decontamination

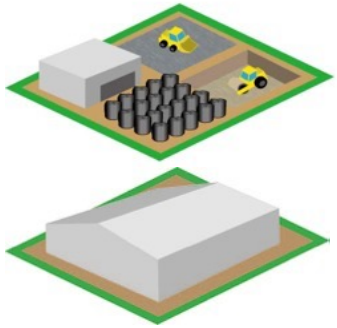


Generate over 13 million m^3 “removed soil” and “waste”

2012- Temporary Storage Site



2015-2045 The Interim Storage Facility (ISF)



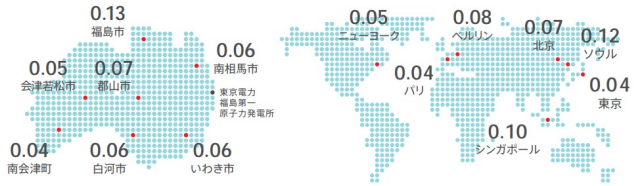
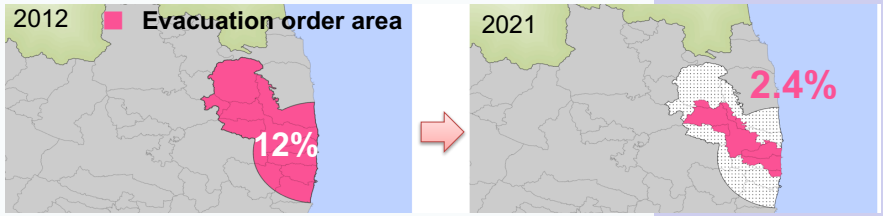
The concentration of radioactive Cs in about 80% of the soils is below 8000 Bq/kg.

-2045 Final disposal Site (FDS) out side of the Fukushima or Reuse

The final disposal is required by law to be completed outside of the Prefecture within 30 years (By March 2045).

However, the location of the final disposal site and the consensus building process were under the discussion.

Evaluation of the decontamination work from Sustainable Remediation view.

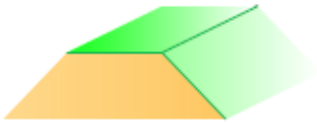
	Environmental	Social	Economic
Pros	• Reducing radiation and air dose rates 	• Reduction from 12% (2012) to 2.4% (2021) of the evacuation zone.  • Government kept their promises to clean up as much as possible	
Cons	• Energy consumption and CO2 emissions from truck use • Loss of good surface agricultural soil	• Took a long time for lift the evacuation (3-11 years). • Need long time and large volume of removed soil and waste management	• Decontaminati on Cost : 5-6 trillion yen (35-40 billion €) • Final disposal cost (Future)

The Japanese Government considered the reduction of radioactivity levels, the lifting of evacuation zones and keeping its promises more important than costs and long-term management of removed soil.

A part of the remaining Issues in Fukushima related with removed soil

1.FDS outside of Fukushima Prefecture by 2045

2. Reuse of the removed soil



Road embankment, agricultural land etc.

Technical/ Technology aspect

- Environmental safety
- Material quality
- Volume reduction tech.
- Storage tech. , etc

Socio economical aspect

- Cost, employment, etc..
- Risk communication
- Social acceptance
- Decision making process
- Stakeholder engagement
- Future of the region, etc

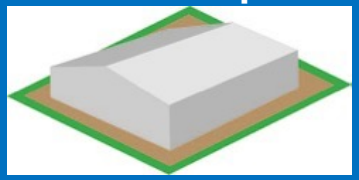
Re-use and FDS requires both Technical and Socio-economical elements

Overview of the Research of RRR(2022-2024),

Research to Renovate and Recover an integrated environment in the Restoration area surrounding the interim storage facility

Theme 1(PL: Kazuto Endo) Technologies for FDS.

- Scenario assessment of technological systems
- Facility requirements for disposal facilities.



Theme 2:(Yuuzo Manpuku) Future design of the affected area

- Quantification with area integration model
- Estimation of ecosystem services

Theme 3: (PL: Tetsuo Yasutaka) Public acceptance and consensus building framework for FDS

- Public acceptance assessment
- Multidimensional fair process design.
- Stakeholder engagement

1. Introduction

Sustainable Remediation and Fukushima accident and decontamination work

2. Research

A) Assessment of public attitude and acceptance of FDS

1) Important factors for public acceptance of the FDS
2) Factors influencing acceptability of FDS
3) Public's Pros and Cons of Policy for the FDS
4) Citizen participation workshop

B) Stakeholder engagement in Fukushima

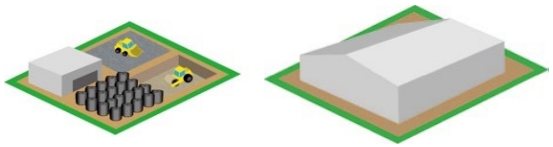
5) Evaluation of the Nagadoro case study

A-1) Important factors for public acceptance of the FDS

Takada et al(2022) Plos One, e0269702

1.Purpose

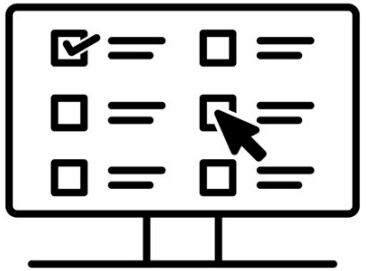
To evaluate the important factors for public acceptance of the final disposal



2.Scenarios for FDS

1. Location of FDS
2. Total number of FDS
3. Decision making process
4. Volume and radioactivity.

3.Web-based survey



4,000 people

4. Conjoint analysis

	Case A	Case B
Decision-making process for acceptance of a disposal site	(2) Offering comments Decisions are made after offering comments of residents	(1) Top-down Decisions are made by mayor/local governor without collecting the opinions of residents.
Volume and radioactive concentration of the substances to be disposed of	(2) Application of volume reduction Substances: High radioactivity in medium quantity **1.3 million tons** (430 times the capacity of a 50-meter pool) **76,000 Bq/kg** (Decrease below 100 Bq/kg* after about 290 years)	(1) No application of volume reduction Substances: Medium radioactivity in large quantity **13 million tons** (4,300 times the capacity of a 50-meter pool) **8,000 Bq/kg** (Decrease below 100 Bq/kg after about 190 years)
Distance of final disposal site to your residential area	(1) The disposal site is in the community (neighborhood) where you live	(2) The disposal site is in the municipality where you live
Total number of final disposal sites	(1) Only one location in Japan	(1) Only one location in Japan

Scenarios for FDS

Takada et al(2022) Plos One, e0269702

Location of final disposal site

- ***Neighborhood***
- ***Within your municipality***
- ***Within your prefecture***

Total number of final disposal sites
(related distributive fairness)

- ***Only one***
- ***Eight in total,*** *one in each region*
- ***46****, one in each prefecture except Fukushima Prefecture*

Decision process
(related procedural fairness)

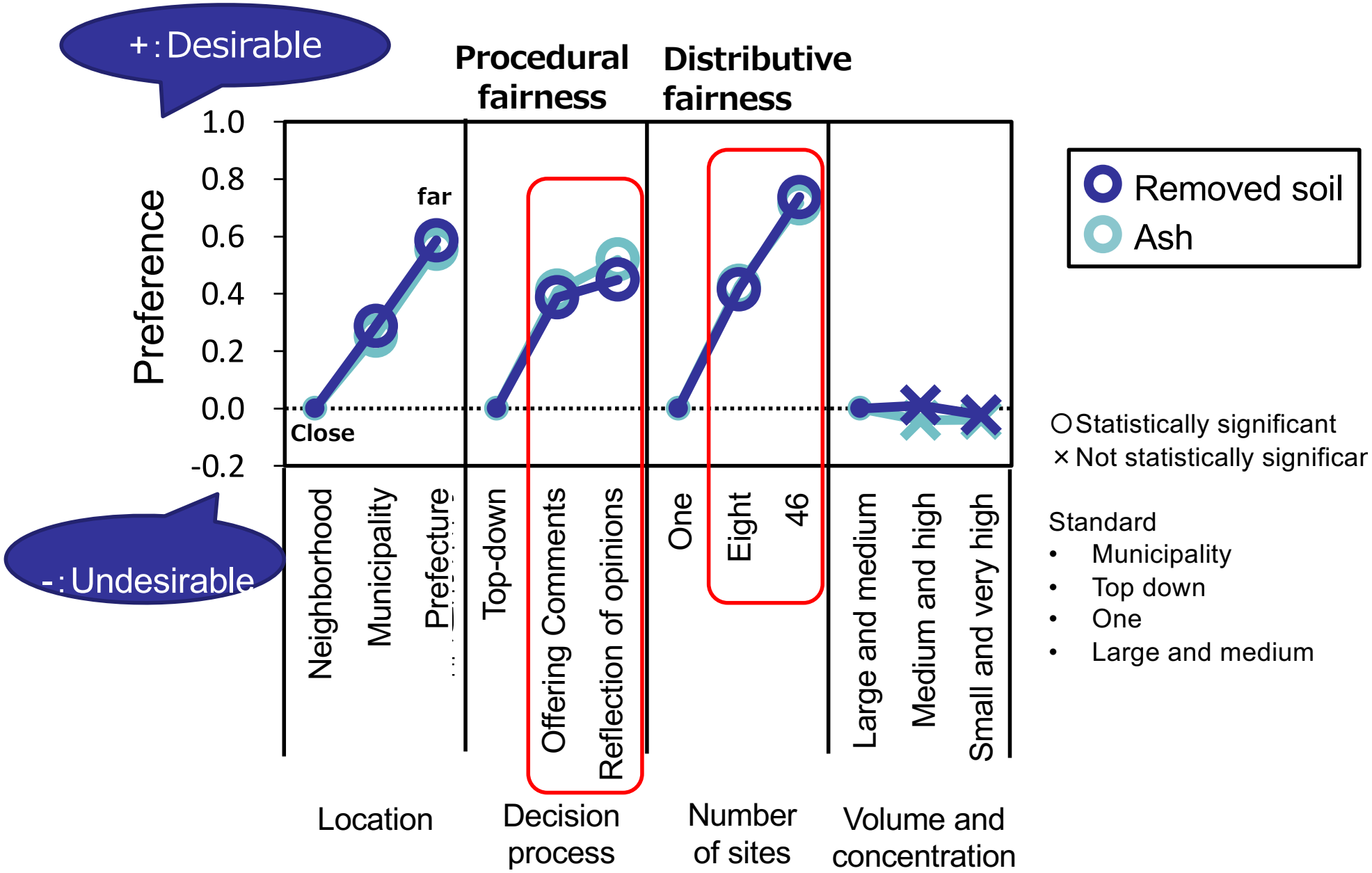
- ***Top-down****.*
  Mayor/local governor decide to accept final disposal site.
- ***Offering comments.***
  Comments from residents are called for, and the mayor/local governor decide to accept final disposal site.
- ***Reflection of opinions.***
  Discourse by residents is held, and a chief decides to accept final disposal site.

Volume and radioactivity.

- ***No treatment***
  - *Medium radioactivity in large quantity*
  - *Removed soil, ca. 13 million t; 8000 Bq/kg*
- ***Volume reduction treatment***
  - *High radioactivity in medium quantity*
  - *Removed soil, 1.3 million t; 76,000 Bq/kg*
- ***Super volume reduction treatment***
  - *Very high radioactivity in small quantity*
  - *Removed soil, 4000 t; 23 million Bq/kg*

Result

Takada et al(2022) Plos One, e0269702



Evident importance of procedural and distributive fairness

1. Introduction

Sustainable Remediation and Fukushima accident and decontamination work

2. Research

A) Assessment of public attitude and acceptance of FDS

1) Important factors for public acceptance of the FDS
2) Factors influencing acceptability of FDS
3) Public's Pros and Cons of Policy for the FDS
4) Citizen participation workshop

B) Stakeholder engagement in Fukushima

5) Evaluation of the Nagadoro case study

A-2)Factors Influencing Acceptability of Final Disposal of Incinerated Ash and Decontaminated Soil from TEPCO‘s Fukushima Daiichi Nuclear Power Plant Accident

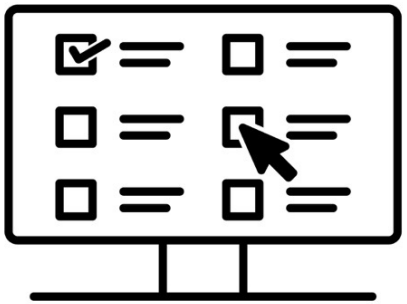
1.Purpose

- To evaluate psychological factors affecting the acceptance of the final disposal.

2.Questionare

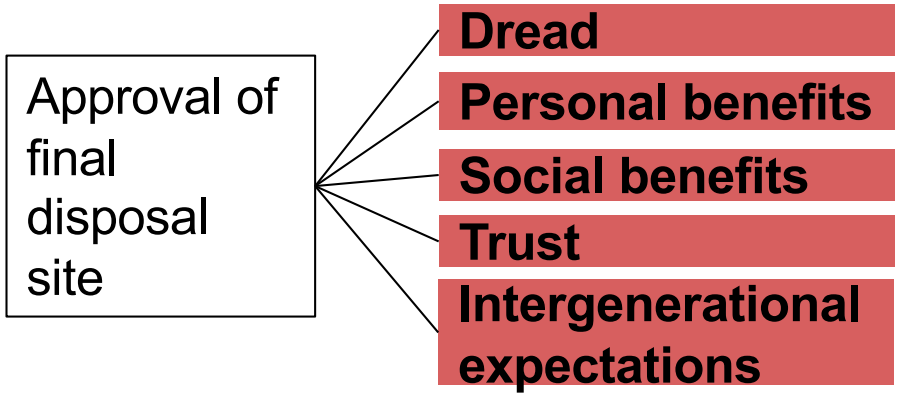
1. Approval or disapproval of final disposal in one's neighborhood.
2. Risk perception(Dread and unknow)
3. Benefits perception
    1. Social benefits
    2. Personal benefits
4. Trust in the MOEJ and Local government
5. Intergenerational expectations
6. Moral foundations

3.Web-based survey



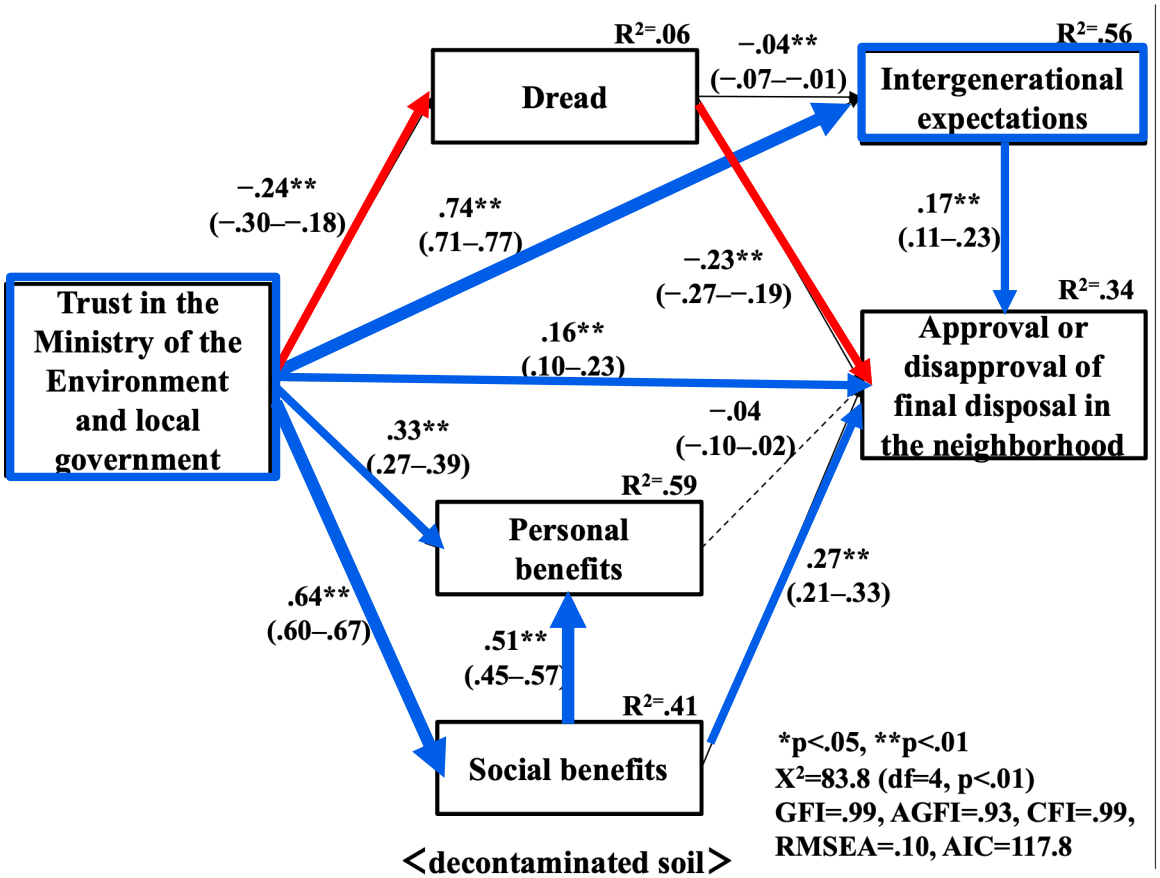
4,000 people

4. Structural equation modeling and cluster analysis



Result and implication

Shirai et al(2023), Journal of Environmental management, 118610



- Trust and intergenerational expectations are critical factors influencing the acceptability of FDS.
- Social benefits increasing acceptability
- Personal benefits having limited impact
- Risk perception(Dread) decreasing acceptability

- "Trust" had a direct effect on "approval or disapproval FDS," as well as a significant effect on all the factors in this study, indicating a substantial indirect effect (decreasing dread, increasing social benefit).

Evident importance of Trust and Social benefits

1. Introduction

Sustainable Remediation and Fukushima accident and decontamination work

2. Research

A) Assessment of public attitude and acceptance of FDS

1) Important factors for public acceptance of the FDS
2) Factors influencing acceptability of FDS
3) Public's Pros and Cons of Policy for the FDS
4) Citizen participation workshop

B) Stakeholder engagement in Fukushima

5) Evaluation of the Nagadoro case study

A-3) Public's Pros and Cons of Policy for the FDS. Questionnaire and Interview.

1.Purpose

- To evaluate the reason of Public's Pros and Cons of Policy for the FDS (FDS will be built outside Fukushima).

2.Questionares

- Web-based survey: 2000

3. Interview

- Interview 40 participants(20 people in favor and 20 people against for the policy) from the questionnaire participants.
- Impressions of the policy, reason for pros and cons of the policy

Agree
Why?

Disagree
Why?

1. Introduction

Sustainable Remediation and Fukushima accident and decontamination work

2. Research

A) Assessment of public attitude and acceptance of FDS

1) Important factors for public acceptance of the FDS
2) Factors influencing acceptability of FDS
3) Public's Pros and Cons of Policy for the FDS
4) Citizen participation workshop

B) Stakeholder engagement in Fukushima

5) Evaluation of the Nagadoro case study

Citizen participation workshop

Shibata and Ohnuma et al.,(2023) Proceedings of the SRA-Japan 36th Annual meeting

Evaluating attitude change of the participants in a citizen participation workshop concerning the reuse and FDS of removed soil.

- 48 citizen, 8 groups
- 40 minutes explanation from 3 Expert and MOEJ.
- 4 hours WS, Discussion among the citizens with facilitator
- After WS, “Sense of involved party” and “Interest” of the removed soils issue increased.
- Perceived risk of re-use has decreased and acceptance of re-use has increased

Participant scores (1:low, 5:high)

	Before	After	t	P
Sense of involved party	3.39 ↗	3.84	-3.28	.002**
Interest	1.89 ↗	3.49	-12.15	<.001**
Trust for experts	3.83	3.87	-0.39	.697
Risk perception(Re-use)	2.68 ↘	2.37	2.86	.006**
Knowledge	2.34 ↗	3.83	-6.73	<.001**
Acceptance of the re-use	2.87 ↗	3.23	-2.46	.018*

Tentative summary of the research results and important factors for social acceptance of FDS

Factor	Implication	Reference
Risk perception	The higher perceived risk, the more opposed to final disposal, and the higher the perceived risk, the less accepting final disposal tends to be.	Takada et al., (2023); Shirai et al., (2023)
Social Benefit	The more social benefits are considered in relation to acceptance of disposal, the more likely people are to be receptive to it.	Shirai et al., (2023)
Trust for Government	The higher the trust in the government (Ministry of the Environment), the more likely they are to accept final disposal.	Shirai et al., (2023)
Interest and knowledge	Agreement was positively correlated with interest in the Nuclear accident, knowledge of decontamination and final disposal policy	Takada et al., (2023);
Expectations of future generations	The higher the expectations of future generations regarding acceptance of final disposal, the more likely they are to accept it.	Shirai et al., (2023)
Procedural fairness(Decision process)	When accepting final disposal, opinion-aggregated or opinion-reflective decision-making shows higher social acceptance than top-down decision-making. This indicates the importance of procedural fairness.	Takada et al., (2022) Murakami et al., (2023)
Distributive fairness(Number of the FDS)	Social acceptance is higher for 8 and 46 final disposal sites than for 1 final disposal site. This indicates the importance of distributive justice in social acceptance. Although it is practically difficult to build 46 final disposal sites, it is important to promote multiple sites, including for recycling.	Takada et al., (2022)

1. Introduction

Sustainable Remediation and Fukushima accident and decontamination work

2. Research

A) Assessment of public attitude and acceptance of FDS

1) Important factors for public acceptance of the FDS
2) Factors influencing acceptability of FDS
3) Public's Pros and Cons of Policy for the FDS
4) Citizen participation workshop

B) Stakeholder engagement in Fukushima

5) Evaluation of the Nagadoro case study

Evaluation of the Demonstration Projects of reuse in Nagadoro

-collaborative activity between MOE, local authority, experts and local people-

*This project was conducted by Ministry of the Environment, local governments, residents and experts. I introduce their challenge and organized from the perspective of Sustainable Remediation and co-expetize process.

Nagadoro district

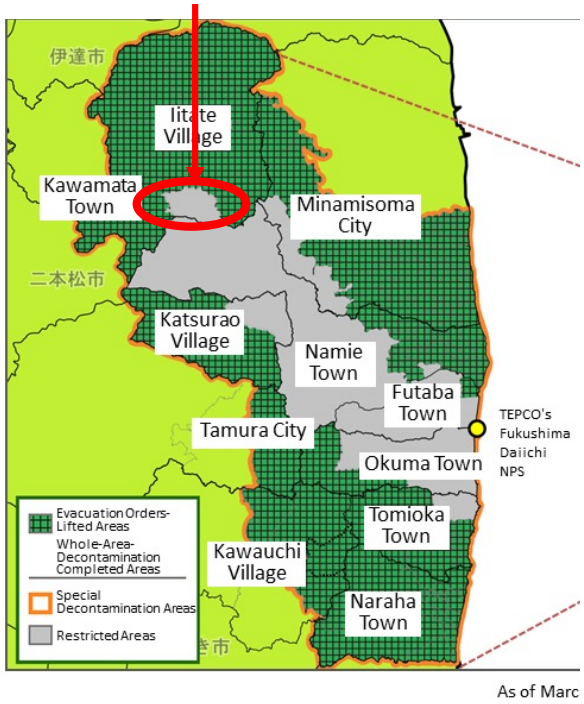


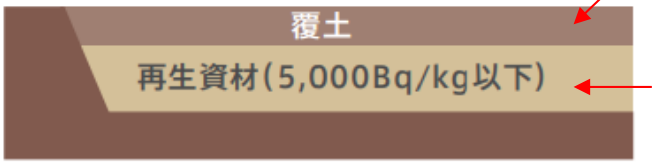
Photo: Ministry of the Environment

https://kankyosaisei.env.go.jp/jigyo/news/pdf/20210607.pdf

Demonstration Projects in Nagadoro

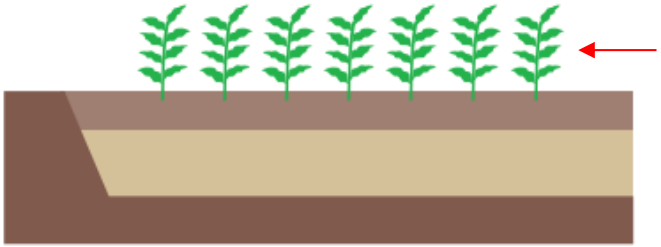
Environmental aspect

1.Developing farm land



50cm shielding soil
Recycled ^{137}Cs contaminated soil (under 5000Bq/kg)

2.Measure the radiation of plant



^{137}Cs in plants ranged from 0.1 to 2.5 Bq/kg, which is lower than the food standard of 100 Bq/kg.

https://kankyosaisei.env.go.jp/jigyo/news/pdf/20210607.pdf

Cultivation experiment with local residents

Photo: Ministry of the Environment

Social aspect

- **Continue exchange of opinions between stakeholders** (13 times official meeting and over a 50 times personal discussion, personal hearing by local authority. **Local authority took the initiative.**)
- **Interactive communication, teaching the agriculture to MOE, taking the request of the residents**, e.g. flowers also be cultivated
- **All residents united to start the project**
- **Work together:** Creation of farmland and Cultivation experiment **with MOE and local residents**

Voice of local residents

- "Doing something first in the world, I want it to be great, a model for other communities to follow."
- "My village is rich in nature and beautiful, and I want to restore its scenery. I want people all over the country to see how the Ministry of the Environment and ourselves are now working hard to restore the area to its pre-disaster state."
- "It's important to have a place where we can come in contact with each other while thinking about the Nagadoro"

http://josen.env.go.jp/plaza/info/monthly/pdf/monthly_2107.pdf
http://josen.env.go.jp/chukanchozou/facility/recycling/project/pdf/iitatedayori_06.pdf
http://josen.env.go.jp/chukanchozou/facility/recycling/project/pdf/iitatedayori_05.pdf

Through this process,

- The residents experienced and gained a better understanding of environmental safety (environmental aspect),
- Regained confidence (social aspect)
- Established a trustworthy relationship with the government(social aspect)
- Positive attitude toward return and future.

These result indicate the importance of the co-expetize process between experts, professionals, and local stakeholders to consider the improving living and working conditions(ICRP publication 146).

Conclusion

- ***About research from the assessment of public attitude and acceptance of FDS***, six indicators were identified as important for increasing the public acceptance.
  - Procedural and Distributive fairness
  - Risk perception
  - Interest and knowledge
  - Social Benefit
  - Trust in Government
  - Expectations of future generations
- Citizen participation workshop is potentially one of the useful method.
- Some of these implications are like those of studies on public perception of high-level radioactive waste. But it is the first result of removed soil and waste(low level contamination) and useful for policy making the MOEJ.
- This may be important not only for FDS but also for re-use of removed soil.

- ***About example of "Stakeholder engagement in Fukushima"*** implies that importance of
  - Co-expertize process(Work together with local resident, authority, MOE and experts).
  - Consider not only environment but also benefit and incentive of local people and future of the area. (The requirements differ from region to region, so the response needs to be localized.)