TOWARDS A BROADER PERSPECTIVE ON NUCLEAR ACTIVITY

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1- Introduction

For some years the "nuclear community" has been making important efforts to extend the reflection on nuclear activity towards a vision that includes the social sciences and humanities. In this way are the publications of the ICRP's "Task Group 94", as well as the workshops developed under its auspices; there are also relevant contributions from different research centers and universities, such as Science & Technology Studies Unit, SCK • CEN (Belgium); Without forgetting that this Conference includes in its program a space that will specifically deal with Integration of social sciences and humanities in radiation protection education and training. It should also be noted that main protagonists of this discipline have produced different works devoted to thinking about ethical problems related to radiation protection. This is the case of Lauriston S. Taylor[1], Bo Lindell[2], Giovanni Silini[3] and, from my country, Abel González[4], to mention just some of them.
These efforts constitute a very important focus point for further developing an approach to nuclear activity based on a broad vision from social disciplines or ethical reflection.
The complexity of nuclear activity deserves an understanding that exceeds the capacity of so-called "hard sciences". A different view, the assumption that this phenomenon can be exhausted only under the understanding of these disciplines implies what is called "epistemological reductionism". Under its general description, reductionism is an approach to understanding the nature of complex things by reducing them to the interactions of their parts, or to simpler or more fundamental things. Its critics use the term to characterize those theories that try to realize an understanding of the science reducing it only to its gnoseológical traits. Or, they maintain, it is reductionist a theory that understands that science is explained only by its method and that, in addition, the method - unique for any discipline that claims to be scientific - comes from those applied in the physical-natural sciences.
Those who do not share this perspective point out that this perspective does not contemplate a series of factors necessarily involved in what we currently understand by science, the ways in which science works concretely
This implies including the complex relationship between science and technology, or the phenomena of the valuation of theories, as well as the problems related to the validation of the application of knowledge, on the one hand; and on the other hand, the financing of scientific research, the structuring of a scientific technological system, the relationship of science with the market and industry, without which it would be impossible to understand completely.[5]

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[1] TAYLOR, L. S.; “The philosophy underlying radiation protection,” American Journal of Roentgenology, vol. 77, no. 5, pp. 914–919, 1957; “Some nonscientific influences on radiation protection standards and practice. The 1980 Sievert lecture,” Health Physics, vol. 39, no. 6, pp. 851–874, 1980.
[2] LINDELL, Bo; “Logic and ethics in radiation protection”, Journal of Radiological Protection, Volume 21, Number 4, Published 20 November 2001.
[3] SOLINI, G., “Ethical issues in radiation protection—the 1992 Sievert Lecture”, Health Physics, vol. 63, no. 2, pp. 139–148, 1992.
[4] GONZALEZ, Abel; “The Argentine Approach to Radiation Safety: its ethical basis”, Hindawi Publishing Corporation, Science and Technology of Nuclear Installations, Volume 2011, Article ID 910718.
[5] See relevant works from the argentine philosopher Enrique Marí or Oscar Varsavsky. MARI, E.; *Elementos de Epistemología comparada*, Puntosur, Buenos Aires, 1982. VARSAVSKY, O.; *Ciencia, política y cientificismo*, CEAL, Buenos Aires, 1969. Or, in the French materialist school, authors like

In the line of argument that has just been presented, it is tried to point out that the "nuclear science"[6] that includes radiological protection as applied discipline requires not only the understanding of an interaction between atoms and their "infinite" derivations, causes and consequences, but also the knowledge of an equally complex interaction between human subjects: Men and women who put into play resources - material, intellectual, symbolic - for the production of nuclear energy and the vast technologies that this implies; of men and women who develop regulatory systems in political and legal frameworks that exceed strictly nuclear issues; of men and women who accept or not the location of nuclear installations in all its varieties, Among other forms of human relations that are arranged around the "nuclear thing".
By accepting this perspective, nuclear activity as a whole becomes even more complex and, at the same time, gains in wealth its capacity for understanding. If one accepts this matrix of thought which assumes that "the nuclear" needs to be comprehensively understood, including the modes of social interaction that allow its concretion and development, then the intervention of the social sciences and humanities constitute an unavoidable tool.
These disciplines enable a vision of the nuclear phenomenon in which the current problems facing nuclear activity are incorporated. That is, the phenomena of its acceptance or rejection, for example, are no longer external to it. This kind of "aberration of meaning" that forces the mixture of phenomena of different nature, nevertheless forms the possibility of solving these problems.

2- Epistemic problems

Radiation protection is a constantly developing discipline. From its achievements the whole nuclear activity has reached very important security standards. Paradoxically, it is also true that events, incidents or accidents in any branch of activity are seen as "shifters" to further advance the frontiers of knowledge, as well as in the regulation field that set new standards of safety.
However, it is striking that the levels of fear, rejection or distrust from the citizens on the nuclear technological applications have not diminished, in spite of multiplicity of applications that suppose, as is known, advances in the field of human health, industry, and power.
Faced with this dilemma, it could be easily hypothetized that more knowledge in the field of radiological safety greater distrust by the population on nuclear activity.
However, it is clear that such a hypothesis is at least very weak: ¿what would have happened if there had not been an increase in radiological safety standards? Would the rejection have been reduced? It would also be indispensable to show other variables that could affect the level of distrust of the population. This would quickly lead to the conclusion that the fact that there is greater knowledge, and therefore better controls, does not actually have a direct relation to that negative perception.
Even so, the contrary idea could take place: the fact that there is constant progress in knowledge and that this knowledge promotes higher safety standards does not affect positively the population's perception of nuclear activity as a whole.
This approach has no anti-scientific claim. Rather the complete opposite. The development of radiation protection is possible from a sustained advance of scientific knowledge, although this is not the only element to consider. However, such progress often face social questions to which it's not so easy to find an answer. This problem is irresolvable if it is addressed only within the frames of disciplines whose object of knowledge revolves around atomic and nuclear phenomena.

Georges Canguilhem or Dominique Lecourt. CANGUILHEM, G., *Le normal et le pathologique*, Paris, PUF, collection «Galien», 1979. LECOURT, D., Pour une critique de l'épistémologie, Paris, Maspero, 1974.

[6] Allow me to use this concept which, although it may seem a neologism, is accepted in a significant number of texts belonging to the field of nuclear activity and institutions such as MIT, which has a specific department with that name: MIT Department of Nuclear Science and Engineering.

It is true that in the nuclear field there is widespread recognition of the existence of problems associated with forms of subjectivity that directly affect the activity, on which have been tried - without much success - solutions. The interest in the area of social communication, institutionalized and perfected in the R & D, regulatory organizations and responsible for the facilities, reflects the genuine concern of scientists, technicians and decision-makers to convey convincing explanations to citizens, without losing scientific rigor.

In short, the idea that a better communication with the population could begin to settle some debates, or at least converge positions, has appeared for some years now. Notwithstanding this effort, the attitude of the population towards the sector has not changed significantly.

The problem that arises once again is that "the social" appears as a phenomenon external to "the nuclear": subjects, institutions, social classes, workers, the public, the environment, stakeholders, maintain a structurally external status to technological applications in the nuclear field. This alienation of subjective, social factors, in relation to the nuclear thing, cannot be overcome from a proposal that does not include as part of its objects of knowledge the decisions, ideologies, fears, values of subjects that in a way or another are linked to nuclear activity.

It is important to raise it without mediations. If the last argument of a nuclear science that wants to explain the phenomena associated with its important activity is based only on the knowledge of its subject – perhaps the most paradigmatic of the history of mankind -, it will face an epistemological problem, that is, the problem of how the production of scientific knowledge is understood, and what is done with it.

Science, understood as a set of methodological procedures that has the destiny to formulate objective knowledge based on a controlled experience and justified by logical and empirical means poses a limitation. It is an instrumental idea of the scientific, in which science is reduced to a cognitive process. In his development he forgets that he cannot get rid of factors that are inescapable.

Science, as a way of giving meaning to the world is a social phenomenon; since signification is a human act, where interactions among rational beings give intelligible form to the world. From this point of view, science is a form of productive work - meaning of the world - that occurs between men and women living in society, regardless the unique knowledge object of each discipline. The particular object to which each discipline is engaged to does not change the characterization of science being a human activity that produces meaning to natural and social world.

Thus, what in general terms can be called "social" is a prerequisite of scientific knowledge and is significantly present in each of its processes; And it is also as decisive for the production of knowledge as the methodological rules of empirical testing or hypothesis formulation[7]. Society is not the depository of a knowledge elaborated by a pre-social science-machine, just as science is not a set of tools isolated from the decisions of men / women.

3 - Science *in* society

For much of the XX° century Western world had greatest hopes in science. The progress of scientific knowledge was not only the bearer of greater wisdom. It was at the same time the driver of material and moral progress for the whole of society. There were those who, moreover, thought that this material wealth could result in a welfare for all humanity. A projection of this approach reaches, in a kind of reincarnation of old platonic political ideas, the fantasies of nations governed by wise / scientists. The magnificent development of scientific knowledge in various disciplines worked with this perspective that sought to extend the success of its activity

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[7] Even authors whom the history and philosophy of science classify as “positivist” or “logical empiricists”, recognize the influence of "the social" in strictly scientific activities. Cfr. REICHENBACH, Hans; *Experience and Prediction*, Chicago, University of Chicago Press, 1938.

to the whole society. In fact, there were profound changes in the relationship between men of science and power structures. According to Daniel Bell,

> In the period immediately following World War II°, a new scientific elite was closely involved in issues of national power in a way unknown to the history of science.[8]

A scientific elite had become a major political player, with the possibility to influence the destiny of its country in the immediate term and in the long run. Obviously, Manhattan Project is the paradigmatic case of what has just been sustained.

But this same process is a contradictory process, at least for science. The massive incursion of scientific and technological issues into the highest political decisions produced a change in scale in the organization of scientific research. Both the military camp and the industry formed a chorus of demands for scientific participation: production technology was urgent and researchers were needed. At the "Fordist" moment of economic production, science began to be developed in large productive units of knowledge: R & D units, the setting up of scientific and technological systems of the most developed nations. The so-called big science began to require huge investments that were generally only available to the states. In addition, because of the scope and complexity of its objectives, the working groups were composed of multidisciplinary staffs.

If before this point in history it could be difficult to argue the isolation of science from the set of social practices, from here, with scientists participating in political decisions, and states developing scientific technological systems, it became theoretically impossible to deny this association.

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Even if the basic / applied science old classification were accepted, in the field of pure research, understanding it as an activity that had as its interest the search for knowledge by knowledge itself, it would be imprudent to deny the projections of application that might arise from their results. The fantastic expressions of the English chemist Frederick Soddy in the early twentieth century, when his successes with Ernest Rutherford began to be known, bear witness. Their first joint investigations concluded in the idea that the phenomenon of radioactivity was a sign of changes in matter: "transmutation"! Exclaimed Soddy. The confusion caused by their results did not allow them to see clearly the full meaning of their feat. They had to deepen their studies almost a year to conclude that the key to their findings was elsewhere: energy. Only a few years later, in 1908, a book authored by the English man was published, in which he stated:

> A race which could transmute matter would have little need to earn its bread by the sweat of its brow (…) Such a race could transform a desert continent, thaw the frozen poles, and make the whole world one smiling Garden of Eden.[9]

Even if it were argued that Soddy-Rutherford's research did not have an initial applied fate, his immediate projections led him to ground the idea that matter could store an "inexhaustible" amount of energy, which in turn could generate the possibility of a "white city," resplendent and

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[8] BELL, D.; *El advenimiento de la sociedad industrial*. Alianza, Madrid, 1994.

[9] SODDY, F.; "The interpretation of Radium", London: Murray, 3rd ed., 1912, p. 251, quoted in WEART, S.; *Nuclear Fear,* Cambridge, Harvard University Press, 1988, p. 5. See also, TRENN, T. J., *The Self-Splitting Atom: The History of the Rutherford-Soddy Collaboration,* Taylor & Francis, London, 1977.

brilliant. In short, even when the idea of a basic science is held for no predetermined purpose, society is intrinsically linked to scientific discoveries.

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But, as it is known, this example is incomplete. As recounted in biographies and histories of science, Rutherford's immediate reaction to the cry of "transmutation" was reprobation. But it did not happen the same when Soddy's fantasies projected that white city, even though it was an equally insecure hypothesis. It is not difficult to figure out the causes for the differences in Rutherford's reactions: transmutation refers to a passed form of "science", destined to sorcerers or alchemists; while urban fantasies were the order of the day in a world in frank process of industrial expansion. Electric power is the soul of an industrial society.

Here is something more subtle: society is not only meant to be a recipient of the potential benefits of science, not only has a passive character to scientific activity; It also creates a material and symbolic space for the development of scientific knowledge. Undoubtedly, there was no place for transmutation at the beginning of the twentieth century, but for the improbable fantasies of the white city of Soddy. And this option is possible because energy had become the "soul" of modern industrial societies. Not only would these discoveries have been possible 200 or 300 years earlier because of a lesser development of science, but they would have seemed untimely, incredible, out of place.

Society will use and take advantage from scientific findings. But it is also the space that gives them meaning.

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About 80 years ago the Irish scientist John D. Bernal published a book whose title expressed a very particular concern: "The social function of science". In these pages he tried, among other things, to consolidate some new foundations on the question of the progress of science. He came to wonder about the uneven progress of scientific disciplines. He suspected that it was not just the genius of some thinkers or intellectuals in the ranks of one or another science; or of best application of this or that method, but there could be some other factor that would produce some speed changes in its histories. He was particularly interested in British scientific development, in a period starting at the beginning of the twentieth century and culminating in the publication of his book (1939).[10] There he detected that technological applications in heavy industry had grown markedly, and that strikingly other areas had stopped their glow. He also warned that it could show a correlation between these advances and setbacks, and unequal funding they had received from the British state some areas at the expense of other.

That there were a greater scientific-technological development in the area of heavy industry from the scientific knowledge produced as a consequence of a decision of the British state does not seem to propose greater difficulties of understanding. Technological applications in heavy industry had an obvious explanation: the production of warlike artifacts after the First World War.

But that the progress of knowledge had some relation to political and / or economic decisions was no longer something that could be readily accepted by scientists and philosophers of science. If scientific knowledge was "objective" could only be so because it self-regulates ie, sets its own laws of dynamics; and because it cannot depend on extra-scientific factors (moral, ideological, political or economic). Thus, if science develops, it can only be due to an advance in theories, in the tuning of hypotheses, or in certain uses of more advanced technologies. That is, always internal elements to science.

This particular assessment of scientific development takes on greater strength when analyzing the particular history of physics in the United Kingdom. Two important articles will be taken as an

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[10] BERNAL, John Desmond; *The social function of science*, London, Routledge, 1939.

example in which one tries to characterize the phenomenon of the professionalization of British physics. The following are the main conclusions of these works:

- The development of a career for a physicist became a very difficult task because “many were unable to do so because of a lack of employment opportunities and were obliged to spend an unacceptable length of time as junior university demonstrators, to take up careers in school teaching, or to leave physics”
- The members of The Physical Society, founded in the last quarter of the 19th century, “played an important role in the social organization of physics. But expressed no direct interest in the industrial application of physics”.
- In the same years, the foundation of a number of provincial university colleges provided a widespread interest in promoting higher education in science and technology. It had two related consequences: an increasing number of employment opportunities, and an increasing number of physicists.
- At the beginning of the 20th century the average salary for a physicist as a teacher was 4.5 times lower than that of a physics assistant teacher.
- The contributions made by science to the war effort not only helped change the public perception of the scientist but also stimulated self-awareness among scientists about their role in peace as in war.
- The title of "physicist" did not exist in the registry of public services, (only “chemical”). Only in 1939 does physics arise as a profession.

The symbolic and material recognition of physics as a science, through which a scientist can develop his or her career, that is, being a physicist, does not depend on the physical itself, but on the material conditions for its development. That is, social institutions give a value, again, material and symbolic major or minor to some scientific disciplines depending on a multiplicity of variables that exceed the very dynamics of science. That is why science here is also intrinsically linked to the fate of dynamics and social order.

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4- Towards a broader perspective of science

What is at the basis of this discussion is a critical epistemological statement of the positivist version of science: an "extended" perspective that allows to observe the insufficiencies of a Reichenbachian / Popperian perspective of scientific activity.
To the original idea of these authors of the order of scientific activity in contexts, which presents a context of discovery and another of justification, will propose a series of corrections that enable to think what has been argued previously.

a- For science to be possible, there must be scientists. The "production of scientists" is not the direct result of scientific activity. It is primarily the result of a series of political and economic decision by a state and / or private institutions. That is to say, the transformation of an individual into a scientist is due to the existence of universities, institutes, laboratories, decisions, all of which exceed the framework of scientific activity itself. It is therefore a "social decision" to call it somehow ambiguous and general. This phase can be called "context of education".

b- Techno-scientific innovations have a two-pronged position facing scientific knowledge. Throughout history is recognized countless inventions whose theoretical background is minimal. And at the same time, there are more and more technical innovations that produce theoretical changes, or at least are their facilitators. Biotechnology is a typical case of this. Techno-scientific developments therefore constitute this novelty, that is to say, the generation of new knowledge regardless of its origin.

c- Scientific knowledge is not only justified or validated through logic and scientific methodology. If it is accepted that there are not only processes of discovery, but also innovation processes of innovation, then it should be accepted that the evaluation of discoveries and innovations involve evaluation mechanisms that go beyond the logical-methodological justification. In this way, a new technology is validated or evaluated according to its feasibility, its applicability, its competitiveness in relation to alternative proposals, and in general according to its usefulness. A discovery / innovation, therefore, exceeds the "degree of truth" of its justification. This context can be denominated “valuation context”.

d- The technological application of knowledge, implies criteria that exceed validation through "it Works". Although this criterion can be considered the main criterion, others may be applied: economic profitability, social utility, cultural contextualization, among others. Scientific policy and management are fundamental here, whether public or private. The society itself introduces its criteria of acceptance of the techno-scientific activity, which is now subject to a global judgment, external to the scientific community.[11]

If these critical approaches to the positivist perspective of science are accepted, it is necessary to incorporate the idea that science, as a phenomenon broader than the capacity for correct application of a method, involves social relations, interactions between men and women, that exceed the traditional framework of the strictly scientific.

To think the phenomenon from this point of view promises, at the same time, to think problems not usually considered: What technological developments and for which purposes?; What processes does this decision take?; Who and in what way do they intervene? What kind of professionals are needed for the proper development of a particular nuclear plan?; What is a "worker"? Is a scientist a worker? What is the "environment"? In what way do citizens participate in nuclear activity? What does the population's distrust face the scientific knowledge of those who operate and regulate the different technologies imply? How to reconcile the claims of economic profitability (or sustainability), social benefit and scientific development? Ethical-political controversies that occur daily in the face of scientific and technological developments and which slip from the hands of a traditional perspective in nuclear science.

Just thinking about the idea of "not in my backyard", which can include assumptions like "I understand the arguments, but I do not want anyway" or "I understand the utility, in fact I use it, but I do not want it either" raises the emergence of paradoxes which escape the idea of the exclusivity of the scientific argument.

The Fukushima Daiichi accident called into question practical problems of enforcement of regulatory standards as well as technological problems. But it conclusively hit the treatment of institutional communication; shook the ways in which the Japanese “nuclear village” understood the place occupied by citizens in a city also inhabited by a nuclear facility; highlighted the problems in the link between regulatory entities and companies operating nuclear plants; made clear the problems that arise to the hierarchical structures before an emergency situation; posed the question of the legitimacy of projecting towards the future the continuity of nuclear-based power production; And also the role of social groups such as the so-called Yakuza[12].

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[11] Tomo esta original perspectiva de ECHEVERRÍA, J.; *La filosofía de la Ciencia*, Akal, Madrid, 1995.

[12] Crf. KINGSTON, J.; “Japan’s Nuclear Village” in The Asian-Pacific Journal, Volume 10, Issue 37, Number 1, September 9, 2012. National Diet of Japan, The Fukushima Nuclear Accident Independent Investigation Commission, Official Report, 2012. HYMANS, J., “Veto Players, Nuclear Energy and Nonproliferation”, International Security, 36:2 (Fall 2011), pp. 154-189.

5- Conclusions

In short, a number of complex problems that cannot be addressed from the reduced field of some scientific discipline that knows only its object of study.
This series of issues are not specific to emergency situations, or a particular country, but at very different levels of severity, they are expressed through nuclear activity as a whole. Addressing these problems from an broader perspective of science, enables a more complex understanding and at the same time better adapted to the difficulties faced by nuclear activity.
For all these reasons it is proposed to reflect on the possibility of incorporating these epistemological principles of an expanded vision of the process of production of scientific knowledge in training programs in radiological protection, with the aim of training professionals to be increasingly attentive to the multiple challenges facing our societies in the 21st century.

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