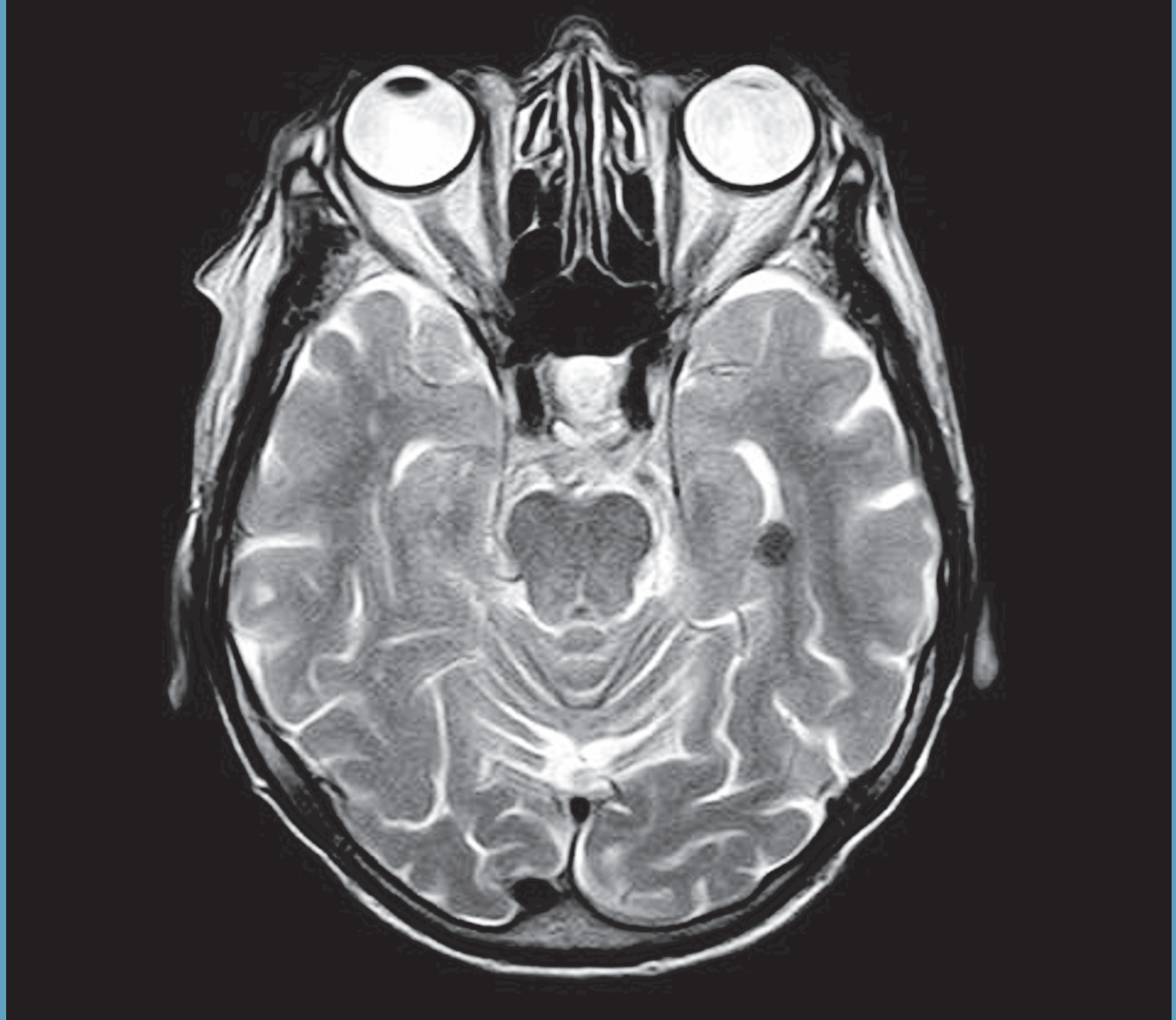
Health effects of ionising radiation and their consideration in RADIATION PROTECTION



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Health effects of ionising radiation and their consideration in radiation protection

Imprint

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Extended Summary

What happened after the nuclear accident of Chernobyl in 1986 seems to happen all over again after the accident of Fukushima in 2011. After Chernobyl it took about a decade until organisations like the International Atomic Energy Agency (IAEA) and the World Health Organisation (WHO) admitted that thyroid cancer caused by radioactive contamination increased in children and adolescents, even though the increase was quite obvious from 1990 onwards. Now that we are in the sixth year after Fukushima, the same authorities together with Japanese authorities downplay the already visible increases in thyroid cancer in the contaminated regions. And it is not only thyroid cancer that shows an increase after these two accidents. Also the incidence of other types of cancer and a lot of other diseases increase in populations affected from the Chernobyl accident, including diseases in the descendants of contaminated people.

While it has already been proven that radiation can cause negative health impacts like thyroid cancer and leukaemia, it is disputed if radiation can also be responsible for other health effects like heart diseases. And it is disputed if low or even very low doses of ionising radiation can cause measurable effects at all.

The effects of high radiation doses on humans (like acute radiation sickness) are documented quite well. But **the effects of low doses are still one of the most disputed topics in radiation protection.** Low doses result from nuclear installations during normal operation, from accident situations in nuclear facilities for workers and the public, from the nuclear bombs on Hiroshima and Nagasaki, but also from medical exposure and natural background.

The health effects of low dose radiation are discussed highly controversially as they are not easy to detect due to lack of detailed data, unreliable medical systems and the very large number of people affected. Furthermore, diseases like cancer cannot be attributed to a single cause.

Looking into recent European legal texts, several questions arise: What are dose limits and levels based upon? What models and epidemiological results have been used to determine these dose limits? Which experts are allowed to give input to the underlying scientific discussions, and whose work is neglected and why?

New insights in health effects of ionising radiation

Radiation protection has long been based mainly on the research of the survivors of the atomic bombs on Japan. The new INWORKS study on a big collective of nuclear workers (Richardson et al. 2015a) confirmed that **low, protracting doses result in risks that are comparable to risks of higher doses**.

Especially the **chronic lymphoblastic leukaemia (CLL)** was long believed to not be radiation induced, but now the results of a new study on Ukrainian Chernobyl liquidators prove that there is evidence for the contrary. (Zablotska et al. 2013)

In August 2016 it became known that two **Fukushima workers** who had developed **leukaemia** after receiving low dose of 16 mSv and 54.4. mSv, respectively, were entitled to workers compensation.

Thyroid cancer incidence after Chernobyl showed no decrease or is even still increasing in several groups of Ukrainian people. (Prysyazhnyuk et al. 2014, Brenner et al. 2011) In his update of the TORCH report, Ian Fairlie (2016) also showed a long latency period for thyroid cancer. A first study about **thyroid cancer after Fukushima** supported the results from Chernobyl studies. (Tsuda et al. 2016a) In 2016, the first worker of the Japanese nuclear enterprise TEPCO with thyroid cancer has been

acknowledged to have gotten the disease due to his work in NPP Fukushima. The man will receive compensation.

New studies show that **breast cancer** is not only caused by radioactive contamination but can even occur at low doses such as doses caused by effects of normal operation or well below 100 mSv like in the study of Pukkala et al. (2006). Breast cancer could also be caused by normal operation of NPPs. (Busby 2009)

Non-cancer diseases comprise a big group of diseases, among them cardiovascular diseases, diseases of the respiratory and the gastrointestinal tract, diabetes, cataracts etc. While the International Commission on Radiological Protection (ICRP) does not assume effects under a dose of 500 mSv, studies show that even at low dose an excess risk can be found (Buzunov et al. 1996, Ivanov 1996, Little et al. 2012) – which is of special interest, because f.e. cardiovascular diseases have a high prevalence and therefore many people can be concerned. **Cataracts** were long seen as deterministic radiation effect (occurring only over a certain threshold), but a new study suggest that they are also stochastic effects without a threshold. (Mämpel et al. 2015)

In several studies an increase in **leukaemia risk for children** who have been exposed in utero or in young years was found (Davies at al. 2006, Noshechenko et al. 2010, Busby 2009)

Normal operation of NPPs can also lead to health effects like childhood **leukaemia**, especially in children living in the vicinity. This is shown by studies from Germany, UK, France and Switzerland (Kaatsch et al. 2007, Bithell et al. 2008, COMARE 2011, Spycher et al. 2011). A recent published study reveals a highly statistically significant 37% increase in childhood leukaemia within 5 km of almost all NPPs in the UK, Germany, France and Switzerland. (Körblein and Fairlie 2012)

Furthermore, recent studies concerning **childhood cancer from natural background radiation** (Spycher et al. 2015, Kendall et al. 2013) and medical exposure indicate the high radio-sensitivity of children.

The ICRP assumes that the life-time cancer-risk following in utero-exposure is about three times higher than the risk of the overall population – but in the light of the depicted studies this assumption seems to be insufficient.

After exposure from ionising radiation (e.g. subsequent to nuclear accidents) **teratogenic effects** have been observed, even in those who were only exposed to low or very low levels of radiation. (Busby et al. 2009; Körblein and Küchenhoff 1997; Körblein 2003, 2004b) Exposure in-utero cannot only cause leukaemia and cancer, but also perinatal mortality, congenital effects etc.

The ICRP judges that, following **prenatal** (in-utero) exposure, a) cancer risk will be similar to that following irradiation in early childhood and b) a threshold dose (100 mSv) exists for the induction of malformations. In the light of recent scientific research this position has to be revised. (Körblein 2011)

Exposure of the germ cells (gonads) can cause mutations in the genetic material which may result in **heritable diseases** in the offspring of the exposed persons. According to ICRP, radiation-induced heritable disease has not been demonstrated in human populations but there is substantial evidence from animal studies of heritable damage to germ cells (ova and spermatozoa) as well as their precursor cells. However, the ICRP decreased its risk estimate for heritable damage between its recommendations of 1991 and the recent ones of 2007 (ICRP 1991, 2007)

Effects in populations exposed to Chernobyl fallout are excluded by the official committees (in particular ICRP), which claim that doses are too low to generate statistically observable increases. This, however, is certainly wrong, because it is known from many studies of chromosome aberrations (e.g. Busby 2015b), either that the doses calculated by the United Nations Scientific Committee on the

Effects of Atomic Radiation (UNSCEAR) are much too low or that there is an enhanced radiobiological effectiveness in the type of internal exposures or chronic delivery received by the Chernobyl groups.

Scientific uncertainty exists about the differences in tissue effects and therefore the risks from external versus internal radiation sources (NAS 2014).

When examining the risk of genetic damage by radiation it is very important to make a distinction between acute exposure to radiation and chronic exposition. Chronic radiation exposure results in permanent radiation of all stages of spermatogenesis. This explains the relatively high number of malformations and other congenital defects of the descendants of occupationally exposed men.

Schmitz-Feuerhake, Busby and Pflugbeil have published very recently a paper in which they bring up arguments for a new assessment. (Schmitz-Feuerhake et al. 2016) The authors criticize UNSCEAR and ICRP for their very low risk factors for hereditary diseases in humans based on reportedly absent genetic effects in the acute exposed Japanese atomic bomb survivors. Nearly all types of hereditary defects were found in cases affected by very low doses. The authors suggest that the results show that current radiation risk models fail to explain or even predict the many observations and should be abandoned.

All the congenital malformations effects are caused by mutation of DNA whether in the parental germ cells and precursors or from implantation to birth. Genetic effects in contaminated areas cannot be clearly distinguished from those resulting from in-utero exposure of embryos and foetuses.

In that light, the behaviour of the international associations (IRCP, WHO) is irresponsible, because at present it is already clear that the radiation risk for future generations will be much higher than assumed according to the existing risk factors, even though the full extent cannot yet be predicted.

Although there are numerous studies in the area of assessment of impacts of nuclear power plants on human health, it is still necessary to make follow-ups, especially to investigate radiation effects of normal operation of nuclear facilities in depth. Particularly in countries with many NPPs in operation and with NPPs situated in densely inhabited areas, **it is necessary to try to arrange for independent studies or independent reviews of existing studies.**

It is of uttermost importance that new insights in radiation effects will be considered in radiation protection law and measures.

European radiation protection legislation – the BSS-Directive

Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, the so-called BSS-Directive, establishes uniform basic safety standards in the EU. It applies to any planned, existing or emergency exposure situation with ionising radiation, caused by artificial or natural sources of radiation.

Based on new insights in health effects it can be concluded that **the dose limits in the BSS-Directive are too high**, they do not provide enough protection, especially for the embryo/foetus, children, pregnant women and young adults.

For the underlying dose calculations, it is important to shift the scientific focus from only studying the atomic bomb survivors to all other studies of consequences of Chernobyl, effects of natural background and of very low and low doses especially from normal operation of nuclear facilities. Recent studies show that using a dose and dose-rate effectiveness factor (DDREF) of two by ICRP is highly underestimating the measured effects. The **DDREF has to be reduced from 2 to 1**, which is now

recommended by the WHO and the German Commission on Radiological Protection (WHO 2013, p.32, SSK 2014).

Genetic and teratogenic effects are seriously underestimated, even though there is scientific evidence of effects like genetically induced malformations, cancers, and numerous other health effects in the children of father and/or mothers who were exposed to low doses of ionising radiation. The protection measures for **pregnant workers** have to be strengthened.

The assumptions of ICRP about the relative biological effectiveness of **neutrons** is also in question. A new approach from Walsh (2012) shows that a weighting of 10 according to ICRP 103 may not be optimal, and this practice should be reviewed.

Dose limits for single organs should be introduced, especially for the gonads and the thyroid.

In case of an emergency, countries have defined their dose levels for start of **emergency protection measures** like iodine tablets or evacuation. These intervention levels are based on the BSS-standards and therefore on recommendations of the ICRP. In Austria, a country without NPPs, some of the intervention levels are lower than in other countries, f.e. staying indoor for children and pregnant women is recommended if an effective dose of 1 mSv/7days is expected. The administration of iodine tablet for children should start if a thyroid dose of 10 mSv is expected. (IntV 2007) This can be considered as better practice. **Protecting people's health has to be the priority under any circumstances, in particular of the descendants.**

Because it has been proven that also very low doses can cause measurable health effects, it is recommended that besides the effective individual dose and single organ doses also the **collective dose** should be used in the BSS-Directive, levels for the collective dose should be determined especially in planned radiation situations.

It may not be possible to make amendments of the BSS-Directive itself (or even the underlying approach of ICPR), but the members states still have time until Feb 2018 to **implement the BSS-Directive into national law**. By doing so, member states could introduce dose limits that are below the maximum dose limits. Many countries have not implemented the BSS-Directive yet, so there is still time left for the interested public to enter the debate.

Medical diagnostics are valuable tools for human health, but can also cause measurable negative effects due to radiation. It contributes in Europe with approximately 1 mSv to the annual average dose, the largest part of it is received by X-ray diagnostics and computer tomography. Therefore, a reasonable reduction of the use of these diagnostic tools can be recommended.

ICRP and the Article-31-Group of Experts are the only expert groups who can at the time-being influence radiation protection legislation. The ICRP has no democratic legitimation. The Article-31-Group is staffed by the member states, but its consulting has often not been made public. **It would be preferable to have independently staffed expert groups with public participation, and whose work is made transparent.**

Permitted food contamination in case of another Super-GAU: the Food Level Regulation

After the accident of Chernobyl in 1986 large amounts of food and feed were contaminated by radioactive material. Not only Belarus, Ukraine and Russia were affected, but also many countries in Europe inside and outside the EC (European Communities at that time). The EC wanted to make sure that only such agricultural products were put on the EC-market that did not exceed a defined level of contamination. Therefore, three regulations for maximum levels in food and feed were established:

These regulations allowed the European Commission to quickly adopt an implementing regulation in case of a radioactive contamination – for the first time such an implementing regulation was applied in 2011 after the nuclear accident in Fukushima. After long years of amending these regulations, in February 2016 a new regulation has entered into force: Council Regulation Euratom 2016/52 for "laying down maximum permitted levels of radioactive contamination of food and feed following a nuclear accident or any other case of radiological emergency" (food level regulation).

But when analysing the underlying assumptions that have led to the food levels, errors and neglected facts become obvious. The maximum permitted food levels in Council Regulation Euratom 2016/52 are too high and should be reduced due to the following arguments:

For dose calculations in the food level regulation an assumption is used that only 10% of all food is contaminated up to the maximum and 1% of liquid food, respectively. This will not be true in a worst case of severe nuclear accident in one of the EU member states and under unfavourable meteorological conditions.

It is assumed that an effective ingestion dose of 1 mSv will not be exceeded it the food levels are not exceeded. But when the assessment of the Art.-31-Group of Experts in Publication 105 (EC 1998) is recalculated, an effective ingestion dose level of 1 mSv will be exceeded for infants and adults using the assumption that in one year only food is consumed of which 10% (1% for liquids) is contaminated up to the maximum permitted level. This recalculation results in 3.1-7.8 mSv instead of 1 mSv.

The underlying data on dietary habits and food consumption are outdated by more than 25 years. Moreover, for only 10 EU member states out of 28, food data have been researched and used in calculations. Dietary habits have changed in the meantime, this can lead to much higher ingestion dose than assumed in the food level regulation.

The Art.-31-Group recommends in its Publication 105 that member states should establish regularly the typical dietary habits for different regions so that in the case of an accident no underestimations of actual consumptions rate occur. This recommendation is very important. The interested public should ensure that member states have their updated dietary data prepared so that on the occasion of implementing a food level regulation they can derogate from the food levels and introduce food levels that are best for ensuring their people's health.

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