9. Radiological Quality of Drinking-Water

9.1. INTRODUCTION

9.1.1. Background

The guideline levels for radioactivity in drinking-water recommended in the first edition of *Guidelines for Drinking-Water Quality* in 1984 [WHO, 1984] were based on data available at that time on the risks of exposure to radiation sources and the health consequences of exposure to radiation.

The 2nd edition of the Guidelines was developed in 1993 [WHO, 1993] following the publication of the 1990 Recommendations of the International Commission on Radiological Protection (ICRP). Since its publication [ICRP, 1991], there have been further developments, most notably, the ICRP publications on prolonged exposures [ICRP, 2000] and on dose coefficients [ICRP, 1996]. These developments have justified a review of the guidelines.

The current guidelines are based on the following:

1. A recommended reference level of the committed effective dose equal to 0.1 mSv from one-year consumption of drinking water.
2. Dose coefficients for adults provided by the International Commission on Radiological Protection.

9.1.2. Purpose

The purpose of these Guidelines for radioactive substances in drinking-water is to guide the competent authorities in determining whether the water is of an appropriate quality for human consumption.

9.1.3. Objective

The objective of the Guidelines is to specify “acceptable” or “permissible” levels of activity concentration in drinking water for radionuclides, of both natural and artificial origin, below which regulation for the purposes of radiation protection is not required. These activity concentrations will hereinafter be referred to as guideline values.

9.1.4. Scope

The Guidelines do not differentiate between natural and man-made radionuclides.
The Guideline values apply to routine (“normal”) operational conditions of existing or new drinking water supplies. They do not apply to a water supply contaminated during an emergency involving the release of radionuclides into the environment. Guidelines and temporary permissible levels (TPLs) covering emergencies are available elsewhere [IAEA, 1996, 1997, 1999, 2001].

9.1.5. Sources of radiation exposure

Environmental radiation originates from a number of naturally occurring and man-made sources. Radioactive materials occur naturally anywhere in the environment (for example uranium, thorium and potassium). Some of them (e.g. uranium, U) can be concentrated by mining and other industrial activities. Several radioactive compounds may arise in the environment from human activities – man-made sources (for example from medical or industrial use of radioactive sources).

By far the largest proportion of human exposure to radiation comes from natural sources — from external sources of radiation, including cosmic and terrestrial radiation, and from inhalation or ingestion of radioactive materials. The United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR, 2000] has estimated that the global average annual human exposure from natural sources is 2.4 mSv/yr – Table I.

There are large local variations in this exposure depending on a number of factors, such as height above sea level, the amount and type of radionuclides in the soil of residence area (terrestrial exposure), the composition of radionuclides in the air, food and drinking water and the amount taken into the body via inhalation or ingestion. In certain local areas – the so called high radiation background areas (parts of Kerala state in India and some coastal areas in Brazil, Ramshar region in Iran, some Tibetian districts in China, etc) – the exposure to natural radiation may exceed the upper level of the typical range by a factor of 3-5, but in limited areas by a factor of 10-15. No deleterious health effects associated with this elevated radiation exposure have been detected.

TABLE 9.1: AVERAGE RADIATION DOSE FROM NATURAL SOURCES [UNSCEAR, 2000]

Source	Worldwide average annual effective dose (mSv)	Typical range (mSv)
External exposure		
Cosmic rays	0.4	0.3 – 1.0
Terrestrial gamma rays	0.5	0.3 – 0.6
Internal exposure		
Inhalation (mainly radon)	1.2	0.2 – 10
Ingestion (food and drinking water)	0.3	0.2 – 0.8
Total	2.4	1 – 10

Overall, exposure to natural sources contributes more than 99% of the radiation dose to the population (excluding medical exposure) – Fig. 9.1. There is only a very small worldwide contribution from nuclear power production and nuclear weapons testing. The worldwide per capita effective dose from diagnostic medical examination in 2000 was 0.4 mSv/yr (typical range is 0.04-1.0 mSv/yr depending on level of health care). The worldwide annual per capita effective dose from nuclear weapon testing in 2000 was estimated 0.005 mSv, from the Chernobyl accident 0.002 mSv, while from the nuclear power production 0.0002 mSv [UNSCEAR, 2000].

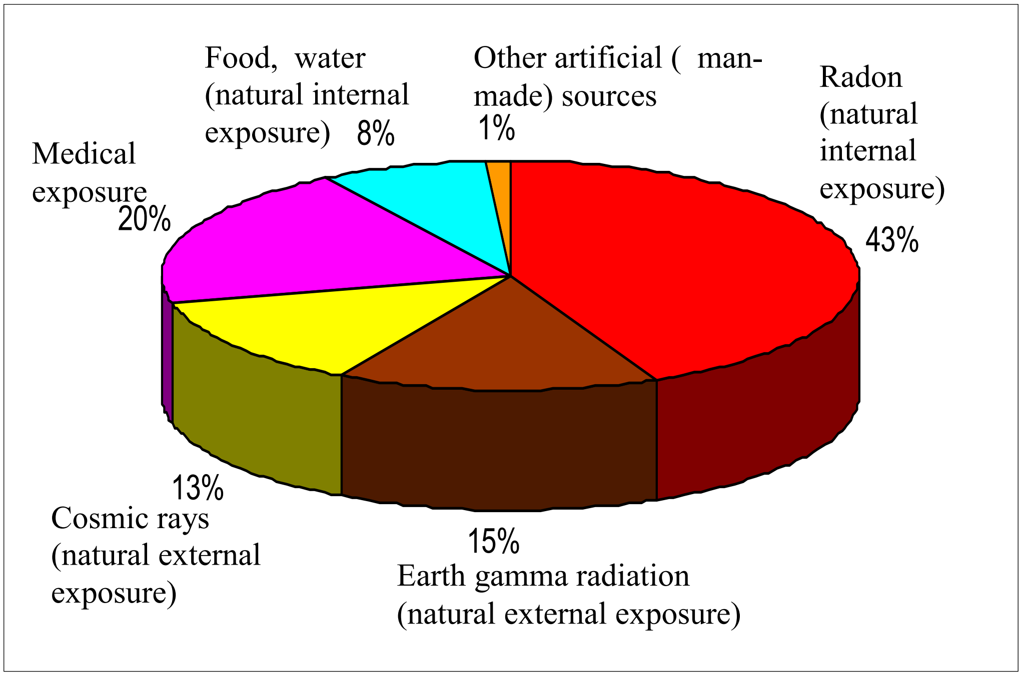


Fig. 9.1. Sources and distribution of average radiation exposure to the world population

9.1.6. Radiation exposure through drnking water

Radiological contamination of drinking water can result from:

- naturally occurring concentrations of radioactive species (such as radionuclides of the thorium and uranium decay series in drinking water sources);
- technological processes involving naturally radioactive materials (for example, the mining and processing of mineral sands or phosphate fertilizer production); or
- manufactured radionuclides, (produced and used in unsealed form) which might enter drinking water supplies in case of improper medical or industrial use and disposal of radioactive materials.

The contribution of drinking-water to the total exposure is very small and is due largely to naturally occurring radionuclides in the uranium and thorium decay series. Radionuclides from the nuclear fuel cycle and from medical and other uses of radioactive materials may, however, enter drinking-water supplies.The contributions from these sources are normally limited by regulatory control of the source or practice, and it is through this regulatory mechanism that remedial action should be taken in the event that such sources cause concern by contaminating drinking water.

9.1.7. Health effects from ionizing radiation through drinking water

There is evidence from both human and animal studies that radiation exposure at low to moderate doses may increase the long-term incidence of cancer. There is evidence from animal studies that the rate of genetic malformations may be increased by radiation exposure.

Acute health effects of radiation, appearing with symptoms of nausea, vomiting, diarrhoea, weakness, headache, anorexia leading to reduced blood cell counts and in very severe cases to death, occur at high doses of exposure of the whole body or large part of the body [IAEA, 1998] Therefore, acute health effects of radiation are practically not a concern for continuously monitored – for radioactivity content – central drinking water supplies. However, extreme situations of possible terrorist use of radioactive materials to contaminate drinking water supplies, theoretically, cannot be excluded..

There were no health effects associated with the slight increase of radionuclide contamination of the drinking water supplies following the Chernobyl accident. Among 3700 water samples monitored in the Bryansk region of Russia after the accident in 1986, temporary permissible levels (TPLs) of gross radioactive concentrations were exceeded in 4.8 % of samples, while there was not a single drinking water sample in over 18,000 samples controlled in 1987-1995 in which the TPLs for radionuclides were exceeded. TPLs were significantly higher than the guidelines values recommended in this document. [IAEA, 2001]. TPLs were significantly higher than the guidelines values recommended in this document. TPLs were established based on relatively high temporary dose limits to the population: it was 50 mSv effective committed dose from internal exposure and also 50 mSv from external exposure during the first year from May 1986, while it was reduced to 30 mSv of effective committed dose in 1987-1988 [Romanenko, 1988].

9. 2. UNITS OF RADIOACTIVITY AND RADIATION DOSE

9.1. Units of radioactivity and radiation dose

The SI unit of *radioactivity* is the becquerel, where 1 Bq = 1 disintegration per second.
The radiation dose resulting from ingestion of a radionuclide depends on a number of chemical and biological factors. These include the fraction of the intake that is absorbed from the gut, the organs or tissues to which the radionuclide may be transported and deposited, and the time that the radionuclide might remain in the organ or tissue before excretion. The nature of the radiation emitted on decay, and the sensitivity of the irradiated organs or tissues to radiation must also be considered.
The *absorbed dose* refers to how much energy is deposited in material by the radiation. The SI unit for absorbed dose is the gray (Gy). 1 Gy = 1 J/kg (joule/kg).

The *equivalent dose* is the product of the absorbed dose and a factor related to the particular type of radiation (depending on the ionizing capacity and density).
The *effective dose* of radiation received by a person is in simple terms the sum of the equivalent doses received by all tissues or organs, weighted to “tissue weighting factors”. These reflect different sensitivities to radiation of different organs and tissues in the human body. The SI unit for the equivalent and effective dose is the sievert (Sv). 1 Sv = 1 J/kg.

To reflect the persistence of radionuclides in the body, once ingested, the *committed effective dose* is a measure of the total effective dose received over a lifetime (70 years) following intake of a radionuclide (internal exposure).

The term ‘dose’ is may be used as a general term to mean either absorbed dose (Gy) or effective dose (Sv), depending on the situation. For monitoring purposes ‘doses’ are determined from the concentration of the radionuclide in a given material. In the case of water, this is becquerels per litre (Bq/L, or Bq/mL). This value is converted to an effective human dose per year (mSv/yr) using a dose conversion factor (mSv/Bq) and the average annual consumption of water in litres per year (L/yr).

9.2 Dose conversion factors

The dose arising from the intake of 1 Bq (by ingestion) of radioisotope in a particular chemical form can be estimated using a dose conversion factor. Data for age-related dose conversion factors for ingestion of radionuclides has been published by the ICRP. Table 9.2. shows the dose conversion factors [ICRP, 1996] – synonyms are dose coefficients or dose per unit intake values (mSv/Bq) – for naturally occurring radionuclides (detectable primarily at higher natural background radiation areas) or those arising from human activities that might be found in water supplies at somewhat higher probability (in case of an incident).

TABLE 9.2 DOSE CONVERSION FACTORS FOR INGESTION OF RADIONUCLIDES BY ADULT MEMBERS OF THE PUBLIC

Category	Radionuclide	Dose per Unit Intake (mSv/Bq)
Natural uranium series	Uranium-238	4.5×10^{-5}
–	Uranium-234	4.9×10^{-5}
–	Thorium-230	2.1×10^{-4}
–	Radium-226	2.8×10^{-4}
–	Lead-210	6.9×10^{-4}
–	Polonium-210	1.2×10^{-3}
Natural thorium series	Thorium–232	2.3×10^{-4}
–	Radium-228	6.9×10^{-4}
–	Thorium-228	7.2×10^{-5}
Fission products	Caesium-134	1.9×10^{-5}
–	Caesium-137	1.3×10^{-5}
–	Strontium-90	2.8×10^{-5}
–	Iodine-131	2.2×10^{-5}
Other radionuclides	Tritium	1.8×10^{-8}
–	Carbon-14	5.8×10^{-7}
–	Plutonium-239	2.5×10^{-4}
–	Americium-241	2.0×10^{-4}

9.3 GUIDELINE VALUES FOR DRINKING WATER

9.3.1. Basis for deriving guideline values for radionuclides

The guideline values for drinking water to be used in trade are presented in Table 9.2. for radionuclides originated from natural sources or discharged in the environment as the result of current or past activities. These values imply also to radionuclides released due to past nuclear accidents which occurred more than one year previously. On contrary, for the period immediately after an accident and the subsequent first year, generic action levels for foodstuffs apply as established in the International Basic Safety Standards [IAEA, 1996] and other relevant WHO and IAEA publications [WHO, 1988; IAEA, 1997, 1999], for certain radionuclides on the basis of recommendations from the Codex Alimentarius Commission, a joint effort of the Food and Agriculture Organization of the United Nations and the World Health Organization [CAC, 1991].

The guideline levels for individual radionuclide content in drinking water are given in Table 9.3. These guideline levels of radionuclides in drinking water were calculated – according to WHO and IAEA guides [WHO, 1996; IAEA, 2002] - on the basis of an annual dose criterion of 0.1 mSv/yr from drinking 2 liters of water per day.

- The recommended reference level of committed effective dose is 0.1 mSv from one-year consumption of drinking-water. This reference level of dose represents less than 5% of the average effective dose attributable annually to natural background radiation and therefore an insignificant additional risk to human health in the whole lifetime.
- Below this reference level of committed effective dose, the drinking-water is acceptable for life-long human consumption and action to further reduce the radioactivity is not necessary.
- For practical monitoring purposes, the recommended guideline values remain 0.1 Bq/L for gross alpha and 1 Bq/L for gross beta activity. These values are to be used for screening only. They should be followed by radionuclide-specific analysis in case of any finding for elevated gross activities in drinking-water.

The guideline values for both artificial and natural radionuclides in drinking water were calculated by equation (1) for adults:

$$GL = (IDC / (h_{ing} \cdot q)) \qquad (1)$$

where

GL	[Bq/mL] guideline value of radionuclide in drinking water,
IDC	[mSv/yr] individual dose criterion equal to 0.1 mSv/yr for this calculation,
h_{ing}	[mSv/Bq] dose coefficient for ingestion by adults,
q	[L/yr] annual ingested volume of drinking water assumed to be 730 L/yr .

TABLE 9.3. GUIDELINE LEVELS FOR RADIONUCLIDES IN DRINKING WATER

Radio-nuclides	Drinking water (Bq/mL)		Radio-nuclides	Drinking water (Bq/mL)		Radio-nuclides	Drinking water (Bq/mL)
H-3	10		Mo-93	0.1		La-140	0.1
Be-7	10		Mo-99	0.1		Ce-139	1
C-14	0.1		Tc-96	0.1		Ce-141	0.1
Na-22	0.1		Tc-97	1		Ce-143	0.1
P-32	0.1		Tc-97m	0.1		Ce-144	0.01
P-33	1		Tc-99	0.1		Pr-143	0.1
S-35	0.1		Ru-97	1		Nd-147	0.1
Cl-36	0.1		Ru-103	0.1		Pm-147	1
Ca-45	0.1		Ru-106	0.01		Pm-149	0.1
Ca-47	0.1		Rh-105	1		Sm-151	1
Sc-46	0.1		Pd-103	1		Sm-153	0.1
Sc-47	0.1		Ag-105	0.1		Eu-152	0.1
Sc-48	0.1		Ag-110m	0.1		Eu-154	0.1
V-48	0.1		Ag-111	0.1		Eu-155	1
Cr-51	10		Cd-109	0.1		Gd-153	1
Mn-52	0.1		Cd-115	0.1		Tb-160	0.1
Mn-53	10		Cd-115m	0.1		Er-169	1
Mn-54	0.1		In-111	1		Tm-171	1
Fe-55	1		In-114m	0.1		Yb-175	1
Fe-59	0.1		Sn-113	0.1		Ta-182	0.1
Co-56	0.1		Sn-125	0.1		W-181	1
Co-57	1		Sb-122	0.1		W-185	1
Co-58	0.1		Sb-124	0.1		Re-186	0.1
Co-60	0.1		Sb-125	0.1		Os-185	0.1
Ni-59	1		Te-123m	0.1		Os-191	0.1
Ni-63	1		Te-127	1		Os-193	0.1
Zn-65	0.1		Te-127m	0.1		Ir-190	0.1
Ge-71	10		Te-129	1		Ir-192	0.1
As-73	1		Te-129m	0.1		Pt-191	1
As-74	0.1		Te-131	1		Pt-193m	1
As-76	0.1		Te-131m	0.1		Au-198	0.1
As-77	1		Te-132	0.1		Au-199	1
Se-75	0.1		I-125	0.01		Hg-197	1
Br-82	0.1		I-126	0.01		Hg-203	0.1
Rb-86	0.1		I-129	0.001		Tl-200	1
Sr-85	0.1		I-131	0.01		Tl-201	1
Sr-89	0.1		Cs-129	1		Tl-202	1
Sr-90	0.01		Cs-131	1		Tl-204	0.1
Y-90	0.1		Cs-132	0.1		Pb-203	1
Y-91	0.1		Cs-134	0.01		Bi-206	0.1
Zr-93	0.1		Cs-135	0.1		Bi-207	0.1
Zr-95	0.1		Cs-136	0.1		# Bi-210	0.1
Nb-93m	1		Cs-137	0.01		# Pb-210	0.0001
Nb-94	0.1		Ba-131	1		# Po-210	0.0001
Nb-95	0.1		Ba-140	0.1		# Ra-223	0.001

Radio-nuclides	Drinking water (Bq/mL)		Radio-nuclides	Drinking water (Bq/mL)		Radio-nuclides	Drinking water (Bq/mL)
# Ra-224	0.001		# U-235	0.001		Cm-242	0.01
Ra-225	0.001		# U-236	0.001		Cm-243	0.001
# Ra-226	0.001		U-237	0.1		Cm-244	0.001
# Ra-228	0.0001		# U-238	0.01		Cm-245	0.001
# Th-227	0.01		Np-237	0.001		Cm-246	0.001
# Th-228	0.001		Np-239	0.1		Cm-247	0.001
Th-229	0.0001		Pu-236	0.001		Cm-248	0.0001
# Th-230	0.001		Pu-237	1		Bk-249	0.1
# Th-231	1		Pu-238	0.001		Cf-246	0.1
# Th-232	0.001		Pu-239	0.001		Cf-248	0.01
# Th-234	0.1		Pu-240	0.001		Cf-249	0.001
Pa-230	0.1		Pu-241	0.01		Cf-250	0.001
# Pa-231	0.0001		Pu-242	0.001		Cf-251	0.001
Pa-233	0.1		Pu-244	0.001		Cf-252	0.001
U-230	0.001		Am-241	0.001		Cf-253	0.1
U-231	1		Am-242	1		Cf-254	0.001
U-232	0.001		Am-242m	0.001		Es-253	0.01
U-233	0.001		Am-243	0.001		Es-254	0.01
# U-234	0.001					Es-254m	0.1

9.3.2. Age-dependency of the guideline values

The dose to a human from radioactivity in drinking-water is dependent not only on intake but also on metabolic and dosimetric considerations. The guideline values assume an intake of total radioactive material from the consumption of 2 litres of water per day and are calculated on the basis of the metabolism of an adult.

The influence of age on metabolism and variations in consumption of drinking-water do not require modification of the guideline values (given in Tables 9.2 and 9.3) as they

a) are based on a lifetime exposure providing an appropriate level of safety, and

b) the higher age-dependent dose conversion factors calculated for children (accounting for the more intensive metabolic rates) do not lead to significantly higher doses due to the lower mean volume of drinking water consumed by infants and children.

Consequently, the recommended reference level of committed effective dose is 0.1 mSv/yr from consumption of drinking-water during a year for any individual independently of her/his age. Therefore, guideline values for radionuclides in drinking water given in Table 9.3 apply to all age groups with no additional health risk from life-long consumption of drinking water complying with these guideline values.

9.4 .MONITORING AND ASSESSMENT

9.4.1 Screening of water supplies

The process of identifying individual radioactive species and determining their concentration requires sophisticated and expensive analysis, which is normally not justified because concentrations in most circumstances are very low. A more practical approach is to use a continuous screening procedure, where the total radioactivity present in the form of alpha and beta radiation is determined without regard to the identity of specific radionuclides. The values of 0.1 Bq/L for gross alpha activity and 1 Bq/L for gross beta activity – published in the previous WHO Guidelines [WHO, 1993 and 1996] continue to be recommended as screening levels for drinking water below which no further action is required.

9.4.2. Strategy for assessing drinking-water

If either the gross alpha activity concentration of 0.1 Bq/L or the gross beta activity concentration of 1 Bq/L is exceeded, then the specific radionuclides should be identified and their individual activity concentrations measured. From these data, an estimate of committed effective dose for each radionuclide should be made and the sum of these doses determined. If the following additive formula is satisfied, no further action is required:

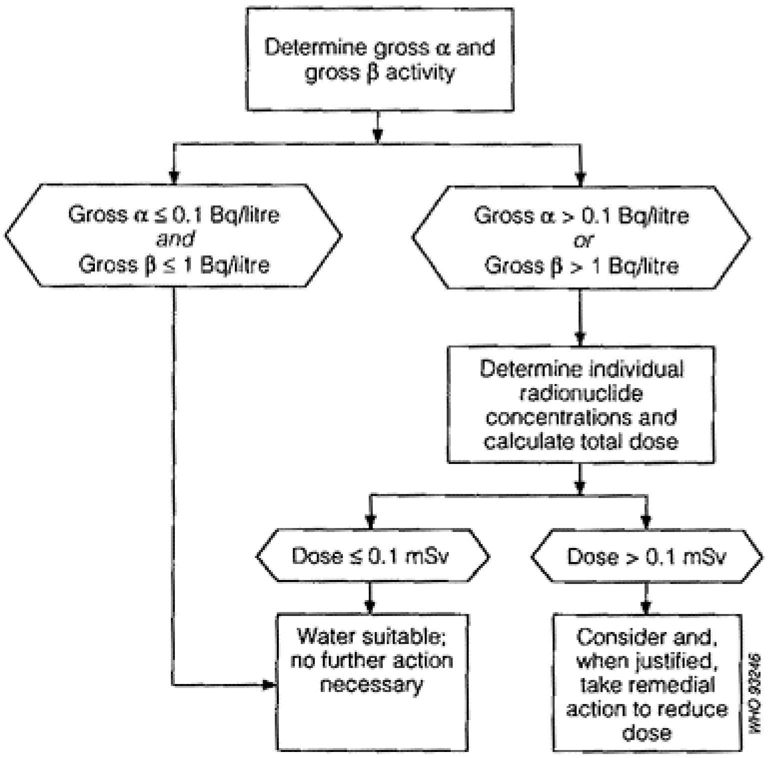
$$\sum_i \frac{C_i}{RC_i} \leq 1$$

where C_i is the measured activity concentration of radionuclide i and RC_i is the reference activity concentration (i.e. guideline value, see Table 9.3) of radionuclide i that, at an intake of 2 litres per day for 1 year, will result in a committed effective dose of 0.1 mSv/yr.

If alpha-emitting radionuclides with high dose conversion factors (see in Table 9.2. and the BSS [IAEA, 1996]) are suspected when the gross alpha and gross beta activity screening values of 0.1 Bq/L and 1 Bq/L are approached, this additive formula may be invoked. Where the sum exceeds unity for a single sample, the reference level of dose of 0.1 mSv would be exceeded only if the exposure to the same measured concentrations were to continue for a full year. Hence, such a sample does not in itself imply that the water is unsuitable for consumption and should be regarded only as a level at which further investigation, including additional sampling, is needed. Gross beta and gross alpha activity screening has to be repeated first, then radionuclide-specific analysis done if the repeatedly measured gross values exceed the recommended practical screening values (0.1 Bq/L and 1 Bq/L, respectively).

The options available to the competent authority to reduce the dose should then be examined. Where remedial measures are contemplated, any strategy considered should first be justified (in the sense that it achieves a positive net benefit) and then optimized in accordance with the recommendations of ICRP [ICRP 1989 & 1991] in order to produce the maximum net benefit. The application of these recommendations is summarized in Fig. 9.2.

Fig. 9.2 - Application of guideline values for radionuclides in drinking-water based on 0.1 mSv/yr committed effective dose



9.4.3. Contribution of potassium-40 to gross beta activity

The gross beta measurement includes a contribution from potassium-40, a natural beta emitter that occurs naturally in a fixed ratio to stable potassium. Potassium is an essential element for humans, and is absorbed mainly from ingested food. Potassium-40 does not accumulate in the body but is maintained at a constant level independent of intake. The contribution to beta activity of potassium-40 is therefore subtracted following a separate determination of total potassium. The specific activity of potassium-40 is 30.7 Bq/gram of potassium. However, not all the radiation from potassium-40 appears as beta activity. The beta activity of potassium-40 is 27.6 Bq/gram stable potassium, which is the factor that should be used to calculate the beta activity due to potassium-40.

It should not necessarily be assumed that the reference level of dose (0.1 mSv/yr, as above) has been exceeded simply because the gross beta activity concentration approaches or exceeds 1 Bq/litre. This situation may well result from the presence of the naturally occurring radionuclide potassium-40 (^{40}K), which makes up about 0.01 % of natural potassium. The absorption of the essential element potassium is under homeostatic control and takes place mainly from ingested food. Thus, the contribution to dose from the ingestion of potassium-40 in drinking-water, with its relatively low dose conversion factor (5 x 10^{-6} mSv/Bq), will be much less than that of many other beta-emitting radionuclides. This situation can be clarified by the identification of the specific radionuclides in the sample.

9.5 RADON

9.5.1. Radon in the air

The largest fraction of the natural radiation exposure we receive comes from a radioactive gas, radon (see Table 9.1 and Fig.9.1). Radon is emitted from uranium, a naturally-occurring mineral in rocks and soil; radon is present virtually everywhere on the earth, but particularly in the air over land. Thus, low levels of radon are always present in all the air we breathe. The term radon in general refers specifically to ^{222}Rn (radon-222). The mean annual radon concentration measured in the outdoor air over the entire United States of America is about 15 Bq/m^3 (0.4 pCi/L), while in the living areas of homes in the USA is 46 Bq/m^3 [NAS, 1999].

9.5.2. Radon in the water

Underground, rock containing natural uranium permanently releases (emanates) radon to water in contact with it (groundwater). As radon evaporates from surface water more intensively, water from wellsnormally has much higher concentrations of radon than lakes and streams. The average concentration of radon in public water supplies derived from surface waters is usually less of 0.4 Bq/L, and it is about 20 Bq/L (540 pCi/L) in ground water sources. Some wells have been identified with high concentrations, up to 400 times the average (in rare cases exceeding even 10 kBq/L).

UNSCEAR in its Report 2000 gives reference to the above NAS report [NAS, 1999] regarding the air-water concentration ratio of 10^{-4}, and calculates the average doses from radon in drinking water as low as 0.025 mSv/yr via inhalation and 0.002 mSv/yr from ingestion as compared to the inhalation dose from radon in the air of 1.1 mSv/yr [UNSCEAR, 2000].

9.5.3. **Risk assessment**

The USA National Academy of Sciences report reiterates the NRC estimate in BEIR VI that 12% of lung cancer deaths in the USA are linked to radon (^{222}Rn and its short-lived decay products) in indoor air. The best estimates of the NRC are that radon causes about 19,000 death annually (in the range of 15,000 to 22,000) out of the total about 160,000 deaths from lung cancer in the USA each year, mainly as a result of smoking tobacco [NRC, 1999].

The NAS Report [NAS, 1999] calculates a roughly hundred-fold smaller risk from exposure to radon in drinking water, i.e. 183 deaths each year. Of the 19,000 deaths, 160 were estimated to result from inhaling radon that was emitted from water used in the home. As a benchmark for comparison, about 700 lung-cancer deaths each year can be attributed to exposure to natural levels of radon while people are outdoors.

The NAS Committee assessed that the risk of stomach cancer caused by drinking water that contains dissolved radon is extremely small and would probably result in about 20 deaths annually compared with the 13,000 deaths from stomach cancer that arises each year from other causes in the USA.

9.6.SAMPLING AND ANALYSIS

9.6.1 Gross alpha and beta activity-concentration analysis

For analysis of drinking water for gross alpha and beta activity, the most common approach is to evaporate a known volume of the sample to dryness and measure the activity of the residue. As alpha radiation is easily absorbed within a thin layer of solid material, the reliability and sensitivity of the method for alpha determination may be degraded in samples with a high total dissolved solid content (TDS).

Where possible, standardised methods should be used to determine concentrations of gross alpha and beta activities. Three procedures are recommended and are listed in Table 9.4.

TABLE 9.4METHODS FOR THE ANALYSIS OF GROSS ALPHA AND GROSS BETA ACTIVITIES IN DRINKING WATER

Method, Reference	Technique	Detection Limit	Application
International Organization for Standardization (ISO) 9695 and 9696 [ISO, 1991 & 1991a]	Evaporation	0.02 – 0.1 Bq/L	Groundwater with total dissolved solid content (TDS)greater than 0.1 g/L
American Public Health Association [APHA, 1998]	Co-precipitation	0.02 Bq/L	Surface and groundwater (TDS is not a factor)

The determination of gross beta activity using the evaporation method includes the contribution from potassium-40. An additional analysis of total potassium is therefore required.
The co-precipitation technique excludes the contribution due to potassium-40 and, therefore, determination of total potassium is not necessary. This method is not applicable to assessment of water samples containing certain fission products, such as caesium-137. However, under normal circumstances, concentrations of fission products in drinking water supplies are so low that they are below the detection limit.

9.6.2 Analytical methods for specific radionuclides

Analytical method for potassium-40

It is impractical to use a radioactive measurement technique to determine the concentration of potassium-40 in a water sample due to the lack of sensitivity in gamma-ray analysis and the difficulty of chemically isolating the radionuclide from solution. Because of the fixed ratio between potassium-40 and stable potassium, chemical analysis for potassium is recommended. A measurement sensitivity of 1 mg/L for potassium is adequate for monitoring purposes, and suitable techniques, which can readily achieve this, are atomic absorption spectrophotometry or specific ion analysis. The activity due to potassium-40 can then be calculated using a factor of 27.6 Bq of beta activity per gram of total potassium.

Analytical method for radon

There are difficulties in applying the reference level of dose to derive activity concentrations of ^{222}Rn in drinking-water [UNSCEAR, 2000]. These difficulties arise from the ease with which radon is released from water during handling and the importance of the inhalation pathway. Stirring and transferring water from one container to another will liberate dissolved radon. According to Pylon technique, detection of radon in drinking water is performed using a water degassing unit and Lucas scintillation chambers. Water that has been left to stand will have reduced radon activity, and boiling will remove radon completely. As a result, it is important that the form of water consumed is taken into account in assessing the dose from ingestion. Moreover, the use of water supplies for other domestic uses will increase the levels of radon in the air, thus increasing the dose from inhalation. This dose depends markedly on the form of domestic usage and housing construction [NCRP, 1989]. The amount and form of water intake, the domestic use of water, and the construction of houses vary widely throughout the world. It is therefore very difficult to derive an activity concentration for radon in drinking-water that is universally applicable.

The global average dose from inhalation of radon from all sources is about 1 mSv/yr, which is close to half of the total natural radiation exposure. In comparison, the global dose from radon in drinking-water is relatively low
All these factors should be assessed on a regional or national level by the appropriate authorities, in order to determine whether a reference level of committed effective dose of

0.1 mSv/yr is appropriate for that region, and to determine an activity concentration that may be used to assess the suitability of the water supply. These judgements should be based not only on the ingestion and inhalation exposures resulting from the supply of water, but also on the inhalation doses from other radon sources in the home. Accordingly, it is necessary to adopt an integrated approach and assess doses from all radon sources, and to determine the optimum action to be undertaken where some sort of intervention is deemed necessary.

9.6.3. Sampling frequency

New water supplies and those not previously sampled should be sampled often enough to characterize the radiological quality of the water supply and to assess any seasonal variation in radionuclide concentrations. This should include analysis for radon. Quarterly sampling of significant surface water supplies and radionuclid-specific analysis would provide sufficient data. Less significant surface and underground water supplies can be sampled once in two years after the radiological quality of a supply has been established [AS, 1998].

9.6.4. Reporting of results

The analytical results for each sample should contain the following information:

- Sample identifying code or information.
- Reference date and time for the reported results (e.g. sample collection date).
- Identification of the standard analytical method used or a brief description of any non-standard method used.
- Identification of the radionuclide(s) or type of total radioactivity determined.
- Calculated concentration or activity value using the appropriate blank for each radionuclide.
- Estimates of the counting uncertainty and total propagated uncertainty.
- Minimum detectable concentration for each radionuclide or parameter analyzed.

The estimate of total propagated uncertainty of the reported result should include the contributions from all the parameters within the analytical method, i.e. counting and other random and systematic uncertainties (errors).

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