New Perspectives for Radiation Protection concepts in the frame of sustainability

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Abstract.
The principles of radiation protection and the systematic approach for radiation risk assessment, risk management and nuclear safety are briefly discussed. Radiation protection is confronted recently with new challenges in the medical sector, with some natural radiation risk paradoxes, with lessons from nuclear reactor accidents, with ongoing long term nuclear waste considerations and is even challenged in its radiation paradigm itself.
Meanwhile outside the sector new approaches develop for health and environmental policies. Sustainable development and precaution, almost not referred yet within the nuclear sector, start to offer opportunities.
The criteria and strategies put forward show some similarities with IRPA efforts to integrate normativity (values), to promote stakeholder engagement, to focus on safety-, radiation protection- or ALARA-culture. ICRP efforts to broaden the anthropocentric scope and to continue justification for a number of challenges are also in line with sustainable development.
It is proposed to open the scope in RP and to enlarge assessment approaches in nuclear developments. Defensive strategies, as prepared by UNSCEAR on attribution of risks at low doses, could handicap a precautionary evolution in future and should be directed to improved risk awareness by transparent risk communication. Moreover societal and distributive equity considerations should be taken into account to gain trust and acceptance.
Ecosystem approaches could moreover help to establish coherency and to reconsider impact assessment instruments.

KEYWORDS: (protection, ALARA, culture, sustainability, precaution, assessment)

INTRODUCTION

A range of interpretations of the concept of sustainability is emerging in the field of technology, energy, environment and health policies. Up to now the system of regulation of exposure to ionising radiation has paid little attention to these dynamics. The nuclear energy sector and IAEA are mainly referring to sustainability for competitive opportunities related to externalities such as the climatic challenge of carbon based energy technologies.
Sustainable development is often a mere political discourse or a marketing argument as seen in the framing of resource efficiency and long term waste improvement in Gen IV in the European SNE-TP[11] .
Sustainable development beyond sector interests and political discourses however considers additional in depth criteria In assessing decisions: these include coherent integration of different problem dimensions, global responsibility and proactive precaution strategies which are not familiar to the nuclear sector. On the contrary ethics, equity and stakeholder involvement, as promoted by IRPA for consideration by radiation protection professionals is becoming a more common process language.
Sustainability assessment approaches are being developed referring to criteria as strategic objectives, discussed in a PhD by E. Laes (Laes 2006) and applied operationally for energy planning purposes by the Belgian Federal Planning Office (BFPO, 2007). These conceptual guidelines for action should be used within an holistic perspective, assessing system impact interactions (Hugé J.et al, 2011) not limited to

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interaction aspects, such as health effect in radiation protection. To reach such broader objectives, impact assessment processes need to be built on transparency and participation. Finally sustainability assessment should be integrated institutionally. While impact assessment is a generic term referring to processes identifying the future consequences of current or proposed actions, sustainability assessment embraces processes that all have as their broad aim the integration of sustainability concepts into decision-making (Pope, 2006). Indeed, sustainability assessment is not a prescribed process, but rather an orientation of practice (Pope & Dalal-Clayton, 2011). It is not as codified as e.g. environmental impact assessment (EIA) and strategic environmental assessment (SEA). While this allows for a degree of freedom and inventiveness in developing more detailed or more context-specific definitions, methods and applications, it also means that sustainability assessment frameworks exist in many forms, but they are always based on criteria of sustainable development and used in a vast number of cases and contexts.
In a research contract for the Belgian Science Policy Agency nuclear energy developments were assessed qualitatively using the principles of sustainable development and applying a clustered factor pathway analysis. This study on nuclear energy governance (Eggermont et al, 2011) was published just before the Fukushima accident, which has illustrated a number of policy recommendations. Moreover a case study was performed by (Hugé J. et al, 2011), conceptually analysing recent progress in Belgian nuclear waste policies. The stepwise planning for decision making was not only left to a technical expert panel but also to an independent forum of lay citizens , aiming a mere open framing of sustainability.
Particular attention is given in this paper to one of the criteria for sustainable development, precaution, as it is particularly relevant for radiation protection. A development of precaution as strategy for decision making in health and environmental policies is briefly discussed. It was edited by an inter-disciplinary group of the Dutch Health Council (Health Council 2008), discussing also the ALARA approach.

This paper first considers major present challenges for radiation protection after a brief review of the radiation protection approach.
A number of requirements for precaution and sustainability development are then projected on these problem areas looking for new perspectives for radiation protection by broadening its scope.
It is noticed that well developed nuclear assessment tools for safety, health, waste and the environment have interesting strengths in depth and in time scope compared to non nuclear approaches. However a number of applications of ionising radiation became very controversial illustrating the weaknesses in nuclear assessment in a societal context as well as a number of safety culture problems. Safety culture, still lacking in different companies is a condition sine qua non for preventing accidents. More proactive thinking could complete assessment scenario's as part of scientific method while ecosystem approaches could enlarge health considerations. Communication in the nuclear sector has improved but still requires a structured transparency commitment. Engagement of relevant stakeholders, also of patients groups and local and environmental organisations, has enriched the risk problem solving perspectives in the nuclear field through confrontation with a variety of world views. But the challenge of distributive equity and trans-generational ethics has emerged as particularly relevant in nuclear impact assessments.

RADIATION PROTECTION APPROACH

This consists of the ALARA principle, safety, health & environmental risk assessment and a system of justification, optimisation and limits.

The radiation protection approach was historically driven by a hierarchy of operational priorities referring to a subdivision of effects:

1. absolute prevention of deterministic effects
2. potential stochastic effects focussed at higher exposures

3. care for low doses to critical groups (aiming as well to limit health effects for individuals, guaranteeing public health concern of exposed groups and including a high level of RP hygiene preventing spread of radioactivity)
4. supposing that the environment is sufficiently protected if man is.

This approach has assumed since decennia that any dose of radiation could cause stochastic biological effects with some risk of detriment to health. The environmental philosophy (4) is anthropocentric.

This approach historically lead to the ALARA principle, defined as an action rule based on value judgement, in order to manage exposure. This was implemented in a basic system of protection: justification of practices, optimisation of protection, complemented for workers and the public by limits (Eggermont, 2005). Justification and Optimisation illustrate the utilitarian ethics (Feltz, 2008) behind this approach, which moreover introduced a lot of flexibility in risk management for sometimes uncertain effects.

Limits have added some egalitarian ethics in ICRP philosophy, in order to guarantee the protection of the health of individuals. It should be noticed however that no limits apply in 90% of the doses to the public (patients, Rn exposure), and even for the majority of workers exposed in NORM industries.

Justification has a generic and a specific dimension. As Health & Environmental governance is rapidly changing and increasingly guided by corporate interests, generic justification is delegated by policy makers to agencies or expert advisory councils for health and environment which make a kind of (medical) technology assessment. Those experts are struggling with complexity, uncertainty and value judgements, which can be interpreted differently. Their legitimacy is questioned. (Anderson, 2008) calls experts 'the priests of enlightenment' as they have lost their virgin status due to their growing problems with conflict of interests, due to the delimitation of their expert mandate and due to their expert culture. It is noticed that perception of lay citizens versus experts is polarising while a need to focus awareness is coming up in all risk domains including radiation protection.

Justification is increasingly applied for particular practices such as CT for children, bodyscan for security reasons, radioactivity in lamps (Belgian Health Council, www.css-hgr.be) and also for nuclear energy in particular conditions, contrary to earlier ICRP proposals for RP purposes (Eggermont, 2005).

Specific justification essentially belongs to the professional responsibility of each expert at each level of radiation protection. It allows for instance the medical practitioner not to apply patient limits for sake of patient benefit. But then the optimisation of protection comes on the foreground not only regarding technology but regarding the whole trans-disciplinary process of patient treatment. Full process insight became very complicated in medical imagery. An integration of radiation protection in quality assurance was necessary. Ethical requirements, risk awareness and safety cultural requirements together with adequate patient communication and even involvement have complemented the risk decision making process in recent years in order to achieve better health care of sustainable nature.

Justification and optimisation exerted much more impact than required traditionally by an authorisation process or even in expert behaviour. They go far beyond strict radiation protection, integrating different aspects of responsibility with a balancing of risks and benefits in particular. Optimisation is vital in nuclear risk management . Its cultural dimension is reconsidered now by IRPA but could be more supported by science based communication models such as RISCOM (Andersson, 2008).

The dose concept as risk indicator is a performant but rather abstract concept, lacking transparency for lay citizens. Since biological targets of exposure seem able to suffer without energy deposition in the target molecule the concept is criticised (bystander effect). Effective dose was not set up for a range of present uses (patient dose in radiology, environmental exposure pathways of low energy). Considering moreover individual predisposition where biological repair capacity can be susceptible to radiation, science is now looking for bio-indicators of health effects.

The dose paradigm is an interesting but no longer sufficient base for risk analysis. The linear dose effect relationship, a problem for many interests and experts, represents an useful operational simplification, which is however not applied uniformly. It is corrected for risk estimation purposes by concepts as dose and dose rate reduction factor (DDREF), a controversial issue especially for half of public exposure related to high dose rates such as X-rays.

The collective dose concept served as useful risk indicator for identifying risks to groups, such as for Rn exposure of categories of workers and the public, but potential misuse was given political concern. Inadequate use may not be a sufficient reason for disqualification of a useful concept. But this is argued more and more in the EU and even at UNSCEAR. The same reasoning could be applied to sustainable development concepts.

Finally at the institutional level risk assessment & management in the nuclear field is constrained by an isolated nuclear culture such as the regulatory framework of the EURATOM treaty and set up in most national regulatory approaches, where overlap of assessment and regulatory procedures with non nuclear fields are difficult to manage.

PRESENT CHALLENGING AREAS FOR RADIATION PROTECTION

In radiation protection not only reactor safety for accidental risks and nuclear waste management for long term risk are challenging areas. Digitalisation of medical imaging and Rn indoor risks are even more important for public health.

- Medical radiation protection

A range of new problems have emerged in the medical sector in the last years resulting in growing regulatory concern and changes in public perception.
Interventional radiology extended from cardiology to neurology and other applications and old problems such as skin burns and cataract due to ionising radiation resurfaced. Such deterministic effects should normally not occur through prevention in radiology. It illustrated potential and recurrent high skin doses for patients. But a deficiency of risk assessment was also noticed for specific standards intended to limit dose accumulation for the lens of the eye. New protection measures are now required together with adequate personal dosimetry, unable in the past to monitor such risk for medical staff. A paradox was however noticed in the controversy on low dose effects: not the stochastic risk limitation but the limit based on a threshold effect had to be reviewed, illustrating that little scientific evidence existed in the past for assuming such high threshold dose (RIHSS, 2007) (ICRP, 2011). The limit for workers for the lens of the eye needs to become stricter with a factor 8 in future basic standards with even uncertainty on the existence of a threshold.

The increasing dose of CT use, already put forward in earlier publications (Vanmarcke et al, 2004) now received concern at world level. More extensive use (health screening, dentistry) or combined use (PET-CT, therapy) of new developments of this technology are requiring elaborated risk assessment. Conceptual adaptations of risk management are needed due to contamination problems. Moreover the use of PET in nuclear medicine has illustrated that extremity dose limits are not necessarily respected for staff and that dose estimation is inadequate in a number of circumstances (Covens et al, 2010). Finally the occurrence of radiotherapy incidents, causing the overexposure of thousands of patients in France and smaller incidents elsewhere, has lead to risk policy changes in Europe, directed by ASN, the French nuclear safety regulator (Smeesters, 2011). In Belgium working groups with engagement of all relevant professional actors and round table conferences with as well as patient representatives helped to clarify issues and to improve risk assessment and management including incident reporting and feedback of experience. But an enforcement of the regulatory institution with more active surveillance in the medical

field was necessary to improve protection. A responsibility in authorisation processes of producers is now put on the agenda by ASN rearding medical devices in UE, in order to better open black boxes of technological complexity and to allow better understanding by hospital physicists.
Without increased risk awareness and safety culture of medical practitioners however, a change will remain limited and confrontations with liability claims more frequent. Patient communication too came up as a new issue for radiation protection in this sector, requiring a lot of research to manage.

- Radon exposure and NORM industry

Since its rediscovery Rn exposure became at the end of the seventies a paradox for safety standards. Natural exposure was illustrated to create a population exposure higher than the limits of 1. mSv/y for the public for nuclear practices. Mixed feelings grow in regulatory bodies how to handle this human enhanced natural lung cancer risk with limited public concern. ICRP hesitated and struggled with coherence of concepts regarding dose conversion. The global pooling of epidemiology however brought up a better understanding of risk, evident even at low air concentrations; the dose conversion factor doubled and coherence was found between miner data and public exposure. Indoor environmental risk standards are a general new concern for sustainable housing . Being a potential cause of about 10% of lung cancers, they have to be improved as put forward by ICRP and WHO.
The very extensive use of resources containing natural radioactivity in a large number of industries, called NORM industries, has pointed out the need to better integrate radiation protection in other health and environmental policies up to waste management of numerous companies. The impact of the phosphate industry in particular was assessed but the long term environmental impact of the richest mine industries in the world such as in South-Africa has not yet been clarified in a sustainability context. RP utilitarian ethics have created instruments such as clearance and exemption to manage and tolerate radioactivity at low level in industry. The extension of risk assessment to long term radon implications of building materials and to huge waste fields of NORM industry could pose new risks for society in future. It asks for sustainability attention at least in zone planning of large areas for future generations. The half life time of the radioactivity source term, Ra-226 is 1600 y. Even accidental risks were discovered in huge waste dumps from NORM industry in Europe where serious chemical risks and heavy metals complete the risk picture of radioactivity around exemption level (Poffijn, 2010). These sites are unfortunately never again accessible for housing, but create not yet a political concern.
Natural exposure is used too much as a referential in case of man enhanced radioactivity. It calls for more ethical reflection. It is also an example of lack of equity (even trans-generational) for reasons of opportunity in the distribution of benefits and risks of practices called “existing exposure situations”.
The impact assessment of this sector could be improved a lot by a broader sustainability assessment but it is noticed that chemical risk and waste assessment at present disregard contrary to the nuclear sector long term risk considerations for nuclear waste management.

- Nuclear accident risk assessment and management

The Fukushima accident has demonstrated the reality of a major impact of low probability, even for reactor technologies used in Western Europe. The hazard of the huge radioactive source term of nuclear reactors and fuel management installations was made crystal clear while numerous inconsistencies were noticed worldwide. The nuclear energy sector had been globalised such like the financial sector without simultaneous globalisation of safety criteria and regulatory supervision. Transparency still seems to be a distant target for nuclear industry and equity is far from realised in the liability of risks (Eggermont et al, 2011). Virtual average scenarios as put forward by ExternE (Laes et al, 2011) had created only an image of competitiveness for the sake of economic opportunities in sustainability comparisons .
Fukushima illustrated for the third time a lack of imagination in risk assessment scenarios as well of a lack of coherence and independency in applying criteria for reactor safety. After demonstration in

Harrisburg that human reliability was neglected in sophisticated MIT engineer tools for probabilistic safety assessment, Chernobyl illustrated the lack of management reliability integration and the importance of safety culture in a complex organisation. Fukushima has now remembered experts of the impact of well known rare natural phenomena, a good reference for robustness and sustainability. But also the impact of marine contamination and build up of radioactivity in coastal sludge with its environmental impact on food chain was not taken up enough compared to atmospheric pathways. Finally the increased vulnerability of society caused by technology choices for a particular socio-economic tissue was underestimated dramatically. Japan had less than 30 % nuclear electricity, half as much as some European countries. Two thirds of this electrical capacity is still unavailable constraining economic revival. Regional vulnerability tests are not yet taken up in ongoing stress tests. They limit impact assessment to a technological reassessment without considering emergencies in real situations of densely populated areas. Here sustainability could be considered by a more trans-disciplinary approach beyond health effects with a (full spectrum) of stakeholder engagement of affected regional communities and companies. It also illustrated that the valuing of life in emergency risk management is much more than monetary terms, and determined by societal network cohesion and culture.
Nuclear and radiation protection risk assessment tools however still remain strong but incomplete instruments which could inspire other sectors looking for safe environmentally sound ways of development.

- Impact assessment of nuclear waste disposal

A challenge for sustainability already occurred in the eighties when ocean dumping of low level nuclear waste had to be banned due to public opposition, criticising the underlying anthropocentric philosophy. Models illustrated a sufficient dilution by the ocean for health risk. The potential value of deep ocean ecosystems was of few concern for nuclear experts but inacceptable for marine ecology. Meanwhile ICRP only slightly adapted its dosimetric approach taking into account doses to some fauna and flora but not yet proposing ecosystem impact assessment. Controversy was created on ethical grounds for this practise which also is a problem of distributive equity as cheap irreversible dumping practice are selected instead of a safe engineered containment solution paid by the polluter. It contributed to the creation of instruments such as the OSPAR convention, which now also constrains authorised marine radioactivity releases by nuclear installations .
The safety assessments for nuclear waste disposal projects are promising. But ethical concerns of trans-generational nature dominate and focus the problem on future site memory and how to guarantee cost coverage in due time. It became clear that health criteria such as limiting cancer risk for the long term are insufficient value references for some cultural settings. The estimation of long term potential doses had little significance regarding model, data and social uncertainties (e.g. future food habit) but was less controversial for nuclear experts than concepts such as collective dose. A search for robustness indicators is more appropriate.
Due to blocked situations in decision making on siting nuclear waste disposal projects, local participatory experiments were developed with successful results in Sweden and Belgium, and were discussed in the EC network COWAM. It was noticed during Belgian regulatory interventions that robust safety criteria can oppose local community preferences emerging from dialogue. An early involvement of radiation protection regulators in participative processes should be made possible allowing them an independent execution of their mission. Participative democracy experiments can as well be opposed by representative democracy initiatives in the decision making process as long as institutionalisation is not realised such as done in France.
Problems in waste management cannot be simply reduced to local issues, neither decoupled from nuclear energy options (Hugé et al, 2011).

It can be noticed that many of the discussed measures to correct interventions to meet radiation protection challenges call for more precise objectives and a more holistic scoping of risk assessment & management.

SUSTAINABLE DEVELOPMENT REQUIREMENTS - PRECAUTION

The concept of sustainability as it emerged in the field of technology, energy, environment and health policy making is discussed by (Hugé et al, 2011). It is based on the UN Rio Declaration and Agenda 21 (UN, 1992) which reaffirmed the early UNEP mission statement from 1980:

"*Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs*"

This means a strategy for a desired future starting from principles or criteria.

Criteria for sustainable development were discussed in a PhD in PISA[2] (Laes, 2006) and were applied by the Belgian Federal planning Office (BFPO, 2007) in a strategic exercise on energy futures. Based on these experiences an interuniversity research project was set up on impact assessment of sustainable energy policies (SEPIA) coordinated[3] by A. Verbruggen from the University of Antwerp and involved in IPCC. Within SEPIA a qualitative sustainability assessment was made of nuclear energy policies (Eggermont et al, 2011) referring to 5 major criteria or principles which also belong to the UN Agenda 21:

- Coherent **integration** and reconciliation of various aspects of development (environmental, social, economical, values,…)

  action field on the human-environment relation including trans-disciplinary science approaches

- Stakeholder **participation** in risk governance

  associating relevant actors in decision making processes for SD as also proposed by IRPA, with transparency in risk communication such as developed and modelled in RISCOM (Andersson, 2008).

- Distributive **equity** in problem solving

  element of responsibility as well intra as intergenerational; considers needs

- **Global** differentiated responsibility

  an extension of justification at each level of responsibility such as in RP but here meant particularly in a globalised world at the most relevant level of policy making which is for us the EU

- P**recaution**ary approach in risk assessment and management

Plausible risk problems characterised by complexity, uncertainty and ambiguity are forcing us to reconsider decision-making approaches . At EU level the European Environmental Agency (EEA, 2002) had argued for legal integration of this component of sustainable development, based on lessons learned from early warnings in the past or from lack of precaution (such as asbestos but also nuclear energy). This study has demonstrated that there is a need for a sufficiently broad scoping of risk. Not having taken into account in due time measures to protect the future can become very expensive as also illustrated by climate change due to anthropogenic CO2 emissions, an emission component without direct health risk. Precaution has been established meanwhile in European and national law as discussed in the reference work "Prudent Precaution" of the (Health Council of the Netherlands 2008).
-Complexity is inherent in our RP job which already is a trans-disciplinary profession. It is by definition oriented towards problem solving and requires an interactive use of different disciplines. But we should be aware of black boxes, created to protect business, without complete clear picture.

[2] Program of integration of social science in nuclear research of SCK.CEN in Mol (Eggermont et al, 2011b)
[3] www.sepia.ua.ac.be

-Uncertainties (as well data, model & science uncertainties) should be made explicit and considered systematically and should be taken up in decision-making. This is required by scientific methodology but the reality is different in complex settings sometimes undermining output statements of risk assessment as illustrated dramatically in Japan during the last 5 months. Uncertainty characterises not only technological behaviour but is also a dimension of the hazard itself as well as the exposure and risk for harmful effects.
-Ambiguity is related to divergent values (the as well normative and interpretative dimension) but can also be created by expert culture and defensive mechanisms of cognitive dissonance. Many potential conflicts of interest can hinder assessment by experts.
A broader than usual approach is needed when these three contextual factors are characterising a plausible risk; the Dutch Health Council calls precaution a strategy to better deal with uncertainties in an alert careful way but remaining reasonable, transparent and looking for a tailor made and proportional (range of) answers, allowing policy makers to decide. Stakeholder involvement is inherent to precaution throughout the whole risk assessment and management process. Precaution considers future generations and looks for the best possible protection for human health and for the quality of the environment for a range of options possible in a given context. Prudent precaution essentially is an adapted strategy, which can easily overlap with prevention already well framed in European safety policies at work. (Zaccai, 2002) remarks that each prevention problem or incident analysis in case of insufficient prevention usually allows us to learn about complexities, uncertainties and even ambiguities that had not been considered enough. Precaution is is much more than a cultural controversy on the reversal of proof. It is applicable as well to financial risks in the past as in the future.

The ALARA principle can be seen as a precursor of the precaution principle and justification and optimisation as instruments to achieve this compound of sustainable development. Assessment approaches for decision support, formalised at EU level and applicable as well in the nuclear as non nuclear field, such as environmental/strategic impact assessment (EIA & SEA) respectively, are broadening the approach. They can be seen as precursors of upcoming sustainability assessment. Such assessments allow to extend health impact assessment (HIA) as currently done in radiation protection but in a more systematic way for including the obligation to consider alternatives. This goes beyond the justification concept in radiation protection.

New cross cutting initiatives, created by international treaties such as OSPAR for reducing marine releases and the Aarhus convention guaranteeing disclosure of information are also challenging existing habits in radiation protection. These initiatives aim to improve transparency on environmental releases and to facilitate stakeholder involvement for a more sustainable decision support in the management of environmental and health effects.

Perspectives for Radiation Protection Dynamics

The dose paradigm and its application for overall risk indication is questioned while evidence for synergistic effects is increasing at different levels. The exposure reality in the environment, at the workplace, for the patient and the public is always a combined exposure requiring more holistic and coherent regulatory approaches.

The new environmental concept for protecting a selection of fauna and flora species, being developed by ICRP, lacks adhesion among radiation protection professionals, nor is it adequate in the new dynamics of sustainability governance. An ecosystem approach considering different stress factors, such as being developed now for the atmosphere with regard to climate concerns, deserves more attention in nuclear regulation. Ecosystems to consider are e.g. the atmosphere, the marine coastal environment, the indoor environment etc..

The ongoing political controversies on effects at low dose from accidents as well as from medical exposure should not been used to develop a defensive strategy questioning the ALARA principle in a dose range of economic significance. On the contrary the complexities we face in RP and the uncertainties on effects and inherent ambiguities in our concepts call first of all for a precautionary strategy embodying sustainable development. Risk awareness as basis for ALARA/RP and safety culture should become a condition sine qua non for taking responsibilities with regard to ionising radiation and should condition training in the future. Guidance should be developed to support justification at all levels of responsibility on a broader base than dose and health considerations and open attention for alternative options should be fostered as well. Moreover the other sustainability criteria allow us to create a broader scope for our impact assessments. Tools are well developed but need improvement as illustrated above for reactor safety and dose/risk monitoring .

Experience learns that stakeholder involvement can contribute a lot in improving insight in interaction. The attention for value judgements, for transparency in risk communication as well as for coherence and consistency could help RP to gain trust and confidence again. But distributive equity is strongly shaping perception and can no longer be neglected notwithstanding conflicts of interest.

Incident analysis could yield feedback of safety experience in a systematic way while emergency planning should consider real challenges and discover better public concern and valuing of life.

For the challenging areas we propose a non exhaustive summary of perspectives in the frame of sustainability:

Medical: Improved risk awareness of physicians in particular towards new effects such as cardio vascular risks; improved proactive communication with the patient; higher responsibility and involvement for producers of complex installations; systematic incident reporting and quality level registration; adequate monitoring of exposure and contamination of staff and patients ; epidemiological investigations of risks of medical exposures; enforcement of trans-disciplinary competences

NORM and Rn: Developing impact assessment including public perception and acceptability of exemption (and clearance measures; sustainable management of NORM waste and sustainability assessment of radon reduction measures in houses and industry.

Nuclear energy: see also the discussion in (Eggermont et a 2011); small inherently safe total energy concepts with more efficient fuel cycle or remote siting (case EPR); distributive equity measures are needed for liability and nuclear waste funding; Gen IV fast neutron reactors and advanced reprocessing require independent sustainability assessment before continuation, considering costs, risks and regulatory challenges. Demonstration of sustainability perspectives regarding limited nuclear waste management improvement spread over a century. Integration of site-specific PSA level 3 and vulnerability assessment of neighbouring regions within the reactor stress tests.

Nuclear Waste; stepwise deep geological robust disposal in international sites established through consensus building. Sustainable solutions for radium bearing wastes, for depleted uranium stocks and tailing piles worldwide

Conclusions

The different present challenges for radiation protection and for the nuclear sector demonstrate that when confronted to a risk complexity, society's approach to risk can no longer be reduced to an isolated approach within a particular sector. Hazards present in most cases a combination of risks while effects can have a synergistic nature dependent of the context. Moreover risks are perceived differently dependant on the balance of advantages. Perception is co-determined by trust shaped by historical experiences and coherence. Finally the existence of trusted adequate regulatory bodies together with transparency in risk communication can considerably facilitate decision-making processes particularly

when they require public support over longer periods. The concept of sustainability and precaution broadens the scope of risk assessment and can strengthen radiation protection and safety.
The EU could take up this sustainability dynamic to reconsider and integrate the EURATOM treaty while reinforcing the regulatory as well as the licensing and controlling role of EC institutions replacing multilateral networks with the aim to create European nuclear safety standards.

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