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Components of total irradiation dose in Switzerland and their ranges

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Doses from various natural and artificial sources can be considered as possible causes for radiation-induced cancer. Therefore it is useful to summarize the doses from each of the existing components of the environmental radiation received by the population. In Switzerland, the major components originate from:

- radon decay products
- natural activity in soil and housing materials
- cosmic radiation
- natural activity in the human body itself.

Smaller components are from:

- releases from nuclear and other industry and from hospitals
- bomb and Chernobyl fallout.

In the following, our present knowledge of the average size of these dose components is described together with their ranges in different areas of Switzerland. There is a discussion of how representative the values are, and on which parameters they depend.

Annual doses in Switzerland and their ranges

Figure 1 shows the mean annual effective doses in Switzerland and their ranges [1,2]. The components are given separately, but every individual gets a combination of most dose components. However, since radon decay products may cause only lung cancer, and since the contributions from other sources to the dose to the lung are comparatively small, the dose from radon is discussed separately. In contrast, doses from other natural sources need to be discussed together, because possible effects are caused by the sum of these components. Therefore, doses from radioactivity in soil, in the construction materials of buildings, in the human body, and from cosmic radiation will be considered together.

Artificial doses are small compared to the doses from natural sources and their variations, except for the Chernobyl fallout in 1986; effects from man made sources are therefore expected to be small, too, and not detectable within the variation of the effects of doses from natural sources. Effects induced by doses from the Chernobyl fallout are also difficult to detect in Switzerland because these doses are decreasing rapidly from year to year, and yearly doses (and also the integrated dose) are small compared to the natural components and their variations [1,2]. In addition, the average doses and also the larger doses of the most-affected part of the Swiss population, in the Tessin [1], are only roughly known. The uncertainties are mainly due to the high diversity of individual food consumption habits and the large variations of the activity in food [1]. Therefore artificial doses from the environment are not discussed separately in this paper.

Measured radon concentrations

Radon-concentrations have been measured in Switzerland since 1981. In the framework of a Swiss federal radon program, intensified studies have been carried out since 1986. Up to winter 1988/89, these studies produced the frequency distribution given in Figure 2 [2]. The raw data have been corrected by weighting for the real frequency of single family houses, blocks, farms and other buildings in the investigated areas and for the population densities in the various cantons of Switzerland. The figure shows a large variation of indoor radon concentrations, with the highest values reaching several kBq/m^3. An example of this wide distribution in one canton with and without weighting correction is presented in Figure 3 [2]. The highest values [$> 1\ kBq/m^3$] and also relatively high average cantonal values are found in the eastern and central Alps and in the western Jura Mountains [2]; average values are measured mainly in the Swiss plain (Mittelland).

Considering that radon concentrations above $200\ Bq/m^3$ in the living rooms may be an indicator for a possible radon problem we may ask where such values have been found up to now. In Figure 4 such places are marked on a map of Switzerland. On a first view, no obvious grouping explainable by the general geological composition of the underground can be detected. A more detailed presentations is given in Figures 5 and 6, in which Switzerland is divided into regions of 24 km times 35 km [3]. (This division is used for the Swiss 1:50 000 scale maps.) In Figure 5 the fraction of homes with at least one room with a radon concentration

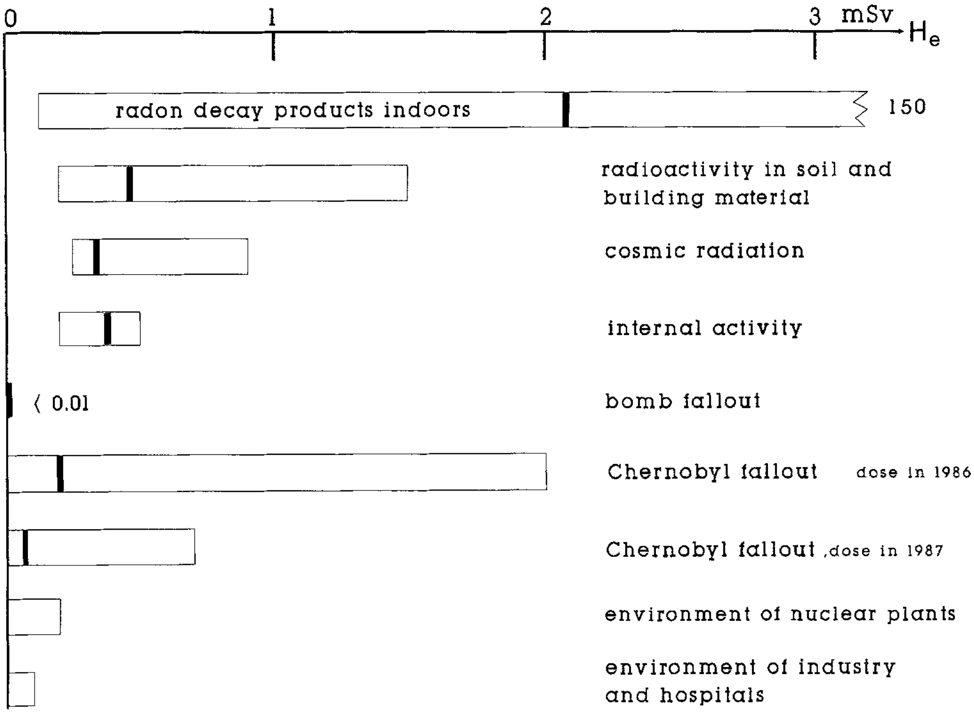

Fig. 1. Mean annual effective doses in Switzerland and their ranges.

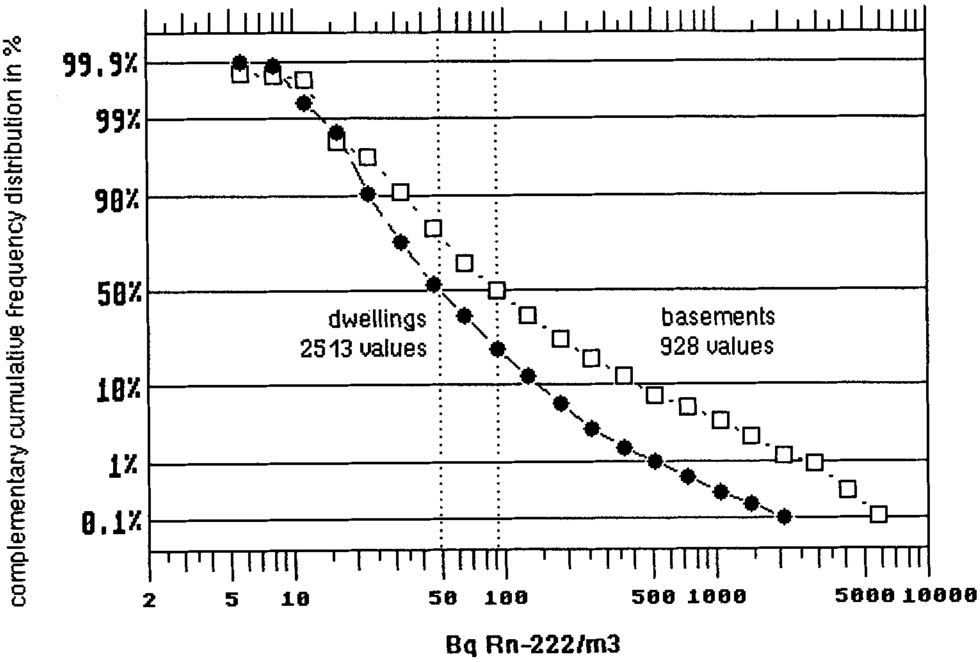

Fig. 2. Frequency distribution of radon concentrations in living and basement rooms in Switzerland. Measured values are weighted by the population densities in different cantons and in different house types [2].

exceeding 200 Bq/m^3 is marked as a function of the number of homes already measured per region. Figure 6 indicates which fraction of buildings has already been measured, as a percentage of the existing number of buildings per region. The two areas with enhanced radon concentrations mentioned previously (eastern Alps and Jura Mountains) are clearly visible in Figure 5. Increased levels may also exist in the south-eastern part of Switzerland.

Discussion of the range of the measured radon concentrations

Several parameters determine the indoor radon concentration:

- the ^{226}Ra activity in the soil
- the escape fraction of ^{222}Rn from the solid matrix into underground free or water-filled space

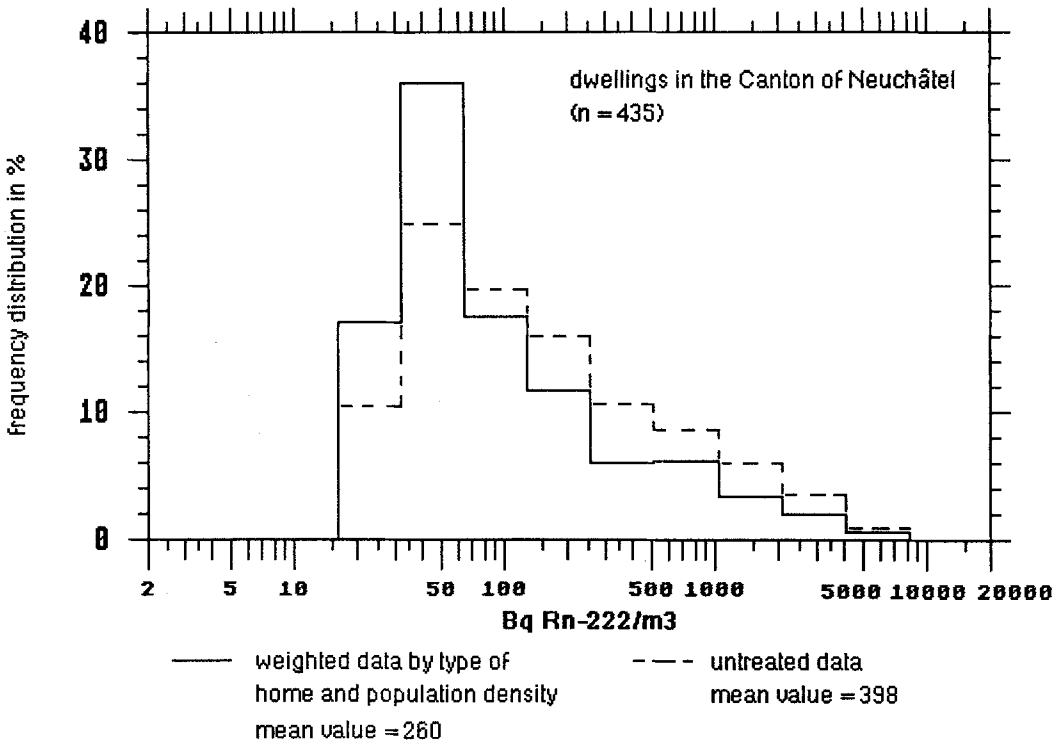

Fig. 3. Comparison of measured radon distribution in living rooms in the canton of Neuchâtel with a calculated distribution. This results from weighting the measured distribution by the real population frequency in different house types [2]. Measurements are included up to winter 1988/89.

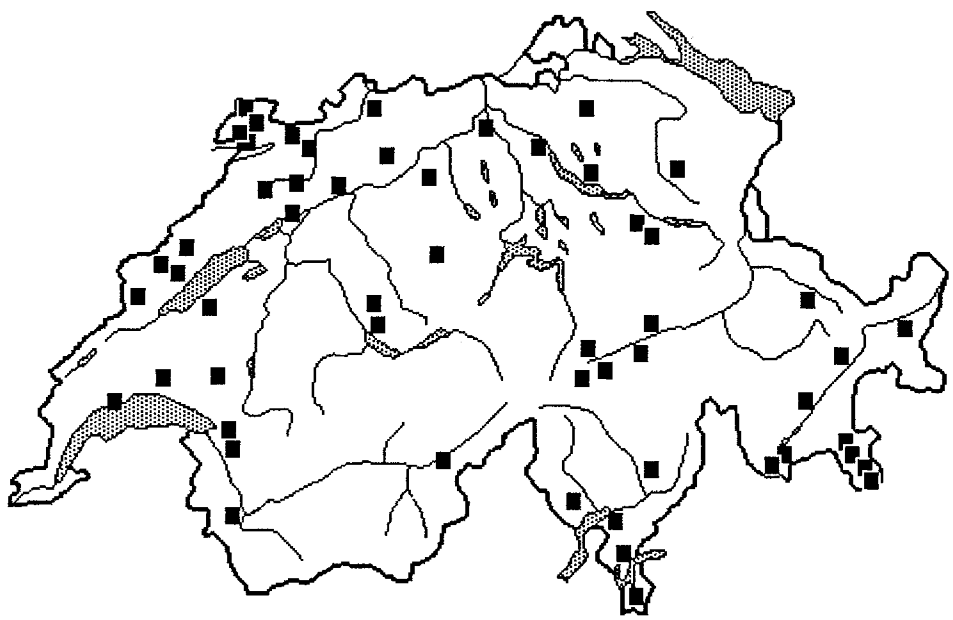

Fig. 4. Distribution of communities in Switzerland where radon concentrations in living rooms above 200 Bq/m^3 were found up to summer 1989 [2].

- the subsurface gas permeability
- the possibilities for radon to enter the basement of a building
- the construction and type of house, determining how much radon penetrates from the basement into higher floors
- seasonal and meteorological conditions yielding different temperature and pressure gradients between the floors, which cause air flow
- the behaviour of the inhabitants, e.g. opening and closing windows and doors, and selecting different durations of heating.

All these parameters work together in contributing to the large variation of indoor radon concentrations demonstrated in Figures 2 and 3. Present knowledge and experience, mainly in areas of the Jura mountains, suggest that the subsurface gas

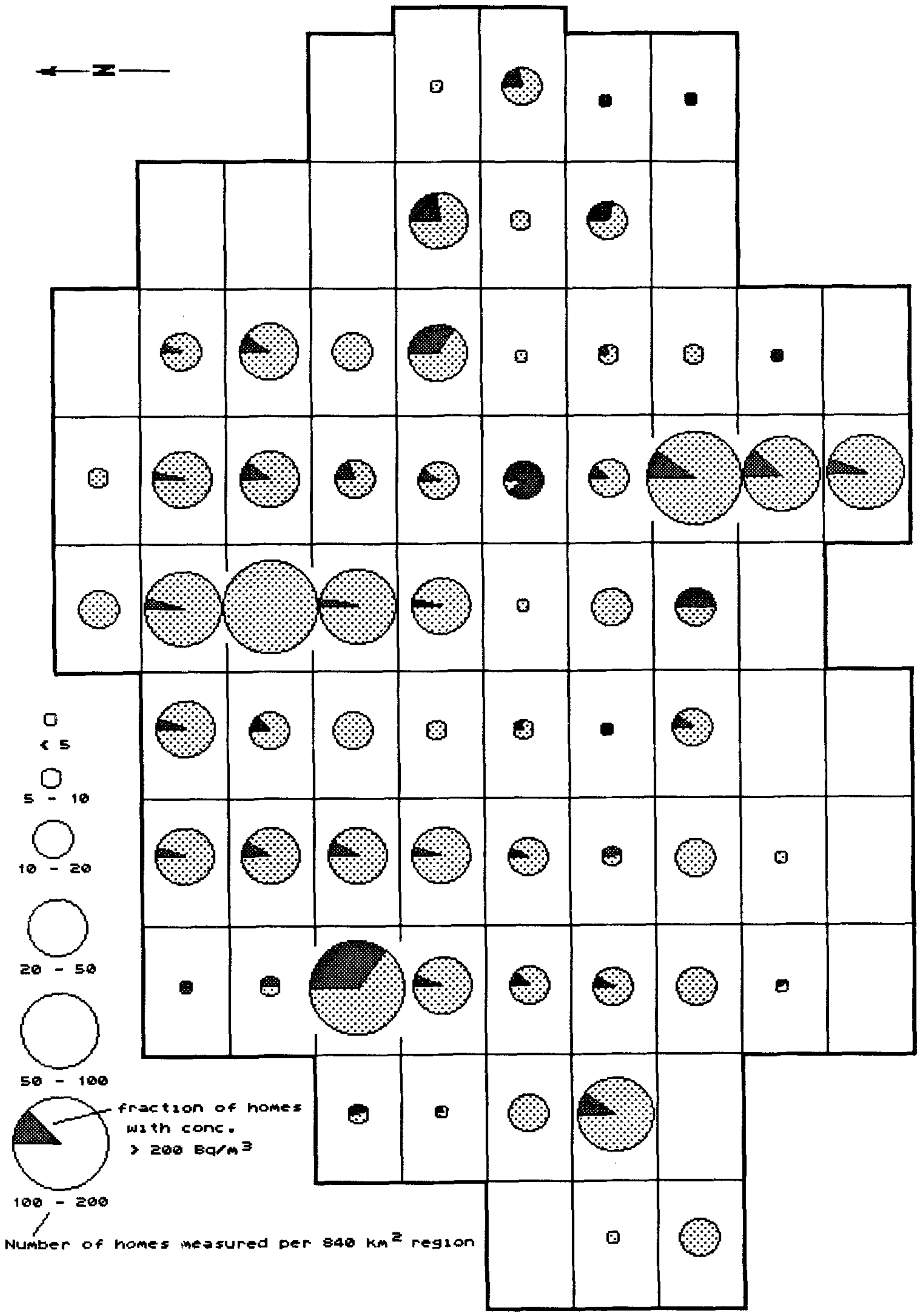

Fig. 5. Regional distribution of measured radon concentrations. The fraction of buildings with concentrations above 200 Bq/m^3 are given as function of the number of buildings measured up to 1990 in each region[3].

permeability is the most important parameter. Variations of four orders of magnitude have been measured for permeabilities in Swiss soils[3]. High radon concentrations seem to build up only if efficient radon transport to the basement of a house is possible. Even "normal" radium levels in the rock may yield considerable radon concentrations if the gas permeability of the soil is very high, as in karstic areas or in rock-slide debris. High ^{226}Ra contents in the soil may amplify the effect of high permeability, as in some alpine valleys. However, a simple correlation between the geological composition of the bedrock and indoor radon concentrations (or lung cancer frequency) cannot be expected (compare Figure 4).

The effects of the parameters mentioned above are only partly known[4]. A special 5-year radon program is investigating the radon situation in Switzerland and will summarize the present knowledge[5]. This program, for example, documents that radon escaping from the wall material of living rooms cannot be the main cause of increased indoor radon concentrations.

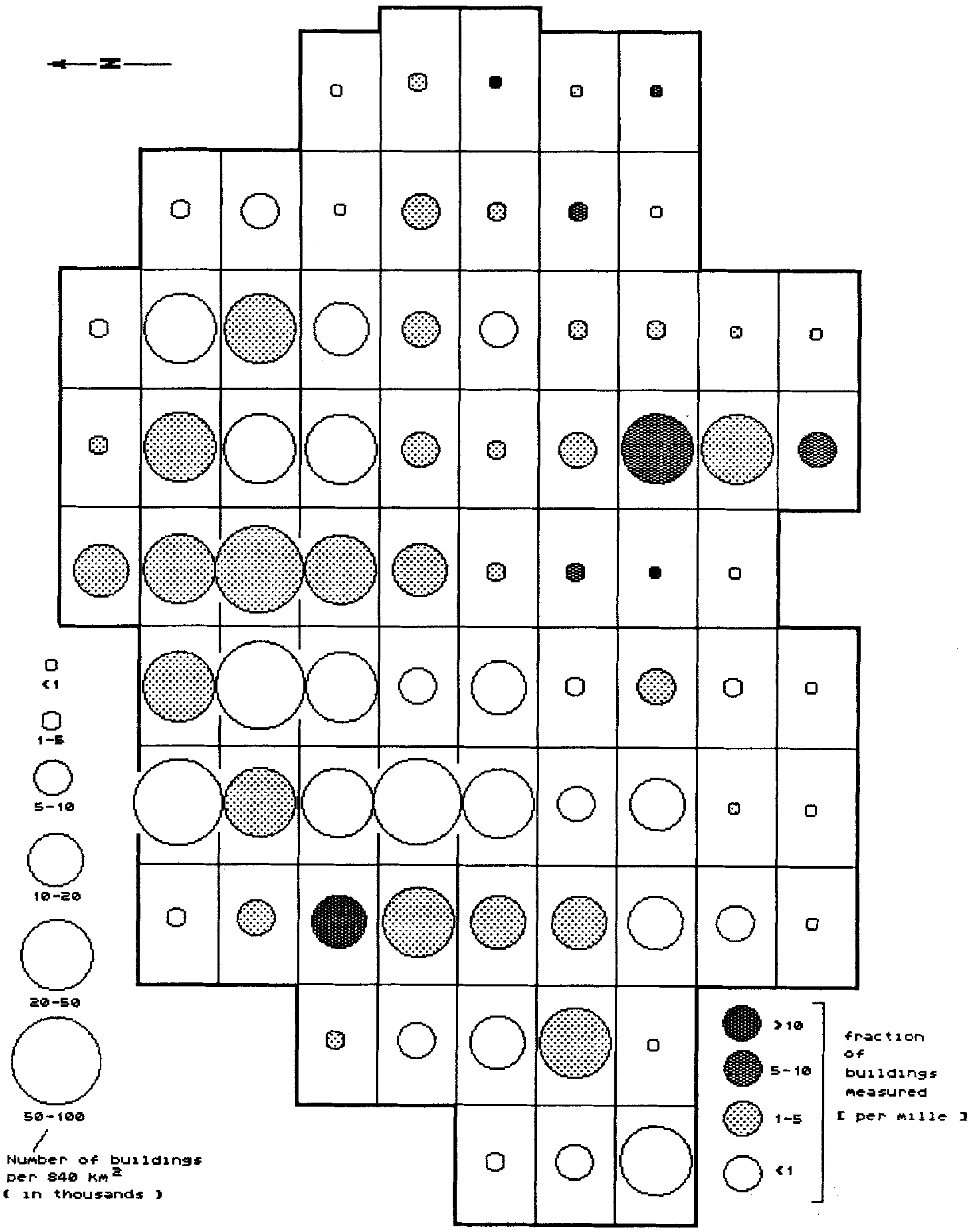

Fig. 6. Fraction of buildings measured up to 1990 as function of the number of existing buildings in each region [3].

For a correlation of lung cancer frequency and radon concentration, at least two additional parameters need to be discussed:

- the fraction of radon decay products present in the air actually breathed, compared to the radon concentration, which is usually determined. This equilibrium factor depends, for example, on the concentration of indoor aerosols, which may be affected by the smoking habits of the inhabitants. In [2] a factor of 0.4 is used;
- the size-distribution of aerosols in the air inhaled, which determines where in the lung they are deposited. The fraction of unattached radon decay products should also be known.

The large number of parameters is mentioned to emphasize that for descriptive epidemiological studies a reliable determination of radon concentrations and doses for groups is difficult. Radon concentrations have been measured in Switzerland in the framework of the federal radon program, until 1988 in about 2500 rooms of 1600 buildings, representing about 1.5% of all Swiss houses (Figure 6). Although this number looks quite small and the density of results varies from area to area

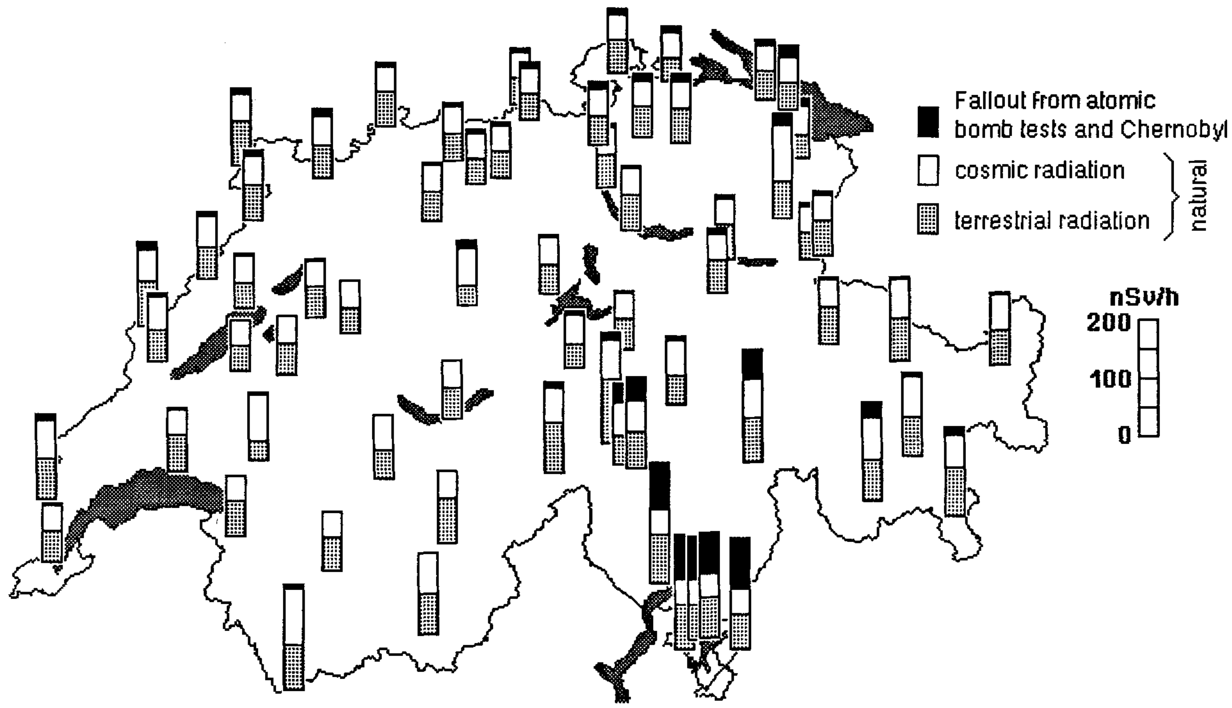

Fig. 7. Natural and artificial components of the local dose rates, calculated from the measurements of a portable Germanium-detector[10].

the results allow the preliminary determination of useful average values for cantons and even some regions[2,6]. These calculations are based on weighting procedures to correct, for example, for the overrepresentation of single family homes, and for bias introduced during the search for homes and apartments where measurements could be performed. The limited number of results and the necessary corrections yield a rather large uncertainty of average values.

For case-control studies it also seems likely to be very difficult to calculate integrated doses for individual persons over one or two decades. Radon has only been measured since about 1980. Furthermore, calculations for individuals are complicated by the fact that people move, and that some apartments and homes have been modified to improve heat-insulation in the last years. However, it seems worthwile to define and to take into account in further measurements of indoor radon concentrations the requirements of possible analytical epidemiological investigations.

Doses from terrestrial and cosmic radiation

Various methods exist for the determination of doses from terrestrial and cosmic radiation. Gamma measurements with a portable Germanium-detector allow us, for example, to calculate and disentangle the dose contributions from different artificial and natural radionuclides in the soil and from cosmic radiation. Some results obtained in 1988 are presented in Figure 7[2]. The figure shows doses outdoors, adopting a simplified conversion of $10\,\mu R/h = 100\,nSv/h$. The artificial contribution in the southern and to a smaller degree also in the north-eastern part of Switzerland is mainly due to the Chernobyl fallout. Because the long lived nuclides penetrate continuously into deeper soil layers this contribution decreases from year to year. The bomb fallout of the early sixties is estimated to contribute at present, on average, about 0.01 mSv per year.

The total dose rate from terrestrial and cosmic radiation varies in Switzerland between about 50 and 150 nSv/h. This variability is due to the different contents of natural radionuclides in the soil (^{40}K, ^{238}U, ^{232}Th and their decay products) and to the different altitudes above sea level.

Systematic variations with geology and altitude are therefore to be expected, and are also observed: for example in the plain (Mittelland) average doses are lower than in alpine regions.

The main difficulty at present in using these results in epidemiological studies is that gamma-measurements are only rarely done indoors. Radiation from terrestrial and cosmic radiation is partly shielded by a building; however, its material contains natural radioactivity which contributes to the indoor dose rate. Factors for converting doses measured outside into indoor doses are given in the literature [e.g. [7,8]]. However, considerable variations exist; in some houses the dose rates are higher and in others lower than outside. The conversion factor is typically between 0.7 and 1.3. In addition, for this dose component it would also be difficult to reconstruct doses received by individuals for the last decades, because nowadays the materials used in house construction may be different from those used earlier.

Conclusions

For epidemiological studies it is necessary to be able to compare differences in cancer frequencies with differences in accumulated doses. Large variations exist in Switzerland for doses induced by radon decay products and by cosmic and terrestrial radiations, and these could be compared with corresponding variations in cancer frequency. Other dose components are smaller or show smaller variations, so that they do not look promising for epidemiological studies.

Annual radon doses vary from about 1 to 20 mSv for different communities in Switzerland. The conversion from radon concentrations given in the third section to doses is based mainly on ICRP recommendation 50[1,2,9]. The reliability of these dose values is, however, limited, because radon concentrations have been measured only in a small number of houses in most communities. In addition, radon concentrations are determined by a large number of parameters, and this leads to radon variations over short distances, sometimes from one house to the next one. In areas where radon doses are high, the number of people is often small, for example in Alpine regions, which makes reliable statistics more difficult to obtain. At present, there are not even any established methodological criteria for finding increased indoor radon levels. However, present investigations and planned measurements in selected areas in Switzerland may yield considerable progress in the near future. It seems worthwhile to make sure that as soon as possible the radon programs will supply the information required for future epidemiological studies. The knowledge of these requirements is also needed if the present data are going to be reevaluated.

The local variations of average doses resulting from terrestrial and cosmic radiation are known with reasonable reliability. The main problem for a possible application in epidemiology, however, is that doses have mostly been measured outdoors and that factors for conversion into indoor doses are only approximately known at present. The task of reconstructing individual doses over a few decades may also present difficulties.

Summary

The present knowledge about dose components in Switzerland and their ranges is reviewed. Considerable ranges are found for doses induced by radon decay-products and by cosmic and terrestrial radiation. Yearly doses from radon decay-products show average values between about 1 and 20 mSv in different communities and individual values up to about 150 mSv. The reliability of these average values is, however, limited, because radon concentrations have been measured up to now only in a small number of houses, and because corrections of the raw data are necessary, increasing the uncertainty of the results. Doses from terrestrial and cosmic radiation show locally variable values between about 0.5 and 1.5 mSv per year. These doses are mainly derived from outdoor measurements. Therefore, these results also are only of limited use in possible epidemiological applications.

Résumé

Contributions de la dose d'irradiation en Suisse et leur variabilité

Ce travail constitue une mise à jour des connaissances sur les contributions à la dose d'irradiation et leur variabilité en Suisse. Des variations considérables ont été mises en évidence pour les doses induites par les descendants du radon, le rayonnement cosmique et les composantes terrestres. Les doses annuelles occasionnées par les descendants du radon montrent des valeurs moyennes comprises entre 1 et 20 mSv dans les différentes communes suisses, des valeurs ponctuelles pouvant atteindre jusqu'à 150 mSv. La fiabilité de ces moyennes est limitée du fait du nombre encore restreint de maisons examinées et compte tenu d'une incertitude additionnelle des résultats impliquée par des corrections nécessaires au niveau des données brutes. Les doses dues à la radiation terrestre et cosmique mettent en évidence des variations locales s'échelonnant d'environ 0.5 à 1.5 mSv par an. Ces doses résultent principalement des mesures en plein air. C'est pourquoi l'exploitation de ces résultats pour des applications épidémiologiques s'avère également limitée.

Zusammenfassung

Dosis-Komponenten in der Schweiz und deren Schwankungsbreiten

Die Dosis-Komponenten in der Schweiz und deren Schwankungsbreiten sind aus heutiger Sicht zusammengestellt. Beachtliche Variationen zeigen sich bei den durch Radon-Folgeprodukte bewirkten Dosen und bei den Dosen infolge kosmischer und terrestrischer Strahlung. Die durch Radon-Zerfallsprodukte bewirkten mittleren Jahresdosen liegen in verschiedenen Schweizer Gemeinden zwischen ca. 1 und 20 mSv; für Einzelpersonen kommen Werte bis ca. 150 mSv vor. Die Zuverlässigkeit der Mittelwerte ist jedoch begrenzt, weil bis

jetzt Radon-Konzentrationen nur in wenigen Häusern gemessen wurden und weil an den Messwerten Korrekturen vorgenommen werden müssen, was die Unsicherheit der Resultate erhöht. Die Dosen, die durch terrestrische und kosmische Strahlung verursacht werden, zeigen örtlich variable Werte zwischen ca. 0.5 und 1.5 mSv pro Jahr. Diese Dosiswerte wurden vorwiegend durch Messungen im Freien bestimmt. Deshalb können auch diese Resultate nur mit Einschränkungen in allfälligen epidemiologischen Studien verwendet werden.

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