Glossary

Absorbed dose
Mean energy imparted by ionizing radiation to an irradiated medium per unit mass, expressed in grays (Gy). 1 Gy = 1 J/kg

Activity
See radioactivity.

Acute effects
Adverse effects that occur within a short period of time (minutes to a few days) after an exposure.

Acute exposure
An exposure occurring within a short time relative to the life of a person or organism, usually consisting of a single exposure or dose administered for a period of 24 hours or less in humans.

Acute radiation syndrome
A set of characteristic signs and symptoms observed after whole-body or large-volume partial-body high-dose radiation exposure.

Age-at-exposure
Age of an individual when the radiation exposure takes place. Cancer risk models based on human epidemiological data predict higher lifetime risks for exposure at younger ages than at older ages.

Atmospheric dispersion
The spreading of radionuclides in air, resulting mainly from physical processes affecting the velocity of different molecules.

Attained age
Age of a person calculated by adding the period elapsed since the radiation exposure took place (i.e. the "time since exposure") and the age of that person when the radiation exposure took place (i.e. the "age-at-exposure").

Becquerel
In the International System, a unit of activity equal to one disintegration per second.

Cancer
A group of related diseases characterized by the uncontrolled growth of abnormal cells.

Cancer risk estimate
The probability of developing cancer from exposure to radiation over a period of time.

Carcinogen
A physical, chemical or biological agent capable of inducing cancer.

Chronic effects
Adverse effects that occur within a long period of time after an exposure (years to lifetime).

Cloudshine
Gamma radiation from radionuclides in an airborne radioactive plume (i.e. radioactive cloud).

Cohort
A defined population group followed prospectively in an epidemiological study. Cohorts can also be used for retrospective epidemiological studies, also called historical cohort studies.

Committed dose
The lifetime dose expected to result from a radionuclide intake.

Conservative
An approach that deliberately chooses an option (e.g. an assumption) that is more likely to overestimate than to underestimate the risk.

Cumulative risk
Cumulative incidence/mortality risk is the probability of individuals getting/dying from the disease during a specified period.

Deterministic effects
Health effects, the severity of which varies with dose; typically, there is a threshold below which they will not occur (e.g. acute radiation syndrome). Deterministic effects are also referred to as "tissue reactions" or non-stochastic effects.

Dose
A general term denoting the quantity of radiation or energy absorbed in a target. Related terms:absorbed dose, effective dose, committed dose.

Dose assessment
Assessment of the dose(s) to an individual or group of people.

Dose coefficients
Factors used to convert the amount of incorporated radioactive substances (radionuclide intake) to the dose in tissues or organs, or the whole-body dose. These factors (also called "dose conversion factors") may depend on the radionuclide, the incorporation route (e.g. inhalation, ingestion), the chemical compound and the age of the person. Usually expressed as dose per unit intake, e.g. sieverts per becquerel (Sv/Bq).

Dose limit
In planned exposure situations, the value of the individual effective dose or equivalent dose that is not to be exceeded. Dose limits do not apply to existing exposure situations or emergency exposure situations.

Dose rate
Dose delivered per unit time.

Dose-response assessment:
Assessment of the relationship between exposure to a particular agent and any adverse health effects in humans as a result of this exposure.

Dose-response relationship
Relationship between the magnitude of a dose and the biological response in an organism, system or (sub)population. Related term: dose-effect relationship.

Effective dose
Sum of the products of absorbed dose to each organ multiplied by a radiation-weighting factor and a tissue-weighting factor that takes into account the radiosensitivity of tissues and organs. Related term: absorbed dose.

Effective half-life (see also half-life)
The time taken for the activity of a radionuclide in the body to halve as a result of all relevant processes (e.g. radioactive decay, biological half-life). The physical half-life is the time required for the activity of a specified radionuclide to decrease, through a radioactive decay process, by half. The biological half-life is the time taken for the quantity of a radioactive material in a specified tissue, organ or region of the body to halve as a result of biological processes.

Emergency worker
A person having specified duties as a worker in response to an emergency.

End-points
In the context of this report, end-points refer to the occurrence of a disease or adverse effect (cancer and non-cancer effects).

Environmental monitoring
The measurement of external dose rates due to sources in the environment or of radionuclide concentrations in environmental media.

Equivalent dose
Absorbed dose averaged over a tissue or organ, further applying a radiation-weighting factor that varies by radiation type and is related to the density of ionization created.

Excess absolute risk (EAR)
Difference in the rate of occurrence of disease between an exposed population and a comparable non-exposed population. It represents the additional risk beyond the baseline risk in the absence of exposure.

Excess relative risk (ERR)
Ratio of the rate of occurrence of disease in an exposed population to that in a comparable non-exposed population. It represents the proportional increase in risk in comparison with the baseline risk in the absence of exposure.

Exposure
The state or condition of being subjected to irradiation from a source outside the body (i.e. external exposure) or within the body (i.e. internal exposure).

Exposure assessment
Evaluation of the exposure of an organism, system or (sub)population to an agent. In the context of this report it refers to radiation exposure. Exposure assessment is one of the steps in the process of risk assessment.

Exposure pathway
A route by which radiation or radionuclides can reach humans and cause exposure. Related term: exposure route.

External exposure (see exposure)

Groundshine
Gamma radiation from radionuclides deposited on the ground.

Half-life (see also effective half-life)
The time taken for the quantity of a specified material (e.g. a radionuclide) in a specified place to decrease by half as a result of any process or processes that follow similar exponential patterns as those of radioactive decay (see also effective half-life).

Hazard identification
Hazard identification is the identification of the type and nature of adverse effects that an agent has, an inherent capacity to cause harm in an organism, system or (sub)-population. Hazard identification is the first step in the process of risk assessment.

Healthy worker effect
The healthy worker effect (HWE) is a bias found in occupational studies when rates of disease among employed people are compared with disease rates for the general population.

Intake
The activity of a radionuclide taken into the body (by inhalation or ingestion or through the skin) in a given time period or as a result of a given event.

Internal exposure (see exposure)

Ionizing radiation
For the purposes of radiation protection, radiation capable of producing ion pairs in biological material(s).

Latency
The time between exposure to a potential hazard (e.g. radiation exposure) and the appearance of a related health effect.

Life Span Study (LSS)
A research program investigating life-long health effects based on epidemiologic studies on atomic bomb survivors. Its major objective is to investigate the long-term effects of atomic bomb radiation on causes of death and incidence of cancer. About 120 000 subjects selected from residents of Hiroshima and Nagasaki identified through the national census in 1950 have been followed since that time, including 94 000 atomic bomb survivors and 27 000 unexposed individuals.

Linear no-threshold (LNT) model
Risk model that assumes that health effects are directly proportional to the dose at all dose levels (i.e. linear dose-response), without any threshold below which such effects are not expected.

Lifetime attributable risk (LAR)
Probability of a premature incidence of a cancer attributable to radiation exposure in a representative member of the population.

Lifetime baseline risk (LBR)
The probability of having a specific disease over the lifetime, in the absence of radiation exposure.

Lifetime fractional risk (LFR)
Fractional increase over the lifetime baseline risk attributable to radiation exposure.

Lifetime dose
Radiation dose resulting from exposure over the entire life.

Modelling (risk modelling)
Quantitative relationships established by using mathematical functions to calculate the magnitude of risks associated with an estimated exposure.

Natural background radiation
Amount of radiation to which a population is exposed from natural sources, such as terrestrial radiation resulting from naturally occurring radionuclides in the soil, cosmic radiation originating in outer space, and naturally occurring radionuclides deposited in the human body.

Noble gas
An inert radioactive gas that does not readily enter into chemical combination with other elements. Examples are helium, argon, krypton, xenon and radon.

Organ dose
The mean absorbed dose in a specified tissue or organ of the human body. Sometimes called tissue dose.

Radioactivity (also called "activity")
The property of the nucleus of unstable atoms that causes them to spontaneously release energy in the form of photons (e.g. gamma rays) or subatomic particles (e.g. alpha or beta particles). The amount of radioactivity is defined as the mean number of decays per unit time. The unit of activity in the International System (SI) is the reciprocal second (s^{-1}), termed the becquerel (Bq).

Radionuclide
Radioactive species of an atom characterized by the constitution of its nucleus.

Remedial action (see remediation)

Remediation
Any measures carried out to reduce radiation exposure, from existing contamination of land areas through actions applied to the contamination itself (the source) or to the exposure pathways to humans.

Risk
Hazard, danger or chance of harmful consequences associated with exposures or potential exposures.

Risk assessment
The cumulative combination and results from the scientific method of evaluating the toxic properties of a given agent and how humans and the ecosystem are exposed. A risk assessment generally determines the likelihood, to what extent, and/or characterizes how humans and/or the ecosystem are adversely affected.

Risk characterization
The last phase of risk assessment, in which all information from toxicity and exposure are combined to calculate risk estimates. This will include all the assumptions and

scientific information used to estimate risk, the uncertainty associated with the assessment, and any other information that may be useful to decision makers.

Risk model
Mathematical function that allows calculation of the magnitude of risks associated with a given exposure.

Sievert
The SI unit of equivalent dose and effective dose, equal to 1 J/kg.

Solid cancers
Cancers originating in solid organs, as opposed to blood cancers such as leukaemia.

Source
Anything that may cause radiation exposure through emission of ionizing radiation or release of radioactive substances or material, and that can be treated as a single entity for protection and safety purposes.

Source term
The amount and isotopic composition of material released (or postulated to be released) from a facility.

Stochastic effect
Adverse effects of ionizing radiation due to transformation of a single cell, that may result in an increased risk of disease a long time after exposure. These effects are probabilistic and include cancer and heritable effects. At low doses, radiation risks are primarily stochastic effects, in particular, cancer.

Survival curve
Mathematical functions representing the probability of being alive at a given age (also called "survival functions").

Teratogenic (see teratogens)

Teratogens
Agents that can disrupt prenatal development when the mother is exposed during pregnancy.

Threshold (or "threshold dose")
Minimal absorbed radiation dose that will produce a detectable degree of any given effect.

Tissue reactions (see deterministic effects).

Abbreviations

ABCC	Atomic Bomb Casualty Commission
AHS	Adult Health Study
ALL	acute lymphoblastic leukaemia
AML	acute myeloid leukaemia
AR	absolute risk
BEIR	Biological Effects of Ionizing Radiation
BfS	Bundesamt für Strahlenschutz (Federal Office of Radiation Protection), Germany
BSS	Basic Safety Standards
CLL	chronic lymphocytic leukaemia
CML	chronic myeloid leukaemia
Cs	caesium
DDREF	Dose and dose rate effectiveness factor
DNA	deoxyribonucleic acid
DS02	2002 dosimetry system (DS02) for the cohort of the atomic bomb survivors of Hiroshima and Nagasaki
EAR	Excess absolute risk
ERR	Excess relative risk
Gy	gray
HPA	Health Protection Agency, United Kingdom
HRA	Health risk assessment
I	iodine
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
ICD	International Classification of Diseases
ICRP	International Commission on Radiological Protection
ILO	International Labour Organization
INFOSAN	International Food Safety Authorities Network
IRSN	Institut de Radioprotection et Sureté Nucléaire
JAEA	Japan Atomic Energy Agency
LAR	Lifetime attributable risk
LBR	Lifetime baseline risk
LFR	Lifetime fractional risk
LNT	Linear no threshold
LSS	Life Span Study
^{m}Ba	metastable barium
mSv	millisievert
NIRS	National Institute of Radiological Sciences, Japan
NPP	nuclear power plant
REID	risk of exposure-induced death
RERF	Radiation Effects Research Foundation
RR	relative risk
Sv	sievert
Te	tellurium
TEPCO	Tokyo Electric Power Company
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
WHO	World Health Organization
Xe	xenon

Annex A. Profiles of the HRA Expert Group members

Dr Makoto Akashi, Chiba, Japan

Dr Makoto Akashi is the Executive Director of the National Institute of Radiological Sciences (NIRS). He was awarded his M.D. degree from Yamagata University School of Medicine and started his medical career as a junior resident of internal medicine in 1981. In 1988 he received a Ph.D. from the Graduate School of Medicine, Jichi Medical School, where he also did his residencies in Internal Medicine and Hematology. He has been a research fellow at the Division of Hematology/Oncology at the University of California at Los Angeles (UCLA) School of Medicine. He has been working at the National Institute of Radiological Sciences (NIRS) in Chiba Japan since 1990. His major interests are: 1) Research on radiation injuries, including molecular and cellular mechanisms, 2) Development of methods for mitigation of radiation injuries, and 3) Biochemistry. His group performed the dose estimation of patients of the Tokaimura criticality accident and their medical treatment. He led the efforts from the NIRS for the establishment of the Radiation Emergency Medical Assistance Team (REMAT) program, aiming to support primary medical care after accidental radiation exposures either inside or outside Japan. He is now playing a leading role in providing advice and support as a radiation emergency medicine expert for the Fukushima Daiichi Nuclear Power Plant accident caused by the Great East Japan Earthquake in 2011.

Dr Billy Amzal, Paris, France

Dr Billy Amzal holds a Maths Engineering Degree from Ecole Polytechnique ("X-Ponts"), a Masters of Public Administration from AgroParisTech and a Ph.D. in Decision Mathematics from Paris-Dauphine University which was awarded by the International Society of Bayesian Analysis and by the International Biometrics Society. Over the last 13 years, he has developed quantitative methodologies to inform and support strategic decision making in healthcare as a national civil servant. He led the model-based drug development function at Novartis Pharma. He then joined the European Food Safety Authority (EFSA) developing the quantitative assessment methodologies for all EFSA Panels. He was also Director of the Data Center at the NIH-sponsored Program for HIV Prevention and Treatment in Thailand. He is now Senior Scientific Vice President at Analytica LASER, an independent scientific consulting and analytical group, and acts as a modelling expert for various Public Health Authorities such as ANSES in France.

Professor Lynn Anspaugh, Salt Lake City, United States of America

Dr Lynn Richard Anspaugh is a Research Professor in the Radiobiology Division of the Department of Radiology at the University of Utah. Before assuming his current position in January 1997 Dr Anspaugh had worked 33 years at Lawrence Livermore National Laboratory (LLNL) in a number of positions, including 10 years as Leader of the Environmental Sciences Division. Dr Anspaugh has been involved in dose-reconstruction studies for persons exposed to fallout from nuclear weapons tests, workers and the general public exposed as a result of the Chernobyl accident, and members of the public exposed

from releases from the Mayak Production Association in Russia. Dr Anspaugh was an elected member of the U.S. National Council on Radiation Protection and Measurements (NCRP), and he is now a NCRP Distinguished Emeritus Member. He is a Fellow of the Health Physics Society, and a 25-year member of the U.S. Delegation to the UNSCEAR. He is the author or co-author of 350 papers and reports, most of which are related to radiation-dose reconstruction activities.

Professor Anssi Auvinen, Tampere, Finland

Dr Anssi Auvinen has a professional background in medicine, with a Ph.D. in epidemiology. He is a professor of epidemiology at the University of Tampere and a part-time research professor at the Finnish Radiation and Nuclear Safety Authority (STUK). He has previously been employed at the Radiation Epidemiology Branch at U.S. National Cancer Institute (NCI) the Finnish Cancer Institute and the Section on Environment and Radiation at the International Agency for Research on Cancer (IARC). He has worked in radiation epidemiology since 1989 and published extensively on the health effects of both ionizing and non-ionizing radiation including cancer risk and other end-points (roughly 90 journal articles on radiation effects). His research contributions have focused on health effects of indoor radon, Chernobyl fallout, occupational radiation exposure and medical uses of radiation. He has participated in the international collaborative studies of nuclear workers, airline personnel, indoor radon and Chernobyl cleanup workers. He has previously worked as an invited expert for the WHO on Chernobyl and radon, as well as for the European Commission (EC DG SANCO) on body scanners.

Dr Nick Gent, London, United Kingdom

Dr Nick Gent was initially trained in medicine at Liverpool University, UK, before specializing in public health and health protection. Dr Gent obtained an M.Sc. in Public Health from the University of Newcastle upon Tyne, UK, and a LLM degree in Environmental Law from the University of Central Lancashire, UK. He is a fellow of the Faculty of Public Health of the Royal College of Physicians of the United Kingdom.

He is a senior medical specialist at the UK Health Protection Agency (HPA) at Porton Down, where he is Deputy Head of the Emergency Response Department, specializing in the scientific and clinical response to the release of chemical, biological, radiological or nuclear materials. His work involves close liaison and collaboration with scientific staff at the HPA Centre for Radiation, Chemical and Environmental Hazards.

In 2009 he was appointed to the WHO roster of experts under Article 47 of the International Health Regulations in the area of public health response to radiation emergencies, and has served as a consultant or expert on a number of WHO and IAEA working groups including the WHO consultations on management of acute radiation syndrome and multi-organ failure (ARS/MOF), the development of the Triage Monitoring and Treatment (TMT) handbook on radiological injuries and the IAEA/WHO EPR-MEDICAL 2005 emergency preparedness and response manual.

Dr Peter Jacob, Munich, Germany

Dr Peter Jacob completed his Ph.D. in mathematical physics at the Technical University of Munich. He is acting Director of the Institute of Radiation Protection at the Helmholtz Zentrum München. His main research interests include the modelling of late health effects after exposure to ionizing radiation with a focus on cancer and cardiovascular disease. Dr Jacob coordinates the European project combining epidemiology and radio-

biology to assess cancer risk in the breast, lung, thyroid and digestive tract after exposure to ionizing radiation with total doses on the order of 100 mSv or below (EpiRadBio). He is the head of the collaborative project 'Personalised assessment of late health effects of radiation exposure and decision support for radiation application in medicine (PASSOS)'. Dr Jacob is member of the German Commission on Radiological Protection and Head of the Radiation Risk Committee. He is member of the German delegation at the UNSCEAR.

Dr Dominique Laurier, Fontenay-aux-Roses, France

Dr Dominique Laurier is the Head of the Laboratory of Epidemiology at the Institute for Radiological Protection and Nuclear Safety (IRSN, France). He holds a Ph.D. in Biomathematics, and received the Accreditation to Supervise Research in Epidemiology from the University Denis Diderot Paris VII (France). He joined the IRSN in 1995. His research focuses on the quantification of risks associated with ionizing radiation at low doses and low dose rates. Dr Laurier is the author or co-author of more than 80 articles in peer-reviewed scientific journals. He has been involved in several European collaborative research projects, and he has contributed to different expert groups or scientific committees at the national or international level, in the fields of public health and radiation protection.

Dr Charles Miller, Atlanta, United States of America

Dr Charles Miller joined the Centers for Disease Control and Prevention (CDC) in January 1992. He is currently chief of the Radiation Studies Branch, Division of Environmental Hazards and Health Effects, National Center for Environmental Health. In this position he provides leadership for the agency's radiological emergency response and consequence management efforts. Previously, Dr Miller worked with the Illinois Department of Nuclear Safety, Oak Ridge National Laboratory, and Anderson (Indiana) University. His primary area of expertise is the transport and dose assessment of radionuclides released to the atmosphere, and other facets of environmental radiological dose assessment. He has authored or coauthored over 100 journal articles, laboratory reports, and meeting papers. Dr Miller is a member of the NCRP and a Fellow of the Health Physics Society. Dr Miller holds a B.S. in Physics/Math from Ball State University, a M.S. in Meteorology from the University of Michigan, and a Ph.D. in Bionucleonics (Health Physics) from Purdue University.

Professor Ohtsura Niwa, Fukushima, Japan

Dr Ohtsura Niwa was trained in radiation biology for his early graduate study at Kyoto University. After obtaining his Ph.D. at Stanford University in 1975, he mainly studied the molecular mechanisms of untargeted mutagenesis and its implications in somatic and heritable effects of radiation. In early 1980s, he discovered that radiation demethylates the endogenous leukaemia virus genome in mice and the activated virus then integrates into new sites in the genome to induce leukaemia. He also discovered mutations of maternally inherited minisatellite sequences in F1 mice born to irradiated male parents in 1990–2010. These were well received as pioneering findings and he was awarded Roentgen Medal in 2005 for the work of radiation induced genomic instability.

He served in a number of academic positions at Hiroshima University, Kyoto University and the National Institute of Radiological Sciences (NIRS), and currently holds a position at Fukushima Medical University. He contributed to the promotion of radiation biol-