Conflict of interests, flexibility of regulations

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Note
In this document the references are coded by Q-numbers (e.g. Q6). Each reference has a unique number in this coding system, which is consistently used throughout all publications by the author. In the list at the back of the document the references are sorted by Q-number. The resulting sequence is not necessarily the same order in which the references appear in the text.

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Introduction into a complex matter

Intricate connections

The nuclear energy system – the complete system of industrial processes directly associated with the generation of nuclear energy – is the most complex energy system ever, not only in the technical sense, but also in economic, political and societal senses.
As a result it is very difficult for the public and policy makers – and even for most people in the nuclear field – to get a reliable overview of the nuclear energy system: it is opaque due to its complexity. This confusing situation is exacerbated by divergent perceptions of the large uncertainties still existing with regard to the inevitable consequences of nuclear power. Economic, political and/or scientific arguments may easily exhibit widely different scopes and turn out to be not always compatible. So it may happen that physical arguments are refuted by economic arguments.

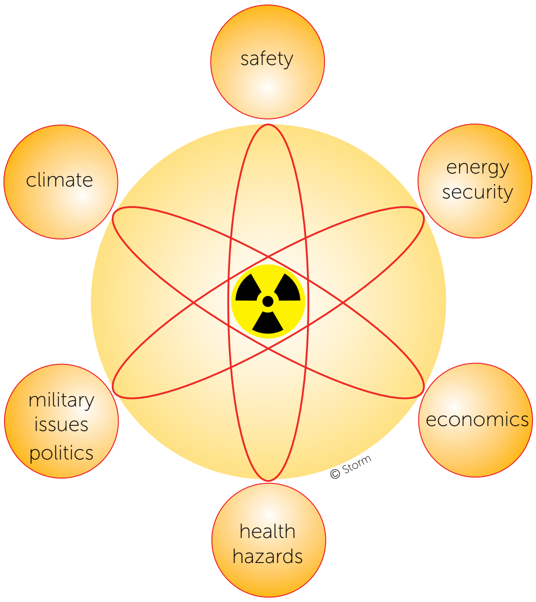

Figure 1
Symbolic representation of the technical, economic, political, military, financial, environmental and societal issues and stakeholders of the nuclear energy complex.

Nuclear security is addressed in the report *Nuclear security, in cauda venenum*.
Climate aspects are addressed in the report *Climate change and nuclear power.*
This report addresses several aspects of nuclear safety and health hazards.
Military are not addressed in this study.although military and civil nuclear technology are inseparable. Economic/financial issues are not discussed either.

Lack of transparency

Not only by its complexity is the nuclear world opaque for the general public, policy makers, scientists outside the nuclear establishment and even for many scientists within, but also as a result of the onesided information flow and the paradigm dominating the nuclear corporate culture. Economic considerations and corporate interests play an important role. Misunderstandings may easily arise from the limited system boundaries and limited time horizon the nuclear industry applies when discussing the benefits of the nuclear energy system.

Reliable insight in nuclear matters is further complicated by the misleading practice of the nuclear industry to present unproved technical concepts as being mature technology, just waiting on the shelf to be implemented on demand. One illustration of this behaviour is the use of the word ‘is’ when discussing concepts existing only on paper, where words like ‘might be’ would be more in order. Many examples of this unfounded optimism are based on concepts from the 1960s and 1970s, such as the uranium-plutonium breeder reactor, the thorium reactor, and technical means to make spent fuel a source of energy and nearly ‘harmless’ to humankind. Another example are the ‘not-to-worry-about’ statements with respect to radioactive waste management.
There are more factors seriously confusing the discussions on the hazards of nuclear power.

Secrecy and unknowns

Large financial, political and military interests are playing a prominent part in the nuclear world. This situation may easily evoke a culture of secrecy. In cases of undesired incidents and critiques from the public corporate and/or political interests come quickly into play, which may easily lead to an over-optimistic view of the benefits and to a downplaying of adverse consequences of nuclear power.
Such a course of events would be in conflict with democratic principles, because the public is generally faced with the consequences of undesired developments, such as massive cost overruns and health hazards. And the costs of decommissioning, the backend of the nuclear fuel cycle, after the shutdown of nuclear power plants are to the account of the taxpayer. These costs are of unprecented size, to be counted in hundreds of billions of dollars, will mean a heavy drain on the economies of the future, the more so because these costs are to be considered pure economic losses: the sole purpose is to remove the products from the economic system and human environment forever.

No empirical figures are available for the energy and material consumption of the full back end of the nuclear energy system, for a number of essential processes still don’t exist in practice. In the few cases empirical figures are available, these figures often exhibit considerable spreads in their estimates. Any statement that presents solid figures without indicating an appreciable uncertainty range, is unscientific and misleading.
Assessment of the implications of nuclear power should be taking the whole cradle-to-grave period into account, because the greatest safety and health risks originate in the activities and processes following the final shutdown of a nuclear power plant, the so-called back end part of the nuclear process chain. It is precisely these processes that are posing the greatest uncertainties and unknowns in relation to safety and health hazards.

Summarised, in addition to secret and inaccessible data there are also unknown data in the nuclear world: technical, financial and societal data on still-non-existant but inevitable processes and activities that will be required in the (near) future to reduce the harm of the nuclear aftermath as much as possible and to keep densily populated areas, like Europe, habitable.

Entanglement of interests

Another factor seriously troubling the transparency of the nuclear world is the one-sidedness of the information flow to people outside of the nuclear world. Information on nuclear matters provided to the public and politicians originates almost exclusively from institutions with vested interests in nuclear power, such as: IAEA, World Nuclear Association (WNA, the official representative of the Western nuclear industry),

Nuclear Energy Institute (NEI) in the USA, Areva, Electricité de France (EdF), the latter two being 90% state-owned in France. The views of the Nuclear Energy Agency (OECD-NEA) rely heavily on the IAEA and WNA. The IAEA plays a dominant role in statements to the world concerning nuclear safety and health effects of dispersion of radioactive materials into the human environment.
How is the situation in other countries of the world?

The two mandates of the IAEA

Communication between the nuclear industry and the general public is dominated by the International Atomic Energy Agency (IAEA). The authoritative 'nuclear watchdog' IAEA has the promotion of nuclear power in its mission statement. Moreover, official publications of the IAEA have to be approved by all member states of the IAEA.

For these reasons it is a misconception to regard the IAEA as an independent scientific institute. One face of the IAEA is looking at the safeguards of nuclear materials and technology, the other face is looking at the promotion of nuclear technology and nuclear power.

Two other international nuclear institutions, the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) have strong connections with the IAEA.

The main task of the ICRP seems to be the formulation of a legal framework for authorities and politicians on how to cope with liabilities which may arise from exposure of people to radiation.

Role of the WHO

The World Health Organization (WHO) also reports on the health aspects of nuclear power, especially in case of large accidents (Chernobyl, Fukushima). Although the WHO is an independent UN organization, its reports on nuclear matters are subject to IAEA's approval.

Deficient information to policy makers

Above mentioned features of the nuclear energy system, such as: complexity, secrecy, entanglement of interests and missing data, ends up in a deficient knowledge of the far-reaching aspects of the nuclear system among the majority of decision makers. Such a situation leaves ample room for the nuclear industry to dominate the advisory role from the perspective of its own interests and agenda. This situation is seriously exacerbated by the systematic denial by the nuclear industry of the health effects caused by exposure to radiation and to radionuclides released into the environment during nominal operation of nuclear power plants and reprocessing plants and especially during the disasters at Chernobyl and Fukushima. Information on this issue is dominated by the IAEA.

Lack of transparency and the other factors mentioned above might render it very difficult for decision makers to compile a sufficiently broad and detailed overview of the pros and cons of a given nuclear issue, to enable independent choices. In this way the democracy cannot perform adequately.

No scientific discourse, absence of feedback

What the nuclear industry terms the 'negative perception of nuclear power' by the general public, many politicians, and scientists outside of the nuclear world is not improved by the practice of the nuclear industry and associated institutions of ignoring critical publications or dismissing them as 'unscientific', 'erroneous' or as 'myths', thus avoiding any discussion of the scientific arguments presented in these publications. Critical studies are not even mentioned in the reports of the IAEA, UNSCEAR and WHO.

The above cited designations are striking in view of the fundamental scientific flaws applied by the nuclear industry in their reports on radioactive waste management, safety and consequences of the Chernobyl and Fukushima disasters, as will be discussed in this report.

Concealment

This report focuses on the concealment of the hazards posed by the immense amounts of radioactivity generated each year by nuclear power stations. Non-radioactive chemical pollution and terroristic threats are left outside the scope. Economic arguments are sometimes mentioned but not discussed.
A culture of highlighting the benefits and concealing the adverse aspects of nuclear power has degenerated into a culture of downplaying and denial of hazards. This report analyses three lines in this culture by comparing empirical evidence to official publications from the nuclear industry, IAEA, UNSCEAR and WHO.

- downplaying and denial of risks posed by radioactive waste
- downplaying and denial of nuclear safety risks
- downplaying and denial of health effects of contamination with radioactive materials as a result of normal operation of nuclear power plants and the disasters of Chernobyl and Fukushima.

Moreover some limitations and the dominant role of the radiological models used by the nuclear industry are discussed.

Après nous le déluge

With respect to radioactive waste problems and health risks the nuclear world seems to foster a culture of downplaying and concealing risks combined with an unrealistic belief in unproved and unfeasible technical concepts. This paradigm is exacerbated by a chronic habitus of short-term profit seeking and living on credit that may be best described as an *après nous le déluge* attitude, justified by questionable arguments and fallacies, such as: "Technology advances with time and future generations will be richer than our generation, so they will have more economic means and better technological possibilities at their disposal to handle the waste problem."
As a result of this paradigm the nuclear industry is building up a giant energy debt, which might pose unprecedented health hazards.

Three international nuclear authorities and the WHO

The international coverage of the hazards of nuclear power is chiefly determined by three international nuclear institutions: International Atomic Energy Agency (IAEA), International Commission on Radiological Protection (ICRP) and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Bertell 2002 reports on the strong connections between IAEA and UNSCEAR and ICRP, the authorities who formute the recommendations and standards regarding allowable radiation doses. The three nuclear institutions are briefly discussed below.

International Atomic Energy Agency, IAEA

Statute and mission statement

The International Atomic Energy Agency (IAEA) is an international organisation that seeks to promote the peaceful use of nuclear energy, and to inhibit its use for any military purpose, including nuclear weapons. The IAEA was established as an autonomous organization on 29 July 1957. Though established independently of the United Nations through its own international treaty, the IAEA Statute [http://www.iaea.org/About/statute.html], the IAEA reports to both the UN General Assembly and Security Council. Eighteen ratifications were required to bring the IAEA's Statute into force on 29 July 1957.
Total Membership: 159 (as of February 2013). The Democratic People's Republic of Korea (DPRK), which joined the IAEA in 1974, withdrew its membership of the IAEA in 1994 [http://www.iaea.org/About/Policy/MemberStates/]. Official publications of the IAEA have to be approved by all member states of the IAEA.

The Mission Statement of the International Atomic Energy Agency reads, the IAEA:

* is an independent intergovernmental, science and technology-based organization, in the United Nations family, that serves as the global focal point for nuclear cooperation;
* assists its Member States, in the context of social and economic goals, in planning for and using nuclear science and technology for various peaceful purposes, including the generation of electricity, and facilitates the transfer of such technology and knowledge in a sustainable manner to developing Member States;
* develops nuclear safety standards and, based on these standards, promotes the achievement and maintenance of high levels of safety in applications of nuclear energy, as well as the protection of human health and the environment against ionizing radiation;
* verifies through its inspection system that States comply with their commitments, under the Non-Proliferation Treaty and other non-proliferation agreements, to use nuclear material and facilities only for peaceful purposes.

The mandates of the IAEA: conflict of interests

The IAEA has two mandates: one as watchdog to prevent malicious use of nuclear technology – a role primarily restricted to guarding against illegal nuclear weapons production and proliferation risk –, the other as *promotor* of nuclear power. Its official publications have to be approved by the member states. These mandates, in particular the promotion of nuclear power, create a serious conflict of interest, thus the IAEA cannot be considered to be an independent scientific institute. No agency can be a true watchdog for an industry it is tasked with promoting.
Political and economic interests may always play a role in decision processes concerning nuclear issues.

International Commission on Radiological Protection, ICRP

Statute

The International Commission on Radiological Protection (ICRP) is an advisory body providing recommendations and guidance on radiation protection. It was founded by the International Society of Radiology (ISR) in 1928 and was then called the International X-ray and Radium Protection Committee (IXRPC). It was restructured and given its present name in 1950 [ICRP 109 2009] Q543. The ICRP has more than 200 volunteer members from about 30 countries. According to the ICRP publication *1959 Decisions* [www.icrp.org]:

> "The Commission has an official relationship with the World Health Organization and the International Atomic Energy Agency. There has been close co-operation with the United Nations Scientific Committee on the Effects of Atomic Radiation, …"

International System of Radiological Protection

The International System of Radiological Protection, developed by the ICRP [www.icrp.org] is based on:

- current understanding of the science of radiation exposures and effects, and
- value judgments. These value judgments take into account societal expectations, ethics, and experience gained in application of the system.

The system of radiological protection that is used across Europe and worldwide is based on the recommendations of the ICRP and the International Commission on Radiation Units and Measurements (ICRU), according to [SCENIHR 2012] Q533. These recommendations are based on three fundamental principles:

- justification
- optimisation and
- dose limitation.

> "The principle of justification requires that any decision that alters the radiation exposure situation should do more good than harm; in other words, the introduction of a radiation source should result in sufficient individual or societal benefit to offset the detriment it causes."
>
> "The principle of optimisation requires that the likelihood of incurring exposures, the number of people exposed and the magnitude of their individual exposure should all be kept as low as reasonably achievable, taking into account economic and societal factors. In addition, as part of the optimisation procedure, the ICRP recommends that there should be restriction on the doses to individuals from a particular source and this leads to the concept of dose constraints."
>
> The principle of dose limitation requires that
>
> "the dose to individuals from planned exposure situations, other than medical exposure of patients, should not exceed the appropiate limits recommended by the Commission."

As part of the system of radiological protection [ICRP 103 2007] Q544 defines three categories of exposure situations, namely:

- Planned exposure situations, which are situations involving the planned introduction and operation of sources. (This type of exposure situation includes situations that were previously categorised as practices).
- Emergency exposure situations, which are unexpected situations such as those that may occur during the operation of a planned situation, or from a malicious act, requiring urgent attention.
- Existing exposure situations, which are exposure situations that already exist when a decision on control has to be taken, such as those caused by natural background radiation.

The principles of justification and optimisation apply universally to all three exposure categories, whereas dose limits apply only to planned exposure situations, except some medical exposure situations. The ICRP recognises three categories of exposed individuals: workers, patients and members of the public. These categories of exposure are known as occupational, public and medical exposure.
It is not clear how the situations in the contaminated areas around Chernobyl and Fukushima would be categorized and what consequences such a categorization would have for the population in the affected areas.

Scope of recommendations

Originally the exposure recommendations of the ICRP were designed for application in known radiation exposure situations: the planned introduction of radiation sources (X-ray and natural radioactive material, such as radium) for medical, scientific and technical purposes. These issues still are by far the main field of the ICRP, as is apparent from the complete list of ICRP publications. Only a minor number of the 140+ ICRP publications deal with exposures as a result of human-made radioactivity from nuclear power.

The main task of the ICRP seems to be the formulation of a legal framework for authorities and politicians on how to cope with liabilities which may arise from exposure of people to radiation and/or radioactive materials [ICRP 103 2007] Q544 and [ICRP 111 2009] Q535.

Generation of human-made radioactivity

Location and content of medical and industrial radiation generating sources are known and usually contain one specific radionuclide, consequently these sources are fairly well under control. With the advent of nuclear reactors the exposure recommendations had to be adapted to situations with a new kind of radiation sources. In nuclear reactors dozens of different radionuclides are generated during the fission process and the content of radioactivity of one reactor may be a trillionfold larger than the radiation potential of the sources before the nuclear era. During the past 60 years an amount of human-made radioactivity greater than the equivalent of more than 12 million exploded nuclear bombs has built up, at hundreds to thousands of facilities and locations worldwide, an amount growing by some 300 000 bomb equivalents each year. Consequently the field to be covered by radiological protection has grown immensely during the past 60 years and is still growing.

Uncontrollability of radiation sources

Report m17 *Pathways of radioactive contamination* addresses the mechanisms of dispersion of human-made radioactive material into the human environment. As every engineer knows: no technical installation is leakfree, leaks are unavoidable. The amounts of radioactive materials leaking into the biosphere are growing year by year for several reasons:

- increasing global inventory of human-made radioactivity
- increasing number of storage locations
- unavoidable ageing of materials, accelerated by the nuclear radiation
- inadequate operational procedures and maintenance.

In addition to these unplanned releases radioactive materials are discharged into the human environment by:

- practice of authorised routine releases, chiefly for economic reasons
- large accidents.

Concomitant problems are that routine releases of nuclear power plants are rarely measured, so remain an unknown, and that unplanned discharges often are discovered only after a length of time, if discovered at all. Moreover unplanned discharges are often kept secret.
The chance of exposure to radioactive substances and ionizing radiation from human-made sources is approaching 100%: in the Northern hemisphere people can be quite sure being exposed to human-made radioactivity. The question is not *if*: the question is: *how much* radioactivity and which radionuclides, and how could exposure be minimised or prevented?

Protection?

What does 'radiological protection' mean to the people living involuntarily in permanently contaminated areas? These areas exist not only in the vicinity of Chernobyl and Fukushima, but also near operating nuclear power plants and reprocessing facilities, which contain and release large amounts of radioactive materials, . How is the word 'protection' in the name 'International Commission on Radiological Protection' to be interpreted by the general public when, after a nuclear incident, the permissable level of radioactivity in food and water is instantly raised, without any scientific argument or discussion, by a factor of 10, 100 or even more, as happpened after the Fukushima disaster?

'Not measured' does not mean 'not present'

Releases of radioactive materials into the human environment are often not measured, at least not over prolonged periods. Contamination of fish and food and drinking water contaminated with various kinds of radionuclides are sparsely monitored, if at all - and even then, only for easily detectable radionuclides, such as cesium-137. The presence of tritium, carbon-14, actinides and many other biochemically active and dangerous radionuclides, can be found only by special equipment.

United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR

Statute

The United Nations Scientific Committee on the Effects of Atomic Radiation was established December 3, 1955. The United Nations General Assembly has designated 27 States as members of the Scientific Committee. The mandate reads [UNSCEAR 2010] Q531:

> "to undertake broad assessments of the sources of ionizing radiation and its effects on human health and the environment."

More information on UNSCEAR can be found in, among others, [UNSCEAR 2013b] Q573.

Atomic versus nuclear

At the time of the establishment of UNSCEAR, the only publicly known sources of atomic radiation were atomic bomb explosions, especially those of Hiroshima and Nagasaki, and from natural sources (uranium- and thorium-bearing minerals). No commercial nuclear power plants existed then and the small number of military reactors in only a few countries around the world were hidden from the view of the general public.
Note that the adjective 'atomic' has long been replaced by 'nuclear' in official publications, likely to avoid association with atomic bombs; only in the names of some international institutes, such as IAEA and UNSCEAR, has the adjective 'atomic' remained unchanged.

Missing notions

In the text of [UNSCEAR 2010] Q531 virtually no mention is made of human-made radioactivity: radiation sources generated by the fission process in nuclear reactors, only sources of natural radiation and radiation from the atomic bombings in Japan are mentioned.
Also missing from the text are:

- references to nuclear power stations, let alone as sources of radiation exposures.
- large nuclear accidents, e.g. Chernobyl
- routine emissions of nuclear power plants, reprocessing plants and uranium mining
- releases of (human-made) radioactive materials into the environment from deteriorating waste storage facilities, leaking pipes and, storage tanks.

A false claim

The Committee [UNSCEAR 2010] recognizes:

> 'that its assessments of radiation exposures from electricity generation, while up to date and detailed for the nuclear fuel cycle, were out of date for the enhanced levels on naturally occurring radioactive material associated with the use of fossil fuels, and moreover had never been assessed in a comparable way for renewable energy sources.'

The first part of this statement – 'while up to date and detailed for the nuclear fuel cycle' – is untrue for several reasons:

- The operational (authorised) emissions of radioactive materials, and resulting exposures of the public to radiation and radioactive materials, by nuclear power plants, reprocessing plants and other nuclear facilities are seldom measured. Generally the authorised emissions increase with time, due to ageing of the facilities. Data on these emissions in the open literature are extremely scarce.

- All radioactive wastes from the nuclear fuel chain (the term 'fuel *cycle*' is incorrect because the chain is not closed) are still stored in temporary, and usually above-ground, storage facilities. The number of these storage facilities is increasing with time and the unplanned leakages are also increasing, due to progressive deterioration and ageing of the materials.
- UNSCEAR ignores the fact that the most crucial processes of the back end of the nuclear process chain, the permanent isolation of radioactive wastes from the biosphere, still exists only on paper. Consequently the emissions of radioactive materials into the environment, and so the exposures to radiation, in the future remain unknown, but certainly will increase.
- What about the radioactive wastes that have been dumped into the sea, including complete military reactors?
- What about the massive and ongoing emissions as a result of large accidents, such as Chernobyl and Fukushima? Did UNSCEAR include these emissions in its assessment?
- UNSCEAR likely omitted from its assessment the exposure to dangerous radionuclides (via dust, groundwater) as a result of uranium mining. Vast areas are exposed to these unreported emissions. The following statement of the nuclear industry is striking [WNA 2016a] Q540:

  "Strictly speaking these [mining and milling wastes] are not classified as radioactive wastes".

One grain of sand and a pile of boulders

Apart from the false claim discussed above, the statement of UNSCEAR contains another remarkable phrase:

> 'and moreover had never been assessed in a comparable way for renewable energy sources.'

Renewables comprise solar power (PV and CSP), wind power, biomass, hydropower and geothermal sources. Except for perhaps geothermal power, the use of renewables does not mobilize radioactive materials. The materials used for renewables, chiefly concrete, steel, aluminium, glass, silicium and organic materials, contain barely detectable amounts of radioactive elements. During the production of these materials from minerals (ores) and biomass minute amounts of natural radioactive materials are mobilized, for example from coal used to produce steel.
For comparison: an offshore windpark of 1 GWe consumes about 5.2 grams of construction materials per kilowatthour during its lifetime. The finished materials and structures contain practically no radionuclides and are fully recyclable.
Averaged over its full cradle-to-grave period a nuclear power plant of 1 GWe consumes 50 g/kWh of construction materials, of which only 5 g/kWh is recyclable. Materials needed for operation and maintenance are not counted here, in common with the wind power figure. In addition to this a NPP consumes and contaminates 17 g/kWh of fresh water, consumes 26 g/kWh of uranium ore (grade 0.1% U) and displaces 130 g/kWh of rock, part of which is weakly radioactive. By processing 26 g/kWh uranium ore, some 3900 Bq/kWh (becquerel per kilowatthour) of radioactive elements (U, Th, Po, Bi, Pb, Rn, Ra and Pa) are mobilised from their host rock and released into the environment as dust or dissolved in groundwater [Diehl 2011].

Also important is the fact that a nuclear power plant *generates* massive amounts of human-made radioactivity: fission products and activation products. The amount of human-made radioactivity leaving the nuclear reactor is a *billionfold* greater than the amount of natural radioactivity of the uranium entering the reactor.

Using a metaphor: the UNSCEAR seems to be worrying more about an amount of radioactivity associated with renewable energy sources, comparable to a grain of sand, than about the amounts of radioactivity, associated with nuclear power, comparable to the size of a massive pile of large boulders.

Natural radiation sources and human-made sources

The work of UNSCEAR seems to be focused on exposure to external radiation chiefly from natural sources. The impression is given that UNSCEAR (and also ICRP) cares more about radiation from natural sources than from human-made sources. Is natural radioactivity more dangerous than human-made radioactivity? If we have to worry about natural radioactivity, why not about radioactivity from nuclear power plants? The human-made amounts present in the human environment may be a billionfold greater than the natural amounts and involve dozens of hazardous radionuclides not occurring in nature, a number of which can easily enter the food chain and drinking water when released into the environment.

Shifting focus?

Only recently has the Committee decided to focus work on internal emitters, tritium, and uranium [UNSCEAR 2010] Q531. Besides this, the UNSCEAR is tasked with conducting:

> 'assessments of radiation effects and risks especially for childern, and of the epidemiology of exposures of the public to natural and artificial environmental sources at low doses and low dose rates'.

This statement may refer to, among other things, the results of the [KiKK 2007] Q392 and [GeoCap 2012] Q494 studies, without mentioning these studies. Yet no firm plans or investigations have been announced by UNSCEAR.

Diificult attribution

Many difficulties are encountered in attributing specific cases of disease to low-dose radiation exposure according to [UNSCEAR 2010] including:

- The lack of specificity in the type or characteristics of disease induced by radiation exposure
- The long delay (years or decades) between exposure and disease presentation
- The high spontaneous incidence of diseases associated with radiation in the ageing general population.

It is not clear what is meant by the third point. What about young people?

Old exposure data set of limited scope

The Committee [UNSCEAR 2010] has judged that:

> "the single most informative set of data on whole-body radiation exposure comes from studies of the survivors of the atomic bombings in Japan in 1945. The atomic bombing exposures were predominantly high-dose-rate gamma radiation with a small contribution of neutrons."

These studies started about five years after the bombings, so the deaths during these first five years are not counted [CERRIE 2004] Q414. Would the methodology of these studies comply with present scientific views and insights?
A second point is that these data sets are concerning only exposure to gamma rays and a small contribution of neutrons from an external source, and consequently do not comprise data on exposure to alpha and beta rays from radionuclides inside the body after contamination with radioactive materials via air, water and food.

A third point is that these data sets are concerning two events of exposure to exclusively external radiation during a short period. Is it scientifically justified to extrapolate a model based on these data sets to situations of prolonged exposure? Or: is a dose of 1 sievert of gamma radiation contracted during 1 hour equivalent to a dose of 0,1 mSv/h of alpha-, beta- and gamma radiation in the course of 10 000 hours?

The above statement of UNSCEAR implies, strikingly, that in the more than 60 years of nuclear activity since the bombs on Hiroshima and Nagasaki, including nuclear weapons tests, operation of military reactors and implementation of large-scale civil nuclear power, no better data sets have been generated. During the period following the studies of the survivors of the atomic bombings in Japan, the amount of human-made radioactivity rose to the equivalent of more than 10 million Hiroshima bombs and is still rising at a present rate of about 300000 nuclear bomb equivalents a year.

Ambiguous report

Apparently the qualifications of UNSCEAR to assess all kinds of radiation sources and their effects on the health of populations and individuals are limited. The text of UNSCEAR 2010 Report, written in bureaucratic language, seems to be ambiguous. On one hand the Committee points out studies and new evidence which should be reviewed, on the other hand the Committe seems to stick to 60 year old data bases and seems to be reluctant to endorse scientific efforts to validate new evidence from sources other than than the official United Nations sources.

The WHO and nuclear health hazards

Constitution

The text below is from [WHO 2009] Q562:

CONSTITUTION OF THE WORLD HEALTH ORGANIZATION[1]

THE STATES Parties to this Constitution declare, in conformity with the Charter of the United Nations, that the following principles are basic to the happiness, harmonious relations and security of all peoples:

Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.
The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition.
The health of all peoples is fundamental to the attainment of peace and security and is dependent upon the fullest co-operation of individuals and States.
The achievement of any State in the promotion and protection of health is of value to all.
Unequal development in different countries in the promotion of health and control of disease, especially communicable disease, is a common danger.
Healthy development of the child is of basic importance; the ability to live harmoniously in a changing total environment is essential to such development.
The extension to all peoples of the benefits of medical, psychological and related knowledge is essential to the fullest attainment of health.
Informed opinion and active co-operation on the part of the public are of the utmost importance in the improvement of the health of the people.
Governments have a responsibility for the health of their peoples which can be fulfilled only by the provision of adequate health and social measures.

ACCEPTING THESE PRINCIPLES, and for the purpose of co-operation among themselves and with others to promote and protect the health of all peoples, the Contracting Parties agree to the present Constitution and hereby establish the World Health Organization as a specialized agency within the terms of Article 57 of the Charter of the United Nations.

[1] The Constitution was adopted by the International Health Conference held in New York from 19 June to 22 July 1946, signed on 22 July 1946 by the representatives of 61 States (Off. Rec. Wld Hlth Org., 2, 100), and entered into force on 7 April 1948. Amendments adopted by the Twenty-sixth, Twenty-ninth, Thirty-ninth and Fifty-first World Health Assemblies (resolutions WHA26.37, WHA29.38, WHA39.6 and WHA51.23) came into force on 3 February 1977, 20 January 1984, 11 July 1994 and 15 September 2005 respectively and are incorporated in the present text.

Objective of the WHO

Quote from [WHO 2009] Q562:

CHAPTER I – OBJECTIVE

Article 1

The objective of the World Health Organization (hereinafter called the Organization) shall be the attainment by all peoples of the highest possible level of health.

Agreement between IAEA and WHO

Quote from [WHO 2009] Q562 p.62;

AGREEMENT BETWEEN THE INTERNATIONAL ATOMIC ENERGY AGENCY
AND THE WORLD HEALTH ORGANIZATION1
Article I – Co-operation and Consultation

1. The International Atomic Energy Agency and the World Health Organization agree that, with a view to facilitating the effective attainment of the objectives set forth in their respective constitutional instruments, within the general framework established by the Charter of the United Nations, they will act in close co-operation with each other and will consult each other regularly in regard to matters of common interest.

2. In particular, and in accordance with the Constitution of the World Health Organization and the Statute of the International Atomic Energy Agency and its agreement with the United Nations together with the exchange of letters related thereto, and taking into account the respective co-ordinating responsibilities of both organizations, it is recognized by the World Health Organization that the International Atomic Energy Agency has the primary responsibility for encouraging, assisting and co-ordinating research on, and development and practical application of, atomic energy for peaceful uses throughout the world without prejudice to the right of the World Health Organization to concern itself with promoting, developing, assisting, and co-ordinating international health work, including research, in all its aspects.

3. Whenever either organization proposes to initiate a programme or activity on a subject in which the other organization has or may have a substantial interest, the first party shall consult the other with a view to adjusting the matter by mutual agreement.

WHO's relationship with the IAEA

In its report [WHO 2011a] Q570 the WHO states:

> WHO and the IAEA are both UN entities. WHO is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries, and monitoring and assessing health trends.
> The IAEA is the UN system agency which works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies.
> WHO collaborates with the IAEA on a number of areas including the medical use of radiation, radiation protection and the safety of the public and workers, and radio-nuclear emergency preparedness and response.
> ...
> Mention has often been made of WHO's 1959 agreement with the IAEA. This is a standard agreement similar to agreements it has with other UN agencies as a means of setting out respective areas of work. This agreement has never once been used to stop or restrict WHO's work.
> The agreement serves the purpose of promoting co-operation and consultation between WHO and IAEA. It was approved by the highest governing body of each Organization.
> The agreement between WHO and IAEA does not affect the impartial and independent exercise by WHO of its statutory responsibilities, nor does it subordinate one Organization to the other.
>
> The clause appearing in Article III dealing with the safeguarding of confidential information is a standard provision in many agreements of this kind (including WHO agreements with the UN, ILO, FAO, UNESCO, and UNIDO). On

the one hand, it ensures each Organization will continue to meet its obligations to protect certain information it is duty bound to safeguard. In the case of information held by WHO, such a clause is relevant, for example, for the protection of clinical and other similar data on individuals. On the other hand, the provision makes clear that subject to such situations, each Organization "shall keep [the] other fully informed [of] all ... work" of mutual interest. Thus, such provisions actually work to improve information flow as they limit the exceptions to the free-flow of information. WHO environmental health experts will continue the scientific collaboration with radiation and health experts at IAEA. This entails not only nuclear safety issues and assistance in radiation emergencies, but also the application of clinical techniques connected with such issues.

WHO activities on nuclear matters are not in any way hampered by the WHO/IAEA agreement. Both Organizations are working tirelessly to assist countries and the global community to deal with this complex emergency.

WHO not independent concerning nuclear issues

How independent are the reports of the WHO on the consequences of radioactive contamination for the local inhabitants resulting from nuclear accidents, for example after the disasters of Chernobyl and Fukushima?
Although the WHO is an independent UN organization, its reports on nuclear matters are subject to IAEA's approval.
According to an agreement between the International Atomic Energy Agency and the World Health Organization (UN Res. WHA12-40, 28 May 1959) the WHO cannot operate independently of the IAEA on nuclear matters. Worth reading are the articles on this issue of [Sinaï 2013] Q526 and [Tickell 2009] Q527 discussing the 'nuclear paradox' and the 'toxic link' WHO-IAEA.

The IAEA ranks higher in the UN hierarchy than the WHO. According to [Bertell 2002] Q420 there are strong connections between the IAEA and UNSCEAR and ICRP, the authorities who formulate the recommendations regarding allowable radiation doses.

In view of the above observtions the authoritive 'nuclear watchdog' IAEA, having strong interests in the nuclear industry, may not be considered an independent scientific institute, .

Regulations and standards under economic pressure

Apart from the energy debt and its potential health risks in the near future, economic pressure as present today is enhancing the health risks of nuclear power. Safety measures are vulnerable to economic pressure and short-sighted actions: the standards, the quality control and the independency of inspections. These issues are briefly addressed in this section. Nuclear safety and economics are at odds.
De-regulation (liberalisation) of electricity markets has pushed nuclear utitlities to decrease safety-related investments and limit staff [Hirsch et al. 2005] Q169.

Liability

The Price-Anderson Act was enacted in the USA in 1957 as a supplemental 'insurance policy' for nuclear power plants. With this act, providing equal liability protection regardless of risk, the cost of additional safety features becomes a financial impediment for a nuclear plant owner. New nuclear reactors must be excluded from liability protection under the Price-Anderson Act [Lochbaum 2004] Q76:

> 'If new reactors are truly so safe that the public need not be protected from technological disaster, then they are also so safe that their owners need not be protected from financial disaster'

This kind of liability protection may be seen as a disincentive for safety, preventing safety upgrades from being incorporated into new reactor designs.
How is the situation in other countries?
In France a similar liability protection is valid, as the reactor operator EdF and the reactor vendor Areva both are state companies.

Relaxation of standards

The high and continually escalating costs of waste management and disposal may provoke undesirable developments and hazardous situations. Standards in regulations may be relaxed to admit higher concentrations of radionuclides in materials for clearance, because of economic reasons. Clearance is the controlled release of materials into the public domain; once released the materials are no longer subject to regulation.

The IAEA [IAEA-293 1988] Q36 proposed to dilute radioactive materials with non-radioactive and to use concrete rubble as landfill or road paving. 'Weakly' radioactive steel scrap – however defined and measured – could be remelted with fresh steel and used for 'special purposes'. Reuse of 'low-activity' contaminated and/or activated steel and concrete by diluting it with fresh steel or concrete, as proposed by the IAEA, is very risky in our view, for several reasons:

- the unknown but potentially hazardous isotopic composition of the scrap and rubble
- the unknown biological behavior of the radionuclides
- problematic detection of a number of radionuclides .
- uncertainties with regard to standards, inspection and control (see section below)
- the high risk of uncontrolled trade in radioactive materials.

Findings of the National Council of Radiation Protection and Measurements [NRCP-141 2002] Q272, concerning potentially radioactive scrap metals, are indicative of an urgent and problematic situation in the USA:

> 'There is an urgency to establish consistent national/international policies and standards.'

In Europe, with its many different countries, the situation is far more complex and probably more problematic. In case of the waste released by dismantling nuclear power plants and other nuclear facilities, it would be wise to avoid shipments and trade of radioactive scrap metal and debris as much as possible by packing the materials at the source: the reactor being dismantled.

Economic arguments may also lead to relaxation of the standards of the routine emissions of radioactive materials. An example is the proposal of the US Environmental Protection Agency (EPA) to dramatically raise permissible release levels. The new standards permit public exposure to radiation levels vastly higher than EPA had previously deemed unacceptably dangerous [PEER 2009] Q422, (www.peer.org/news , October 28, 2009). EPA increased permissible public exposure to radiation in drinking water with factors of 1000 to 100000 involving the nuclides ^{90}Sr, ^{131}I and ^{63}Ni. What about ^{129}I? If ^{131}I is present, ^{129}I is also present. In the most extreme case the new standard would permit radionuclide concentrations 7 million times more lax than permitted under the Safe Drinking Water Act. Other aspects of the new EPA proposal are lax cleanups and higher exposures to other sources, such as relaxed dirty bomb standards.
EPA made not clear on base of what physical and medical evidence the standards could be relaxed. In view of the reliance on models within the nuclear industry and the ease to adapt models to changing needs of the nuclear industry, any relaxation of standards should be based on verifiable empirical evidence.

Regulations and quality control

On base of what scientific and medical evidence would the qualifications be defined such as: ‘weakly’ radioactive, ‘low-activity’ and ‘special purposes’?
Who controls the sorting of the materials into the categories: ‘free release’, ‘to be diluted’ and ‘waste’?
How are ‘special purposes’ defined and how is ‘restricted reuse’ controlled?
Which radioisotopic composition has the radioactive component of the debris or scrap? Has that composition been measured or has it been estimated based on models from the early 1970s? What is known about the biomedical activity of the radionuclides in the debris and scrap? Another problem is the problematic detection of a number of hazardous radionuclides.
In view of the large problems already existing with regard to illegal trafficking and smuggling, great risks are looming here, even without relaxing the standards. Large volumes and masses of debris and scrap, sometimes of high value on the free market, are involved in decommissioning and dismantling nuclear facilities. Experiences in the past with waste handling by private companies are not always encouraging in this respect.
If the handling and management of radioactive debris is left to private companies, profit seeking may prevail over of safety and health. Financial motives for short-term ‘solutions’ may be backed by financial constructions which leave the liability for failures and mishaps at the customer, in case the taxpayer. Such financial constructions seem to be involved in the contracts for decommissioning and dismantling of the Sellafield reprocessing plant under the authority of the British Nuclear Decommissioning Authority [NDA 2006] Q365.

How independent are the inspections?

Economic arguments may also lead to reduced quality controls by official inspectors. Several incidents at nuclear power stations in the USA during the past years point to such a development. In a number of countries the nuclear industry urges simplified and shortened license procedures to speed up the construction of new nuclear build, with minimalisation or even elimination of the participation by the local authorities and the public.

It is conceivable that even the independency of the controlling institutions would be liable to suffer under economic pressure. The above described relaxation of the exposure standards by the US EPA points in that direction. How is the situation in other countries?

The Roussely report [Roussely 2010] Q427 calls for a reduction of the scope, and so for a reduction of the independency of the French Safety Authority ASN (Autorité de Sûreté Nucléaire):

> 'En France, il convient que l'État définisse un modus vivendi équilibré avec l'Autorité de Sûreté, c'est-à-dire réaffirme le rôle régalien qu'il ne devrait pas abandonner à une autorité indépendante.
> … Il convient d'éviter que des événements de portée très limité conduisent à jeter une suspicion injustifiée sur l'ensemble d'une technologie.'

In English translation:

> 'In France, the government must define a balanced modus vivendi with the Safety Authority, that means to re-establish sovereignty which it should not relinquish to an independent authority.
> … It must be avoided that events with very limited effects result in unjustified suspicion of a technology as a whole.'

Which independent authority judges an event, e.g. an incident or design error, to have 'very limited effects' not only at the moment of discovery but also in the long run?
For what reasons could an 'event with very limited effects' cast 'unjustified suspicion of a technology as a whole', in case nuclear technology?
The decision process on nuclear power in France is controlled by the president and the Corps des Mines (a technocratic elite), effectively without the participation of the parliament [Schneider 2008] Q428.

Downplaying the consequence of severe accidents

Two faces of the IAEA

Communication between the nuclear world and the general public is dominated by the International Atomic Energy Agency (IAEA). The authoritive 'nuclear watchdog' IAEA has the promotion of nuclear power in its mission statement. Moreover, official publications of the IAEA have to be approved by all member states of the IAEA. For these reasons it is a misconception to regard the IAEA as an independent scientific institute. One face of the IAEA is looking at safeguarding nuclear materials and technology, the other face is looking at the promotion of nuclear technology and nuclear power.

Entanglement of interests

Information on nuclear matters to the public and politicians originates almost exclusively from institutions with vested interests in nuclear power, such as: IAEA, World Nuclear Association (WNA, the official representative of the Western nuclear industry), Nuclear Energy Institute (NEI) in the USA, Areva, Electricité de France (EdF), the latter two being 90% state-owned in France. The views of the Nuclear Energy Agency (OECD-NEA) rely heavily on the IAEA and WNA. The IAEA plays a dominant role in the statements of the nuclear world concerning nuclear security and health effects of dispersion of radioactive materials into the human environment.

How independent are the reports on the consequences of radioactive contamination for the local inhabitants, for example after the disasters of Chernobyl and Fukushima?
According to an agreement between the International Atomic Energy Agency and the World Health Organization (UN Res. WHA12-40, 28 May 1959) the WHO cannot operate independently of the IAEA on nuclear matters (see also the preface of [WHO 2013a] Q553).

Downplaying

The IAEA, WHO and the nuclear industry claimed that the death toll of the disaster at Chernobyl was 31, later rised to 'less than 50'. Apparently only the victims of deterministic effects. An independent assessment estimated the death toll world wide of the Chernobyl disaster at nearly one million people [Yablokov et al. 2010] Q419. This estimate is based on numerous publications from Russia, Belarus and Ukraine, which the IAEA and WHO did not include in their studies. In addition to these casualties there are innumerable people with incurable diseases and malformations following the disaster in 1986.

At present the nuclear industry is strongly downplaying the gravity of the Fukushima disaster, which is classified as 'non-catastrophic'. In the view of the nuclear industrial the worst effects are economic losses, financial liabilities and less support for new nuclear power stations.

The long latency periods of stochastic health effects due to radioactive contamination give the nuclear industry the opportunity to downplay the effects and even to deny in many cases that radioactivity caused the observed adverse health effects. Other factors are blamed to be the cause of observed disorders, sometimes even psychosomatic factors: 'radiophobia', the anxiety of radiation. [WHO 2005] Q498 pays much attention to 'mental health problems' and other issues:

> "Poverty", "lifestyle" diseases now rampant in th former Soviet Union and mental health problems pose a far greater threat to local communities than does radiation exposure."

and:

> "Persistent myths and misperceptions about the threat of radiation have resulted in "paralyzing fatalism" among residents of affected areas."

Little attention is paid to physical ill effects. The WHO does not mention non-cancerous diseases as possible ill effects caused by radioactive contamination, but attributes these effects to other factors. These statements are not proved by investigations nor by scientific arguments. The IPPNW 2011 study Q452 states:

> "An inadmissable chain of argument is often applied: non-cancerous – therefore not induced by radiation – therefore not a result of Chernobyl – end of debate."

In 2005 the WHO published in its Media Centre a publication [WHO 2005] Q498 titled:
Chernobyl: the true scale of the accident. 20 Years Later a UN Report Provides Definitive Answers and Ways to Repair Lives (This media document refers to [Chernobyl Forum 2005] [Q497]). The title in itself is a testimony of an unscientific approach. What is the 'true scale'? Are definitive answers possible without large-scale independent medical investigations during an appreciable number of years?
Worse is the following quote from this document:

> "Because of the relatively low doses to residents of contaminated territories, no evidence or likelihood of decreased fertility has been seen among males or females. Also, because the doses were so low, there was no evidence of any effect on the number of sillbirths, adverse pregnancy outcomes, delivery complications or overall health of the childern."

With this statement the WHO commits a fundamental scientific sin: reversal of argumentation by adapting the observations to the models the WHO believes in: 'not the theoretical models are wrong or imperfect, but the observations are (!)'. This may remind the reader a famous scene in the play *Leben des Galilei* by Bertolt Brecht, when the cardinals said to Galileo Galilei: 'We do not need to look (in your telescope) because it cannot be true.'

In addition the WHO assumes the doses were low, but are these doses actually *measured* among the affected population?

Reliable investigation of the effects of radioactivity in the human evironment needs the registration of cases over a long time span. By means of epidemiological studies an independent assessment of the consequences of exposure to radioactivity is possible. Unfortunately such registrations usually remain undone, intentionally or for economic reasons.
Epidemiological studies are also needed to analyse the effects of chronic exposure to low doses of a mixture of radionuclides via water and food in contaminated areas, not only after a large accident, but also near nominally operating nuclear power plants and reprocessing plants.

Quote from [Rosen 2013] Q561:

On February 28th, 2013, the World Health Organization (WHO) published its
Health risk assessment from the nuclear accident after the 2011 Great East Japan earthquake and tsunami.
This report concluded that

> "for the general population inside and outside of Japan, the predicted risks are low and no observable increases in cancer rates above baseline rates are anticipated."[1] The assessment is based on preliminary dose estimations, published by the WHO in May 2012 [2], which were severely criticized by the German Section of IPPNW, independent researchers and Japanese civil organizations.[3]. This analysis discusses the eight main objections to the current WHO report and shows why it should not be considered a neutral scientific assessment of the actual health risks of the affected population, nor a valid basis for future decisions and recommendations.

8. The authors' neutrality has to be doubted

It remains unclear why a report, written mainly by the IAEA and collaborating nuclear institutions, would need to be published in the name of the WHO.

In order to understand why the WHO has to rely so heavily on experts from the nuclear sector, it has to be reiterated at this point that the WHO is subordinate in questions of nuclear safety to the IAEA. According to Articles 1.3. and 3.1. of the "Agreement between the IAEA and the WHO" from 1959, the WHO is bound by agreement not to publish anything concerning radiation without consent by the IAEA.36 The IAEA, however, was founded with the specific mission to "promote safe, secure and peaceful nuclear technologies" and to "accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world."37 With these motives, the IAEA and its national member organizations cannot be seen as impartial voices on nuclear energy. The influence of the IAEA on the work of the WHO has therefore rightly been criticized for obstructing independent research on the health effects of nuclear radiation.

Economic impact of the Chernobyl disaster

The economic damage and losses of the Cherobyl disaster are not easily to define and to assess. According to the [Chernobyl Forum 2006] Q523 is in Belarus the total cost over 30 years estimated at US$235 billion (in 2005 dollars). The on-going costs are better defined; in their report, The Chernobyl Forum stated that between 5% and 7% of government spending in Ukraine still related to Chernobyl, while in Belarus over $13bn is thought to have been spent between 1991 and 2003, with 22% of national budget having been Chernobyl-related in 1991, falling to 6% by 2002. Much of the current cost is related to the payment of Chernobyl-related social benefits to some 7 million people across the three countries.
A significant economic impact at the time was the removal of 784,320 ha (1,938,100 acres) of agricultural land and 694,200 ha (1,715,000 acres) of forest from production. While much of this has been returned to use, agricultural production costs have risen due to the need for special cultivation techniques, fertilizers and additives.
The costs of dismantling and cleanup of the Chernobyl site are not included in above estimates. It is not clear if cleanup is being considered a feasible option.

Economic impact of the Fukushima disaster

Obviously the socio-economic impact of the Fukushima disaster is extensive. Many tens of thousands of people have been evacuated from their homes, without any prospect of a safe return. Various effects of Fukushima are discussed by [Dorfman et al. 2013] Q288.
Liabilities and compensation claims of the disaster might be measured in hundreds of billions of euros. The cleanup of the site is preliminary estimated at some €250bn [NDreport 2011] Q524. One may wonder if these extreme costs will counterbalance the benefits of nuclear power. Fukushima might be not the last nuclear disaster of its class.

Economic preferences versus security

The economic connection

Non-Proliferation Treaty
Investments in nuclear power plants, reprocessing plants and other nuclear facilities are exceedingly high. Not surprisingly the nuclear industry seeks new markets, to sell their products or technology to other countries, however questionable from a political point of view. In 1970 the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) entered into force. Since that date numerous violations of letter and spirit of the NPT, involving many countries, such as, USA, Canada, Russia, France and China (Schneider 2007). Do economic motives prevail over security risks?

MOX fuel
As explained in Part A, the use of plutonium in MOX fuel generates high risks of diversion, hijacking and theft of bomb-usable fissile material. From an energy point of view there are no physical arguments in favour of recycling plutonium in light-water reactors, for the energy balance of the use of MOX is negative. The recovery of plutonium by reprocessing spent fuel and the fabrication of the MOX fuel elements consume more energy than can be generated from the MOX fuel, if all processes from cradle to grave are included in the energy balance. Especially the decommissioning and dismantling of the reprocessing plant will require a massive investment of energy, materials and human effort.
So for what reason MOX is still used, despite the very serious security issues it raises? Just for short-term profit making, to generate some return on the extremely high investments of the reprocessing plants?

Independence
Nuclear security may easily become at odds with economic preferences if the required investments do not generate a return on investment in the short term. Safety measures are vulnerable to economic priorities and short-sighted choices: the standards, the quality control and the independence of inspections. The strained connections between economics and nuclear security is clearly expressed in the French Roussely report [Roussely 2010] Q427.

Radiological protection recommendations

The International System of Radiological Protection that is used across Europe and worldwide is based on the recommendations of the International Commission on Radiological Protection ICRP and the International Commission on Radiation Units and Measurements (ICRU), according to [SCENIHR 2012] Q533. These recommendations are based on three fundamental, essentially economic, principles:
- justification
- optimization
- dose limitation.

The principles of justification and optimization apply universally to all three exposure categories defined by the ICRP, whereas dose limits apply only to planned exposure situations, except some medical exposure situations.
The main task of the ICRP seems to be the formulation of a legal framework for authorities and politicians on how to cope with liabilities which may arise by exposure of people to radiation and/or radioactive materials, see for example [ICRP 103 2007] Q544 and [ICRP 111 2009] Q535.

Life extension of nuclear power plants

De-regulation (liberalisation) of electricity markets has pushed nuclear utitlities to decrease safety-related investments and limit staff Hirsch et al. 2005] Q169.

Extension of the operational lifetime of a nuclear power plant may be the single most important determinant of nuclear electricity production in the coming decades according to the IAEA, as quoted by [Hirsch et al 2005]. This trend is clearly grounded in economics: the cost of the currently operating reactors escalated during construction by a factor 2-5, so there is a strong incentive to extend the operational lifetime of the reactors beyond their intended design lifetime. New reactors are even more expensive; costs overruns are the rule in the nuclear industry.
Licensing procedures for lifetime extension are based on the as-designed quality of materials and structures. However, the reactors in question are now in the wear-out phase of the bathtub function, implying that the failure rate of components is increasing exponentially.
As the world's nuclear power plant population gets older, there are efforts to downplay the role of ageing, including conveniently narrowing the definition of ageing. There are ageing effects leading to gradual weakening of materials which may have no observable consequences during reactor operation, but which could lead to catastrophic failures of components and thus subsequent severe radioactive releases. Most notable among those is the embrittlement of the reactor pressure vessel, increasing the hazard of vessel bursting. Failure of the pressure vessel of a PWR or a BWR constitutes an accident beyond the design basis.

Relaxation of clearance standards

The high and continually escalating costs of waste management and disposal may provoke undesirable developments and hazardous situations. Standards and regulations may be relaxed to admit higher concentrations of radionuclides in materials for clearance, because of economic reasons. Clearance is the controlled release of materials into the public domain; once released the materials are no longer subject to regulation.
The International Atomic Energy Agency (IAEA) proposed to dilute radioactive materials with non-radioactive and to use concrete rubble as landfill or road paving ([AEA-293 1988] Q36. 'Weakly' radioactive steel scrap – however defined and measured – could be remelted with fresh steel and used for 'special purposes'. Reuse of 'low-activity' contaminated and/or activated steel and concrete by diluting it with fresh steel or concrete, as proposed by the IAEA, is very risky for several reasons:
- the unknown but potentially hazardous isotopic composition of the scrap and rubble
- the unknown biological behavior of the radionuclides
- problematic detection of a number of radionuclides .
- uncertainties with regard to standards, inspection and control
- the high risk of uncontrolled trade in radioactive materials.

Findings of the National Council of Radiation Protection and Measurements [NRCP-141 2002] Q272, concerning potentially radioactive scrap metals, are indicative of an urgent and problematic situation in the USA:

> 'There is an urgency to establish consistent national/international policies and standards.'

In Europe, with its many different countries, the situation is far more complex and probably more problematic. In case of the waste released by dismantling nuclear power plants and other nuclear facilities, it would be wise to avoid unconditioned waste shipments and trade of radioactive scrap metal and debris as much as possible by packing the materials at the source: the reactor or reprocessing plant being dismantled.

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