Nuclear health hazards

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summary

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Errors are the responsibility of the author.

Summary

Widely divergent views exist on the health hazards posed by nuclear power. This study assesses a number of reports from the nuclear industry on this issue, and balances the official statements against empirical evidence, scientific logic and basic natural laws. Political, military and economic aspects are not addressed although these certainly underlie the differences.

Generation of man-made radioactivity

A unique feature of nuclear power is the generation of human-made radioactivity. The amount leaving the reactor in spent fuel and other materials is a billion times greater than what enters the reactor in the fresh nuclear fuel. During the past 60 years, civil nuclear power has generated some 11 million times more anthropogenic radioactivity than was released by the Hiroshima and Nagasaki atomic bombs in 1945. This amount is still present in the human environment, at countless sites, and it is still rising at a current rate of about 300 000 bomb equivalents a year.

Dispersion of natural and human-made radioactivity

A nuclear power plant is not a stand-alone system: a sequence of industrial processes is required to extract uranium ore from the earth's crust, and to fabricate nuclear fuel from it that can be used in nuclear reactors. Another, larger, series of industrial processes is required to manage the radioactive waste safely. Jointly these processes are called the nuclear process chain; in fact the nuclear system may be the most complex energy system ever designed. When discussing the benefits and adverse effects of nuclear power the complete nuclear process chain should be taken into account.

Large masses of naturally-occurring radioactive materials are mobilised into the biosphere during the mining of uranium ores, especially radon and thoron gases. Massive amounts of human-made radioactive materials are routinely released during the normal operation of nuclear reactors and reprocessing plants. In addition to routine discharges, radioactive materials are dispersed as a result of technical failures and accidents. Radioactive effluents include gases, vapours, aerosols, dusts, particulate matter, and radionuclides dissolved in aqueous liquids, including very large volumes of water which is itself radioactive (tritiated water). In addition solid radioactive materials end up in the environment, such as scrap and rubble. Dispersion may also occur from the incineration of radioactive waste, the intentional or unintentional burning of materials contaminated by radionuclides for heating or cooking, and by forest fires in contaminated areas.

Biomedical aspects of radioactive contamination

Nuclear radiation strongly interacts with cellular matter. Radiation destroys or modifies biomolecules such as DNA, which may cause harmful effects in an organism. Alpha and beta radiation can be blocked by clothing and skin and therefore may seem relatively harmless. However, alpha and beta-emitting radionuclides are extremely dangerous inside the human body, for living cells are not protected by the skin or clothing. The alpha and beta rays cause a large number of damaged biomolecules inside living cells. Moreover, several radionuclides accumulate in specific organs causing locally high radiation doses.

Contamination by radioactive materials involves more than exposure to radiation alone. In addition to the radiation, chemical factors are important in judging the hazards of radioactive substances inside the body, such as:

- biochemical properties of the radioisotope itself and of its decay products
- biochemical reactions initiated by the ionizing radiation of the radioactive decay, via primary and secondary ions
- biochemical reactions initiated by the energy transfer of the recoil and of the secondary electrons.

Many radionuclides released into the environment enter the food chain and drinking water and as a result people in the contaminated areas are internally exposed to those radionuclides for prolonged periods. In addition people are exposed to skin doses and by breathing radioactive gases and particulate matter. Health effects caused by prolonged exposure to a gamut of radionuclides are not investigated. What are the synergistic biomedical effects?
The classical radiologic models discern deterministic (also called non-stochastic) effects and stochastic (also called probabilistic) effects. The former occur after exposure to extremely high doses of radiation and become evident within hours to weeks (ARS: Acute Radiation Syndrome), the latter are caused by lower doses and can have incubation periods of years to decades.
Relatively recent studies have proven the existence of 'non-targeted' and 'delayed' radiation effects. These effects had probably been observed in earlier studies but had gone unrecognised as they fell outside the then accepted paradigm of radiation effects. The observed phenomena pose many fundamental questions to be answered and will result in a paradigm shift in the understanding of radiation biology.

Observed health effects

Due to the long incubation periods it may take years before stochastic health effects become observable. In the years since the Chernobyl disaster in 1986 a great variety of diseases have been reported in the contaminated areas in Ukraine, Belarus and Russia: cancers and non-cancer diseases, lethal and non-lethal diseases, such as:

- multimorbity classified as radiation-induced premature senescence
- cancers and leukaemia
- thyroid cancer and other thyroid diseases
- damage to nervous system, mental disorders
- heart and circulatory diseases
- infant mortality, stillbirths, low birth-weight
- congenital malformations
- endocrinal and metabolic illnesses
- diabetes
- miscarriages and pregnancy terminations
- genetic damage, hereditary disorders and diseases
- teratogenic damage, such as: anencephaly, open spine, cleft lip/palette, polydactylia, muscular atrophy of limbs, Down's syndrome.
- chromosomal damage
- radiation-induced cataracts
- vascular vegetative dystony (the "new Chernobyl syndrome")

Epidemiological studies in Germany and France proved a relationship between the increased incidence of childhood cancers and leukemia and the living proximity of the childern's homes (for childern under 5 years old) to normally operating nuclear power plants. These effects cannot be explained by the radiological models applied by the nuclear industry.

Limitations of the current radiological models

The radiological models used by the nuclear industry are based on the effects of gamma- and X-ray radiation from sources outside the human body. UNSCEAR states: "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."
The models are based on studies that started about five years after the atomic bombings, so the deaths during these first five years are not counted.
What was the original purpose of these 60-year-old models? To estimate the acute radiological risks for

military personnel in the Cold War with the threat of nuclear weapons during the 1940s and 1950s, at a time no civil nuclear power plants existed? Or to estimate the health hazards for millions of people in 21st century posed by chronic exposure to a vast number of radionuclides discharged by hundreds of civil nuclear power plants over the course of decades?
The methodology and scope of these studies do not comply with present scientific views and insights that are based on the vast amounts of emprirical data that became available during the past decades. Epidemiological studies proved that the existing exposure and health risk models are unable to explain the empirical observations, so the models should be revised.
During the disasters of Mayak, Chernobyl and Fukushima amounts of radioactivity equivalent to many thousands of exploded Hiroshima bombs have been discharged into the environment.
What are the effects if the exposure is chronic as a result of continuous intake (food, water), inhalation of radioactive gases, dust and aerosols? What are the effects of bioaccumulation in the food chain?

Like any scientific model the radiological models have their inherent limitations, because a model is by definition a simplication of the reality. In addition a model has also limitations due to the basic assumptions and to the choice of the input parameters. Models are only usable within the boundaries of a well-defined system. How are the radiological system boundaries defined?

Entanglement of interests

Physically an NPP is part of an intricate network of industrial activities. In turn this technical system is part of a complex of interests, with miltary, political, economic, social, environmental and health aspects. For reason of the diversity of interests it is not simple for the public and policy makers to get a reliable overview of the nuclear energy complex as part of the society.
Information concerning civil nuclear power to the general public and to policy makers is globally dominated by the International Atomic Energy Agency (IAEA).

IAEA

The IAEA is an international autonomous organization, established on 29 July 1957 independently of the United Nations, through its own international treaty with the member states.
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 its 159 member states. For above reasons the IAEA cannot be considered to be an independent scientific institute.

ICRP and UNSCEAR

Two other international nuclear-related institutes, 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 for how to cope with any liability which may arise from planned exposure of people to radiation and/or radioactive materials in medical, scientific and technical applications. 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) care more about radiation from natural sources than from human-made sources.

Role of the WHO

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. As a consequence the official reports of the WHO on nuclear health hazards do not deviate from the IAEA viewpoint. With respect to health effects of exposure to radiation and radioactive materials, the IAEA, UNSCEAR and WHO are speaking with one voice.

Significance of the Second Law of thermodynamics

All observable changes in our world are subject to the Second Law of thermodynamics. In the publications of the nuclear industry we found no evidence of awareness of the consequences of the Second Law. One of the important Second Law phenomena is usually called ageing: as a result of unavoidable spontaneous processes materials and structures deteriorate with time; this process is exacerbated by nuclear radiation. The consequences of ageing for nuclear safety and health hazards are significant, especially with regard to:

- leaks and unintended discharges
- risks of large nuclear accidents
- storage of radioactive waste in temporary storage facilities or shallow burial disposal sites
- spent fuel cooling pools and dry cask storage of spent fuel
- lifetime extensions of reactors.

In addition the highly optimistic presentations of the potential of the next generation of nuclear technology, promising inherently safe nuclear power, nearly unlimited energy resources, less radioactive waste and moreover shorter-living radioactivity, are evidence of ignorance of the Second Law. These concepts, most of them originating from the 1950s and 1960s, are implicitely based on the assumptions of the availability of perfect materials and of 100% perfect separation processes, both assumptions are in conflict with the Second Law. The conclusion has to be that these 'advanced concepts' are inherently infeasible.

Downplaying and denial of health effects of radioactive contamination

From the reports of the IAEA, UNSCEAR and WHO on the subject of health effects of the disasters of Chernobyl (1986) and Fukushima (2011), a picture emerges of the nuclear industry marked by downplaying and even denying health effects caused by exposure to radiation and contamination by radioactive materials. The Mayak (Kyshtym) disaster in the East Ural in 1957 has long been kept secret and is still being concealed.

Apparently the nuclear industry takes the view that if the relationship between exposure to radiation and a specific health effect in a particular person cannot directly be proven within a short timespan, the cause of the observed disease *must* be non-nuclear. This view is not backed by any epidemiological proof nor other evidence. Non-cancerous diseases are not recognized as radiation-induced health effects, attention is paid mainly to acute radiation syndrome (ARS, radiation sickness). According to IAEA/UNSCEAR/WHO the death toll of Chernobyl was less than 50 persons. Other institutions came to estimates of 100 000 to 1 million deaths, taking into account all health effects caused by exposure to radioactivity.
IAEA, UNSCEAR and WHO place full reliance on radiological models for assessment of exposure doses and of dose-effect relationships, with little or no input of empirical evidence that became available after the conception of the models in the 1940s and 1950s. Biochemical behaviour of radionuclides inside the human body are not included. Chronic exposure to radionuclides inside the body, via ingestion (food and water) and inhalation (gases, dust) are not covered by the investigations either.

In the publications of IAEA/UNSCEAR/WHO we found no indications of awareness of the implications of the German and French epidemiological investigations (and many other studies) that found a significant connection between the incidence of childhood cancer and the proximity of normally operating nuclear power plants. These incontestable results cannot be explained by the models and way of reasoning of the nuclear industry. From a scientific point of view the conclusion should be: the models are inadequate and have to be rivised.
A strong economic component can be sensed in the assessments, the economic consequences of nuclear disasters appear to be considered more serious than detrimental health effects and human suffering.

No reliable investigations

Reliable assessments of the health effects of the Chernobyl and Fukushima disasters are hampered by several factors, such as:

- poor detectability of many dangerous radionuclides
- long latency period of health effects from exposure to radioactivity, coupled to a short time horizon of the investigations
- limited measurements of radioactive contamination
- limited scope of the IAEA and WHO investigations
- absence of adequate epidemiological studies
- secrecy of medical data
- short time horizon of the nuclear institutions
- economic interests.

Elementary scientific flaws

Remarkable are the methods used by the IAEA, UNSCEAR and WHO in their reports on the consequences of the disasters of Chernobyl and Fukushima. When dicussing the health effects caused by exposure to radioactive materials, these institutions commit elementary scientific flaws in their reports.

Missing proofs

We found conclusions that are not backed by empirical evidence. Detrimental health effects are attributed to 'radiophobia', 'fear of unknowns', 'bad lifestyle'. In the reports of the IAEA/UNSCEAR/WHO the proofs of above assertions are missing: no investigations are performed or reported which would underpin these statements.

According to the radiological paradigm of the IAEA/UNSCEAR/WHO non-cancerous diseases are not considered as possible ill effects caused by radioactive contamination, but are attributed to other factors.

Models prevail over empirical evidence

Empirical data that deviate from the applied radiological models are ignored and observations of detrimental effects are attributed to non-nuclear causes if they don't fit the theoretical models used. If the nuclear industry cannot *prove* that there are no detrimental health effects of exposure to radioactive materials and radiation, a reasoning based on models is *not* a scientific proof.

No scientific discourse

In the IAEA/UNSCEAR/WHO reports we found no discussion of scientific reports with results diverging from their own view; the titles of such reports are not even mentioned. Avoidance of a scientific discourse might be seen as a serious flaw of any scientific investigation, the more so in case of a complex matter as the consequences of a nuclear disaster.

Critical opinions are, without reference to the sources, dismissed as 'unscientific', 'myths' or 'erroneous'. The IAEA/UNSCEAR/WHO fail to elucidate their meaning of these terms and to found their qualifications on scientific arguments, thus avoiding any discussion of the scientific arguments behind the diverging opinions.

Problems for the future

Most likely the frequency and seriousness of releases of radioactive materials into the environment will increase with time due to several factors, such as:

- Increasing amounts of radioactive materials are piling up in a growing number of temporary storage facilities. Because no definitive and safe disposal facilities are operational a fraction of these materials will escape into the environment due to inherent deficiencies of technical systems and human behaviour.
- Unavoidable deterioration of materials and structures of spent fuel elements and of temporary storage facilities of radioactive wastes, as a consequence of the Second Law of thermodynamics, enhanced by the nuclear radiation from the waste. Due to these ageing processes the fraction of the radioactive waste escaping into the environment likely will increase with time, as well as the risks for large nuclear accidents.
- Escalating costs and a growing backlog result in increasing economic pressure, potentially exacerbated

in case of an economic decline. These factors may cause:
  - decrease of safety-related investments and staff at nuclear power plants and possibly also at other nuclear facilities
  - relaxation of official discharge and clearance standards and regulations
  - less frequent and less independent inspections
  - increasing tendency to conceal failures, leaks and shortcomings
  - search for cheaper ways, and consequently less effective ways, to store increasing amounts of radioactive waste
- Illicit trafficking likely will increase as a consequence of above mentioned factors. Illegal trade and smuggling of radioactive materials and equipment is already a significant problem, little numerical data have been published.
- A related problem is the illegal dumping of radioactive waste at sea or in sparsely habitated regions.
- Nuclear facilities are vulnerable to terroristic suicide attacks, possibly initiating severe accidents.
- Severe accidents could also be initiated by hostile actions in an armed conflict anywhere in the world. The consequences of an accident like the Chernobyl and Fukushima disasters do not stop at the national borders.
- Postponing adequate waste management solutions to the future for economic reasons increases the risks of nuclear terrorism: dirty bombs dispersing radioactive materials or even primitive nuclear explosives made from MOX fuel. The risks may be growing by the increasing threat of terroristic organizations.
- Accidental and inadvertent releases of radioactivity into the environment, including large-scale accidents, can also be caused by natural disasters. As growing amounts of radioactive materials are present within the human environment and adequate actions are longer delayed, the risks of disasters grow and the released amounts may grow as well.
- Nuclear power plants that are beyond their original design lifetime are now in their wear-out phase, characterized by a growing failure rate of technical systems. Lifetime extension greatly enhances the risks of large-scale accidents, their frequencey as well as their severity. The same holds true for the ageing spent fuel cooling pools, high-level waste storage facilities and reprocessing plants. This development comes on top of the unpredictable risks of natural disasters.

Flexibility of regulations

Under economic pressure regulations on allowed concentrations of radionuclides in drinking water and food are relaxed by factors 100, 1000 or more, without scientific and medical arguments. This causes a vast increase of contamination by radioactivity of hundreds of millions of people. This effect comes on top of the increasing inventories of radioactive materials in nuclear installations and the deteriorating materials and structures containing the radioactivity. In addition inspections and quality controls may be scaled down, likely also for financial reasons.

Nuclear power and society

From the official publications of the nuclear industry and its associated institutions emerges a picture of their way of thinking and of communicating with the general public. Some characteristics of that picture are:

- entanglement of interests
- prevailing economic preferences
- systematic downplaying and denial of nuclear health hazards, using questionable methods
- unrealistic believe in technological possibilities in the future.

A factor causing increasing health hazards in the future may be the ‘living-on-credit’ culture within the nuclear industry, featuring systemic postponement of radioactive waste management actions to the future.