Interview to:

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Radioecology

- **There is not a unique definition of Radioecology. From your point of view, what would be the most appropriate definition? (or at least an adequate definition)**

Having emerged concomitantly with the civil use of nuclear energy during the 1950s, radioecology is situated at the crossroads between risk induced by environmental radioactivity and its consequences on both, man and the environment. Radioecology therefore is a highly multidisciplinary scientific branch of environmental sciences which gathers a variety of disciplines such as biology, chemistry, physiology, ecology, biogeochemistry, geophysics, ecotoxicology, mathematics (models, statistics), metrology,… among others.

Possible definition: Radioecology is a branch of environmental sciences which gathers multidisciplinary approaches to describing, understanding and predicting: 1) the fate of radioactivity (artificial and natural, as carried by radionuclides) in environmental (ecological) systems, 2) its impact on man (via the environment) and on the environment itself (biota, ecosystems) in order to feed human and ecological risk assessment, 3) biogeochemical processes by means of radioactive tracer studies.

- **Concerning the discipline of Radioecology, what is its main scientific role? The processes, the effects, ...?**

Radioecology has both scientific and operational roles. The primary scientific role is to advance knowledge and understanding on the processes driving **radionuclides transfer** within the environment (abiotic media and living systems) and on the subsequent **radiation effects** on life (from organic molecules through organisms and up to ecosystems). Both are equally needed to feed risk assessment in the frame of human health and environment protection, and both still suffer from significant uncertainties. This role is paralleling very similar approaches undertaken to deal with other pollutants (heavy metals, pesticides, medication products residues, organic pollutants, etc…).

Historically, more focus has been devoted for a long time to the transfer issue, due to the preference given to an **anthropocentric** view where the environment was restrictedly considered as a simple vector of radioactivity transfer from a source to man. A rebalancing of efforts is now on its way to improve knowledge on the effect issue as well. This is illustrated by the ongoing efforts aimed at mastering environment protection against radiation, like the **biocentric** view focused on effects in non-human organisms as developed by ICRP, and the the upcoming **ecocentric** view focused on populations and ecosystems to account for interactions between species (including man) and biodiversity, as recently recommended by IUR.

However, two other important roles of radioecology need not be forgotten. The first one is to support other environmental sciences with radioactive tracer techniques which form a very powerful method to investigate aspects such as large scale marine and atmospheric circulation, various dating of environmental materials, large and small scale biogeochemical processes and cycling. The second one stresses the operational role of radioecology, that is to develop suitable concepts and tools for emergency preparedness, and to identify and develop innovative technical solutions for remediation and decontamination in post-accidental situations.

○ How has Radioecology evolved in the last decades?

Since 50 to 60 years of existence, the historical evolution of radioecology and its activities have evolved along four successive phases.

1st phase: birth of radioecology

Prior to the tragic Chernobyl event that happened in April 1986, the founders of radioecology promoted a wide array of investigations expanding from the study of pathways of transfer to man, and effects of radiation on various animals, plants, and full ecosystems. These investigations however were mostly concerned with external γ irradiation at rather high doses, as illustrated by the various large scale experimental irradiation studies carried out in the US, Canada and Europe based on γ irradiation sources placed for long duration in natural systems.

2d phase: facing real health and environmental problems

The next phase has been prompted by the Chernobyl accident which strongly influenced radioecology, initially with a strong stimulation due to attraction of large funding from international sources (European, in particular), and later with a decline associated to political trends with respect to nuclear energy, essentially. Chernobyl drastically boosted R&D towards fulfilling human radioprotection needs (pathways of transfer) as a consequence of the urgent need to assess the impact on human health of the contamination (essentially ^{137}Cs and ^{90}Sr) spread over large territories. During more than one decade, this led to spending large efforts on modelling the transfer of radionuclides within the environment towards man, through ingestion, inhalation or by external irradiation, at the expense however of radioecotoxicological studies on wild species and their related ecosystems which were assigned a lower priority during this period.

Next, during the 1990s until the end of the 20th century, a vigorous political debate has evolved almost worldwide questioning the public acceptance and usefulness of considering further atomic energy developments to face the growing planetary energetic needs. Some countries, essentially in Europe, decided to withdraw from the further use of nuclear energy technology, due to emphasis placed on its danger. A major consequence for these countries has resulted in the disruption of many of their research groups and competence in radioecology. This dis-aggregation of non-critical mass research groups led some observers to question the future of radioecology, either as a scientific discipline (its "last gasp", as stated by a scientific journalist of the Science Journal in 2002) or as a unique expertise to parallel atomic energy activities (Stone, 2002). This 2d phase has therefore been dominated by an **anthropocentric** view over radioecology and the environment.

3d phase: growth of environment protection worldwide consciousness

Finally, by the turn of the 20th century, a worldwide movement back to using nuclear energy production systems has been observed. This movement has been driven by closer attention to the requirements for sustainable development, greater awareness of climatic disruption promoted by fossil fuel burning, and increased economical pressure from the continuous rise of the oil fuel rates. Also, the upcoming general context of environmental protection driven by recent societal concerns rooted in several large scale environmental critical issues, such as climate change and biodiversity decline, impacted radioecological priorities towards better appraisal of effect studies on nature, and the methodologies necessary to assess the potential risks. It is in this context that radioecology started to move on to the issue of the radiological protection of the environment.

A major driver was to reconsider the long-standing past ICRP paradigm having simply subordinated environment protection to that of humans, owing to the fact that *Homo sapiens* was among the most radiosensitive species. Following the ICRP Committee 5, created in 2005 to propose and develop a system framework for the radiological protection of non-human biota, a number of Institutes, Universities and international bodies have contributed to elaborating a methodological concept based upon "reference organisms", as derived from the "reference man" concept in human radioprotection. This concept moves to non-human biota as targets of protection, therefore leaving the previous anthropocentrism to adopt a **biocentric** view to environment protection.

4th phase: facing again largescale ecological impact (Fukushima accident)

By the end of this 3d phase during the early 2010s, a growing part of the radioecology community (led by IUR), stressing the shortcomings arising from a system of protection restricted to individual organisms as this is the case with the "reference organism" approach, proposed to improve the situation by enlarging the system towards an "ecosystem approach" featuring a more **ecocentric** view over the environment.

It is in this context that the Fukushima accident occurred in March 2011. It has revealed that properly assessing the long-term consequences remains a crucial issue which requires that continuous attention is devoted to knowledge and expertise in radioecology. Furthermore, it is particularly realized that proper understanding of the ecological consequences of the Chernobyl spread of radioactive contamination is still quite controversial, and therefore difficult to exploit in view of anticipating the Fukushima accident consequences. More generally, it is also realised that the sustainability of using nuclear energy and radioactivity for civilian purposes needs to be grounded to societal acceptance. Societal acceptance in turn is highly dependent on the transparent explanation of risks and the demonstration that continuous effort is dedicated to close uncertainties with appropriate knowledge and understanding.

This 4th phase is just starting now, and its construction is ahead of us…

- **From your point of view, what are the "hot issues" in radioecology nowadays?**

Certainly, one quite hot issue in radioecology, reinforced by the Fukushima accident, is the long term ecological impact at low and chronic levels of radiation within realistic environmental contamination scenarios, that is also involving additional stressors.

This requires both, the development towards full maturity of methods for ecological risk assessment (as mentioned above) that will give access to anticipation, and the development of a supporting basis of science on radiation effects in various biota to explore the diversity of processes underlying bioaccumulation, radiosensitivity, propagation of effects through the whole scale of biological organisation (from molecules up to ecosystems) and transfer, more generally. One should mention here that stimulating basic science on radiation effects in non-human biota in view of developing environment protection, is likely to yield significant clues to improve human radioprotection as well. Both fields need joint brainstorming and common work.

It is to be stressed that the Fukushima accident drives also to better address marine radioecology, and technical solutions for remediation and decontamination, as no significant progress has been made in this field in spite of the large post-Chernobyl R&D investments.

The International Union of Radioecology

- **For those who are not familiar with the International Union of Radioecology (IUR), could you explain us a little bit about its objectives, members, organization?**

The International Union of Radioecology was founded in 1977, registered as an International Association under Belgian law, and declared as a non-political and non-profit scientific organisation dedicated to the worldwide development of radioecology.

The Union has attracted a few thousands of scientists during its history, and it currently gathers nearly 600 active members from the 5 continents around the world. The action of IUR is driven under three major characteristics - independence, democracy and voluntary work - the scientific community thus assembled under the IUR banner really proves to be committed to developing radioecology. The Board of Council is elected for 4 years terms, and makes all important decisions during the General Assembly called to meet annually. It consists in 12 members. The first 6 are elected form the worldwide membership and include the executive Board represented by the President, the vice-President, the General Secretary and the Treasurer running the day-to-day operation of the Union. The 6 additional members, called "Regional coordinators", are elected each from their relevant region among 6 around the world. Given its independent status, the IUR funding is limited essentially to the annual membership currently fixed at 40 € (or the equivalent in US $) and sponsoring collected from supporting organisations as an Institutional fee. The funding is directed to support radioecological actions (as detailed below), with especial emphasis devoted to supporting young researchers initiatives and achievements.

The objective of the Union is to promote radioecology worldwide, in all its dimensions, from research activities up to expert advice and operational management. Essentially focused on radioactive elements, radioactivity being potentially toxic for life, radioecology contributes to the worldwide effort that is continuously undertaken towards the sustainable development of nuclear activities, especially the civil use of nuclear energy.

The overarching role of the Union is to perpetuate a "think tank" capacity on radioecology issues through the maintenance of a network of scientists and professionals. IUR is currently the only organisation

capable of networking worldwide all scientists with interest in radioecology, and the Union develops especial efforts to link together all existing/emerging regional networks (European, Asian, American,…) through formal institutional agreements, also with similar neighbour NGOs such as SETAC dealing with chemical pollutants.

The Union's activities therefore are based upon four major tools: thinking and development work in dedicated task groups, scientific meetings/workshops/conferences, teaching and training, and linkage based on its website to allow for information exchange and communication within the network.

- Dedicated Task Groups are mobilised and formed in response to various contextual drivers (daily news, need, recent discovery, especial creativity arising from a group of members,…) allowing to reach a critical mass on a given subject and to support its longer term maintenance.

- Congresses, workshops and seminars are organised, sometimes in association with other partners, to review recent knowledge advances and to promote discussions that fund the emergence of consensus or the specification of problems to be solved in priority.

- The network daily life is maintained and supported by its web site (www.iur-uir.org), being together a dissemination tool (newsletter, publications, conferences announcement, …) and a tool for exchanging information within the membership.

- Teaching is undertaken to stimulate young talents and transmit knowledge from senior scientists, further supplemented by the provision of prices and awards, "Young Investigators" and "V.I. Vernadsky" awards created in 2004.

- **Within the IUR activities (working groups), which ones would you highlight?**

A Task Group is created when a group of radioecologists, generally assembled at the incentive of a leader, is reaching a critical mass and is willing to promote brain storming and development, on an innovative issue. Among international organisations dealing with radioactivity and the environment, IUR deliberately places itself at the forefront of the scientific side, and this is why many significant developments in radioecology which are now tackled internationally actually started through an innovative idea first seeded within an IUR Task Group. This is clearly the the case for 2 on-going task groups on "protection of the environment" and the "multipollution context".

Hence, the most recently created task groups, like the "non-lethal methods for radioecology" and the "ecosystem approach" task groups are illustrations of the future trends, and will most probably turn out as important issues for tomorrow's radioecology. Meanwhile, other task groups like "speciation", "Arctic and Antarctic regions", "radioecology and radioactive waste" are more or less continuously on-going, and they contribute also to maintaining an innovation spirit in these particular fields.

- **The International Union of Radioecology was created in the seventies of the last Century, How has IUR evolved since its creation?**

IUR is a more than 30 years old lady now. It went through several periods in its life, some with much brilliance, others with more difficulties… It has been led by a number of different presidents and Board of Councils, and has accumulated a lot of experience. Occasionally, it has suffered various pressures and has even sometimes been declared to be about to disappear, but it always survived and it still shows today a strong motivation and willingness of a large and worldwide community of scientists, deliberately committed via voluntary work… this is a very strong demonstration of the strengths of its foundation.

As current president of IUR, only being one particular contributor, I am hoping to find the time and resource necessary to assemble a core group of senior radioecologists, including those who carried out important responsibilities, aiming to publish the unique history of our organisation, that is accompanying and informing the safe development of nuclear activities since more than 30 years, irrespective of the national or industrial particular interests.

- **From your point of view, what are the main benefits of having an organization such as IUR? How does IUR contribute to Radioecology?**

The first benefit of IUR is emerging from the size and extension of its membership which allows to stimulate coordination and networking on a worldwide scale. This includes liaison with other international organisations, such as IAEA, UNSCEAR, the European Commission, ICRP, NEA, etc…), the Union being maintaining formal agreements with most of them.

Another important benefit arises from its scientific expertise, grounded in the will to build an advanced knowledge on the relationships between ionising radiation and the environment as a prerequisite to further development and acceptance of the civil use of nuclear energy. Embracing all together radioactivity, the environment, health and the assessment of risk, it holds a strategic position and a remarkable integration of skills to assemble critical masses on scientific innovation and prospective view.

Finally, it must be recalled that IUR forms the only independent network of radioecologists that is free of any particular interest-driven influence. Its positions and the directions it promotes are therefore important inputs for society who wants to be correctly informed about the risks associated to nuclear techniques and industry.

- **The IUR has recently made a public consultation through its web page, focussed on how to prioritise the future research activities on radioecology. The feedback from the radioecology community has been very significant. Could you please comment on the main results/conclusions obtained from this consultation?**

This consultation has been set up as a response to the solicitation from the European Alliance in radioecology to provide the IUR view on the strategic research agenda (SRA) which had been set up by the STAR European Network of Excellence. Given that a prior consultation directly asking for the 3 highest priorities within the 15 lines of research identified in the SRA had already been carried out, IUR considered a different perspective in order to provide the Alliance with valuable and new inputs to feed a prioritization process.

The IUR questionnaire therefore was built on key questions relating to the position of radioecology with respect to its major drivers: radioprotection science, environmental sciences and society at large. For each question, a wide range of possible answers was suggested and professionals with interest in radioecology were asked to rank these from high to low importance. We sent this questionnaire out towards the overall community, worldwide. Exploiting the various collaboration agreements signed by IUR with other environmental radioactivity and radioecology international associations, we managed to get quite a significant rate of feed back in spite of the short consultation duration (less than 3 weeks), amounting to 170 responses from 58 countries, a success which timely illustrates the interest given to IUR from the community (as discussed above).

A quite interesting array of responses emerged on the directionswith highest priorities that shall be privileged to construct a performing strategy for the future in radioecology.

These are briefly reported below (reporting only on the responses for the highest priorities):

- Environment protection shall evolve in coherence with both the human radiation protection system and other environment protection frameworks with equal importance.

- The high priority targets for radioprotection are human individuals, ecosystems, and populations of animals and plants.

- The high priority scientific approaches for radiecology shall be placed on ecological inference (ecosystem-centered), tracer studies and biogeochemical cycles.

- Inputs of highest importance to society from radioecology are to improve the understanding of processes (tranfers, effects, interactions). Other inputs (regulation and assessment tools, predictions for ERA, in-situ observations) are also important, all equally.

It appears from this consultation that the radioecology community largely points towards more ecology (ecocentrism) in the future than before. Meanwhile, the community does not forget about the importance of its long standing “environmental” contribution to human radioprotection. A further exploitation work to be carried out would be to examine if specific views on priorities are existing depending on the regions of the world considered.

The future of Radioecology and the role of IUR

- **As you are aware, in Europe it has been recently created the European Radioecology Alliance. What would be the relationship between the Alliance and the IUR in the future? Are there synergies, complementarities, between both organizations?**

It is not the role of the Union to speak on behalf of the Alliance, but I believe that the Alliance leaders are convinced that IUR, the oldest network of scientists in this field, can help to maintain good liaison with the rest of the non-European world. Indeed, the IUR consultation obtained a 99 % score from the community recommending that the Union "should coordinate on a worldwide basis other continental initiatives such as to ensure an optimised and balanced development of efforts". Therefore, IUR on its side is fully supportive of this European initiative which has a high potential to stimulate radioecology research in Europe, and beyond.

- **Looking to the future, the EU is preparing the Horizon 2020 programme. Under the foreseen global umbrella for radiation protection, from your point of view, what would be the role of radioecology in Horizon 2020? What risks and/or benefits (if any) might arise for Radioecology?**

I have expressed already my view on this issue when giving the introductory lecture at the last ICRER international conference in Hamilton, Canada (2011).

The highest challenge upon the IUR scientific community, highlighted by the Fukushima accident, is upon radioecology's maturity. Some questions raised are as follows. Is its level of excellence suitable to properly describe, explain, anticipate and master environmental risks? Do we have the right and optimal answers to the many immediate and longer term problems faced by our Japanese colleagues dealing with the contamination spread over the territories and affecting the population? Is our scientific understanding ripe enough to anticipate what will the long-term impact of the contamination on the environment be (land and sea)?

From my perspective, the major directions to be followed that will best contribute to maintain political and societal recognition of the interest of radioecology are:

- to move beyond the long-standing dominance of an exclusively anthropocentric attitude in developing radioecology. This attitude has bee rooted in an old philosophical paradigm of human technology dominance over nature, which the unfortunate nuclear accident at the Fukushima Daiichi power plant has questioned,

- to develop, therefore, a capacity suitable to constructing in addition a more eco-centric attitude, which means leaving the status of radioecology as a subsidiary to human radioprotection only. Essentially, this means to better balance efforts dedicated to transfer and effects studies, over populations of all life species interacting in ecosystems (including human beings). Sustainability of all forms of life on the planet, and not only that of human beings, has become a general issue which urges to master the risk associated to environmental stressors and toxicants, including radionuclides. More eco-centrism will help radioecology to be recognized as a self-standing risk assessment discipline on its own, exactly in the spirit that its founders had in mind when they chose its name, some 60 years ago or so.

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