FIRST THOMAS S. TENFORDE TOPICAL LECTURE: THE ETHICS OF RADIOLOGICAL PROTECTION

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Abstract—The International Commission on Radiological Protection system of radiological protection is based on three pillars: science, ethical and social values, and experience. As far as ethics and the protection of humans are concerned, the system combines the values of beneficence/non-maleficence, prudence, justice, and dignity. Beneficence and non-maleficence are directly related to the aim to prevent deterministic effects and to reduce the risk of stochastic effects. Prudence allows taking into account uncertainties concerning both the deterministic and stochastic effects of radiation on health. Justice is the way to ensure social equity and fairness in decisions related to protection. Over the past decade, the system has also integrated procedural values such as right to know, informed consent, stakeholder involvement and self-help protection, and reflecting the importance to properly inform and also preserve the autonomy and dignity of the individuals potentially or actually exposed to radiation. In practice, the search for reasonable levels of protection and tolerable exposure levels is a permanent questioning that depends on the prevailing circumstances in order to act wisely; i.e., with the desire to do more good than harm (beneficence/non-maleficence), to avoid unnecessary exposure (prudence), to seek fair distribution of exposures (justice), and to treat people with respect (dignity).

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INTRODUCTION

At the occasion of an address to the Ninth Annual Conference on Electrical Techniques in Medicine and Biology in 1956, Lauriston S. Taylor, then incumbent president of the National Council on Radiation Protection and Measurements and also chairman of the International Commission on Radiological Protection (ICRP), declared: “Radiation protection is not only a matter for science. It is a problem of philosophy, and morality, and the utmost wisdom” (Taylor 1957). “Wisdom,” one of the four cardinal virtues of the ethical tradition inherited from Classical Antiquity, is a key value from many religious and philosophical systems, including Confucianism, Hinduism, and Amerindian oral traditions. By using the term “wisdom,” Dr. Taylor emphasized that beyond its undeniable and compelling scientific and ethical basis, radiological protection was also a question of insight, common sense, good judgment and experience. Through his formulation, he thus brought to light the three pillars of the system of radiological protection that had gradually built up for almost half a century and to which he had already contributed much personally; namely science, ethics and experience.

It should be noted at the outset that there are very few writings devoted to the ethical dimension of radiological protection compared to the vast literature related to the associated scientific, technical and practical aspects. The first contributions directly addressing the subject of ethics only appeared in the 1990s. Among them, it is worthwhile mentioning the pioneering contribution of Giovanni Silini who reviewed the ethical foundation of the system at the occasion of the Sievert Lecture he delivered in 1992 (Silini 1992). He concluded his lecture emphasizing that the system has been developed rationally, but at the same time with the desire to act reasonably. Also interesting to note are articles published subsequently by academics questioning the ethical theories underpinning the system (Oughton 1996; Schrader-Frechette and Persson 1997), which ultimately led to recognizing that the radiological protection system is rooted in the three major theories of ethics by combining the respect of individual rights (deontological ethics), the furthering of collective interest (utilitarian ethics), and the promotion of discernment and wisdom (virtue ethics) (Hansson 2007). In turn, inspired by these reflections, eminent professionals in radiological protection have seized the subject (Gonzalez 2011; Valentin 2013).

This relatively recent interest in ethical aspects of radiological protection is certainly not unrelated to the difficulties encountered for decades by radiological protection professionals facing the questions and concerns of citizens.
In the ethical context, the desire to do good is called beneficence, and the desire to do no harm is called non-maleficence. These two ethical values have a long history in moral philosophy dating back long before they were formalized and closely associated in the context of modern medical ethics in the late 1970s, following the publication in 1978 of the so-called Belmont report and in 1979 of the works of philosophers Tom Beauchamp and Jim Childress (USDHEW 1978; Beauchamp and Childress 2001).

In its most general meaning, beneficence is the action to promote the well-being of others. By developing recommendations seeking to protect people against the harmful effects of radiation, the Commission undoubtedly contributes to serve the best interest of individuals and indirectly the quality of social life. This is achieved in practice by ensuring that deterministic effects are avoided and stochastic effects are reduced as far as achievable given the prevailing circumstances. Non-maleficence is the moral duty to avoid needless harm that can result from any action. It is closely related to prevention, which aims at taking all measures to keep a situation from deteriorating. It therefore aims to limit risk by eliminating or reducing the likelihood of hazards. Taken together, beneficence and non-maleficence aim to act so as to promote the well-being of others and at the same time protect them against potential damage.

From the outset, the development of radiological protection has built on the desire to avoid harm. The first recommendations of the Commission in 1928 clearly stipulated: “The dangers of over-exposure to X-rays and radium can be avoided by the provision of adequate protection and suitable working conditions. It is the duty of those in charge of X-ray and radium departments to ensure such conditions for their personnel” (ICRP 1928). The firm intention to remove what at the time were known as “injuries to the superficial tissues and derangements of internal organs and changes in the blood,” and applied to all known deterministic effects over time, remains to this day one of the primary objectives of protection. However, things have become more complex after World War II with the increased knowledge about the carcinogenic effects of radiation. Noting the absence of evidence as to the existence of a threshold for these types of effects and in view of the uncertainty concerning the nature of the dose-effect relationship in the induction of malignancies, the Commission saw “…no practical alternative, for the purposes of radiological protection, to assuming a linear relationship between dose and effect, and that doses act cumulatively.” By adopting this position, the Commission was fully aware “…that the assumptions of no threshold and of complete additivity of all doses may
be incorrect,” but it considered that there was no alternative given the information available at that time (ICRP 1966). Consequently, as any level of exposure to radiation was assumed to involve some degree of potential harm, the Commission supplemented the current objective of preventing harm associated with deterministic effects with an additional objective of limiting the probability of occurrence of damage associated with stochastic effects.

Since then, despite the considerable scientific progress over the decades that followed, the objective of protection remained unchanged, although the wording has evolved as the issue of low doses is still not resolved. As many protective actions fail to completely eliminate exposures, the objective of reducing stochastic effects closely combines the pursuit of beneficence and non-maleficence in order to ensure that the residual risk must not be disproportionate to the benefit provided by the protection. It is worthwhile to underline that this professional responsibility is mirrored in the medical field, where beneficence means that physicians have a duty to act in the best interests of the patients. As many treatments involve some degree of harm, it is also the duty of the physicians to take all positive steps to prevent or to remove harm from the patients in order to respect the non-maleficence obligation. As in radiological protection, beneficence and non-maleficence in medical practice are closely interwoven, and the ethical obligation for the physician is to ensure that the damage induced by the treatment to the patient is not disproportionate to the benefit it brings.

**PRUDENCE**

The ICRP system of protection of humans is based on a wide spectrum of scientific knowledge ranging from metrology to epidemiology and going through disciplines as diverse as anatomy, physiology pathology or radiobiology. All this knowledge is integrated in a series of models of varying complexity, which when associated with physical and biological data gathered from experience, allow (1) estimation of threshold doses for deterministic effects and detriment for stochastic effects and (2) assessment of the effective dose associated with any internal and external exposure to the different radionuclides (Fig. 1). The use of models inevitably introduces uncertainties in the estimations associated with the lack of precise information on some parameters and therefore requires relying on value judgments. Despite the ongoing effort undertaken to critically evaluate and reduce these uncertainties, the Commission is led to use as a default option a series of inferences, extrapolations, and assumptions. This situation is not specific to ionizing radiation but in fact concerns all risk assessment procedures for hazardous substances (NA/NRC 1994).

One of the key assumptions concerning radiation risk, mentioned above, is the absence of a threshold for stochastic effects, which was adopted in the 1960s to respond to the uncertainty on the relationship between dose and effect, especially for low doses.

From an ethical point of view, to decide and act without the full knowledge of the consequences falls within the virtue of prudence. It is worth noting that the term prudence only appeared in the most recent formulations of the Commission’s recommendations in relation to the linear no-threshold (LNT) model. Thus one can read: “The Commission considers that the continued application of the LNT model…provides a prudent basis for practical purposes of radiological protection…” or again: “The LNT model is not universally accepted as biological truth, but rather, because we do not actually know what level of risk is associated with very-low-dose exposure, it is considered to be a prudent judgment for public policy aimed at avoiding unnecessary risk from exposure” (ICRP 2007). More interestingly, the term prudence is explicitly used in connection with the different types of radiation effects defined in the system:

- **Deterministic effects:** “It is prudent to take uncertainties in the current estimates of thresholds for deterministic effects into account… Consequently, annual doses rising towards 100 mSv will almost always justify the introduction of protective actions” (ICRP 2007);
- **Stochastic effects:** “At radiation doses below around 100 mSv in a year, the increase in the incidence of stochastic effects is assumed by the Commission to occur with a small probability and in proportion to the increase in radiation dose… The Commission considers that the LNT model remains a prudent basis for radiological protection at low doses and low dose rate” (ICRP 2007); and
- **Heritable effects:** “There continues to be no direct evidence that exposure of parents to radiation leads to excess heritable disease in offspring. However, the Commission judges that there is compelling evidence that radiation causes heritable effects in experimental animals. Therefore, the Commission prudently continues
Prudence has a long history in ethics across cultures. It is considered as one of the main virtues finding its roots in the Western tradition developed by Plato and Aristotle as well as in the teachings of Confucius, Buddhist philosophy, and the ancient traditions of the peoples of Eurasia, Oceania, and America (Zoelzer 2013). Prudence is essentially a practical provision to make decisions about what is uncertain. It is the virtue of deliberation and judgment in order to make choices without the full knowledge of the scope and consequences of our actions. It is also the ability to choose and act on what is in our power to do and not to do. Prudence, therefore, has a direct relationship to action and practice. As such, prudence is one of the core values structuring the radiological protection system.

In modern times, the virtue to act prudently by policy makers gradually became known as the precautionary principle that was popularized by the Rio Conference on the environment (UNCED 1992). This principle, which originated in the German and U.S. administration in the 1970s and later formulated in juridical terms in international and European law (Ashford 2007), has been much debated in connection with the ethics of decision-making in recent years, including the radiological protection domain (Streffer et al. 2004). Those who are in favor of the principle see it as a breakthrough in the management of uncertain risk. For detractors, the principle is mostly a disincentive to entrepreneurship. In fact this debate, often obscured by academic and legal considerations, does not add much to the experience of over half a century in radiological risk management based on practical wisdom inherited from ancient philosophers. In reality, this management, which requires skill in gathering knowledge and making judgments, can be considered as a precursor to a reasoned and pragmatic application of the precautionary principle. Interestingly, the Commission does not elaborate on this point. It just mentions in its most recent recommendations that the use of the so-called LNT model remains a prudent basis for radiological protection at low doses and low dose rates, considered “to be the best practical approach to managing risk from radiation exposure and commensurate with the ‘precautionary principle’ (UNESCO, 2005)” (ICRP 2007).

The implications of this prudent attitude have been significant for the subsequent structuring of the radiological protection system. The detailed study of the evolution of the Commission’s recommendations over the past decades shows that this central assumption led to gradually shaping the system as it stands now (Lochard and Schieber 2000). First, as any level of radiation exposure presents a risk, exposing individuals must bring them directly or indirectly more advantages than drawbacks. Second, if an exposure situation is considered advantageous, action must be taken to restrict resulting exposures considering the assumed risk. Third, in any case, all individual exposures must be maintained below levels judged socially acceptable given the circumstances. This is very clearly summarized by the Commission as follows: “The major policy implication of the LNT model is that some finite risk, however small, must be assumed and a level of protection established based on what is deemed acceptable. This leads to the Commission’s system of protection with its three fundamental principles of protection” (ICRP 2007). The ethical values underlying these principles are developed in the next section.

In a completely different vein, another consequence of the adoption of the precautionary attitude is the duty of vigilance vis-à-vis the effects of radiation resulting in an obligation to monitor and support all exposed populations. Specifically, prudence implies the obligation to (1) detect, and if necessary cure, possible pathologies (that are induced by radiation or otherwise); (2) supply epidemiological research; and (3) relentlessly pursue basic research in the fields of radiobiology in an attempt to reduce the uncertainties that remain.

**JUSTICE AND DIGNITY**

The radiological protection system, like any system, consists of a set of interdependent elements interacting among themselves in order to achieve its goal (Fig. 2). The so-called three fundamental principles of protection (justification, optimization, limitation) are central to the system and apply to the different types of exposure situations (existing, planned, and emergency) and categories of exposure (occupational, public, and medical exposure of patients). They are also related to the protection criteria
(reference levels, dose constraints, and dose limits) applied to sources or individuals to restrict exposures and also to what is called here the basic requisites for the practical implementation of the system (accountability, transparency, and stakeholder involvement), which are both common to the three types of exposure situations. The following sections present how the values of beneficence/non-maleficence and prudence are combined with the values of justice and dignity within the system.

The principles of radiological protection

The principle of justification requires that any decision that alters a radiation exposure situation should do more good than harm. This means that by reducing existing exposure or introducing a new radiation source (planned exposure situation), the achieved benefit to individuals and society should be higher than the associated disadvantages in terms of radiation risk as well as detriments of any other nature. Thus, the justification principle combines the ethical values of beneficence and non-maleficence with prudence, since part of the estimated detriment may be associated with hypothetical stochastic effects given the no-threshold assumption. The principle of optimization of protection, in turn, requires that all exposures should be kept as low as reasonably achievable taking into account economic and societal factors and using restrictions on individual exposures to reduce inequities in the distribution of exposures among exposed groups. This is the cornerstone of the system. On the one hand, it is the principle of action that allows the practical implementation of prudence. On the other hand, it also allows the introduction of fairness in the distribution of exposures among people exposed. This dimension of fairness, or equity as designated by the Commission, refers directly to the ethics of justice. Finally, the principle of limitation of individual exposures requires that all individual exposures do not exceed the protection criteria recommended by the Commission. Like the principle of optimization, the principle of limitation refers directly to the ethical value of prudence, with extension to justice by restricting the risk in an equal manner for a given exposure situation and category of exposure.

It must be emphasized that the Commission has never referred to justice, neither in its most recent recommendations nor in the earlier ones. However, the idea of limiting individual exposures in order to correct possible disparities in the distribution of health damage due to radiation among exposed populations appeared as early as Publication 26 (ICRP 1977). It is only in Publication 60 that the term inequity is used for the first time. One can indeed read: “When the benefits and detriments do not have the same distribution through the population, there is bound to be some inequity. Serious inequity can be avoided by the attention paid to the protection of individuals” (ICRP 1991).

Ethically, justice is an age-old question that refers to individual and collective well-being, yet it remains an elusive ideal because at a rational level, it can be only relative justice. There is no universal definition of justice. What is right is a matter of agreement between citizens at some point, somewhere. Justice is a complex ethical value with meanings that cover three categories of problems: (1) distributive justice, concerning fairness in the distribution of advantages and disadvantages among groups of people; (2) restorative justice, concerning fairness in compensation for losses; and (3) procedural justice, concerning fairness in the rules and procedures in the processes of decision making. The higher form of justice is equity; that is to say, the principle that everyone is entitled to receive fair and reasonable treatment. Equity refers to the fair distribution of burdens and benefits, goods, service, job and salaries, but also risks within the society. The principle of equity or fairness requires that, to the extent reasonable, situations that are alike should be treated in the same way. In political and economic terms, equity is the principle that leads to correction of inequalities faced by people in order to restore equal opportunities. However, from a social perspective, an equitable distribution does not mean equality. It is a balance that allows making inequalities acceptable when equality is not a reasonable solution (Sandel 2010).

The protection criteria

Any exposure situation, whether natural or man-made, generally results in a wide distribution of individual exposures. In addition, the implementation of protection measures can induce potential distortions in this distribution that may aggravate existing exposure discrepancies. In this context, the protection criteria of the radiological protection system play a dual role. First, they aim to reduce inequity in the distribution of individual exposures in case some individuals are subject to much more exposure than the average through the use of the so-called dose constraints (planned exposure situations) or reference levels (existing and emergency exposure situations) to restrict individual exposures. Dose constraints and reference levels are integral parts of the optimization process and thus must be chosen depending on the prevailing circumstances by the entities in charge of protection. The second role of protection criteria is to ensure that in situations where exposures are predictable, they do not exceed values beyond which the associated risk is no longer considered tolerable given the social context. This is accomplished through the dose limits recommended by the Commission for occupational and public exposures in planned exposure situations. As dose constraints and reference levels, dose limits are tools to restrict individual exposure in order to insure fairness in the distribution of risks across the exposed group of individuals. However, given the predictable dimension of the planned exposure
The basic requisites

For the practical implementation of its recommendations, the Commission sets out a number of requirements relating to the procedural and organizational aspects of radiation protection. It gives some indication of the type of infrastructures and managerial arrangements to ensure an efficient implementation of these requirements but does not go into detail. It merely lays down some broad principles, leaving to other international organizations the task of developing them (IAEA 2014). Three of these requirements deserve to be highlighted because they are common to all exposure situations: accountability, transparency, and stakeholder involvement. Ethically, they refer, respectively, to the ethics of responsibility, procedural justice, and the question of human dignity.

Accountability can be defined as the principle that people who are in charge of decision making must answer for their actions to all those who are likely to be affected (positively or negatively) by these actions. This definition responds directly to the ethics of responsibility, which states that each individual must respond for the foreseeable consequences of her/his actions. In terms of governance, this means the obligation of individuals or organizations to report on their activities, to accept responsibility, and to make arrangements to be ready to answer for the consequences if necessary. As such, responsibility includes one of the aspects of transparency. The concept of accountability explicitly appeared in ICRP Publication 60. It says: “The first stage of responsibility is the duty to establish objectives, to provide the measures needed to achieve those objectives, and to ensure that these measures are properly carried out. This is essentially a prospective concept. Those bearing responsibility should then have the authority to commit the resources needed to meet their responsibilities. There is also a retrospective component of responsibility, sometimes called accountability, that requires a continuing review of performance to be made so that failures can be identified and steps taken to prevent recurrence.” It is also mentioned: “There should be a clear line of accountability running right to the top of each organisation. The delegation of responsibilities does not detract from that accountability. There is also an interaction between the various kinds of organisation. Advisory and regulatory agencies should be held accountable for the advice they give and any requirements they impose” (ICRP 1991). These principles are reaffirmed in much the same terms in Publication 103 (ICRP 2007).

Transparency in relation to ethics refers to procedural justice and concerns the fairness of the process through which information is intentionally shared between individuals and/or organizations. Transparency does not simply mean communication or consultation. It relates to the accessibility of information about the activities, deliberations and decisions at stake but also the honesty with which this information is transmitted. It is part of corporate social responsibility by ensuring that decision-makers act responsibly in the social, economic, and environmental domains in the interest of individuals and groups concerned. Clearly, security or economic reasons can be put forward to justify the control or limitation of outgoing information from a business or an organization. However, to allow good transparency, explicit procedures must be in place from the outset that exhibit accountability features (Oughton 2008).

Regarding the radiological protection system, transparency on exposures and protection actions for workers has been integrated since the 1960s in the ICRP recommendations. One can thus read: “Workers should be suitably informed of the radiation hazard entailed by their work and of the precautions to be taken” (ICRP 1966). This requisite has since been expanded in the subsequent recommendations (ICRP 1990, 2007). It was, however, not until the 2000s that transparency became a general principle applicable both on information about exposures and protection actions but also on the decision-making processes concerning the choices of protection by policy makers. Moreover it was generalized to all categories of exposure: occupational, medical, and public. This was introduced for the first time in Publication 101b of the ICRP dedicated to the optimization of protection and bearing the evocative subtitle, “Broadening the process:” “Due to its judgmental nature, there is a strong need for transparency of the optimisation process. All the data, parameters, assumptions, and values that enter into the process must be presented and defined very clearly. This transparency assumes that all relevant information is provided to the involved parties, and that the traceability of the decision-making process is documented properly, aiming for an informed decision” (ICRP 2006).
In practice, the application of transparency depends on the category of exposure and the type of exposure situation; e.g., through training for workers, informed consent in the medical field (ICRP 1992, 2007), or the right to know principle for the public in the case of security screening (ICRP 2014a). Finally, in its latest recommendations, the Commission emphasized that “...scientific estimations and value judgements should be made clear whenever possible, so as to increase the transparency, and thus the understanding, of how decisions have been reached” (ICRP 2007), recognizing that the requisite of transparency should apply wherever value judgments are involved in the radiological protection system.

As highlighted above, accountability and transparency present related ethical aspects. Together they allow citizens to be aware of up-to-date information necessary to make informed decisions, and they also allow for citizen intervention in the decision making process. These two principles are becoming more widespread in many fields (Leshner 2009) and become key to a good governance policy in organizations. Following this policy, the Commission decided recently to apply to itself these principles by integrating them into its own Code of Ethics alongside the values of independence and impartiality (ICRP 2014b).

Stakeholder involvement has become, in recent decades, an essential part of the ethical framework in private and public sector organizations. Inclusiveness is one of the essential procedural values, along with transparency and accountability needed to make ethical decisions in organizations. This value has recently appeared in the radiological protection field, which has long been perceived to be rather paternalistic. It is most likely Lauriston Taylor who first suggested engaging with stakeholders in our profession. In the Sievert Lecture he gave in 1980, we can indeed read: “Aside from our experienced scientists, trained in radiation protection, where do we look further for our supply of wisdom? Personally, I feel strongly that we must turn to the much larger group of citizens generally, most of whom have to be regarded as well-meaning and sincere, but rarely well-informed about the radiation problems that they have to deal with. Nevertheless, collectively or as individuals, they can be of great value … in developing our total radiation protection philosophy” (Taylor 1980). Beyond the undeniable visionary side of this position, the continuity with the 1956 declaration is remarkable. Once again Taylor invokes wisdom and philosophy. Concretely, engaging stakeholders in radiological protection emerged in the late 1980s and early 1990s in the context of the management of exposures in contaminated areas by the Chernobyl accident and contaminated sites by past nuclear activities in the United States (Beierle and Cayford 2002; Lochard 2004). Indeed those situations in which citizens found themselves directly confronted with radioactivity in everyday life posed new questions, which the system in force at the time had difficulty answering. This was clearly recognized during the first major international conference devoted to the restoration of environments with radioactive residues in 1999 as evidenced by the closing statement of the conference: “The case studies amplified the difficult issue of using an interventional approach. Most were constrained to use the practice based dose limitation system” (Meinhold 2000). Incidentally, it was in large part these difficulties that led the Commission to abandon the process-based approach using practices and interventions and to move to a situation-based approach (ICRP 2007). Stakeholder involvement was first introduced by ICRP in Publication 82 [“Many situations of prolonged exposure are integrated into the human habitat and the Commission anticipates that the decision-making process will include the participation of relevant stakeholders rather than radiological protection specialists alone” (ICRP 1999)] and became a requisite in Publication 103 in relation to the principle of optimization of protection [“It should also be noted that the Commission mentions, for the first time, the need to account for the views and concerns of stakeholders when optimising protection” (ICRP 2007)].

Engaging stakeholders in the decision-making process related to optimization is an effective way to: (1) take into account their concerns and expectations, as well as the prevailing circumstances of the exposure situation; (2) adopt more effective and fair protection actions; and of course (3) favor their empowerment and autonomy, especially in situations where they are directly confronted with radiation. Experience from Chernobyl and more recently Fukushima demonstrated that empowerment of affected people helps them to regain confidence, to understand the situation they are confronted with, and finally to make an informed decision to act accordingly (ICRP 2009; Lochard 2013). In other words, engaging stakeholders demonstrates respect, and in the case of post-accident situations, works to restore the dignity of affected individuals.

Considering the respect of human dignity as a founding value of the radiological protection system is not obvious a priori. In ethical terms, dignity is an attribute of the human condition: the idea that something is due to the human being because she/he is human. This means that every individual deserves unconditional respect, whatever her/his age, gender, health, social condition, ethnic origin, and/or religion. This is what is enshrined in the Universal Declaration of Human Rights, which states that: “All human beings are born free and equal in dignity and rights” (UN 1948). Personal autonomy is the corollary of human dignity. This is the idea that individuals have the capacity to act freely and morally. Implemented with the concern of transparency, accountability and inclusiveness, the radiological protection system is indeed respecting and promoting the autonomy of people facing radioactivity in their daily lives, whether
at work, as a patient, or simply as citizens confronted, for example, by radon in their homes (ICRP 2014c) or x rays in airports (ICRP 2014a).

**REASONABLENESS AND TOLERABLENESS**

The problems of decision-making regarding (1) which protection action is ensuring that exposures are kept as low as reasonably achievable given the prevailing circumstances and (2) which level of risk can be considered as tolerable for the exposed individuals are central to the radiological protection system. As seen above, both are a direct consequence of the no-threshold assumption for stochastic effects. Reasonableness is intimately linked to the optimization principle and tolerableness to the limitation principle, which together aim at reflecting prudence and justice in protection. As early as the end of the 1950s, when faced with "the existing uncertainty as to the dose-effect relationships for somatic effects," the Commission recommended "that all doses be kept as low as practicable." Also recognizing that humans could not avoid completely the use of ionizing radiation, the Commission concluded that in practice it was necessary to limit doses so that the risk "is not unacceptable to the individual and to the population at large" (ICRP 1959). However, it took several decades for the Commission to clarify what was meant by "as low as practicable" and "not unacceptable" and on which criteria to ground the decisions about these intentions.

By successive adjustments, the initial formulation "as low as practicable" became "as low as readily achievable, economic and social considerations being taken into account," then "as low as reasonably achievable, economic and social considerations being taken into account" in ICRP Publication 22, which was entirely devoted to the elucidation of the previous formula (ICRP 1973). It is also in this publication that the techniques of cost-benefit analysis were introduced to determine "the acceptability of levels of exposure to radiation proposed for a given activity..." which from there will play a leading role in the structuration of the practical implementation of radiological protection through the optimization principle. Despite all efforts to anchor the optimization of protection in the rationality of classical economics, the process to maintain levels of exposure as low as reasonably achievable remains essentially a matter of judgment mixing quantitative and subjective values (ICRP 1983) and field experience. This led to successive incorporation into the optimization process of components developed in the field of management techniques (ICRP 1990) and approaches calling on the direct involvement of all parties involved in the implementation of protection (ICRP 2006).

Regarding tolerability, from the 1970s, the Commission relied upon the emerging discipline of risk assessment to try to find a scientific rationality to the 'non-acceptable risk level' question. Building on the work of the Royal Society (RS 1983) and the Health and Safety Executive (HSE 1988) of Great Britain, the Commission developed an approach based primarily on comparing radiation risk with other similar risks in society to determine the degree of tolerability of an exposure (or of the associated risk). This approach allowed distinction between unacceptable and tolerable levels of exposure depending on the exposure situation (ICRP 1990). Although rational, this conceptual framework, like that of the cost-benefit analysis, does not escape the necessary use of value judgments to finally decide about the tolerableness of the risk. It is interesting to note that ultimately the Commission defines tolerable exposures as those that are "not welcome but can be reasonably tolerated," thus making reasonableness a key component of tolerability.

The quest for reasonableness and tolerableness are eminently ethical questions. Decades of efforts to find these two concepts on recognized fields have shown that scientific rationality is not sufficient, and it is necessary, beyond the dose, cost, and risks, to balance many societal and ethical considerations. This in turn requires experience accumulated over time and a lot of common sense. As the philosopher Nicholas Rescher wrote a long time ago, the fundamental constituents of reasonableness (and we can add tolerableness) are: "...the willingness to use rational methods of inquiry, the regard for considerations of equity, the ability to view human actions and statements with perspective and judgments, the impartiality of approach to the means of adjudicating conflicting interests, the esteem for the judgement of others when based upon knowledge and experience, the respect for the agreed goods and goals of (competent) fellows" (Rescher 1954). These lines undoubtedly illuminate the remark made by Lauriston Taylor a few years later about radiation protection (see Introduction). Reasonableness and tolerableness qualify on the ethical level the complex relationship between science on one side (in this case the science of radiation) and actions on the other side (the protection of exposed people). This is done by combining the core ethical values of beneficence, non-maleficence, prudence, justice, and dignity that are entangled in the radiological protection system. In practice, the search for reasonableness and tolerableness is a permanent question that depends on the prevailing circumstances in order to act wisely based on accumulated knowledge and experience; i.e., with the desire to do more good than harm, to avoid unnecessary risk, to seek for fair distribution of exposures, and to treat people with respect.

**CONCLUSION**

The focus in this article is on the ethical values underpinning the ICRP system of radiological protection for
humans. It is worth noting in passing that this system is larger and also encompasses the protection of nonhuman biota, which integrates the specific dimensions of the ethics of the environment (ICRP 2003; Oughton 2003). As underlined above, the protection of humans is rooted in the three major theories of moral philosophy (deontological, utilitarian, and virtue ethics) and relies on four core values (beneficence/non-maleficence, prudence, justice, and dignity). Studies of oral and written traditions that guided populations of different cultures through the ages show that these core values are also largely shared worldwide (Zoelzer 2013). Integrated into the three structuring principles of justification, optimization, and limitation, the core values allow for acting virtuously while taking into account the uncertainties associated with the effects of low dose and for evaluating the criteria for judging the adequacy of these actions.

Radiation protection professionals suffer from a lack of public confidence, which dates back to the history of the development of nuclear weapons and nuclear power. Their involvement in the management of accidents at Chernobyl and Fukushima has not helped to restore this confidence and even in some cases has aggravated the gap with the population. For decades, the profession has tried to respond to criticism of all kinds but also to legitimate questions from citizens. Professionals are challenged to respond appropriately to the nature of the health risk and its importance given the circumstances, as well as to putting this risk into perspective with other comparable risks. Despite all the deployed efforts, “risk-communication” has not succeeded in reversing the trend, and the temptation is great for some professionals to think that the fear of radiation is powered by irrationality or even some kind of phobia. Although there is certainly no miracle solution in this field, a few recent experiences in relation to contaminated sites from past activities and the management of nuclear accidents show that it is possible to engage in constructive dialogue with the public if the goal is not only to explain science but also to listen and respond to citizens’ expectations. Relying on this experience, it is conceivable to develop a narrative about the risk of radiation based on the intimate experience of the stakeholders, the history of the development of radiological protection in relation to the major events of the past century, as well as the ethical values that underpin the radiological protection system. A clearer understanding of the ethical values and related principles will undoubtedly help citizens to better understand what is at stake in the various exposure situations with which they are daily or sometimes unexpectedly confronted. Just as with science, ethics alone is unable to provide a definitive solution to the questions and dilemmas generated by the use or presence of radiation. However, it certainly can provide useful insight to facilitate the dialogue with people unfamiliar with the quantitative notions of radiation risk and the principles of radiological protection who represent the vast majority of citizens.

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