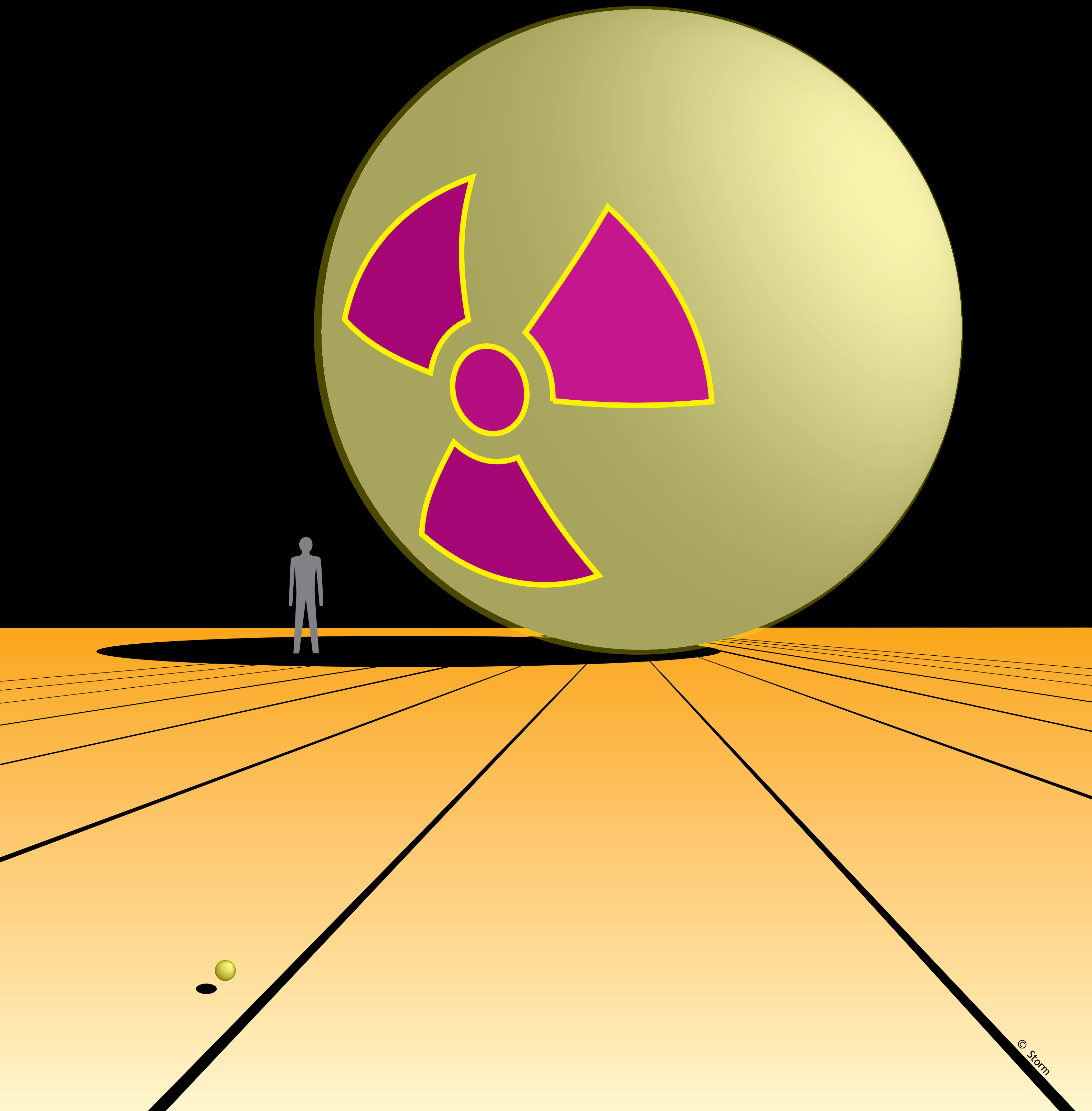
Nuclear Security

in cauda venenum



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summary

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In cauda venenum

A Latin phrase from ancient Rome, meaning: the poison is in the tail. Using the metaphor of a scorpion, this can be said of a story or a development that seems to proceed gently, but turns vicious towards the end.

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With this study WISE hopes to contribute to a thorough debate on the issue of nuclear security. It is not an easy debate and it is of utmost importance to exchange ideas, views and well-researched arguments and facts. We alle share the desire for a safe world free of nuclear disasters. We will only get there if we dare to face the challenges, even if they are more complicated than often said.

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Peer de Rijk, director WISE International

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Summary

Nuclear security

A unique feature of applied nuclear technology is the generation of fissile materials and massive amounts of human-made radioactivity. As a result civil nuclear technology raises unique hazards and security issues, encompassing a number of pathways along which severe damage can be inflicted to the political, economic and societal stability on a regional, national or even global scale:

- Terroristic use of nuclear explosives.
- Proliferation of critical nuclear technology to politically unstable countries.
- Armed conflicts involving nuclear installations and materials.
- Terroristic attacks with conventional weapons on nuclear installations containing fissile materials and large amounts of highly radioactive materials: nuclear power plants, spent fuel cooling pools and reprocessing plants.
- Severe accidents involving one of above mentioned installations.

The consequences of the last two potential events are indistinguishable: both cause large-scale dispersion of massive amounts of human-made radioactivity over vast regions, affecting millions of people.

Scope

Military issues are not addressed here, although military and civil nuclear technology are inextricably intertwined. This study discusses three aspects of nuclear security. For that reason this report is divided into three parts:

- The first part covers the origin of artificial fissile materials and human-made radioactivity from civil nuclear power reactors, and how these materials could play a role in terroristic actions and the equivalent impacts of accidental onsite events.
- The second part covers the role of computer models in the perception of nuclear security. and the role of natural phenomena which make inherently safe nuclear systems impossible. Further it addresses the mechanisms of Chernobyl-class disasters and their increasing likelihood.
- The third part discusses the strained relationship between at one hand the economic paradigm and the downplay culture of the nuclear industry plus the entanglement of interests, and nuclear security on the other hand,

Terroristic nuclear explosives

In principle there are five different fissile materials which can be used foor atomic bombs: highly enriched uranium (HEU), uranium-233, plutonium, neptunium and americium. Except HEU these materials become available in separated form by reprocessing of spent nuclear fuel. By theft terrorists could acquire sufficient materials to fabricate a crude nuclear bomb. Without reprocessing the only way to obtain bomb material is enrichment of uranium to a high U-235 assay (HEU).

Safeguards of the fissile materials in a reprocessing plant cannot be perfect: 1-5% of the materials are unaccounted for due to unavoidable, and often unnoticed, process losses. The risks of plutonium theft are high due to the frequent transports of separated plutonium and the MOX fuel that is made from uranium and plutonium for use in conventional power reactors. MOX fuel (Mixed OXide) can be used to make a crude nuclear weapon, without advanced technology.

There are reasons of concern regarding the security of the stockpiles uf uranium-233.

Neptunium and americium are not safeguarded internationally.

Illicit trafficking and theft

Another cause for concern is illegal trade and smuggling of nuclear materials, only a small step from nuclear criminality and terrorism. Transports of hazardous materials are difficult to detect, when detection is even possible. This problem increases with time due to increasing amounts of radioactive materials and declining inspections. One of the consequences is the uncontrolled release of radioactive materials into the public domain and insidious exposure of a growing number of people to radionuclides. Serious accidents and terroristic actions cannot be ruled out. Political instability, for whatever reason, exaggerates the risks of illicit nuclear transports with malicious intent.

Chernobyl-class disasters

Serious disruption of political, economical and societal stability could also result from a large-scale release of radioactive materials caused by a terroristic attack with conventional explosives on a nuclear power plant, spent fuel cooling pool, or reprocessing plant. The consequences of such an attack could develop into a Chernobyl-class disaster.

Spent nuclear fuel has to be actively cooled for many years after discharge from the reactor due to its residual heat generation. Interruption of the cooling before the required period of time, and depending on the age of the spent fuel, will inevitably lead to meltdown of the fuel elements. A number of mechanisms are conceivable - some of which have actually occured - which could cause a fuel meltdown. At high temperatures the cladding of the nuclear fuel reacts with water, generating hydrogen. Violent steam and hydrogen explosions coupled with the dispersion of tremendous amounts of human-made radioactivity into the environment are unavoidable. The contaminated areas could cover 100 000-200 000 square kilometers and millions of people might be affected, as happened in the Chernobyl and Fukushima disasters.

Installations vulnerable to the above scenario are nuclear reactors and on-site and off-site spent fuel cooling pools. Each year an operating nuclear reactor generates about 1000 nuclear bomb equivalents of human-made radioactivity, a spent fuel cooling pond contains an even greater amount. A reprocessing plant may contain 0.1 to 1 million nuclear bomb equivalents, distributed over thousands of tonnes of conditioned and unconditioned, liquid and solid wastes, and spent fuel in cooling pools awaiting reprocessing. Violent explosions and meltdown of fuel are also possible in reprocessing plants. Possible triggers of such a scenario are accidents, natural disasters, human failures and terroristic actions.

Reprocessing of spent fuel

Assessing the whole chain of processes and activities related to nuclear power and the security issues they raise, one component of the chain stands out: the reprocessing of spent fuel. By reprocessing bomb-usable fissile materials, plutonium, neptunium and americium, are separated from spent fuel and become in principle available to terrorists for making nuclear explosives. In the sequence of reprocessing the highly radioactive fission products are dispersed over large volumes of solid, liquid and gaseous wastes, and the radioactive gases are released into the environment. The bulk of the remaining radioactive waste is stored in the reprocessing plants in an easily dispersible form. Due to cumulation over decades these amounts of dangerous highly radioactive reprocessing wastes are immense and the risks of dispersion into the environment are growing over time.

In spent fuel the fissile materials and fission products are in the most condensed condition and in the least accessible form for malicious actions. Each operation which breaks the integrity of the fuel elements enhances the security risks and renders safe definitive disposal of the extremely radioactive material much more expensive.

The environmental and security problems raised by reprocessing of spent fuel would increase even more if closed-cycle reactors (breeders) and partitioning & transmutation (P&T) systems were to come on line. With these systems massive amounts of plutonium and other fissile materials would be separated, shipped and spread amongst numerous vulnerable facilities. In addition the amounts of high-level radioactive waste, mainly in easily dispersible form, would greatly increase due to the repeated reprocessing of the spent fuel in these closed-cycle systems.
Fortunately breeders and P&T systems have proved to be technically unfeasible, due to facts the designers of these advanced systems did not account for. Conditio sine qua non of the breeder and P&T systems is the availability of perfect materials and the possibility of complete separation of a complex mixture of highly radioactive chemical species into pure fractions. Both conditions are impossible, as follows from the Second Law of thermodynamics.

Reprocessing turns out to be an exceedingly polluting and expensive technology which became essentially superfluous when the breeder and P&T systems proved to be unfeasible. The use of MOX fuel in conventional light-water reactors has a negative energy balance and raises serious security problems. Other purposes of reprocessing as proposed by the nuclear industry are based on fallacies, or are impractical for various reasons.

Reliance on computer models

Computer models are widely used in the nuclear world, not only to assess nuclear security issues, but also to estimate radiation doses for individuals and populations of areas contaminated by radioactive materials and to estimate the expected health effects of exposure to radioactivity.
Each computer model has its inherent limitations by definition, in addition to the limitations set by the choices of the variables incorporated into the model and the choices of the values of the model parameters. Generally the models are applied rigidly, incorporating little or no practical evidence even as this evidence becomes available as time goes by.

Inherent safe nuclear power is inherently impossible

Computer models, regulations and safeguards usually start from as-designed quality of nuclear installations and perfect supervision of quality and operations. According to the reactor safety model studies of the nuclear industry a large-scale accident could be expected once every 2500 years. Empirical evidence proves this frequency to be once every 10-20 years, so the models have little practical application.
Nuclear installations are subject to the bathtub hazard function, like any technical construction and living organism. The bathtub hazard function implies that the failure rate rises exponentially during the wear-out phase. This phase follows an operational life during a number of years at a relatively low rate of failures. The rising failure rate is caused by unavoidable ageing processes governed by the Second Law of thermodynamics. In addition human behavior is an unquantifiable and unpreventable risk factor. Therefore inherent safe nuclear reactors are inherently impossible, let alone inherently safe nuclear power. This includes the whole system of industrial activities needed to generate nuclear power (the nuclear fuel chain or fuel cycle).

Despite empirical evidence of the shortcomings the nuclear industry shows an unshakeable faith in its technical models and paper regulations, often ignoring the fact that not all relevant processes and phenomena are known and that not all factors are predictable and quantifiable. In proposed advanced technical concepts the nuclear industry does not show any notion of the implications of the Second Law of thermodynamics with respect to the feasibility of those concepts.

Radiation protection models

The official radiation protection models for assessment of health hazards posed by radioactive materials are based on a limited set of variables and parameters. Biological behavior of any one kind of radionuclide inside the human body is not accounted for in the models, let alone the biological behavior of a number of different kinds of radionuclides acting simultaneously. Chronic exposure to radionuclides, for example via food and drinking water in a contaminated area, is not included either.

Due to the long latency periods and anonymous character of stochastic health effects, it is rarely possible to attribute a certain disease of an individual to radioactive contamination. The relationship between exposure to radioactive contamination and its detrimental health effects can only be demonstrated in a statistical way by means of epidemiological studies involving very large numbers of people during many years.
The nuclear world recognizes only deterministic health effects as radiation-induced; these effects occur after exposure to very high radiation doses. Official nuclear institutes do not recognize non-cancer diseases as possibly radiation-induced and systematically attribute them to non-nuclear causes, without backing by scientific investigation.
Empirical evidence from previous events is not incorporated in the official assessments of health hazards of nuclear accidents. The applied exposure and effect models have a strong economic component and can easily be adapted to the political and economic needs of a given moment and/or place.
Economic principles play a dominant role in the recommendations of the International Commission on Radiological Protection (ICRP) for allowed exposure of the general public and individuals to nuclear radiation. These recommendations generally form the basis of the policy of governments on the subject of radioactivity.

The faith of the International Atomic Energy Agency and other official nuclear institutes in computer models can be so rigid that empirical observations that are not compatible with the radiation protection models are systematically dismissed as irrelevant, without any scientific evidence. This is found in, among other, the official reports on the health effects in the affected regions after the Chernobyl disaster.

Economic preferences and nuclear security

Economic preferences and commercial choices can greatly increase nuclear security risks. The numerous violations of the Non-Proliferation Treaty probably have economic background. Hardly other than short-term economic motives can be conceived for reprocessing of spent fuel and the use of MOX fuel in conventional reactors.
Then there is the relaxation of the official standards for operational routine discharges of radionuclides into the environment by nuclear power plants and reprocessing plants. Due to ageing the frequency of leaks and spills will rise at an accelerated rate and so will the costs to repair the leaks and to prevent their occurrence. Raising allowable radioactive discharge limits for the nuclear operators keeps their costs down, while resulting in higher exposure standards for the general public, often by large factors, without scientific justification. Similar relaxation of exposure standards may be expected in case of a future nuclear accident, as occurred after the Fukushima disaster.
Another example is the relaxation of standards for clearance of radioactive construction materials for unrestricted use in the public domain. This will become a hot issue when heavily contaminated nuclear installations are dismantled; safe guardianship and disposal of the massive amounts of radioactive debris and scrap will be very expensive.
Economic reasons push the trend of lifetime extension for of nuclear power stations beyond the designed lifetime of 40 years. It is not clear how the owners of the plants and the supervisory institutes incorporate

the unavoidable ageing and the bathtub function in their security assessments, or how independent or how thorough the inspections are.

Entanglement of interests

Information to the general public on nuclear matters is dominated by the authoritive International Atomic Energy Agency (IAEA), often called the ‘nuclear watchdog’. The IAEA has the promotion of nuclear power in its mission statement and its official publications have to be approved by all its member states. For these reasons it is a misconception to view the IAEA as an independent scientific institute. Besides dominating the public relations of the nuclear industry, the IAEA dominates also the publications of the International Commission on Radiological Protection (ICRP) and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The views of the World Nuclear Association (WNA) and Nuclear Energy Agency (OECD-NEA) rely heavily on the IAEA. The World Health Organization (WHO) cannot operate and publish independently of the IAEA on nuclear matters. For that reason statements of the WHO on nuclear matters do not deviate from the IAEA statements.
The long latency periods and the non-specific character give the nuclear industry ample opportunity to play down the health effects of radioactive contamination.

Après nous le déluge: heading for a future disaster

The chances of nuclear terrorism and of Chernobyl-class nuclear accidents are greatly increasing as long as the nuclear industry upholds in its current frame of mind, characterized by a short time horizon, living on credit and an *après nous le déluge* attitude. Nuclear security problems and associated health hazards are growing with time and will persist for the next century, even were the world’s nuclear power stations to all be closed down today.

Effective and durable isolation from the biosphere of all radioactive wastes, including spent fuel, fissile materials and the future decommissioning and dismantling wastes, is the only way out of the mounting hazards of the nuclear heritage. The involved activities will require unprecedented investments of energy, materials, human resources and economic means, to be measured in trillions of euros. These future investments will not contribute to the improvement of the economic infrastructure and must be considered to be pure losses. Even if the last nuclear power plant could be shut down today, the economy would have to sustain a nuclear workforce to perform the demanding task of decommissioning and dismantling far beyond the year 2100. This workforce does not contribute to any improvement of the energy supply. Its sole task is to prevent the many disastrous consequences of the nuclear legacy. One might wonder if enough young people would opt for the required rigorous education and training, and if a free market-oriented economy would be able to support such a workforce for such a long period with no return on investments. What are the prospects of that in times of a declining economy?
Serious nuclear security problems and large-scale disasters seem inevitable.