Titolo

"REMME & DARP – Radioactivity Environmental Monitoring Measurements Evaluation and Dose Assessment for Radiation Protection purposes"

Collaboration Agreement n° 33904

ENEA IRP Activity Report

Descrittori

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Summary

The project " REMME & DARP- Radioactivity Environmental Monitoring Measurements Evaluation and Dose Assessment for Radiation Protection purposes" was done in the framework of the Collaboration Agreement between the Radioactivity Environmental Monitoring Group of the Joint Research Centre (JRC) of the European Commission and the Radiation Protection Institute of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA).
The aim of REMME & DARP was to collect the available information about dose assessment for the public on the basis of the environmental radioactivity data in the European Union. The dose assessment is an important part of the system of radiological protection in routine and emergency situations also to verify the public safety. This final report explains the proposal of a procedure to perform the dose assessment for the Public based on environmental radioactivity data. Moreover this document describes the whole of the work and research carried out in performance of the Collaboration Agreement.

Sommario

Il progetto "" REMME & DARP- Radioactivity Environmental Monitoring Measurements Evaluation and Dose Assessment for Radiation Protection purposes" è stato realizzato nell'ambito dell'Accordo di Collaborazione tra il Radioactivity Environmental Monitoring Group del Centro Comune di Ricerca (CCR) della Commissione Europea e l'Istituto di Radioprotezione dell'Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile (ENEA).
L'obiettivo di REMME & DARP è stato raccogliere le informazioni disponibili sulla valutazione della dose per il pubblico sulla base dei dati della radioattività ambientale nell'Unione Europea. La valutazione della dose è una parte importante del sistema di radioprotezione nelle situazioni di routine e di emergenza anche allo scopo di garantire la sicurezza pubblica. In questo report finale è descritta la proposta di una procedura per la valutazione della dose per il pubblico sulla base dei dati sulla radioattività ambientale. Inoltre, nel presente documento sono riportati tutti i dettagli dell'intero lavoro e delle ricerche svolte nell'ambito dell'Accordo di Collaborazione.

Note Il documento include tutti i contenuti del report ad interim del dicembre 2017 con diffusione solo interna JRC REM group e -ENEA IRP.

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Table of contents

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Abstract

This report describes in detail the results obtained in performance of the Collaboration Agreement n° 33904 between ENEA IRP and JRC Radioactivity Environmental Monitoring (REM) group, and contains a summary of the principal work carried out and results obtained.
The Member states reports to JRC information on Environmental Radioactivity using REMdb and EURDEP. A lot of Member States published a periodical national monitoring report and specific publications on dose assessment for the public.
This document includes a comparative study on *Dose Assessment Methodologies for the Public on the basis of the Environmental Radioactivity Data in the European Union*.
This study is a proposal of the harmonisation of dose assessment for the public on the basis of the Environmental Radioactivity Data in the European Union.
The methodology proposed is mainly based on the UNSCHER 2000, ICRP Publication 101a, ICRP Publication 103, ICRP Publication 119, NO153, Radiation protection 129 and HPA-RPD-019.

1 Introduction

The aim of this report is to summarize the available information about dose assessment methodologies for the public on the basis of the environmental radioactivity data in the European Union.
This scientific issue in the radiation protection field is the objective of the Collaboration Agreement (CA) N. 33904 between the Institute for Transuranium Elements of the Joint Research Centre (JRC) of the European Commission and the Radiation Protection Institute of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA).
The dose assessment is an important part of the system of radiological protection also to verify the public radiation safety. In this report are not treated specific evaluations about exposures from natural radiation sources.
In some European Country specific reports on dose assessment of the public are published, and in other Member States the dose evaluation is part of an Environmental Monitoring Report or Yearbook.
This report tries to collect all public and available information on dose assessment methodologies for the people by mean of examples, without being exhaustive.

2 Scope

On 03 March 2016, the ratification of the Collaboration Agreement N. 33904 between the Institute for Transuranium Elements of the Joint Research Centre (JRC) of the European Commission and the Radiation Protection Institute of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), signed respectively by Ms. Betti and Ms. Fantuzzi was finished.
The Collaboration Agreement defined the mutual cooperation in the area of Nuclear Safety, in the radiation protection field and the objectives are the following:

a) Radioactivity Environmental Monitoring Measurements and Dose Assessment for Radioprotection purposes
b) Assessment of large scale atmospheric releases after a nuclear accident.

In order to fully achieve the objective a) of this Collaboration Agreement, JRC and ENEA performed this summary report in which are reported the dose assessment procedures for the public on the basis of the Environmental Radioactivity Data applied by EU MSs, with a proposal of a dose assessment methodology for the public on the basis of the Environmental Radioactivity Data.

2.1 Legal framework

Ionizing radiation sources and substances have many beneficial applications (i.e. medicine and industry), but the radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and controlled.
Under the terms of Article 36 of the Euratom Treaty, Member States shall periodically communicate to the Commission information on environmental radioactivity levels which could affect population. Additionally, the Italian Legislative Decree 230/1995 (transposition of Council Directive 96/29/EURATOM) requires measurement of

radioactivity in the environment surrounding a nuclear installation (in accordance with Article 54).
Regulating radiation safety is a national responsibility, however, radiation risks may transcend national borders, and it is indispensable an international cooperation to promote and increase radiation safety globally by exchanging experience and by improving capabilities to prevent accidents and control hazards, to respond to emergencies and to moderate any dangerous consequences.
The environmental radioactivity monitoring data from EU countries must be periodically communicated to the European Commission so that it can carry out evaluations and compare radiation exposure of the population in different countries.
On the basis of this data and in cooperation with its Joint Research Centre (JRC-Directorate G), the Commission publishes reports on environmental radioactivity in the EU.
Additionally, the Radioactivity Environmental Monitoring (REM) project facilitates the online exchange of information on radioactivity among EU countries and the Commission (through the EURDEP system).
In 2000 the European Commission issued Recommendation 2000/473/Euratom, providing guidance to EU countries on monitoring the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole.

3 Considerations for dose assessments

The dose evaluation is an important part of the radiation protection system to verify and ensure the health of the population. The term dose used in this work refers to the effective dose, E, reported in millisievert (mSv) which is usually used for a priori estimation and dose assessment. The Effective Dose, E, represents the sum of the annual dose from external irradiation (E_{ext}) and the committed effective dose following the intake of radioactivity (E_{int}) in a solar year. The intake of radionuclides includes inhalation and ingestion of radionuclides respectively present in the atmosphere and incorporated into foods [1].
In order to assume the ingestion rates of various foods in the calculation of individual dose, it is possible to refer to different data set publications such as EC or National Statistical publications; reports of the Food and Agriculture Organization of the United Nations (FAO). Habit data, like inhalation rates, consumption of water and occupancy fraction, were reviewed in line with the main recommendations from international bodies concerning realistic dose assessment [2, 3] or conservative generic values [4].
The realistic estimation of doses should consider different groups of individuals which are representative of the different subset of the population (e.g. infant, child, adult).
The annual committed effective dose could be computed by using the formula:

$$E = E_{ext} + E_{int}$$

Relevant aspects to be considered can be the following:
- In the dose assessment on the basis of environmental monitoring data, the E_{ext} depends on the used measurement quantity; generally the absorbed dose in air (reported in Gy) is converted in external effective dose to adults using the factor 0.7

Sv/Gy [1]. The occupancy fraction is related to the time spent indoor and the shielding factors of buildings [1].

- The contribution from deposited radionuclides should be computed considering the effective dose equivalent factors for external irradiation outdoors. The contribution to the dose of the public from the nuclear reactors release could be calculated applying the collective dose per unit release [1].
- Internal doses should be calculated using data concentrations of radionuclides in the environment and the different intake pathway (concentration in water and food expressed in Bq/ liter and Bq/kg; concentration in air expressed in Bq/m^3).
- Dose coefficients are given for members of the public for intakes by inhalation and ingestion for a large number of radionuclides, relating the intake of a specific radionuclide to the corresponding organ and effective dose committed within 50 years for adults and up to age of 70 years for children [5, 6].

Furthermore the dose assessment should be divided in two different categories:

The specific dose assessment for the reference group of the public: which is the critical group representative of those receiving the highest doses (e.g. citizens of villages near NPP)

The generic dose assessment for the public of a regional group of a specific Memeber States not necessary located near a nuclear facility.

In the first case (a), it is possible to analyse the collective effective dose (S) reported in man-sieverts (man Sv), which is defined as the sum of all the individual effective doses received in the reference group and is accompanied by the total number of individuals.

4 Radiological Monitoring Reports of European Member States

In some European Country specific report on dose assessment of the Public are published, and in other Member States the dose evaluation is part of Environmental Monitoring Report or Yearbook. All the information readily available of national competent authorities and main laboratories of European Member States in public document are collected in the Table 1 and 2, the reported data could be not exhaustive.

Table 1 Summary of national competent authorities and main laboratories of European Member States

	Country codes	Country	Web page
1	AT	Austria	www.lebensministerium.at; www.bmg.gv.at; www.ages.at
2	BE	Belgium	www.fanc.fgov.be; www.sckcen.be; www.ire.be
3	BG	Bulgaria	www.bnra.bg
4	CY	Cyprus	www.mlsi.gov.cy/dli; www.moh.gov.cy/sgl
5	CZ	Czech Republic	www.sujb.cz; www.suro.cz
6	DE	Germany	www.bmu.de, www.dwd.de, www.bsf.de
7	DK	Denmark	http://sundhedsstyrelsen.dk; www.risoe.dtu.dk
8	EE	Estonia	http://www.envir.ee; http://keskkonnaamet.ee/
9	ES	Spain	www.csn.es; www.cedex.es; www.ciemat.es
10	FI	Finland	www.stuk.fi
11	FR	France	www.asn.fr; www.irsn.org
12	GB	United Kingdom[1]	www.defra.gov.uk; www.food.gov.uk; http://www.sepa.org.uk/
13	GR	Greece	http://eeae.gr/en/
14	HR	Croatia	http://cms.dzrns.hr/
15	HU	Hungary	http://www.osski.hu/index_en.php; https://www.antsz.hu; http://www.haea.gov.hu;
16	IE	Ireland	http://www.epa.ie/
17	IT	Italy	http://www.isprambiente.gov.it/it; http://www.iss.it/
18	LT	Lithuania	www.gamta.lt; www.rsc.lt; www.nmcrvi.it
19	LU	Luxembourg	www.ms.public.lu;
20	LV	Latvia	http://meteo.lv; www.pvd.gov.lv; http://www.bior.gov.lv
21	MT	Malta	http://ohsa.org.mt/
22	NL	the Netherlands	www.rikilt.wur.nl; www.vrom.nl; www.rivm.nl
23	PL	Poland	http://www.rivm.nl/, www.paa.gov.pl
24	PT	Portugal	www.itn.pt

[1] In this paper, the United Kingdom is considered a member of the European Union pending future actions provided by BREXIT.

Table 2 - Summary readily publication of national competent authorities and main laboratories of European Member States (last updating 2017) .

MS	Ref. Year	Publ. Period	Publ. Year	Report Title	Internet-link
AT	2013-2014	biannual	March-16	RADIOAKTIVITÄT UND STRAHLUNG IN ÖSTERREICH 2013 UND 2014	http://bmg.gv.at
BE	2015	annual	December-15	RADIOLOGICAL MONITORING IN BELGIUM SUMMARY REPORT 2014	http://www.fanc.fgov.be/GED/00000000/4300/4330.pdf
BG	2013			НАЦИОНАЛНИЯТ ДОКЛАД ЗА СЪСТОЯНИЕТО И ОПАЗВАНЕТО НА ОКОЛНАТА СРЕДА	http://eea.government.bg/bg/soer/2011/soerbg1r.pdf
CY	2004-2009		2010	ΜΕΤΡΗΣΕΙΣ ΡΑΔΙΕΝΕΡΓΕΙΑΣ ΣΤΟ ΠΕΡΙΒΑΛΛΟΝ ΤΗΣ ΚΥΠΡΟΥ 2004 – 2009	http://www.mlsi.gov.cy/mlsi/dli/dliup.nsf/44E28D6B2820F4C4C2257E2D003ADC5E/$file/ENV_RAD_2004_09_FINAL.pdf
CZ	2016	annually	2017	ZPRÁVA O VÝSLEDCÍCH ČINNOSTI SÚJB PŘI VÝKONU STÁTNÍHO DOZORU NAD JADERNOU BEZPEČNOSTÍ JADERNÝCH ZAŘÍZENÍ A RADIAČNÍ OCHRANOU ZA ROK 2016	https://www.sujb.cz/fileadmin/sujb/docs/zpravy/vyrocni_zpravy/ceske/VZ_SUJB_2016_FIN_cast_II.pdf
DE	2014	annually	October-2016	UMWELTRADIOAKTIVITÄT UND STRAHLENBELASTUNG IM JAHR 2014	https://doris.bfs.de/jspui/bitstream/urn:nbn:de:0221-2015072112949/1/JB2013.pdf
DK	2016	six months	2017	RADIOACTIVITY IN THE RISØ DISTRICT JULY-DECEMBER 2016	http://orbit.dtu.dk/files/133202203/Halv_rsrapport_Juni_2017_wo_No.pdf
EE	2014	annually	May-15	KESKKONNA IONISEERIVA KIIRGUSE SEIRE 2014. AASTA TULEMUSED	http://keskkonnaamet.ee/public/kiirgus/kiirgusseire_aruanne_2014.pdf
ES	2013	annually	2014	PROGRAMAS DE VIGILANCIA RADIOLÓGICA AMBIENTAL RESULTADOS 2013	https://www.csn.es/documents/10182/1001013/Programa%20de%20vigilancia%20radiol%C3%B3gica%20ambiental.%20Resultados%202013
FI	2014	annually	2015	YMPÄRISTÖN SÄTEILYVALVONTA SUOMESSA	http://www.julkari.fi/bitstream/handle/10024/126942/stuk-b190.pdf?sequence=1
FR	2015	annually	2015	BILAN DE LA SURVEILLANCE DE LA RADIOACTIVITÉ EN POLYNÉSIE FRANÇAISE EN 2014 SYNTHÈSE DES RÉSULTATS DU RÉSEAU DE SURVEILLANCE DE L'IRSN	http://www.irsn.fr/FR/expertise/rapports_expertise/Documents/environnement/IRSN_Surveillance-Polynesie-2014_SESURE-2015-34_FR.pdf
FR	2015	annually	2015	EXPOSITION DE LA POPULATION FRANÇAISE AUX RAYONNEMENTS IONISANTS	http://www.irsn.fr/FR/expertise/rapports_expertise/radioprotection-homme/Pages/Exposition-population-francaise-rayonnements-ionisants-2015.aspx#.VqCZ1p1wZaQ
FR	2011-2014		2015	BILAN DE L'ÉTAT RADIOLOGIQUE DE L'ENVIRONNEMENT FRANÇAIS DE JUIN 2011 À DÉCEMBRE 2014	http://www.irsn.fr/FR/expertise/rapports_expertise/Documents/environnement/IRSN_surveillance_France_2011-2014.pdf
GB	2015	annually	Oct-16	RADIOACTIVITY IN FOOD AND THE ENVIRONMENT, 2015	https://www.food.gov.uk/sites/default/files/rife-2015.pdf
GR	-	-	-	-	-

MS	Ref. Year	Publ. Period	Publ. Year	Report Title	Internet-link
HR	2014	annually	2015	PRAĆENJE STANJA RADIOAKTIVNOSTI ŽIVOTNE SREDINE U REPUBLICI HRVATSKOJ	At the moment reports are available on request.
HR	2014	annually	2015	IZVJEŠTAJ O ISPITIVANJU PRAĆENJE-PRAĆENJE STANJA RADIOAKTIVNOSTI ŽIVOTNE SREDINE U REPUBLICI HRVATSKOJ TIJEKOM 2014	At the moment reports are available on request.
HU	2013	annually	Apr-15	A HATÓSÁGI KÖRNYEZETI SUGÁRVÉDELMI ELLENŐRZŐ RENDSZER 2013	http://www.hakser.hu/eredmenyek/2013/hakser2013.pdf
IE	2014	annually	Jun-14	RADIATION DOSES RECEIVED BY THE IRISH POPULATION 2014	http://www.epa.ie/radiation/publications/rad/RPII_Radiation_Doses_Irish_Population_2014.pdf
IE	2010-2011		Nov-12	RADIOACTIVITY MONITORING OF THE IRISH ENVIRONMENT 2010–2011	http://www.epa.ie/radiation/publications/rad/RPII_Env_Mon_Rep_10_11_12.pdf
IT	2015		Jul-15	MANUALE RETE RESORAD	http://www.arpa.veneto.it/temi-ambientali/agenti-fisici/file-e-allegati/resorad/Manuale%20della%20rete%20RESORAD.pdf/view
IT	2002		Oct-05	RETI NAZIONALI DI SORVEGLIANZA DELLA RADIOATTIVITÀ AMBIENTALE IN ITALIA 2002	http://www.paa.gov.pl/sites/default/files/2000L191-37.pdf
IT	2014-2015		2015	ANNUARIO DEI DATI AMBIENTALI - EDIZIONE 2014-2015	http://www.isprambiente.gov.it/it/pubblicazioni/stato-dellambiente/annuario-dei-dati-ambientali-edizione-2014-2015
LT	2014	annually	2015	APLINKOS APSAUGOS AGENTŪROS 2014 METAIS VYKDYTO VALSTYBINIO APLINKOS RADIOLOGINIO MONITORINGO REZULTATAI	http://gamta.lt/files/RM%20duomenys%202014_AAA_tinklalapiui1437985949061.pdf
LU	2016	monthly	2016	SURVEILLANCE DE LA RADIOACTIVITÉ DANS L'ENVIRONNEMENT AU GRAND-DUCHÉ DE LUXEMBOURG	http://www.sante.public.lu/fr/publications/s/surveillance-radioactivite-lux-2016-1
LV	2004-2007		2008	NACIONĀLAIS ZIŅOJUMS PAR VIDES STĀVOKLI 2008	http://meteo.lv/fs/CKFinderJava/userfiles/files/Vide/Stavokla_parskati/Nacionalais_zinojums_vides_stavoklis.pdf
MT	-	-	-	-	-
NL	2013	annually	2015	ENVIRONMENTAL RADIOACTIVITY IN THE NETHERLANDS RESULTS IN 2013	http://www.rivm.nl/dsresource?objectid=rivmp:282813&type=org&disposition=inline&ns_nc=1
PL	2014	annually	2015	ANNUAL REPORT ON THE ACTIVITIES OF THE PRESIDENT OF THE NATIONAL ATOMIC ENERGY AGENCY AND ASSESSMENT OF NUCLEAR SAFETY AND RADIOLOGICAL PROTECTION IN POLAND IN 2014	http://paa.gov.pl/strona-180-president_s_annual_report.html

MS	Ref. Year	Publ. Period	Publ. Year	Report Title	Internet-link
PT	2013	annually	2015	PROGRAMAS DE MONITORIZAÇÃO RADIOLÓGICA AMBIENTAL (ANO 2013)	http://www.itn.pt/docum/relat/radiolog/rel-vig-radiol2015.pdf
RO	2014	annually	2015	RAPORT ANUAL PRIVIND STAREA MEDIULUI ÎN ROMÂNIA, ANUL 2014	http://www.anpm.ro/documents/12220/2209838/RSM.2014.pdf/4dbde2ae-a7a4-43ef-8abc-67511d11715f
SE	1950-2007			SSI RAPPORT 2007:02	http://www.stralsakerhetsmyndigheten.se/Yrkesverksam/Miljoovervakning/Radioaktiva-amnen/Radionuklider-pa-partiklar-i-luft/
SI	2014	annually	Jul-15	ANNUAL REPORT 2014 ON RADIATION AND NUCLEAR SAFETY IN THE REPUBLIC OF SLOVENIA	http://www.ursjv.gov.si/fileadmin/ujv.gov.si/pageuploads/si/Porocila/LetnaPorocila/2014/Annual_report.pdf
SI	2014	annually	Mar-2015	NADZOR RADIOAKTIVNOSTI V OKOLICI NUKLEARNE ELEKTRARNE KRŠKO	http://www.nek.si/uploads/documents/Porocilo2014.pdf
SK	2014	annually	May-2015	ZÁVEREČNÁ ROČNÁ SPRÁVA ČASTKOVÉHO MONITOROVACIEHO SYSTÉMU „RÁDIOAKTIVITA ŽIVOTNÉHO PROSTREDIA“ 2014	http://www.shmu.sk/File/radioaktivita/Zaverecna_sprava_CMS_Radioaktivita_2014_final.pdf

5 Preliminary analysis of National reports

The preliminary study of the National reports has shown the inhomogeneity in the results of dose assessment for the public resumed in Figure 1 [7]. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) methodologies is the most commonly cited to calculate the dose for the public because this Committee has historically described the exposure of members of the general public to several different natural and man-made sources of radiation [8]: cosmic radiation, terrestrial radiation, natural sources (e.g. radon gas), sources of naturally occurring radioactive material (NORM), man-made sources for peaceful and military purposes, radionuclide from accident.

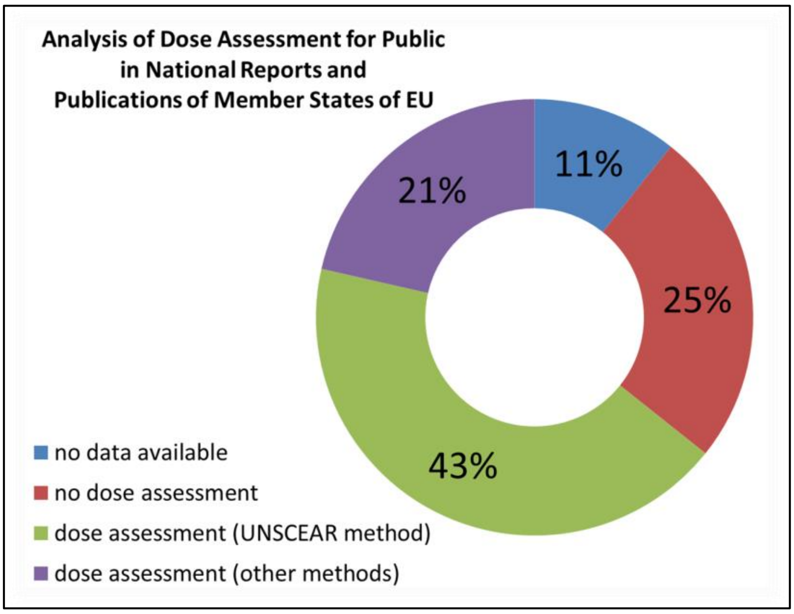

Figure 1 Preliminary results of the study on dose assessments to the population of the European Union [7] show that no data was found for 3 countries, in 7 national reports there were not dose evaluations and for 18 Member States there are dose assessments for public in available publications (in 12 cases the dose calculations refer to UNSCEAR methodologies) .

In the publications analysed there are rarely diversification in dose assessments for different population groups (adults, children, and infants), while in some specific site monitoring reports, the effective collective dose is estimated within 30 km from the site.
In some cases the dose data are also integrated with specific values of nuclear site monitoring, with reference to atmospheric releases and artificial radionuclides present in the various matrices, and sometimes are analysed the dietary habits of the reference group.
In dose assessment due to the intake of artificial radionuclides by foods, Cs-137 is the reference radionuclide and in many cases Sr-90 and C-14 are also considered.
Data are presented in a very heterogeneous way but can identify three different data classes:
- Concentrations of radionuclides expressed (Bq/liter, Bq/kg) evaluated for water and reference foods (e.g. milk, cereals, vegetables, fruit, fish, meat), comparable to the notifiable levels or international reference values [9], without any reference to food consumption.

- Daily intake values per person (Bq/day), calculated from the activity concentrations measured in fresh and raw food samples and statistical indications of average food consumption.
- Average concentrations of artificial radionuclides evaluated on average meals consumed in representative places (e.g. hospitals, universities, restaurants) [10] [11] [12] [13] [14] [15] [16] [17].

In all documents it is concluded that the analysed data reveal a good radiological state for foods consumed in all Member States and most of the time the results of measurements are less than or equal to the detection limits of the equipment used. Rarely the theoretical dose values due to the introduction of artificial radionuclides (from food, drink and inhalation) are supported by in vivo measurements on population target groups [10] [11].

6 Proposal of a procedure to perform the dose assessment for the Public on the basis of environmental radioactivity data in routine situation

In this work the retrospective dose assessment to the public is presented, considering a specific individual identified by a representative person and using measures activity concentrations in environmental media.

This is not always possible, as full measurement data may not be available or measurements are below limits of detection, and modelling is then required. An assessment in which the limit of detection is assumed to be the actual activity concentration will not give a realistic assessment of doses. Preferably, the assessment should be based on modelling with the model results being checked to ensure that they are less than the detection limits [2].

The process of estimating annual dose to the public is explained in details in ICRP Publication 101a [18]. The basic concept is the impossibility to measure directly the dose and a number of different methods are available for this purpose from deterministic calculation to more complex probabilistic techniques.

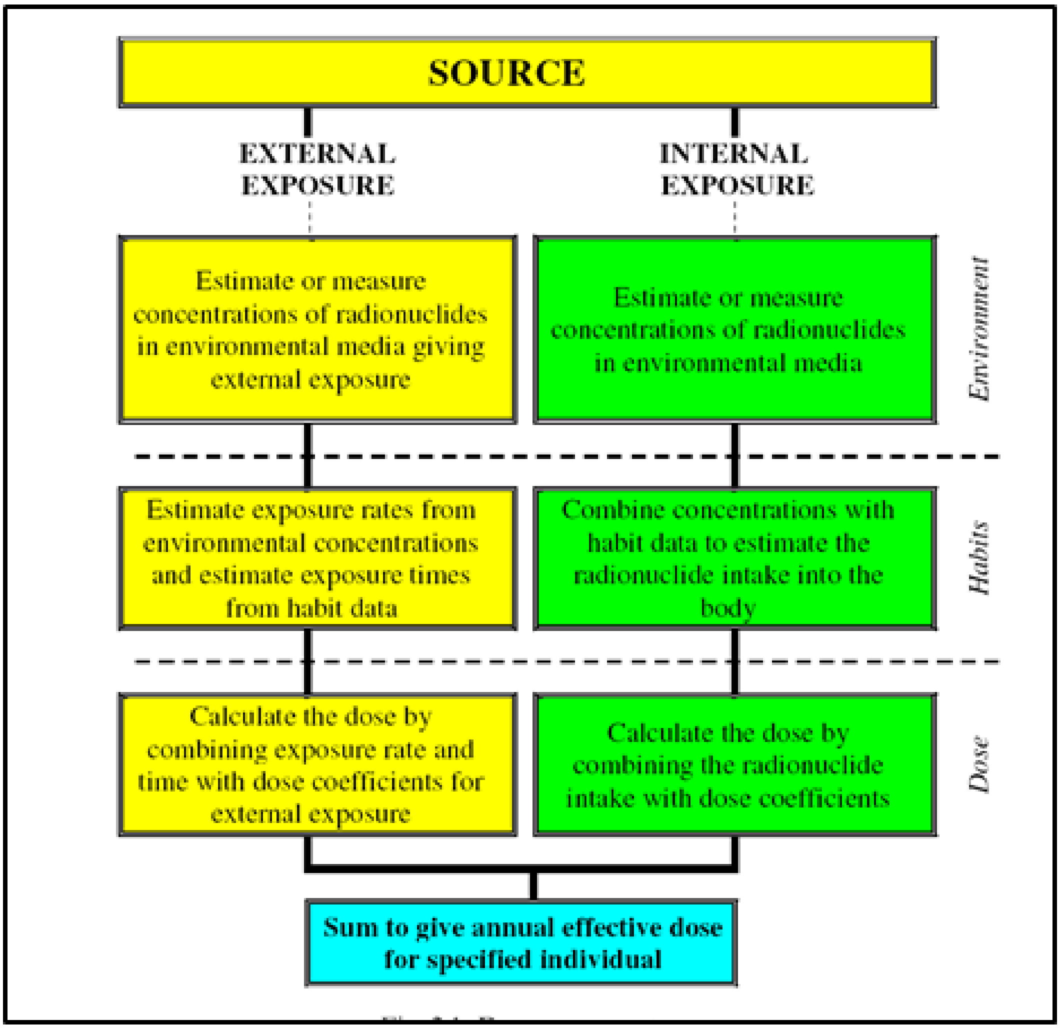

Figure 2 Dose assessment process according to ICRP101a [18]

Dose assessment can be described as a multistage process (see Figure 2) as follows:

- First stage: identification of radiation fields (i.e. radionuclides and emitted radiation) and sources quantification.
- Second stage: estimation of radionuclides concentration under investigation in environmental media:
    - o external exposure factors and quantification of possible contributions (e.g. external dose rate, radioactivity concentration in air /soil/ water);
    - o internal exposure factors and quantification of potential contributions (e.g. radioactivity concentration in air/ food/ water that may be taken into the body).
- Third stage: information about habit data based on exposure scenario of the relevant person or group (e.g. amount of time spent in different radiation fields for external exposition; information on food and water consumption and air breathed for internal exposition).
- Fourth stage: using of dose coefficients that either relate radioactivity concentrations in air or soil to external exposure rates, or that convert a unit of intake into dose and sum the contributions from external and internal exposure to assess effective dose.

Starting from environmental data the dose assessment may be done with a deterministic approach and the simplest deterministic method for the assessment of compliance is a screening evaluation. This method typically makes use of simplifying assumptions that lead to a very conservative estimate of dose based on, for example, concentrations of radionuclides at the point of discharge from the source. Another simplifying assumption is to consider a single age group (e.g. adult) in estimating dose to the public to compare with the dose constraints and dose limit. If the results of relatively conservative screening assessments demonstrate that doses are well below the relevant dose constraint, there may be no need for further detailed assessment of dose. A number of screening methods have been developed and are available for application [18].

The main goal is identify the group or groups receiving higher doses on a case-by-case basis and verify that the highest exposure - taking all pathways into account - is compared with the dose constraints and dose limit to determine compliance.

7 Description of proposal procedure

The assessment of the effective annual dose E to a representative individual requires to quantify the contributions due to external exposure Eext and the internal exposure Eint (see chapter 3) due to ingestion and inhalation of radionuclides, E_{ing} and E_{inh} respectively:

$$E = E_{ext} + E_{ing} + E_{inh}$$

The pathways of transfer of radionuclides through the environment commonly evaluated in UNSCEAR dose assessments are illustrated in Figure 3.

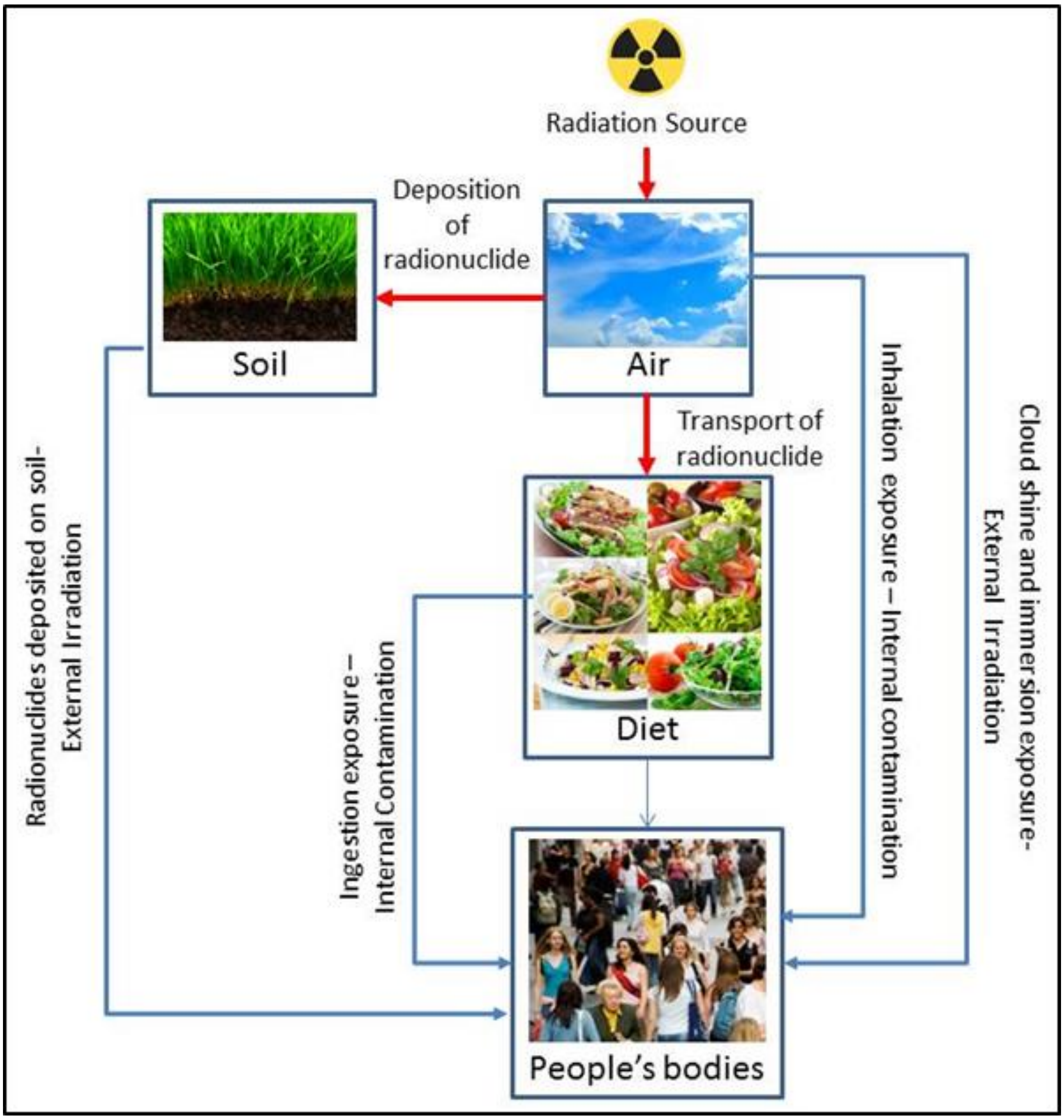

Figure 3 Pathways of transfer of radionuclides through the environment

When measurement results are not available at any point in the chain, the calculation of the movement of radioactivity from different compartment are described in models which use transfer coefficients to describe environmental behaviour and transport of radionuclides.

Any models used should be robust, fit for purpose and have been validated against measurement data. Models need to take account of both accumulation in the environment (e.g. Pu-239 has a long half-life and can build up in the local environment) and progeny ingrowth (e.g. Pu-241 decays into Am-241, which is more radiologically harmful). A realistic assessment relies on the parameter values in the model and the habit data used being a realistic representation of the situation around the site [2].

7.1 First stage : radiation sources identification

Radionuclides are generally released in trace quantities to the environment as a result of authorized releases and in critical situations during explosion in the atmosphere of nuclear weapons or nuclear accidents (e.g. Chernobyl and Fukushima). In this work these radionuclides are defined man-made radionuclides, such as transuranium elements (e.g. Pu-239, Am-241, Np-237, Cm-242), H-3, Sr-90 and gamma emitting radionuclides (e.g. Co-60, Ru-103, Ru-106, Cs-134, Cs-137, I-131) and they are considered accountable for the increment of dose in the public respect to the natural contribution due to radioactivity present in the environment.

7.2 Second stage: radionuclides concentration in environmental media

According to the Recommendation 200/473/Euratom on the application of Article 36 of the Euratom Treaty concerning the monitoring of the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole it is important to assess external exposure by monitoring ambient dose rate and air, water, soil and foodstuffs to assess internal exposure. In the following Table 3 the sample types and measurement are reported.

Table 3 Sample types and measurements (Annex I, Commission Recommendation 2000/473/Euratom [9])

Media	Measurement category	
	Dense network	Sparse network
Airborne particulates	Cs-137, gross beta	Cs-137, Be-7
Air	Ambient gamma dose rate	Ambient gamma dose rate
Surface water	Cs-137, residual beta	Cs-137
Drinking water	Tritium, Sr-90, Cs-137 Natural radionuclides as monitored in compliance with Council Directive 98/83/EC	Tritium, Sr-90, Cs-137 Natural radionuclides as monitored in compliance with Council Directive 98/83/EC
Milk	Cs-137, Sr-90	Cs-137, Sr-90, K-40
Mixed diet	Cs-137, Sr-90	Cs-137, Sr-90, C-14

It is recommended to consider for all measurement the radionuclide in the Table 3 provided by dense network: Cs-137, H-3, Sr-90. If are available other man-made radionuclide concentration it is recommended to take account in the dose assessment.
In dose assessment it should be considered all measured values greater than the decision threshold according the ISO 11929 [19], even if they are lower than detection limit.
In the Recommendation 200/473/Euratom the reporting level for external ambient gamma dose rates are not specified. External irradiation derives primarily from gamma radiation arising from the decay of the radionuclides naturally present in the environment or released from man-made practices or events. For the purpose of this calculation of dose of the public only the contribution of man-made source of radiation should be considered rather than the background contribution.

7.3 Third stage: habit data

Examples of habit data for ingestion of foodstuffs (milk, green vegetables, beef) according to ICRP [18] for the three age groups and according IAEA for adults [20] respectively in Table 4 and Table 5.

Table 4 Habit data for ingestion of foodstuffs according to ICRP 101a [18]

Three age categories	Milk consumption (kg/year)	Green vegetable consumption (kg/year)	Beef consumption (kg/year)	Inhalation rate (m^3/h)
Infant (1-year old)	320	30	20	0.22
Child (10-year-old)	240	35	30	0.64
Adult	240	80	45	0.94

Table 5 Habit data for ingestion of foodstuffs according to IAEA publication SRS n°19,2001 [4]

World Region	Milk consumption (kg/year)	Grain, root crops, vegetables and fruits consumption (kg/year)	Beef consumption (kg/year)	Water (L/year)
Far East	65	510	40	600
Near East	140	600	55	600
Africa	80	380	35	600
South America	135	470	90	600
Central America	155	445	70	600
North America	325	535	205	600
Europe	250	410	100	600
Oceania	410	500	200	600

To highlight the big variation of consumption data and its variability the following Table 6 contains the Italian reference data for the three categories milk, green vegetables, beef, and for water consumption.

Table 6 Italian habit data of foodstuffs according to the *Istituto Superiore per la Protezione e la Ricerca Ambientale* of Italy[21]

Three age categories	Milk consumption (L/year)	Green vegetable consumption (kg/year)	Beef consumption (kg/year)	Water (L/year)
Infant (<1-year old)	256	18	14	256
Child (7-12 years-old)	91	128	43	365
Adult (>17 years)	80	179	60	584

In the following Table 7 are reported various referenced data for inhalation rate of air.

Table 7 Reference data for inhalation rate of air

Three age categories	Inhalation Rate(m^3/year)			
	UNSCEAR 2000 (2000)	IAEA,SRS n°19 (2001)	ICRP 101a (2006)	ISPRA Pub.57/2010 (2010)
Infant	1927 (0.22 m^3/h)	1400 (0.16 m^3/h)	1927 (0.22 m^3/h)	1051 (0.12 m^3/h)
Child	5606 (0.64 m^3/h)	-	5606 (0.64 m^3/h)	5606 (0.64 m^3/h)
Adult	8234 (0.94 m^3/h)	8400 (0.96 m^3/h)	8234 (0.94 m^3/h)	8147 (0.93 m^3/h)

It is recommended to use the more appropriate database for a more realistic dose assessment really referred to local habit, e.g. the dietary intake of foods and nutrients [22]. The losses in food preparation and the associated variation in intakes of radionuclides can additionally be used in estimating the ingestion of radionuclides to ensure that doses are not systematically overestimated. Drying foods increases the concentrations in the dried products, typically by a factor of 5 compared with the fresh foods. Boiling meat considerably reduces the radionuclide content. Radionuclide contents in vegetables and fruits are also significantly affected by washing, peeling, and cooking. However, there are not specifically recommendations this for these calculations [1].

7.4 Fourth stage: dose coefficients and effective dose assessment

As described at the beginning of paragraph 6.1 the assessment of the effective annual dose E to a representative individual consist in the sum of the contributions due to external and internal exposure. The background radiation should be not accounted for the estimation of man-made radionuclide analysis. The measurements of dose rate could be used to assess the external dose and gamma spectroscopy method could validate the assessment of dose due to man-made radiation source.
Data of soil deposition of particular radionuclides in specific area of interest could be alternatively used for estimation of the external doses: using specific conversion coefficients, the surface contamination could be converted into dose rate values above undisturbed ground (e.g. lawns), ploughed soil or solid surfaces (e.g. asphalt or concrete). But in general the monitoring of levels of radioactivity in soil does not allow a direct assessment of the exposure of the population according the Recommendation 200/473/Euratom. The exposure related to soil contamination is more directly assessed on the basis of ambient dose rate and foodstuff contamination.

The external exposure should be determined on the basis of environmental monitoring data by the use of the calculation model in which the building shielding and human occupation indoor time are considered.
The external exposure could be computed applying the following formula:

$$E_{ext} = H^*(10)_{indoor} + H^*(10)_{outdoor} = H^*(10)_{detect.} \times (1 - F_0) + H^*(10)_{detect.} \times F_0 \times F_S$$

Where:

$H^*(10)_{detect.}$ is the result of measured data without the contribution of natural radiation background,

F_0 is the indoor occupancy factor,

F_S is the general building shielding factor, it is the ratio of indoor to outdoor dose rate and its value could be equal to 0.2 [1].

In order to combine indoor and outdoor dose rates to compute total doses, the UNSCEAR continues to use an indoor occupancy factor F_0= 0.8, which implies that people spend 20% of the time outdoors, on average, around the world. The estimated 80% of time spent indoors is considered likely to be low for industrialized countries in temperate climates and high for agricultural countries in warm climates [1]. Furthermore to define the human occupation time it is possible to refer to statistical information for population of specific area or to conduct interviews to limited groups of people
It should be clarified that the releases from nuclear installations of radionuclides that contribute to external exposure are, in general, too low to be measured in air or deposition at distance beyond the installation site and point of release. Long-term average dispersion of radionuclides in air may be estimated using dispersion models and real meteorological parameters at the release point, analyzing the local area surrounding the point of release (1-50 km).
The internal exposure contribution due to the ingestion of contaminated food and/or drinking water could be estimated on the basis of environmental monitoring data by the use of a simple calculation model:

$$E_{ing} = \sum_p \sum_i E_{ing,p,i} = \sum_p \sum_i C_{p,i} \times R_{ing,p} \times D_{ing,i}$$

Where:

$E_{ing,p}$ (Sv/year) is the annual effective dose from consumption of nuclide i in foodstuff subset p/ water,

$C_{p,i}$ is the concentration of radionuclide i in foodstuff p/water at the time of consumption (Bq/kg),

$R_{ing,p}$ is the consumption rate for foodstuff p/ water (kg/year),

$D_{ing,}$i is the dose coefficient for ingestion of radionuclide i (Sv/Bq).

In the equation it is recommended to consider the dose arising from drinking water.
If data from measurements on food are unavailable or insufficient, the concentrations of radionuclides in foodstuffs can be roughly estimated from data on soil deposition or water concentrations by using known coefficients of radionuclide transfer from soil or water to plants and animals.

The annual effective dose from inhalation Einh (Sv/year) is:

$$E_{inh} = \sum_i E_{inh,i} = \sum_i C_{air,i} \times R_{inh} \times D_{inh,i} \times (1 - F_0) + \sum_i C_{air,i} \times R_{inh} \times D_{inh,i} \times F_0 \times F_R$$

Where:

$C_{air,i}$ is the radionuclide concentration in air (Bq/m^3),

R_{inh} is the inhalation rate (m^3/year),

$Dinh_{,i}$ is the inhalation dose coefficient for the i radionuclide (Sv/Bq),

F_0 is the indoor occupancy factor,

F_R is the ratio of indoor to outdoor air concentration. This parameter should be assigned a value of 0,3 during a specific release. Estimates of inhalation exposure from releases of radionuclides from nuclear installations may be made using dispersion model [1].

The effective dose coefficient from intake (Sv/Bq) will depend on the metabolism, age and life expectancy (adults: 50years, other ages: 70years) of the individual as well as the physicochemical behaviour of the radionuclide concerned. Dose coefficients are usually evaluated using representative ‘reference’ values for the various factors, such as those related to metabolism, and are therefore averages either for complete populations or for particular subgroups in a population. For adults the doses per unit intake are integrated for 50 years. For infants the doses are integrated to the age of 70 years from the age at intake [20].

For dose assessments the dose coefficients published in the EURATOM Directive should be used. Where data are provided for more than one chemical form of an element and the actual chemical form is not known, the defaults should be taken from ICRP Publication 72 [23]. If required, dose coefficients for tritium and 14C in a vapour state should be taken from a Communication regarding the EURATOM Directive [23]. Expert judgement should be used to determine the most appropriate chemical form for use in the assessment, rather than assuming the chemical form that leads to the highest dose coefficient [2].

According to ICRP publication [18] the evaluation has to be performed with different dose coefficient for various ages, however it is recognised that the use of three age categories is recommended for estimating the annual dose to the representative person dose assessments as defined in Table 8.

The fractional distribution of the population within these categories is 0.05, 0.3 and 0.65 for infants, children and adults, respectively [1].

Table 8 Three age categories recommended for estimating the annual dose to the representative person dose assessment in ICRP 101a

Three age categories (UNSCEAR-2000-annex a)	Three age categories (ICRP101a)
Infant : 1-2 years	Infant : 0-5 years Dose coefficient and Habits: 1-year old
Child : 8-12 years	Child : 6-15 years Dose coefficient and Habits: 10-year-old
Adult : >17 years	Adult : 16-70 years Dose coefficient and Habits: >17 years

It is possible to evaluate a more adequate dose for a restricted range of age using the specific habit data and the ratio of dose reported on specific tables for a subset of radionuclides [18].
In dose assessment for the public it should be specified the age range, the used dose coefficient and also the habit data for reconstructing clearly the computing settings.

8 Uncertainty in dose assessment

In regard to the treatment of uncertainties in dose assessment, the goal of the methodology is to perform a good evaluation of dose to support judgments and decision to be made on radiological protection. Uncertainty associated with estimation of dose should incorporate the uncertainty and variability in the estimated environmental media concentration (i.e. radionuclide concentration in air, water, soil and food) and uncertainty and variability in the habit data (i.e. breathing rate, food and water ingestion rates, time spent at various activities), indoor presence, indoor to outdoor activity concentration in air.
The ICRP states that the final decision on how to include uncertainties in the estimation of dose for compliance purpose should be made by the regulatory authority.
The source of uncertainties through the dose-assessment process could be identified in technical uncertainties (environmental measurements have associated uncertainties), limitation in the representativeness of samples and/or measurements, and human errors.
It is commonly know that low level radionuclide activity are characterized by low statistics of counting and uncertainty upper than 20%. These uncertainties cannot be eliminated but they should be reduced as far as possible by means of quality assurance procedures applied in the laboratory. Regular training and exercises should be conducted for the staff of the environmental laboratory to maintain the experience of personnel as an important precondition for high quality of data produced.
In dose assessment procedure could be recommended to consider the upper limit of the confidence interval in the formulas instead of the best estimate of measurand because of a cautionary approach. If the result of the dose does not respect the dose limit a process of optimization in the parameters choice and measurement data is recommended for verifying the absence of an overestimation of the result.

9 Examples of dose assessment for public of ENEA Casaccia site (data 2016)

The proposed methodology was applied at the 2016 environmental data of ENEA Casaccia Site.
In this application the public was identified with the critical group which is located near the ENEA Casaccia Site and which consumes mainly local product monitored in ENEA IRP-SFA Environmental Laboratories. This reference group is intended to be representative of individuals likely to receive the highest doses [2]. The procedure was applied for infant, child and adult as defined by ICRP 101a.

9.1 First stage : radiation sources identification

The radionuclide used for dose assessment of the public are the specific radionuclide which are identified in the environmental monitoring program of ENEA Casaccia, selected in function of the facility and research nuclear plants present in the site:

- Gamma radiation emitters : Co-60, I-131, Cs-137,
- Gross alpha and beta,
- Pu-238, Pu-239/240,
- Sr-90.

9.2 Second stage: radionuclides concentration in environmental media

The radionuclide concentrations used for dose assessment of the public were the measurement data produced by ENEA IRP-SFA Environmental Laboratories and reported on the 2016 Annual Environmental Radioactivity Report of ENEA Casaccia Research Centre.
The release of radionuclide from the nuclear facility in air and water are considered respectively in the measurement of external dose and in the foodstuff because of the transferring by the water of river during the irrigation of fields (no fishing activities are possible in the stream).

9.3 Third stage: habit data

The habit data used for dose assessment were:
- Italian ISPRA reference data for foodstuff consumption [21],
- ICRP 101a data for breathing rate and
- UNSCER 2000 data for occupational and shielding factors.

9.4 Fourth stage: dose coefficients and effective dose assessment

The coefficients for dose assessment used in this example were tabled Annex IV of Italian law (D.Lgs.230/95 and subsequent amendments); in Table 9 are reported the data used for dose assessment for all the measurements with concentration major than detection limits for each measurement matrix.

Table 9 Dose coefficient selected for dose assessment of public in ENEA Casaccia site according the Italian law. Only the coefficient of the radionuclide detected in the sample are reported in the table.

Radio-nuclide	Absorption Type for particulate	Dose Coefficient for INFANT (1-2 years)		Dose Coefficient for CHILD (7-12 years)		Dose Coefficient for ADULTS (> 17 years)	
		Inhalation (Sv/Bq)	Ingestion (Sv/Bq)	Inhalation (Sv/Bq)	Ingestion (Sv/Bq)	Inhalation (Sv/Bq)	Ingestion (Sv/Bq)
Sr-90	M	$1.0\ 10^{-7}$	$7.3\ 10^{-8}$	$5.1\ 10^{-8}$	$6.0\ 10^{-8}$	$3.6\ 10^{-8}$	$2.8\ 10^{-8}$
Cs-137	F	$5.4\ 10^{-9}$	$1.2\ 10^{-8}$	$3.7\ 10^{-9}$	$1.0\ 10^{-8}$	$4.6\ 10^{-9}$	$1.3\ 10^{-8}$
Pu-239/ Pu-240	M	$7.7\ 10^{-5}$	$4.2\ 10^{-7}$	$4.8\ 10^{-5}$	$2.4\ 10^{-7}$	$5.0\ 10^{-5}$	$2.5\ 10^{-7}$

The considered foodstuffs were green vegetable, milk and cereals. Beef was not produced in the monitored area around the nuclear site.

Table 10 Evaluation of internal and external effective dose to the public in ENEA Casaccia site in 2016

	E_{int} (μSv/year)	E_{ext} (μSv/year)
Infant	0.8	40
Child	1.3	
Adult	1.1	

The contribution of external dose is computed starting from the data of the TLD measurements for the period of one year, considering the mean value of stations located in main wind directions and subtracting the Casaccia mean background in the same year (it is important to specify that no radiological events occurred in 2016). A better evaluation of external effective dose should be done with spectroscopic measurements.

Nevertheless the sum of the two components of external and internal dose is in compliance with the dose limit of 1 mSv for the three age categories.

10 Conclusion

In the first phase of the REMME & DARP project of the Collaboration Agreement between Radiation Protection Institute (IRP) of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and the Radioactivity Environmental Monitoring Group of the Joint Research Centre (JRC) of the European Commission the procedures for public dose assessment were analysed starting from the available data of different reports of the Member States.
Globally the information presented by each Member State could be considered of good quality. However, the provided information highlighted inhomogeneity in data themselves and in the assessment methods (e.g. the periodicity of the data publication from monthly to every two years, the structure and the presentation of the results). Moreover, the use of the own language in almost all the national reports requested specific efforts to allow the overall analysis.
The proposal of procedure for dose assessment collects a lot of information available in this research field, but the used criteria might not be exhaustive enough to cover all situations. In the four stages of dose assessment it is essential to specify the habit data, the intake parameters (rate of breathing, human habits as well as water and foodstuff consumptions, indoor occupancy factor), otherwise the data produced are not really comprehensive and cannot be compared each other.

The Specific Deliverables 1 and 2 of Objective 1 “Harmonization f Dose Assessments for the public in routine situations on the basis of the Environmental Radioactivity Data” were reported in the two posters:

- G. Iurlaro, M. De Cort, E. Fantuzzi, M. Marin Ferrer **“REMME & DARP – Radioactivity Environmental Monitoring Measurements Evaluation and Dose Assessment for Radiation Protection purposes”** , Convegno Nazionale AIRP di Radioprotezione, Trieste 19-21 October 2016
- G. Iurlaro, M. De Cort, E. Fantuzzi, M. Marin Ferrer **“Radioactivity Environmental Monitoring Measurements Evaluation and Dose Assessment for Radiation protection purpose in routine and emergency situations”**, NERIS Workshop 2017, Lisbon

The Deliverable 3 of Objective 1 was resumed in the internal preliminary report and reported in this final report and, in conclusion, an oral presentation **“Dose assessment methodologies for the public on the basis of the environmental radioactivity data in the European Union”** was done for disseminating this research work with MS Experts at the “EURATOM Article 35-36 Experts’ meeting 2018”, in September 2018.

The objective 2 “Quantification of tools for the assessment of large scale atmosferic releases after a nuclesr accident” was studied starting with a specific study of the ARGOS simulations. An analysis of a symplified accident scenario of a transboundary nuclear accident impact evaluation was presented in a poster at the European Radiation Protection Week, section 2 ”Management of emergency and post-accident situations: how to optimize population evacuation zones and related decision making processes”:

- G. Iurlaro, M. A. Hernandez-Ceballos, S. Scarpato, L. De Felice, C.-M. Castellani, I. Vilardi, G. Cinelli, L. Sperandio, K. Bogucarskis, M. Sangiorgi, M. De

Cort "**Analysis of the wind dynamics in estimating the transboundary nuclear accident impact and evaluation of protective countermeasures for the public: case study in Italy** ", European Radiation Protection Week 2017, Paris.

The REM group is working on the implementation of REM data base, the existing database for environmental radiological data, and the preliminary poupose and the results were disseminated at "EURATOM Article 35-36 Experts' meeting 2018", in September 2018:

- **REM database developments 2016-2018** (M. De Cort, DG JRC Ispra)
- **Proposal of a new on-line graphical query tool for the REM database** (M.A. Hernandez Ceballos and M. Sangiorgi, DG JRC Ispra)

APPENDICES

Articles 35 and 36 of EURATOM Treaty

Article 35

Each Member State shall establish the facilities necessary to carry out continuous monitoring of the level of radioactivity in the air, water and soil and to ensure compliance with the basic standards.

The Commission shall have the right of access to such facilities; it may verify their operation and efficiency.

Article 36

The appropriate authorities shall periodically communicate information on the checks referred to in Article 35 to the Commission so that it is kept informed of the level of radioactivity to which the public is exposed.

European Commission REM data bank

REM is an on-line data bank containing a unique collection of environmental radioactivity measurements from a wide number of different sources, media and countries.

The bank was set up by the Joint Research Centre of the European Commission at Ispra to help integrate and preserve some of the vast quantities of data concerning artificial environmental radioactivity produced in the aftermath of the Chernobyl accident with the overall aim of making them widely available in a coherent form for scientific study and for obtaining a European picture of the contamination situation.

Currently, the data are being supplemented with the routine monitoring measurements communicated to the Commission by the Member States under Article 36 of the Euratom Treaty. Included in the bank are the results of radionuclide measurements on both environmental samples and foodstuffs; best represented are air, deposition, water, milk, meat and vegetables. Most data currently in the bank refer to the artificial nuclides and most especially Cs-137.

Nowadays the data cover the 28 EC member states, Iceland, Norway and Macedonia countries.

European Commission EURDEP

The European Radiological Data Exchange Platform (EURDEP) is a network for the exchange of radiological monitoring data between most European countries almost in REAL TIME. Monitoring information is collected from automatic surveillance systems in 39 countries. These data reflect essentially the natural radiation background, if NO radiological events occur.

The participation of the EU member states is regulated by the Council Decision 87/600 [25], Euratom Treaty art.36 and the Recommendation 2000/473/ Euratom. The participation of non-EU countries is on a voluntary basis. There is however a bilateral agreement that participating to EURDEP automatically means that data delivery will continue during emergency.

Data are collected from the national data servers through dedicated channels. Collected national datasets get distributed among several mirrored file servers to ensure a higher data availability especially during a radiological accident.

Freely accessible public maps allow viewing the monitoring data in a simple, intuitive way.

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List of abbreviations

EURDEP - European Radiological Data Exchange Platform
ICRP – International Commission on Radiological Protection
UNSCEAR - United Nations Scientific Committee on the Effects of Atomic Radiation
IAEA – International Atomic Energy Agency
ISO- International Organization for Standardization
ISPRA – Istituto Superiore per la Protezione e la Ricerca Ambientale (renamed ISIN- Ispettorato Nazionale per la Sicurezza e la Radioprotezione)