Radiological protection in the Spanish nuclear industry under Franco, 1939-1975*

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Abstract

In debates about nuclear controversy, the issue of occupational safety in radioactive facilities is rarely foregrounded; it has historically been relegated to second place compared to the attention given to potential harm to the general population. Aiming for, at least, partially filling this historiographical gap, this article deals with the development of occupational radiological protection in Spain under the dictatorship of General Franco (1939-1975). It covers the rise of radiological protection measures on an international level and the subsequent development of legislation in the case of Spain, a process that paralleled the growth of the nation's nuclear program. Finally, it explores the main evidence of the impact of ionizing radiation on Spain's working population.

Keywords: ionizing radiation; radiological protection; Francoism; Spain.

To José Antonio Suárez González del Rey,
in memoriam

The discovery of X-rays in 1895 and radium in 1898 and their immediate application in various fields led to studies of the biological effects of ionizing radiation relatively soon. Despite early evidence of its harmful effects on human health, the dominant perception in western societies during the first third of the 20th century was that such radiation was harmless and even beneficial to health (Dommann, 2006, p.93-96; Serwer, 1976, p.VII-VIII; Navarro et al., 2008, p.1041-1042). The emerging consumer societies of the 1920s perceived ionizing radiation as a fascinating, useful technology for daily life, as well as a therapeutic panacea and a source of health (Duffin, Hayter, 2000, p.260-261; Lambert, 2001, p.31-33; Herran, 2008, p.27-34).

Historiography has explored the rise of a perception of risk among medical personnel dealing with these new technologies and the adoption of the first radiation protection measures (Dommann, 2006, p.96-98). The lack of consensus about units of measurement and levels of exposure limited the adoption of protection measures to cases of improper use. The first voluntary protection rules for X-rays were adopted in Germany in 1913 and Great Britain in 1915. After the First World War, the growing concern about the harmful effects of ionizing radiation led to the establishment of national committees on the issue, although until the end of the 1920s, there were no internationally recognized protection recommendations (Serwer, 1976, p.VIII; Lambert, 2001, p.33).

Apart from communities of experts, the first health concerns arose in the 1920s in industrial sectors such as watch dial painting, which had grown significantly during the war. The widespread use of radium paint, which was favored because of its phosphorescent effect that made messages more visible, led to the appearance of lesions among workers in the sector, who were primarily women. The workers inhaled radium when applying the paint or swallowed it when they moistened the brushes on their lips. After accumulating in the bone tissue, radium caused cases of necrosis of the jaw, anemia, leukemia and cancer. Despite clinical and epidemiological evidence, recognition of the harmful nature of radium paint, and adoption of measures limiting exposure and mandating compensation for victims, did not occur until the mid-1930s (Clark, 1997; Nugent, 1989).

It is important to point out that organisms and institutions that pioneered radiation protection before the Second World War were professional scientific organizations, not government ones (Serwer, 1976, p.IX). Thus, during the 1929 Second International Conference on Radiology, the International X-Ray and Radium Protection Committee (henceforth IXRPC) was created. In 1950, this was renamed the International Committee on Radiological Protection (henceforth ICRP). The main task of the IXRPC was to craft recommendations on radiation protection measures and to raise public awareness of the issue. However, given its lack of executive capabilities, its recommendations were not easily accepted or practiced by administrative bodies responsible for the issue (Lambert, 2001, p.33-34).

Besides the lack of executive capability, the main problem for this committee and other similar organizations continued to be the difficulty of establishing consensus about the levels of exposure to ionizing radiation that were considered harmful. As in other industrial

sectors closely linked to scientific and technical development, from the 1920s on, ionizing radiation was included in the same preventive philosophy and risk control measures that were being incorporated into the chemical industry, based on the belief that exposure to harmful substances below certain concentrations was harmless (Sellers, 1997, p.175-176). This same philosophy was also spread during the 1930s to risks like asbestos fiber or silica dust (Markowitz, Rosner, 1995; Wikeley, 1992; Menéndez-Navarro, 2002, 2011). In 1934, the IXRPC recommended a maximum exposure value called a tolerance dose, fixed at 0.2 roentgens a day, below which it estimated that the probability of health risks was nil. The recommendations were mainly aimed at medical and technical workers, and the effects evaluated were basically short- and medium-term ones, with scarcely any consideration given to the long-term risk (Walker, 2000, p.8). In 1941, the U.S. Advisory Committee on X-Ray and Radium Protection set the first tolerance doses for the main sources of internal radiation used at the time (radium and radon gas). In fact, those recommendations provided the basis for the radiological health programs for personnel involved in the Manhattan Project (Walker, 2000, p.8-9).

The inauguration of the so-called atomic age after the explosions at Hiroshima and Nagasaki, and the growth of the nuclear sector after the end of the Second World War, called into question the radiation protection methods. As well as the fact that the number of people exposed to radiation in civil and military life was rising, the generation of new radioactive substances based on fission processes (radioisotopes given to patients internally), and the emergence of evidence about the mutagenic effects of low doses of radiation, all led to questioning of the consensus about the existence of safe levels of radiation exposure (Walker, 2000, p.10-18). In the years immediately after the Second World War, this current of thought brought a measurable reduction in the permissible levels and modification of the units of measurement. However, this approach had to contend with growing political pressure for the development of new arms, which led the Atomic Energy Commission in the U.S. (hereafter AEC), for example, to undertake experiments on human subjects without prior consent or information about the effects of plutonium (Welsome, 1999; Kutcher, 2009). The Cold War context was crucial to the legitimation of these and other risky practices, in which radiological protection was put on the back burner for political reasons.

The purpose of this article is to explore the development of radiological protection in Spain during the dictatorship of General Franco (1939-1975), a topic that has merited little attention from historians so far. To do this, we will first discuss the rise of radiation protection measures in the U.S. and the international arena after the Second World War. Then we will analyze the birth and growth of Spain's nuclear program during the Franco years, as well as legislative developments during that period in terms of radiation protection in the workplace. Lastly, we will examine the available evidence about the impact of ionizing radiation on the health of Spanish workers exposed to it.

Radiological protection in the postwar world: the case of the U.S.

The needs generated by the arms race after the Second World War were crucial to the development of radiation protection in the U.S. Uranium mining was one of the sectors that

came under pressure due to the new international geopolitical scenario. It is estimated that, from 1946 to 1970, over five thousand miners worked to extract the uranium demanded by the U.S. military industry. Although the AEC was, until the mid-1960s, the only buyer of uranium mined in America, private mines were beyond its jurisdiction. Mining operations in states like New Mexico, Arizon, Utah and Colorado mostly employed socially isolated population groups, like Navajo Indians or members of the Mormon community. The deficient working conditions in the mines, the lack of measures to reduce radon and other radioactive dust, the failure to provide information to the population exposed to radiation and the lackluster response of officials at the AEC or the Public Health Service led to clearly elevated mortality rates due to cancer among exposed miners (Ball, 1993; Eichstaedt, 1994; Hecht, 2009, p.901). Until 1967, there were no radiation protection measures in U.S. uranium mines (Nelkin, 1991).

The media and public debate focused mainly on the environmental effects of the nuclear tests developed in various locations after 1946, particularly the Marshall Islands, the Pacific and the Nevada desert. After a test carried out on Bikini Atoll in March 1956, which directly affected the crew of a Japanese fishing vessel working in the area and led to the evacuation of the islands' population, public controversy about radioactive risks grew. The debate pitted the benefits to national security derived from the nuclear tests against the risks to the general population from nuclear fallout. This, together with the growing civilian use of atomic energy, made the risks of ionizing radiation a real public health concern in American society, beyond the occupational exposure of a limited number of workers (Walker, 2000, p.18-20).

Scientific uncertainty about the long-term effects of low doses of radiation added to a debate that was eminently political in nature. However, the answer came from the field of technical intervention. After carrying out an important research study on the health risks of low doses of radiation, the U.S. National Academy of Sciences proposed a compromise solution: although the nuclear tests did not (in its opinion) constitute a public health risk, the genetic effects of radiation were undeniable, so that radioactive emissions should be kept "as low as possible", a recommendation that could be extended to medical uses of radioactivity (Walker, 2000, p.21).[1]

In response to the growth of public awareness, and following the recommendations of the Academy of Sciences, the ICRP and the National Committee on Radiation Protection in the U.S. (hereafter NCRP) reduced the maximum permissible dose to one-third of the previous amount, and they implemented new units of measurement, like the 'rad' (which indicated the dose absorbed by the tissue in terms of ionizing effects) and the 'rem' (which indicated radiation's relative ability to cause biological harm) instead of the roentgen. In 1959, both organisms established recommendations on the permissible levels for the population living close to radioactive facilities (0.5 rem/year) and for the general population (0.17 rem/year), levels that represented one tenth and one thirtieth, respectively, of the permissible doses for the working population, which was set at 5 rems/year. To give this level a certain flexibility and allow for occasional higher exposures, a formula was created that took into consideration the age of the worker. The maximum permissible dose of radiation (D), expressed in rems, was determined using the formula D = 5 (N-18), where N corresponds to the age of the worker in years. This meant that in

well-documented cases of doses below 5 rems/year in previous years, a worker might be allowed to receive up to 12 rems/year. The AEC accepted the NCRP's recommendations in 1960. In any case, these were levels acceptable to the emerging nuclear industry and compatible with the maintenance of the arms race and the defense of "national security" (Walker, 2000, p.23-26).

The reduction in nuclear testing beginning in 1963 and the growing number of nuclear power stations being opened and built, which peaked in 1967, led to a change of priorities in public opinion in the United States. The safety risks associated with the reactors, the effluent from power stations, the thermal pollution of water used in refrigeration in the nuclear facilities, emissions in the vicinity of the plants in different phases of maintenance and terrorist threats to these types of facilities caused great public anxiety and drew preferential attention from regulatory agencies (Walker, 2000, p.29).

In these agencies, risk management in nuclear facilities, whether by increasingly reducing exposure levels or by using barrier protection, used to be basically considered as technocratic management, and it was imbued with ideas about the need for strict hierarchy in risk awareness and decision-making (Winner, 1987). Recent contributions in the area of social studies of technology have shown that this hierarchical approach was a product of the military origins of the nuclear program and the secrecy surrounding the Manhattan Project, which was subsequently extended to the development of the H-bomb and the emerging nuclear industry. For example, at Hanford Site, a facility linked to the Manhattan Project in which plutonium production was developed in the 1940s, only a small number of staff in the medical department were informed of the health risks of radiation. They were in charge of implementing and overseeing compliance with safety procedures to protect the workers, who were kept in complete ignorance of the risks. In the 1950s, this concept of safety and radiation protection based on authority and control was transferred to the nuclear power stations (Parr, 2006).

Despite significant differences in the maintenance work and handling of radioactive material in the various types of nuclear facilities in the U.S., this rigid culture of risk control based on the application of technical rules and compliance with certain standard procedures was maintained until the 1980s (Perin, 2005). On the other hand, these studies confirm the great variety of radiological protection practices in the different nuclear facilities, a process mediated not only by technological availability but also national and political differences as well as discrepancies in management culture (Parr, 2006, p.821; Hecht, 1996).

The development of radiological protection regulations in Spain under Franco

Internationally isolated, with a scientific and technical system decimated by exile and purges and a country devastated by the Civil War (1936-1939), the Franco regime realized very early that atomic energy had the potential to revitalize the industry in Spain and reinforce the country's military and diplomatic capacity. Nuclear energy was also seen as representing the modernizing ideals of the regime (Presas i Puig, 2005, p.197-198; Ordóñez, Sánchez-Ron, 1996, p.185-187). In 1948, the Spanish government set up the Junta de Investigaciones Atómicas, and three years later founded the Junta de Energía Nuclear (Atomic Energy Board,

henceforth JEN), the state body that pioneered Spanish atomic development (Romero de Pablos, Sánchez-Ron, 2001, p.13-49). The creation of the JEN ensured state control over atomic energy issues, and it also acted as consulting body to the government on development. In terms of goals and responsibilities, then, the JEN was analogous to the various national atomic energy commissions being established at the time in some industrialized countries, such as the AEC in the U.S. and the Comissariat à l'Énergie Atomique in France, both of which were founded in 1945, or Italy's Comitato Nazionale per le Ricerche Nucleari, created in 1952 (Sánchez Vázquez, 2010, p.48-49).

The definitive boost to the development of the Spanish nuclear industry came with American support for the Franco regime and Spain's growing geostrategic role in the context of the Cold War. Two years after Spain and the United States signed agreements on Economic Aid and Mutual Defense in 1953, the director of the AEC and the Spanish ambassador in Washington signed a bilateral agreement for collaboration on 'civil uses of atomic energy'. The agreement included providing an experimental reactor for Spain, which began operating in 1958, and the lease of enriched uranium (Romero de Pablos, Sánchez-Ron, 2001, p.128). The Franco regime did everything possible to popularize new nuclear technologies among the Spanish people by using the mass media, which it controlled, to extol the virtues of industrial and medical applications of the new technologies (Menéndez-Navarro, 2007a; Medina-Doménech, Menéndez-Navarro, 2005).

After the first stage of absolute control by the state, from the mid-1950s on, Spanish electrical companies started showing an interest in accessing the large-scale production of electrical energy made possible by nuclear technology, and at the end of the decade, government and industry allied to develop Spain's nuclear program. In 1963, construction of the first three nuclear power stations was authorized, confirming the electrical industry as the driving force behind nuclear development in Spain. The development of Spain's nuclear facilities was completed with eight new power stations, all authorized during Franco's time (Sánchez Vázquez, 2010, p.81-83).

How did Spain develop regulations for radiological protection? Was the Franco regime's interest in developing atomic energy paralleled by prevention and compensation measures for workers who had been exposed in the nuclear sector? In this section we will try to provide an overview of these issues; as with other occupational safety matters under Franco, there was a marked delay in the adoption of health protection measures for workers.

Spanish legislation approved during the Second Republic (1931-1936) defined "pathological alterations produced by radium, X-rays and other radioactive substances" as occupational diseases (España, 15 jul. 1936, p.516). The Ley de Enfermedades Profesionales (Occupational Diseases Law) approved in July 1936 (España, 15 jul. 1936, p.515-517) required compensation for workers affected by such illnesses. The law was barely in place when, a few days later, the Civil War broke out (Menéndez-Navarro, 2007b, p.182-183).

After the conflict, the Franco regime privileged compensation over prevention of occupational hazards by ramping up national insurance, although this policy was limited to workplace accidents and to the problem of silicosis that was compromising sectors like lead or coal mining; the latter was key to the energy supply during the era of autarchy (Menéndez-Navarro, 2008, p.93-97). The problem of ionizing radiation was not dealt with either in terms

of compensation or of prevention during the first phase of Spain's nuclear development. The set of regulations on the prevention of occupational hazards in force from 1940 to 1971, called the Reglamento General de Seguridad e Higiene en el Trabajo (General Regulations on Safety and Hygiene in the Workplace), only provided non-specific hygiene recommendations, with no explicit mention of ionizing radiation (España, 3 feb. 1940).

The situation started to change in the mid-1950s, when the growth in nuclear activities and the expected growth in industrial production of atomic energy, as well as Spain's return to the international scene after the isolation of the post-Civil War period, made it necessary to establish a set of regulations that reflected international guidelines. The Spanish health care system and some professional sectors were receptive to the recommendations of work groups and resolutions on radiological protection adopted in international assemblies of the World Health Organization from 1956 on (DGS, 1961, p.IX-XV). In 1955, the Dirección General de Sanidad (Department of Health, henceforth DGS), the government body responsible for public health in Spain created a National Health Commission on the Applications of Atomic Energy, whose first task was to oversee the use of radioisotopes imported for medical use (Romero de Pablos, Sánchez-Ron, 2001, p.149). From 1956 on, the DGS ran a course on "Medical radioactivity and the defense of populations against nuclear attack". The topics covered included such issues as the management of radioactive elements in industry, workplace accidents and occupational diseases linked to exposure to ionizing radiation, and individual and collective monitoring measures for those exposed. Also covered were the problems of radioactive effluents from nuclear power stations and how to organize radiation protection services for the plants (DGS, 1959, p.63-66). Environmental pollution due to radiation was the main topic at the Fifth National Meeting of Healthcare Workers in Madrid in April, 1959 (Reunión Nacional…, 1959, p.276-281). Radiation protection was also the focus of the opening presentation in the First National Medical Conference of the Spanish Red Cross, held in Madrid in May, 1959 (DGS, 1961, p.XI).

However, responsibility for radiological protection would mainly fall to the JEN, whose foundational decree assigned it that duty and whose technical resources in the field far surpassed the DGS. Ever since its creation, the JEN contained a Medicine and Personnel Protection Section whose missions included overseeing radioactive exposures and monitoring the health of personnel exposed in the JEN's work centers (Romero de Pablos, Sánchez-Ron, 2001, p.154-155). In 1955, the JEN created the Consultant Commission for Medicine and Animal Biology, which was to evaluate the use of radioactive isotopes and sources of ionizing radiation in the field of medicine (Romero de Pablos, Sánchez-Ron, 2001, p.95). In 1957, the Isotopes Section was created, and immediately protection regulations for the use of radioactive isotopes were issued (DGS, 1961, p.204-233). The imminent opening of the first experimental reactor, called JEN-1, in 1958, led to the creation in 1957 of a Nuclear Safety Group within the JEN, whose members received special training in the National Laboratory of Nuclear Technology at Oak Ridge, U.S. In 1958, the Consultant Committee for Nuclear Safety was created (Caro et al., 1995, p.240-242).

In December 1959, over a decade after Spain's nuclear program was launched, the government approved the first set of regulations specifically devoted to protection from ionizing radiation. The regulations acknowledged the risks such radiation posed to public and

occupational health and explicitly mentioned the obligations stemming from Spain's recent incorporation into the European Organisation for Economic Co-operation, created in 1948 to administer aid from the Marshall Plan; later, in 1961, it would become the Organisation for Economic Co-operation and Development. Amongst other obligations, this implied recognizing the radiological protection recommendations imposed by the organization on its member states (España, 28 dic. 1959, p.16467). The 1959 regulations governed protection of the so-called controlled zones, in which higher exposures could occur, protection of the working population who were occasionally exposed, protection of residents in the so-called surveillance zones (close to the plants), and of the general population. In line with international guidelines, the regulations mandated measurement of radiation levels in the controlled zones, called for regular medical checkups for those exposed and adopted the doctrine of reducing exposure levels of workers in the sector to "as low as practically possible" (Walker, 2000, p.32). The maximum permissible concentrations of isotopes in drinking water and in inhaled air and the maximum permissible doses of exposure for workers and the general population were based on the ICRP's 1958 recommendations, which in turn were based on the conclusions of the U.S. National Academy of Sciences of 1956. In other words, maximum exposure for workers was set at 5 rems/year, using the formula D = 5 (N-18) to allow for exceptional cases of up to 12 rems/year. For people with no workplace exposure but who might occasionally enter the controlled zones, the maximum permissible dose was 1.5 rem/year, and for individuals living near hazardous facilities the maximum dose was 0.5 rem/year. Lastly, for the general population, the maximum cumulative dose up to the age of thirty was 5 rems (España, 28 dic. 1959, p.16468; España, 2 feb. 1960). The regulations also made it mandatory to instruct and inform exposed workers about the health risks, as well as precautions and radiation protection rules.

The supervision of the application of these measures and assessment of the nuclear industries was entrusted to the Section for Protection Against Ionizing Radiation, created within the DGS, and working closely with the JEN's Protection Services. Lastly, the regulations called for creating a consulting and evaluation body for the DGS, named the Interministerial Commission for Protection against Ionizing Radiation (España, 28 dic. 1959, p.16468). One of the first initiatives of the DGS Section for Protection Against Ionizing Radiation, which was in charge of training medical personnel specialized in the subject, was the creation of a *Manual de protección radiológica* (Radiological Protection Manual) for medical students and post-graduates, published in 1961 (DGS, 1961, p.3-8). The text echoed the principal developments in the field and reproduced, among other materials, the International Labor Office Agreement on protecting workers from ionizing radiation, passed in June 1960 (DGS, 1961, p.234-247).

As with the 1959 regulations on radiological protection, the 1964 Nuclear Energy Law stemmed from obligations derived from international agreements signed by Spain. These demanded the enactment of a law regulating the peaceful use of nuclear energy that would cover civil liability in the case of a nuclear accident and coverage for risks linked to the nuclear industry. When construction of the first Spanish nuclear power stations began in 1963, passing such legislation became urgent. The law aimed to provide coverage and encouragement for activities linked to nuclear development, from prospecting and exploitation of uranium and thorium deposits to running the nuclear power stations, by combining legal guarantees for

those potentially affected by such activities with economic viability for the nuclear industry, now configured as a private sector (España, 4 mayo 1964).

In the field of radiation safety and protection in the new nuclear facilities, the law assigned to the JEN the responsibility for carrying out risk analysis and appropriate inspections when authorizing construction and startup of the facilities. The legal text called on the JEN to train experts in the area and ordered the DGS to collaborate with the JEN in studying safety criteria and protection measures. In this sense, the law gave the JEN the functions of a regulatory organization, confirming the central role of this state body in the radiation protection field. This option enshrined a model that contained significant contradictions, since a single institution, the JEN, was in charge of safety in the facilities and protection of the workers and citizens, as well as being responsible for promoting nuclear energy. This situation was not resolved until the so-called transition to democracy, when the JEN delegated its oversight of nuclear safety and protection from ionizing radiation to the Nuclear Safety Council, created in 1980 (Romero de Pablos, Sánchez-Ron, 2001, p.230-236).

The Nuclear Energy Law incorporated general principles on radiation protection and occupational safety requirements in the power stations and other radioactive facilities, leaving details on the issue to be determined in specific regulations. However, such regulations were not approved for eight years. The Regulations on Nuclear and Radioactive Facilities were not approved until 1972 (España, 24 oct. 1972), and in any case did not require revision of the maximum exposure doses approved in 1959, although those doses had been widely questioned on an international level since the mid-1960s (Walker, 2000, p.36-44).

The 1964 law made it mandatory to provide exposed workers with the training and information necessary to protect themselves. The first information booklets designed to provide JEN workers with a basic knowledge of radiation protection appeared in 1965 (JEN, 1965). These booklets, which were written in simple, straightforward language, aimed to make workers understand the nature of radioactive material, as well as introducing the concepts of radiation, contamination and permissible doses. They were designed in comic format with explanatory vignettes in each section, in order to make radiation dangers easier to understand even for the least educated workers. In the section on radiation protection, there was no particularly relevant information, except for references to the work of the Medical Service and recommendations for proper use of protective material and clothing. However, no opportunity was lost to stress the "very low number of accidents due to radioactivity" in the experience of other countries (JEN, 1965, p.22-23), without, of course, evaluating the slight possibility of serious radiation accidents in the short term or mentioning the potentially serious long-term health effects. Lastly, the booklet offered ten basic rules for protection, which included the guidelines on using protective clothing, the need to undergo medical checkups and the use of the dosimeter (JEN, 1965, p.27).

The 1964 law mandated so-called 'risk analyses' among the necessary project requirements for building a nuclear power station. This report had to contain the necessary information for carrying out an analysis of the facility from the point of view of occupational safety and radiological protection, as well as an evaluation of the risks posed by the reactor, both under normal conditions and in emergency situations. The object of the report was to justify that the power station did not represent an undue health and safety risk, either for the workers

or the surrounding environment. The report had to include, among other information, all the barrier protection systems developed to avoid contamination around the power stations. In addition, it had to take into account the mechanisms and procedures established to try to avoid and limit possible consequences for the health of workers in radioactive environments (España, 4 mayo 1964, p.5691-5692).

The Regulations on Nuclear and Radioactive Facilities, endorsed in 1972, eventually provided a much-needed update to the requirements for personnel in power stations and other radioactive facilities, derived from the 1964 law and the Agreement of the International Labor Office of 1960 on the protection of workers from ionizing radiation, which was ratified by the Spanish government in 1967 (España, 5 jun. 1967; España, 24 oct. 1972). The Regulations defined the different phases of authorization for the facilities and the associated formalities. Even so, the Regulations lacked provisions for the dismantling and closure of nuclear and radioactive facilities, issues that were not introduced until 1999 (España, 31 dic. 1999).

Finally, in 1976, the JEN's Work Ordinance was approved (España, 24 mar. 1976). On the topics of security measures and radiological protection, the ordinance referred to the Nuclear Energy Law of 1964 and also the 1971 General Ordinance on Safety and Hygiene in the Workplace. This set of general guidelines for the prevention of occupational hazards went beyond earlier preventive structures, which had become obsolete, and adapted preventive policies to the socioeconomic and technological reality of developing Spain in the 1960s (España, 17 mar. 1971). The 1971 Ordinance included an entire section on ionizing radiation, which recapitulated the most important aspects of specific regulations (information and training of exposed workers, regular medical checkups, personal protection measures, etc.) (España, 17 mar. 1971, p.4392). As for radiation exposure limits, the Ordinance reiterated the same formula seen in the 1959 regulations, without including any new maximum doses (España, 17 mar. 1971, p.4392).

The impact of ionizing radiation on Spain's working population

How did these exposure levels affect Spain's working population? Given the extent of Spain's nuclear facilities, there is a surprising lack of specific epidemiological studies on the occupational impact of ionizing radiation. The most relevant and comprehensive research was carried out in the 1990s and consisted of a retrospective study of mortality in 5,657 JEN workers, employed between 1954 and 1992. Of these, 1,535 (27.1%) had been employed in the extraction of uranium minerals, and overall their average exposure to ionizing radiation was 8.6 years. Dosimeter readings, available for 60.1% of the working population examined, were taken into account. The study compared the mortality rate of this cohort to the Spanish average, with rates standardized by sex and age, as well as using the Poisson distribution models to analyze lung cancer mortality in the cohort (Rodríguez Artalejo et al., 1997).

The study concluded that the mortality rate among JEN workers was no higher than that of the general population. The cohort of workers studied only showed significant excess mortality, compared to the general population of Spain, in the case of non-malignant respiratory pathologies and bone tumors. The study confirmed that the second cause of death among workers was cancer (Rodríguez Artalejo et al., 1997, p.206-208). The only observation

of higher overall mortality compared to the population of Spain was found in the group of uranium miners, which had especially significant rates in terms of excess mortality due to lung cancer. It was not, however, possible to establish a clear relationship between mortality due to pulmonary carcinoma and the levels of exposure to ionizing radiation in the cohort studied (Rodríguez Artalejo et al., 1997, p.202).

The results of this broad epidemiological study were not in line with Francoist compensation politics for occupational injuries. Illnesses caused by ionizing radiation were not recognized as an occupational disease in Francoist legislation until 1961, in other words, 25 years after they were defined as such in the Occupational Diseases Law of the Spanish Republic. The decree defined at-risk sectors as the medical technology industry involving radiotherapy and X-rays, clinics where these technologies were used, chemical and pharmaceutical laboratories in which radioactive substances were used, and, of course, the extraction and treatment of radioactive minerals, although it did not directly mention the nuclear power stations (España, 30 mayo 1961, p.8145). It was not until 1971 that a case of radiation sickness was first acknowledged as an occupational disease under Francoist legislation; it involved a hospital worker employed in the radiology department (INP, 1972, p.251). Between 1972 and 1975, eight more cases were recognized, all of them healthcare workers (INP, 1973, p.239; 1975, p.262-263; 1976, p.312).

The restrictive policy on compensation for radiation damage has continued to the present day, leading to the fact that some cases have gained public attention in Spain, such as that of former employees of the Fábrica de Uranio de Andújar (Andújar Uranium Factory, henceforth FUA), a facility belonging to the JEN. The FUA, which operated from 1959 to 1981, was a facility for obtaining uranium concentrate by treating minerals mined in the south of Spain (Caro et al., 1995, p.89-94). Various official reports and media coverage showed the existence of exposure levels for some tasks to be much higher than the maximum permissible dose. In the late 1990s, the workers' association reported that fifty of the plant's 126 regular employees had died of cancer. At that point, a group of 77 former workers filed a lawsuit to get their ailments and those of the deceased recognized as occupational disease, charging factory managers with failing to provide health protection measures for the workers. Evidence that the cancer mortality rate clearly exceeds that of the population not exposed to the risk of ionizing radiation has not, so far, been acknowledged by authorities at the factory (Contreras Vázquez, 2008).

Episodes of serious radioactive contamination that took place during the Franco era have not been recognized either, in terms of their impact on the health of the population. On January 17, 1966, a USAF B-52 bomber flying over southeastern Spain crashed in the air with a refueling plane and dropped four hydrogen bombs, two of which detonated, spreading plutonium over a fairly wide area in the village of Palomares, in Andalucía, in the most serious environmental contamination incident to date (Megara, 2006, p.46-50; Ordóñez, Sánchez-Ron, 1996, p.212). Although much less important, in November 1970, there was a radioactive leak in the JEN facility in Madrid. The leak occurred in a facility designed for treating low and medium-level liquid radioactive waste and storing high-level waste. A failure in the welding of a drainpipe caused a spill into the center's sewage network. After the accident, earth from the adjacent area was dug up and analyzed, and

environmental monitoring programs carried out later by the Nuclear Safety Council did not show abnormal levels of radiation in the area (Romero de Pablos, Sánchez-Ron, 2001, p.236-239). The accident was not reported in the press, which was silenced as usual during that time. However, it did get the attention of the general media years later, when the complaints of some of the workers were publicized (Los informes..., 24 oct. 1994).

Final considerations

Spanish regulations granting workers radiological protection were adopted somewhat late compared to the international context and they came little or no time before facilities with radioactive hazards went into operation. Despite early recognition of the effects of ionizing radiation as an occupational illness in legislation under the Republic in 1936, the Franco administration did not follow suit until 1961. This striking delay in occupational health policies for compensation and prevention occurred also in industrial sectors like asbestos, which hazards emerged during the Franco years (Menéndez-Navarro, 2012). Once the regime's international isolation was overcome, Franco's authorities, faced with the imminent opening of the first Spanish nuclear reactor, endorsed risk-protection policies for ionizing radiation that were based on the existence of a tolerable dose of radiation. During the period when Spain's nuclear power stations were being opened and put into operation, the authorities maintained the maximum exposure levels at the level set by regulation in 1959, without taking into account the debates and new recommendations being made at an international level. The lack of resources of the DGS and the Nuclear Energy Law of 1964 made the JEN responsible for monitoring health in radioactive facilities and protecting citizens from nuclear risks. It had to reconcile this task with its mission of promoting the development of nuclear energy in Spain. These limitations, and the delay in the publication of the regulations called for in the 1964 law, which were postponed for almost a decade, also failed to contribute to updating and appropriately monitoring exposure risks.

Available epidemiological evidence confirms the impact of ionizing radiation on the working population of the JEN. This impact contrasts with the tiny number of cases recognized as occupational disease due to ionizing radiation during the Francoist period. Although this aspect requires further investigation, it is quite possible that a large fraction of the workers affected by illnesses linked to exposure to ionizing radiation were not recognized by the Franco administration, condemning the concern to public invisibility, which has only been questioned in cases like that of the former FUA workers.

NOTES

*This article is a revised version of a chapter on radiological protection from Sánchez Vázquez's 2010 doctoral thesis, p.189-215.

[1] In this and other citations of texts from non-English languages, a free translation has been provided.

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