Radiation Protection Framework and Implementation Models in Public and Industrial Applications outside Emergency Zones:

Case Studies from Japan after Fukushima Accident and Lessons Learned

JU Schmollack, TÜV Rheinland Industrie Service
M Brinkmann, TÜV Rheinland Japan

International Experts Meeting on Radiation Protection after the Fukushima Daiichi Nuclear Power Plant Accident
IAEA Headquarters, 17–21 February 2014, Vienna, Austria

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- **Introduction and Background**

TÜV Rheinland in Japan

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Experiences after March 2011

Public questions and demands:

- What is the radiological situation in our school / kindergarten?
- Can our children go there? Do we need to take any counter-measures?
- Is food safe? Can we still grow vegetables in our gardens?
- Can children play in a sandbox? Can we use our sports fields?…

…and after decontamination measures:

- Was the decontamination successful? How do I make sure that all decontamination work was done as planned? Can we trust the official measurements?
- Is it safe to go back? Can we live our life as it was before? What should be taken in consideration?
- Can our children go to school or kindergarten?...

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Experiences after March 2011

Requests from business (manufacturers, exporters, suppliers, touristic operators, local business associations etc):

- Are our employees and work places safe?
  Which dose limits have to be applied to our employees?
- How can we avoid contamination of our products during manufacturing, packaging and transportation?
- How can we bring evidence that our products are not contaminated?
- Is our business environment safe radiologically? Why our foreign partners have concerns?
- How to bring customers back to our location? How to convince them that our places and products are safe?
- Which legal limits should be applied in Japan in this situation and how are they related to the international requirements?

Systematics of Radiological Limits and Reference Levels based on ICRP

	Primary limits/constraints of effective dose for members of the public	Secondary limits
▪ Emergency Level **No-Go-Area for Products**	~ 20 - 100 mSv e.g. sheltering 10 mSv /7 days evacuation 100 mSv/7 days	Note in case of emergency: - different time scales - avertable dose plays a role

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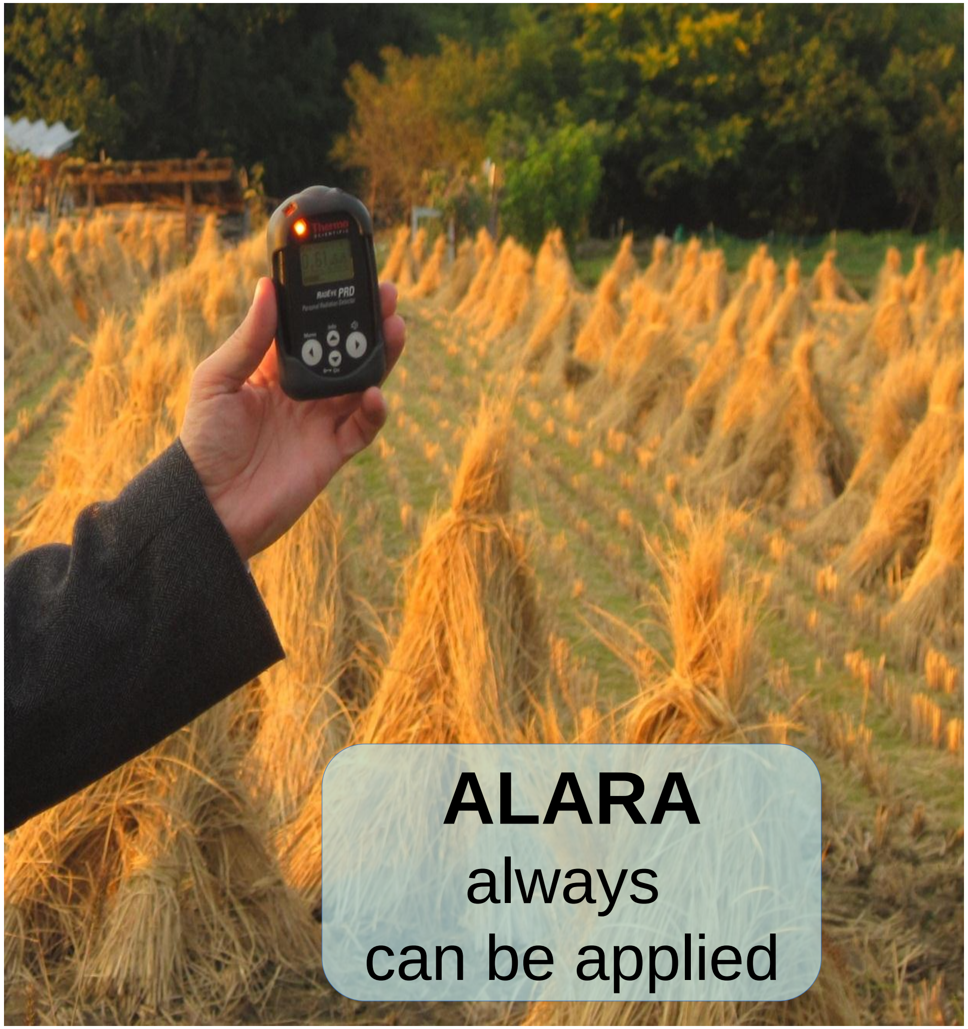
Why is it important to understand radiological situation below intervention levels as early as possible?

- Contamination, not necessarily above limits, concerning consumers
- Avoid contamination of the supply chain and of processed products
- Measurements in the final, processed product are too late; damage of trust and reputation
- Avoid economic impact by “Collective damage”: not only contaminated products affected by consumers reaction but also other products if no evidence is available
- Modern society can apply RP measures earlier than in the past



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Radiological Situation – Schematic

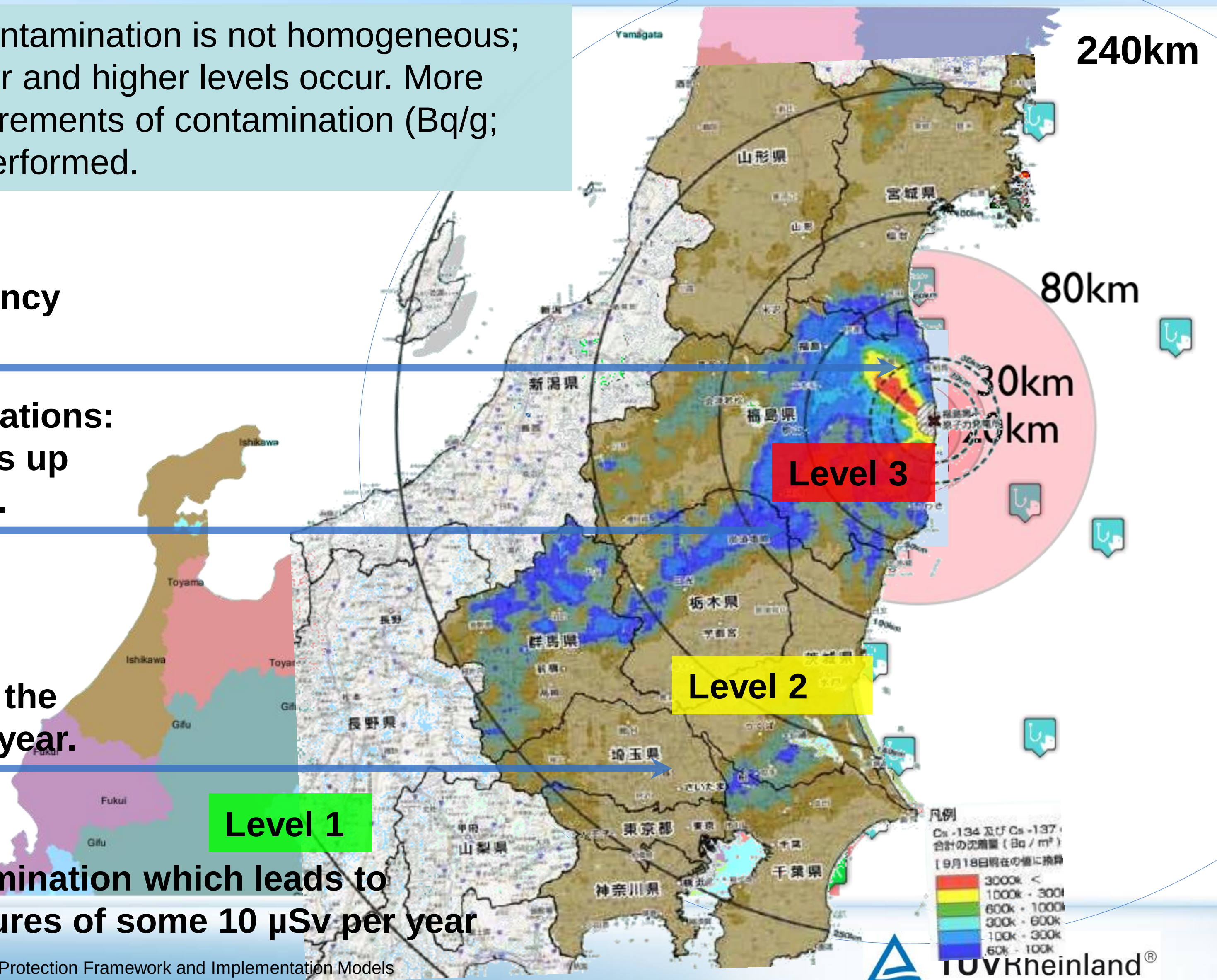
Note: Distribution of contamination is not homogeneous; local clusters with lower and higher levels occur. More comprehensive measurements of contamination (Bq/g; Bq/m²) are still to be performed.

Areas with emergency measures in place.

Relevant contaminations: E.g. effective doses up to 20 mSv per year.

Contaminations in the level of 1 mSv per year.

Contamination which leads to exposures of some 10 µSv per year



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How did we fill the gaps?

Surface contamination

- Based on comparison with national and international contamination limits analogue to IAEA Safety Standards TS-R-1 was found adequate

  < 4 Bq/cm² for 1-mSv-level
  < 0.4 Bq/cm² for the trivial level

- Starting with conservative nuclide vector considering uncertainty in the nuclide composition, detector efficiency and limits
  Later Cs-134/Cs-137 consideration only was sufficient

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How did we fill the gaps?

Products

- Exposure scenarios for estimation of effective dose during normal usage
  -> definition of secondary limits in Bq/cm² and/or Bq/kg

- Levels defined for effective dose 1mSv per year
  and
  in the order of 10 µSv per year

- Note: The secondary limits are specific for the specific application, i.e. case-by-case consideration necessary

Example: Company acceptance standard automotive industry

5 Radioactive substances

In addition to the specifications contained in the GADSL, the rule applies that overall gamma-activity must not exceed the limit value of 0.1 Bq/g.

The surface contamination on items and packages shall be kept as low as reasonable achievable and shall not exceed the limit of 4 Bq/cm² for beta and gamma emitters.

These limits are applicable when averaged over any area of 300 cm² of any part of the surface. Non-fixed and fixed contamination needs not to be distinguished.

Additionally, the gamma ambient dose rate above background shall not exceed 0.1µSv/h at the surface of packages, containers and items.

How did we fill the gaps?

Decontamination of living and working environment

- Exposure scenarios for estimation of effective dose during normal usage
- External exposure: Measurements of Gamma dose rate (µSv/h) and specific activity (Bq/g)
- Consideration of (removable) surface contamination on objects
- Inhalation: resuspension of contaminated soil (dust)
- Ingestion pathway: for agricultural use and water supplies

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- **Case Decontamination: 1 mSv-Goal**

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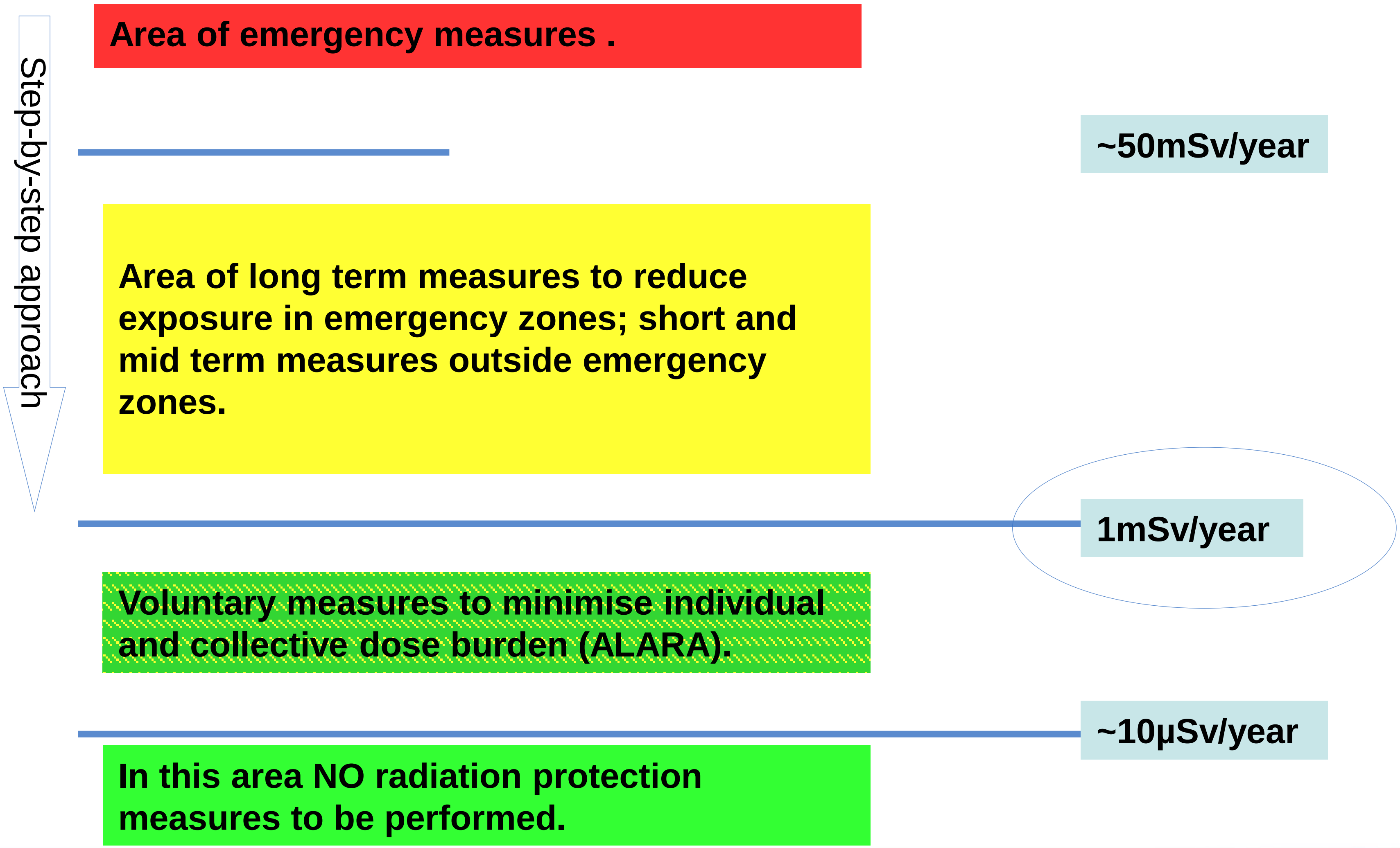
Scheme for Decontamination Goals



Case Decontamination Minamisoma: 1 mSv-Goal

- Purpose: Evaluation of the radiological situation at schools and kindergartens by TÜV Rheinland after decontamination measures
- Benefit:
  - Assurance of safety of small children attending local schools/kindergartens
  - Providing local community and authority with scientific material for decision-making
  - Empowering local authorities with independent assessment of efficiency of decontamination efforts –> trust building
- Estimated radiation exposure considering:
  - External exposure inside and outside buildings
  - Internal exposure by on-site drinking water and ingestion by dust
  - Ingestion by eventually contaminated food not considered

Methodology: Measurements

- Complete dose rate screening of buildings and surrounding environment with scintillation monitors/NBR technique; collecting representative as well as minimum and maximum dose rate values.
- Stationary measurements at potential accumulation points for radioactive contamination, such as rainwater collecting systems, entrance to the building, boundary of the location adjoining to non-decontaminated environment.
- Direct measurements of surface contamination on surfaces inside and outside the building. Especially such objects which potentially could be touched during normal use were considered.
- Collecting of soil samples at different locations.
- Collecting a sample of the water which potentially is used for washing and cooking (tap water).
- As far as it was meaningful, collecting aerosol/dust samples.
- Background estimation for dose rate and surface contamination

Exposure Scenarios Based on Real Living Conditions: Questionnaire as Basis

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(4) 校舎の外（アウトドア）での活動時間を学年ごとに教えてください。

校舎の外（グランドなど）でおよそどのくらいの時間を過ごされるか、学年別にお答えください。　その他の場所の項は具体的な場所名をご記入ください。　幼稚園（保育園）、小学校、中学校の項目で該当箇所のみご記入ください。

学年	児童（生徒）数	グランドでの１日当たりの時間	その他の場所での１日当たりの時間 場所名：	その他の場所での１日当たりの時間 場所名：
幼稚園（保育園）児	１３６名	0時間	0時間	0時間

Goal:
Identification of realistic leaving conditions -> basis for one scenario

Measurements, Methods, Results and Consequences Need to Be Explained and Justified –> Detailed Reports

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内容

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Measurements Results are Not Just Numbers: Complex Exposure Scenarios Need Explanation

	µSv / h	hours/day	days/year	mSv / year	
Outside Building					
Scenario 1	0.1	0	300	0	No outside stay according to questionnaire
Scenario 2	0.1	4	300	0.12	typical dose rate assumed, duration of 4 hours assumed.
Scenario 3	1.0	2	300	0.6	dose rate on surface of wooden materials (factor 2 considered, see section 3.1)
Mixed Scenario	1.0 0.1 0.07	1 3 7	300 300 300	0.3 0.09 0.15 0.54	outside on wood outside typical inside maximum

Radiation exposure

Measure-ment units

Living conditions

Based on questionnaire

Based on long term outside stay and representative dose rate

Based on max dose rate

Complex scenarios

Specific local conditions

Resulting dose per year

Radiation Protection Recommendations

- Although estimated effective dose was below 1 mSv per year easy measures for minimisation of radiation exposure and monitoring were proposed e.g.:
  - significant contaminated wooden objects (floor plates, toys etc) should be sub-sequentially exchanged or at least painted
  - surface contaminated metallic objects (corrosion) should be painted
  - places near heavily contaminated roofs (mainly concrete plates which can not be decontaminated) should be moved; long term exchange of roof plates
  - Control measures at site boundary and at water drainage systems

1. On all wooden surfaces outside the building (wooden floor on the outer corridor, wooden borders of flower pots etc) increased dose rate and surface contamination was detected. Radioactive contamination is embedded also into deeper layers of the wood and is hard to remove by washing.

   Recommendation: Replacement of the material is recommended. Meanwhile avoid stay on wooden material.

2. Increased surface contamination detected on horizontal surfaces of metallic slides, including steps.

   Recommendation: careful removal of rusty surface and covering with paint. Caution: avoid generation and dispersing of dust during removal

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Stakeholder Dialogue: Presentation of Results for Minamisoma City and School Officials

Local community, parents and public regained confidence in decontamination measures

Local authority obtained evidence for successful decontamination

Repetition recommended to confirm stability

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- **Case Tourist Attractions: 10-μSv-Goal**

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RP system and rational of exposure limits (simplified)

In this area emergency measures must be performed.

~50mSv/year

Area of long term measures to reduce exposure in emergency zones; short and mid term measures outside emergency zones.

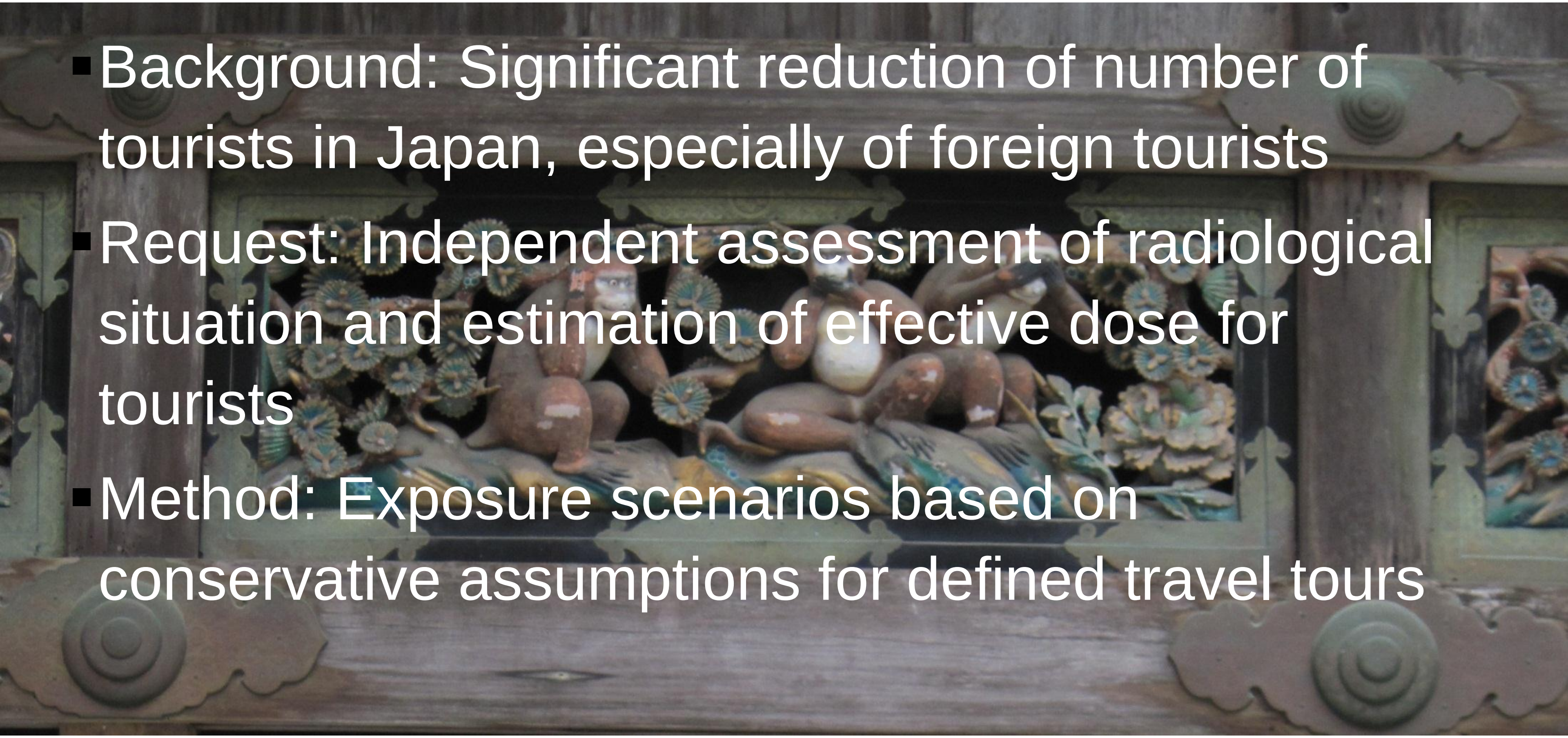
1mSv/year

Voluntary measures to minimise individual and collective dose burden.

~10µSv/year

In this area NO radiation protection measures to be performed.

Radiological Certification of Tourist Destinations



- Background: Significant reduction of number of tourists in Japan, especially of foreign tourists
- Request: Independent assessment of radiological situation and estimation of effective dose for tourists
- Method: Exposure scenarios based on conservative assumptions for defined travel tours

Case Tourist Attractions: 10-µSv-Goal

- External exposure, no ingestion considered
- Exposure by inhalation of eventually contaminated dust was considered to be neglectable more than 1.5 years after accident
- Estimation of natural background by lowest measured dose rate and verification by gamma spectrometry of soil samples
- Origin of contamination from Fukushima proved by ratio Cs-134 : Cs-137
- Duration of stay inside/outside was based on real travel tours and enveloping assumptions
- Detection limit of methodology is roughly 10 µSv
- Results: Effective dose expected to be in order of 10 µSv

- Note: For people living in certain areas with slightly elaborated contamination levels (e.g. Nikko), effective dose of course might be higher than for the tourists

Independent radiologically assessment of more than 35 tourist destinations in Japan by TÜV Rheinland

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Certification of tourist travel packages regarding radiologically safe environment: 10-µSv-level!

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- **Summary**

Lessons Learned and Open Issues

- No clear definition of obligatory classification levels -> Weakness of current radiation protection framework after emergency:
  Balanced approach from emergency level to cut-off level is necessary. It allows from the beginning reliable classification and definition of RP measures – BUT needs definition as part of the general RP framework and sub-sequentially of national laws!
- Clear limits for contamination of products are necessary in advance
- Exclusion of non-affected areas/products/applications:
  Derivation of practical and measurable units from ICRP exposure reference values e.g. surface contamination values (Bq/cm²) from 10µSv/year proposed
- Trust:
  Integration of independent evaluation into the radiation protection framework is necessary for the effective stakeholder dialogue
- Approach for superposition of multiple exposure pathways covering external exposure + ingestion + inhalation not clarified yet

Thank you for your attention!

For requests please contact:

Dr. Jens-Uwe Schmollack Jens-Uwe.Schmollack@de.tuv.com

Industrial Services

Head of Competence Area Nuclear Technology and Radiation Protection

Coordinator Nuclear Safety and Radiation Protection Asia Pacific

TÜV Rheinland Industrie Service GmbH
10882 Berlin, Germany

Alboinstraße 56

Berlin Office:

Tel.: +49 30 7562 1567

FAX: +49 30 7562 1522

TÜV Rheinland Japan Ltd

Shin Yokohama Daini Center Building

3-19-5, Shin-Yokohama, Kohoku-ku

Yokohama 222-0033

Yokohama Office:

Tel.: +81 45470 1861

FAX: +81 45473 5221