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State-of-the-art techniques in radiation dosimetry – technological segments and applications

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ABSTRACT

This work presents a study based on patent filings as a resource for identifying technological trends in the field of radiation dosimetry for a view of the state-of-the- art techniques, in addition to the main actors involved and patent search process in the area of ionizing radiation. It aimed to make an analysis of patent portfolios to outline an application scenario for the knowledge developed in the area. It was carried out through consultation using the Questel Orbit search and analysis system having the word "dosimetry" and its similars, by semantic similarity, for the years between 1999-2019. The results are discussed regarding the main deposits, depositors, time evolution, technological segments and geographic coverage. They point out that companies that operate simultaneously in the area of energy power generation and medical applications have a significant contribution to the production of patents. Studies focused on the development of dosimetric systems move several technological segments, mainly environmental and medical technology.

Keywords: **Dosimetry, Dosimetric systems, patent, state of the technique, Questel Orbit.**

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1. INTRODUCTION

Peaceful use of radiation includes medical, environmental and industrial applications that demand precise control of the dose deposition to produce the expected effects of the irradiation processes. With the use of different sources and a wide range of energy involved, from low doses used in medical applications to high doses used in industry, it is necessary to develop different systems and materials, with specific properties for each application [1]. For example, thermoluminescent dosimeters widely used in radiotherapy and imaging diagnosis [2]; chemical dosimeters used in the control of industrial irradiation processes [3]; and dosimetric systems based on gas detectors used to measure environmental contamination [4]. In all cases, they are essential instruments to guarantee control of monitored events. Thus, there is a wide variety of commercial dosimeters available. Nonetheless, not individually have a broad application dosimetric system, or even entirely without any technical limitation such as signal fading over time after irradiation. Therefore, continuous efforts are aimed at the development of materials with dosimetric properties and associated systems, within the various existing categories, being, therefore, an area of science directly linked to a technical application [5].

The state of the art in different fields of knowledge is a bibliographic definition that seeks to map and discuss academic productions, as an inventory of what has already been built and produced on a given theme [6]. On the other hand, the state-of-the-art techniques is related to the patenting of technical creations that guarantee to its owner the technological domain and appropriation of the results obtained from the inventive process. This is an important aspect of the production of science linked to technology and, thus, defines production in Research and Development (R&D), since its purpose is the search for innovations through scientific knowledge that is reflected in the development of new technologies. In practice, a patent holder is assured to exclude third parties from exploiting it without his authorization [7].

The patent process, as an administrative act, involves steps from a proposal to the granting of a Patent Letter, which can be extended in Brazil in up to ten years, being monitored through the *Instituto Nacional da Propriedade Industrial* (INPI) [8]. This is because it involves tracking possible similar inventions that restrict the description of the final object to be patented, to ensure

that it is truly innovative. This process is sometimes use with purpose to intervene in the action of competitors in the market, important not only to protect the use of his invention, but also in market factors, including advertising and final image of assignees. In this sense, it is common to be referred to as "players" in competition for performance in the technological market [8]. The patent itself is defined as an institute for asserting the invention, which may be linked to a product or process, but its strategic use expands its value with an amplification of its market meaning, provided by a critical assessment of the movements of players and inventions related to a given technological segment. As a methodological differential, research through a patent database allows the study of technological trends and R&D activities of a certain sector [9]. In this sense, it helps in decision making regarding investments in research aimed at solving practical engineering issues, among other technical issues, such as in the case of ionizing radiation dosimetry.

Thus, it is understood as strategic the survey of the historical and current scenario of this field of knowledge, as a way of monitoring and prospecting technological trends in radiation dosimetry, the technical use of phenomena that respond proportionally to the absorbed dose . It is one of the ways to delimit the commercial interest in certain technological segments, in addition to mapping the main companies within this market, expanding the application perspectives for the researches developed. It assists in the positioning of those active in the area, both in the development of theoretical and experimental research, in the production of technology, or even as an agent within this technical-scientific specialty. In this sense, a technological mapping adds relevant information to bibliographic studies of an exclusively academic nature, and the main objective of this work is to contribute to an expansion of the vision of this field of activity, R&D. It is, therefore, an analysis of several families of patents related to radiation dosimetry that have dominated research and inventions in recent decades, with an emphasis on the most recent proposals.

2. MATERIALS AND METHODS

2.1. Questel Orbit System

Questel Orbit is an information industry system, special provider of intellectual property information services that has a leading position in the area of patents as well as trademark information.

The system includes patent data for 107 countries and organizations, full-text patent data for 23 countries and organizations, and patent design data for 50 countries and organizations. Therefore, the use of Questel-Orbit as a data source guarantees the sufficiency and reliability of the data [10]. It has a comprehensive collection of intellectual property databases with a refined keyword search field, allowing the search associated with the mapping of technological segments, thus enabling the identification of application domains for certain fields of science, such as dosimetry of radiations [9].

2.2. Scope of search

A search for similarity was performed using the keyword “dosimetry” as a term. This search engine is based on an algorithm that takes into account patent rankings and citations that return results from starting families that appear as top. The information used in this type of search is:

- European Classification (ECLA) ;
- International Patent Classification (IPC);
- United States Code;
- Cited patents and concepts [10].

It is obtained from an advanced command line and for this work no restrictions on the percentage of similarity between the patent families were assigned . Relevance scores are based on the degree of similarity and frequency of the search term. The Questel Orbit Gold license was used and, therefore, the results were extracted through the harmonization of data from WO , EP, US, GB, CA, FR, DE and CN publications , that is, patents required and/or granted by World Intellectual Property Organization – WO (WIPO), European Patent Office – EP (EPO), United States of America – US , United Kingdom – GB , Canada – CA , France – FR , Germany – DE and China – CH, which is the greatest coverage provided by the system.

2.3. Verification of the preliminary mapping of the patent scenario

To verify the suitability of the term chosen for the search regarding the ability to return a broad result, but within the scope of the study area, that is, radiation dosimetry, and to verify its scope to other relevant terms and related concepts, a preliminary analysis was performed of the patent scenario to be explored . The result is shown in Figure 1 that demonstrates that the choice of the term "dosimetry" was effective to cover, by similarity, the technologies and applications related to this field of knowledge, as it resulted in the extraction of patents involving other terms that

assertively expand the query such as "radiation dosimeter", “radiation dose”, “dose rate” and “dose distribution”.

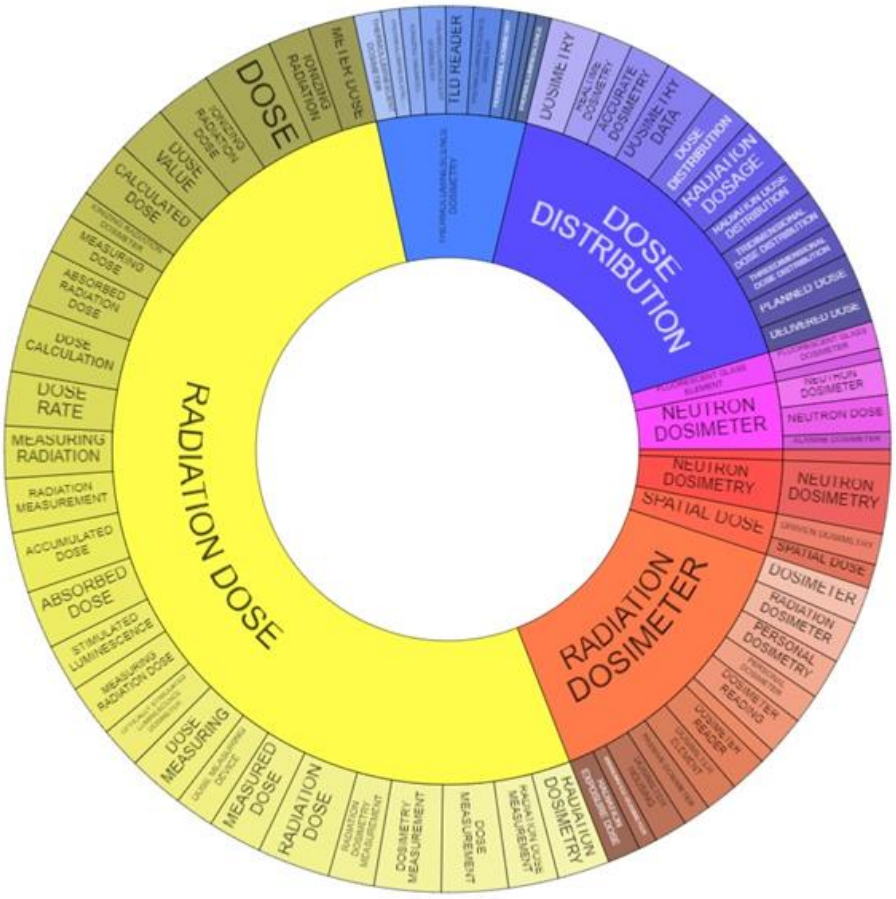

Figure 1: *List of technologies and applications, extracted and harmonized by semantic analysis of the term “dosimetry” by the Questel Orbit system.*

The system correctly identified that the search for dosimetry, in general, is strongly related to radiation dosimeters, radiation dose, dose rate and dose distribution, in addition to being able to directly cover specific dosimetric systems, since we also see they are systems effectively used in radiation dosimetry, such as, for example, those associated with thermoluminescent dosimeters.

3. RESULTS AND DISCUSSION

3.1. Scenario of companies holding patents in radiation dosimetry

The main companies holding patents in the area of dosimetry are presented in the order in which they were extracted by the search that makes reference to the number of patent families. When referring to patent families, by definition, patents filed in several countries are considered to protect an invention, where the priority right of the first filing is extended to subsequent filings in other countries [11]. Thus, by way of example and for a better understanding of the results, we can cite one Landauer patent family directed to radiation dosimetry, composed of optically stimulated luminescence sensor material (OSL) that has a reflective support to improve the efficiency of exposing the optically stimulated luminescence material (OSLM) to the OSL sensor, that is, to the stimulation light, thus increasing the detection efficiency of the luminescent light emitted by the OSLM, as described in the patent [12]. It was submitted to the US national office with first filing in 2012, being granted and published in 2016. In 2013 applications were also made in Japan, Korea, United Kingdom, Canada and the World Intellectual Property Organization, being discontinued in Korea and abandoned in Canada, however active the others, forming a family of patents. In other words, the patent is repeated in several countries, although it does not necessarily present the same text, since the filing requirements vary according to the office where the patent is applied for [11].

The result of the search for companies holding patents in dosimetry resulted in a collection of the top thirty, with almost a third of them being public bodies, teaching and research institutions. In Figure 2 is introduced from a graph depicting the applicant's having the largest number of patents in their portfolios in the analyzed area. At first, among the highlights are the Toshiba cluster of companies and the French public research body *Commissariat à l'énergie atomique et aux énergies alternatives* (CEA). Among these thirty companies, almost half (12) are headquartered in Japan and nine in the USA, demonstrating that they are production centers in technology focused on the field of radiation dosimetry. France appears as the seat of two important public research centers, the CEA and the Centre National de la Recherche Scientifique (CNRS). Separately, we also have companies in South Korea, Sweden, Netherlands, Germany, Russia, China and Taiwan. On the other hand, it is necessary to evaluate the recent activity of these institutions, which can be obtained by analyzing

the legal status of patent applications, including patents in force, pending or expired, in the year 2019.

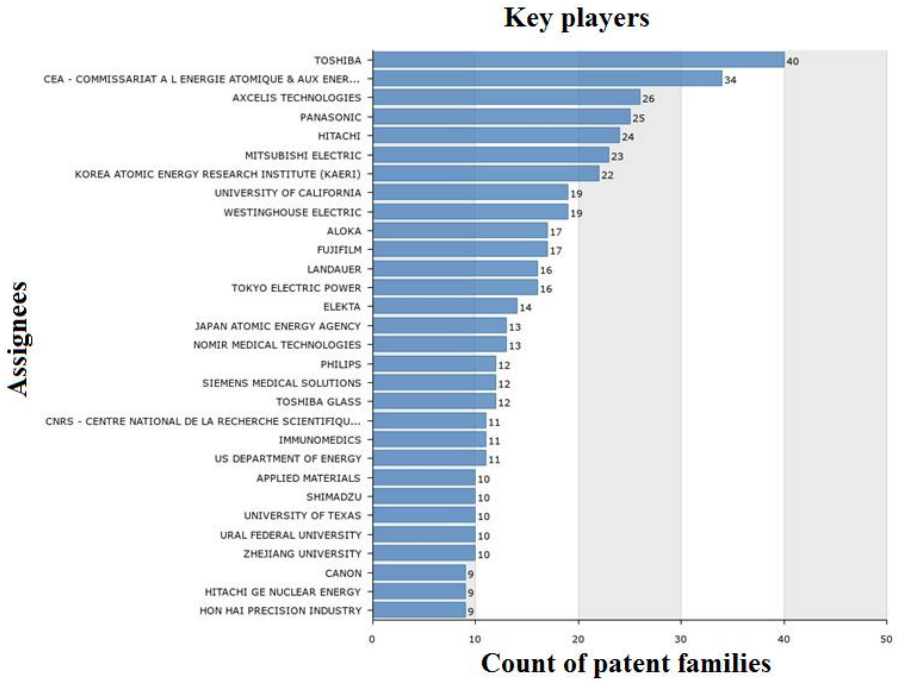

Figure 2: *Leading patent holder companies in dosimetry.*

The graph shown in Figure 3 illustrates the main applicants in the group of patents analyzed according to their legal status. This information makes it possible to identify applicants who have already withdrawn from the sector (patent expiry) and those who are still active (applications pending and patents granted still in force). It is observed, for example, that the French agency CEA is currently less expressive in the field of dosimetry than other public research institutions, such as the Korean Korea Atomic Energy Research Institute (KAERI). Among public institutions, we also note the absence of active patents from the US Department of Energy.

Among private companies, Toshiba continues to stand out, as it has the largest number of patents between pending (9) and in force (8). It acquired Westinghouse Electric in 2006, which is also prominent in the field of dosimetry, with patents active, but none under review [13]. It is also observed that Panasonic, which appears among the most relevant in the sector, actually has the most

patents expired, being surpassed by many, such as the Swedish Elekta, and the Japanese Hitachi and Fujifilm. Hitachi stands out for presenting 14 patents between pending (5) and active (9).

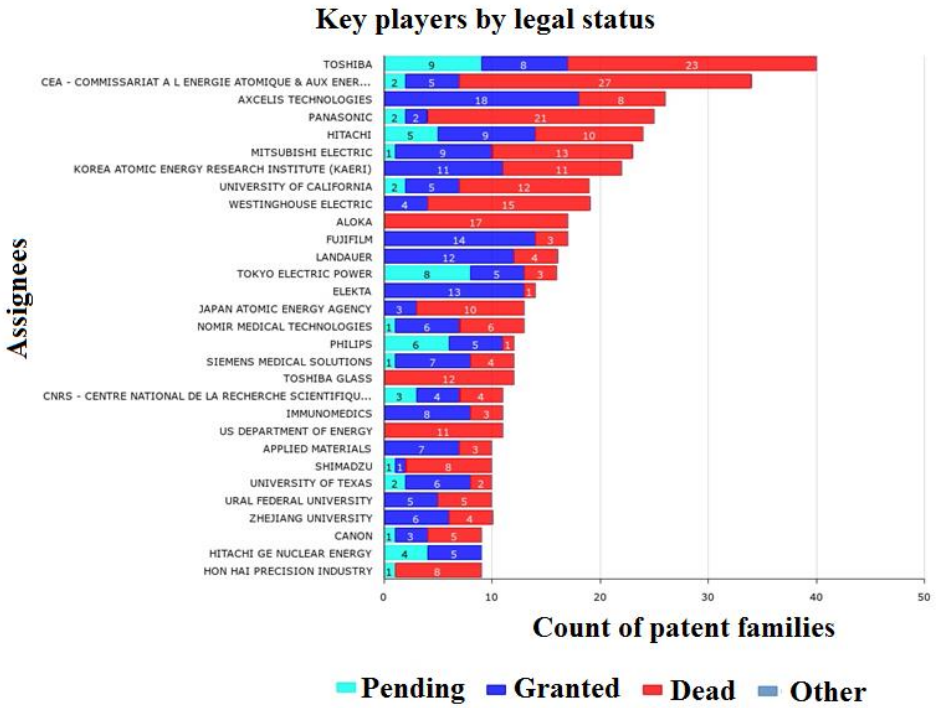

Figure 3: *Relation of the number of patents pending, in force and expired in 2019 filed by the main holder companies.*

Patents that are pending are generally due to the year of their first publication and are therefore in the process of being granted. In this sense, patents pending relate to recent activity in the development of inventions in the studied field. Compared to Hitachi, Fujifilm has 14 active patents, but none under review. Hitachi joined part of Aloka in 2007, associating itself in the production of technologies, which explains the absence of active patents of the latter [14]. Both Toshiba, Hitachi and Fujifilm, as clusters of companies, operate in various market segments and, with regard to dosimetry, file patents both related to medical imaging equipment and power generation in nuclear reactors, but neither all directly linked to exposure monitoring, but to system components [15-19]. On the other hand, Landauer presents itself as relevant for working exclusively offering products and services in dosimetry [20]. It has twelve patents in force, although none are pending.

A more reliable way to check which of these companies are active in the production of inventions is to check the first year of publication of their latest patents and these data are presented in Figure 4, in a graph that allows analysis to identify new applicants and those who do not are more involved in the field. This information also helps to explain the volume of patent families per assignee by observing the size of the bubbles (the larger the bubble, the greater the volume of patents involved in the indicated period). Toshiba's constant performance is observed over the last decades, especially in 2015. The participations of CEA, Axelis Technologies, Hitachi, Mitsubishi Electric and KAERI are also shown to be constant.

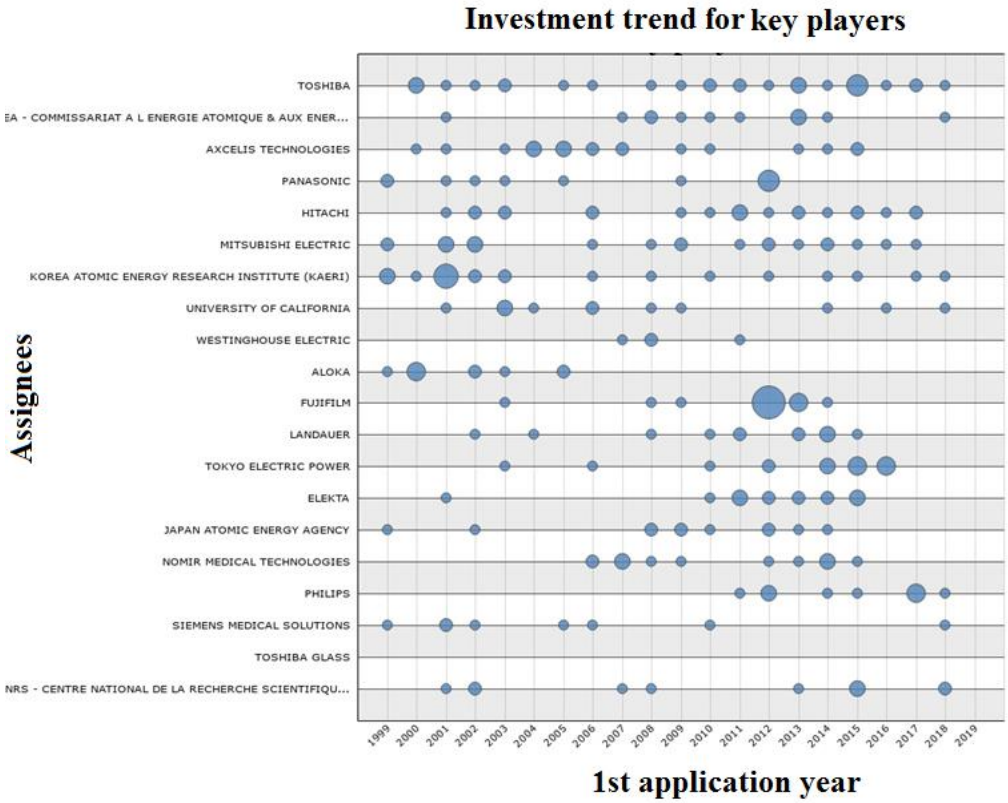

Figure 4: *Patent applications by year of first publication.*

Panasonic seems to end participation in 2012, with the publication of a good volume of patents, which explains that it is still linked as one of the main inventors in dosimetry. Fujifilm had its publication peak in 2012, but presented the last one in 2014, which explains why it has no patent under review. Note the entry in this extract of the market of Nomir Medical Technologies in 2006

and Philips in 2011; as well as the termination of the interests of Westinghouse Electric in 2011 and Aloka in 2005, both incorporated respectively by Toshiba and Hitachi [13,14]. For an overview of the companies highlighted in the area, Figure 5 lists the number of citations of the respective patents per applicant.

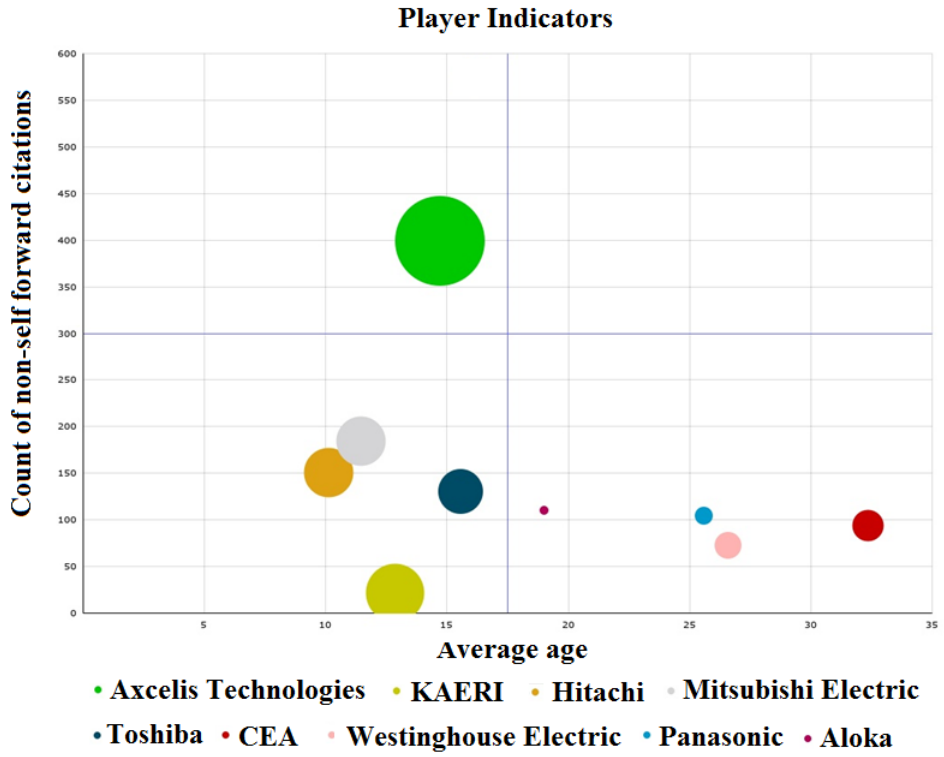

Figure 5: *Comparison of portfolios of companies holding patents by citations.*

The Figure 5 shows a relevant indicator-based graphic and performance in the industry analyzed by number of citations (vertical axis) relative to the average age of the portfolio (horizontal axis). The size of the bubbles corresponds to the number of patent families that have at least one family member as a granted patent. The larger the bubble, the greater the competition potential within the sector. The portfolios positioned farthest to the right of this graph correspond to the pioneers in the studied area. A position in the upper right corner indicates a pioneer with a strong impact on the studied field (blocking potential). The leftmost wallets on this chart are the newcomers' wallets. A

position in the upper left corner corresponds to a recent player who quickly became important in the field (strong impact).

Therefore, we have as pioneers in the area Aloka, Westinghouse Electric, Panasonic and CEA. However, despite its pioneering spirit, none of these currently have blocking potential, since their patents do not restrict the others. As recent but highly competitive companies in the sector are Toshiba, Hitachi, Mitsubishi Electric and KAERI [21]. With a strong participation in the segment appears Axelis Technologies, which acts as an industry for the development and manufacture of semiconductors through ion implantation technology, and, therefore, having a prominent participation in ion beam dosimetry [22-24].

Another important aspect to be evaluated, with regard to the main patent applicants, is the interaction between them for the composition of knowledge in the area. It is also a question of identifying whether private companies interact with public research institutions. For this purpose, Figure 6 presents a map of citations between companies.

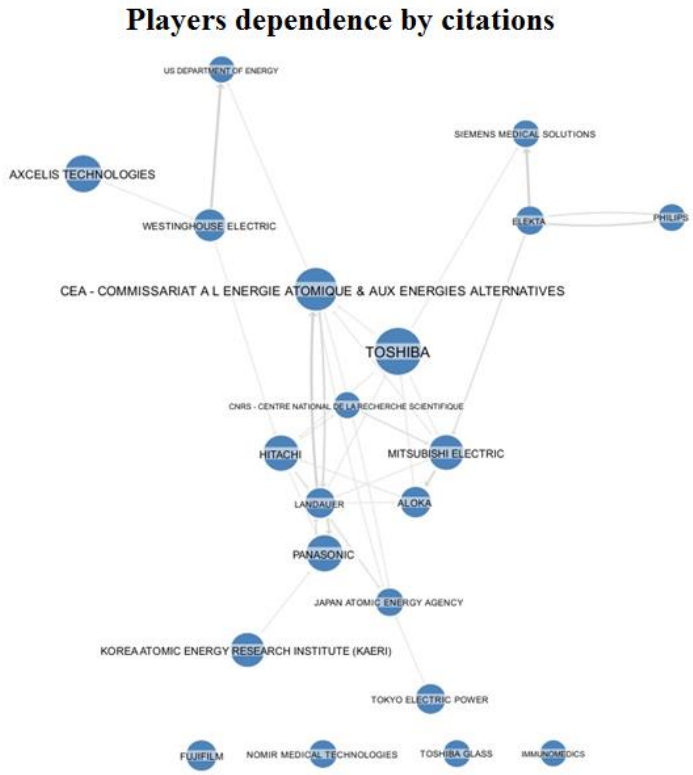

Figure 6: *Map of citations between patent holder companies.*

This information identifies portfolios that have strong interactions with each other. A portfolio heavily cited by most participants is likely a pioneer or blocking portfolio. The quotations represent a strong relationship between the inventions and thus the citation analysis provides a means of identifying documents that may have had an impact on the development of a technology. When we look at quotes from public research bodies and institutes these patents indicate the relevance of research carried out under the state's interests. In particular, in the energy production segment in reactors, the State's priorities are also linked as the main customer of the developed technologies, since, even if the production and distribution of energy in a country can be offered by private companies, they meet the demand of the local population, by the limits of distribution and, thus, in a field of strategic control of the States.

The pioneering spirit of the companies Aloka, Westinghouse Electric, Panasonic and CEA is confirmed, as well as the prominent performance of the companies Toshiba, Hitachi, Mitsubishi Electric, since all appear in the center of the quotes with great interaction between them and with the others. There is a good interaction between public research institutions and private companies, with emphasis on CEA and CNRS, both from French. CEA, for example, references state energy agencies such as the US Department of Energy and Japan Atomic Energy Agency, but is also referenced by private companies Toshiba and Mitsubishi, in addition to the intense exchange of quotes with Landauer. KAERI, on the other hand, cites the South Korean Panasonic, domestic, state and private actors, respectively.

Some actors are more isolated, such as Fujifilm and Nomir Medical Technologies. Isolated interactions are seen between some companies like Siemens in relation to Philips and Elekta. The relationship between Philips and Elekta is explained by a partnership in research for the recent development of a coupled linear accelerator system and magnetic resonance (MR) equipment, exemplifying how citations can indicate a relationship between inventions and also between actors. [25-27]. In a patent filed by Elekta, for example, there is a description of a radiotherapeutic device, comprising a linear accelerator that can rotate around an isocenter coupled to an MRI device, arranged around the isocenter. The proposal includes the use of radiofrequency (RF) coil windings of RM imaging system for since made a conductive material, for conducting the radiofrequency signal through the skin. A "skin effect" is described as the tendency of the high frequency signal to be transmitted in a superficial layer only. Thus, was indicated that while keeping at 15 times the

transmission in terms of depth of the skin, a good quality X-ray transmission can be obtained if combined with the properties of the RF coil, establishing the event relationship with aspects of dosimetry. Thus, a path described as significantly better for the transmission of radiation to the patient is proposed, acting in the absence of homogeneity and dispersion [28]. It is observed that Elekta, as a radiotherapy equipment developer, mentions Philips in the description of the physical project, as a partner in the development of the MR equipment.

3.2. Technological segments

For an overview of the technologies currently focus of interest in R&D in the area of dosimetry, a search for specific applications within this field was carried out through the relationship between the patents found and the technological segment in which it belongs, the result can be seen in Figure 7. It is based on the codes of the International Patent Classification (IPC) contained in the set of patents in question, where the codes IPC were grouped into 35 segments of technology, as available via Questel Orbit system [10].

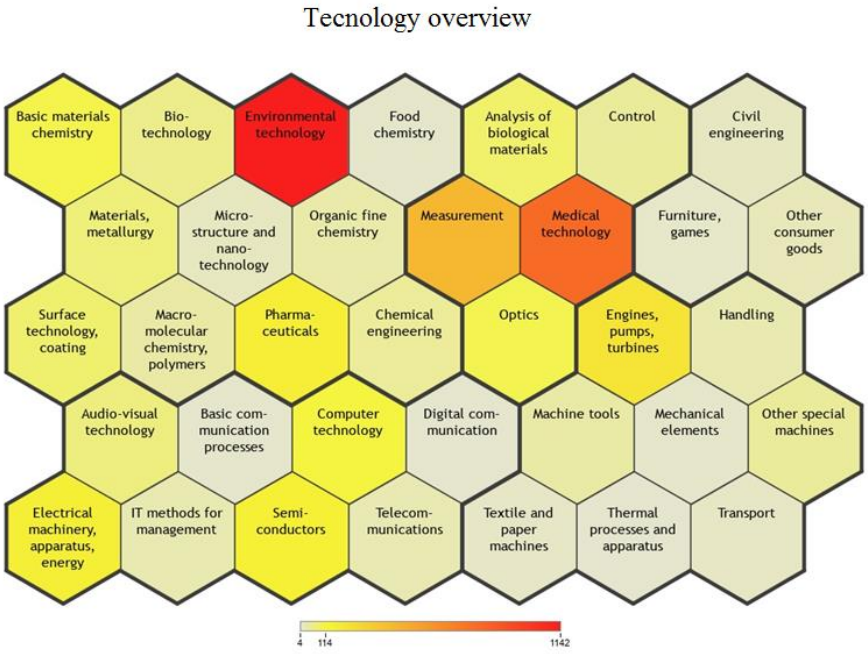

Figure 7: *Relation between patent families and technological segments according to the International Patent Classification (ICP) code.*

This figure helps to identify the diversity or specificity of the applicants' patent portfolio. Thus, it is possible to identify that the main segments that have fostered the development of research in the area of dosimetry are the medical applications of the use of radiation and monitoring of environmental contamination, with an emphasis on the latter. With regard to the control of exposures due to environmental contamination, those possibly caused by nuclear energy generating companies stand out [29]. In this sense, its current expressiveness may be linked to the Fukushima Daiichi nuclear accident in 2011. In fact, we observe patent publications aimed at efforts to innovate techniques for measuring and controlling environmental contamination resulting from the event [30- 32].

On the other hand, the categories represented least also used as a means of identifying u behind potential applications of patents, since they are provided at least in the scope thereof and therefore appear related to the fields. Thus, for example, we have the direct use of semiconductor materials such as luminescent dosimeters [33] and biological materials used as dosimeters, based on the OSL phenomenon [34]. Patents aimed at semiconductor materials indicate the need to increase the energy range to be measured by other dosimeters of the same category by increasing the detection sensitivity per unit area. This encourages the development of new materials, produced from known semiconductor materials [33-35]. Also new polymeric materials with luminescent properties have been proposed as scintillators for *in vivo* dosimetry, associated with intensity-modulated radiotherapy modalities, with very precise dose planning, although their experimental validation is still of great importance [36]. With the proposals for *in vivo* dosimetry, the associated use of artificial intelligence devices appears as a need for new systems, another important trend verified through patents [37].

We can see the wide range of technological segments that benefit from studies aimed at radiation dosimetry, involving professionals from different areas of knowledge. In Figure 8, these same segments are presented, now directly related to companies holding patents, for a specific view of their interest and field of action. The graph in Figure 8 shows the technological segments protected by the main players in the area of dosimetry. It is useful to identify patents in a domain that can have multiple uses, breadth that can be conferred for several portfolios, covering both low and high doses of radiation, as well as relating to both the field of equipment and medical exposures

and energy production in nuclear reactors. We noticed a distribution that highlights coverage of at least six different technological segments for the same company.

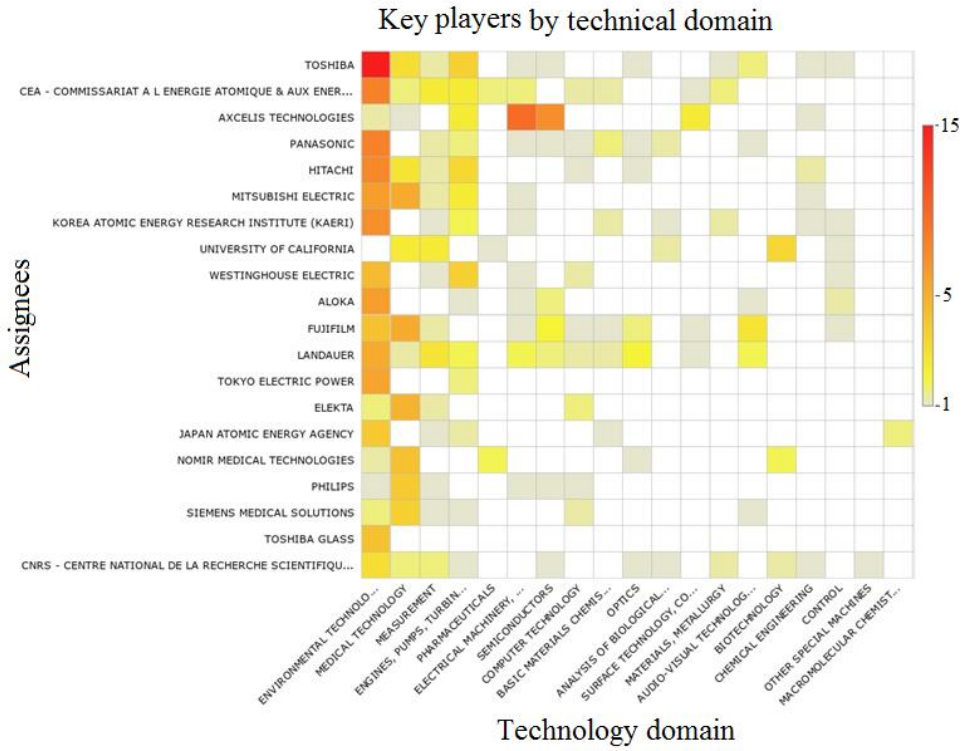

Figure 8: *Main companies holding patents by operation in the technology segment.*

It is possible to observe the main clusters of companies aimed at the peaceful use of radiation acting simultaneously in the Environmental Technology segments; Medical Technology; Engines, Pumps and Turbines. They are Toshiba, Hitachi, Mitsubishi Electric, Fujifilm and Landauer, which are companies active both in medical/occupational dosimetry and in the context of nuclear reactors and environmental control of radionuclide contamination.

The result shows that CEA, as a research institute, develops works in ten different segments, as well as the CNRS. On the other hand, following the fields of action of the University of California, for example, it is possible to observe an exclusive role in the field of biological applications, as it involves the fields of Medical Technology; Measurement; Pharmaceuticals; and Biotechnology. The segment of interest of Axcelis Technologies as developers of semiconductor materials, using ion implantation technology, is also clear, which highlights the Motors, Pumps and Turbines

segments; Electrical Machinery; Semiconductors; and Surface Technology [38,39]. It is also possible to distinguish companies that operate exclusively in the field of power generation in nuclear reactors, such as Westinghouse Electric (incorporated by Toshiba); Tokyo Electric Power; and Japan Atomic Energy Agency [40].

Finally, it is considered that the Environmental Technology; Medical Technology; Measurement; Engines, Pumps and Turbines; Surface Technology; they are highlighted because they are directly related to the field of activity of companies and their production processes and, therefore, must be protected by patents. In other words, dosimetry itself is a measurement system with several control applications.

However, we see that other domains appear less prominent because they involve specific companies with their respective dosimetric work systems, becoming segments that are impacted by research aimed at the production of dosimetric materials. This is the case of Semiconductor segments; Basic Materials Chemistry; Optics; Analysis of Biological Materials; Materials, Metallurgy; Chemical Engineering; and Macromolecular Chemistry. These segments can relate, for example, to systems based on luminescent phenomena of organic and inorganic materials; based on optical properties and spectroscopy tracking; or from polymeric films. On the other hand, the other segments appear to be related to a market of potential applications.

Within this logic, we can use the Swedish company Elekta as an example. It develops and markets clinical solutions for the treatment of cancer and, with regard to dosimetry, this refers to radiotherapy planning. In this sense, it concentrates Information Technology portfolios, being at the forefront located in the Medical Technology and Measurement segments and, at the second level, also in the Computer Technology segment. It is expected that their inventions will generate impacts in this last segment hrough efforts in the development of software and other related devices [41].

3.3. Geographical coverage of patents and market protection

The study referring to the geographic coverage of the main families of patents in dosimetry shows, as in Figure 9, the applicant's protection strategy and, thus, can help to identify the target markets of its products and/or services. Although the protection of international markets requires high costs, they present advantages for companies that operate globally. Also, it generally involves protection in countries where major competitors are installed and not necessarily their consumer

market. In this sense, they seek to block the development of competing inventions and not necessarily market protection, even if it ends up being a consequence of the final quality and innovation of the products and services offered [42].

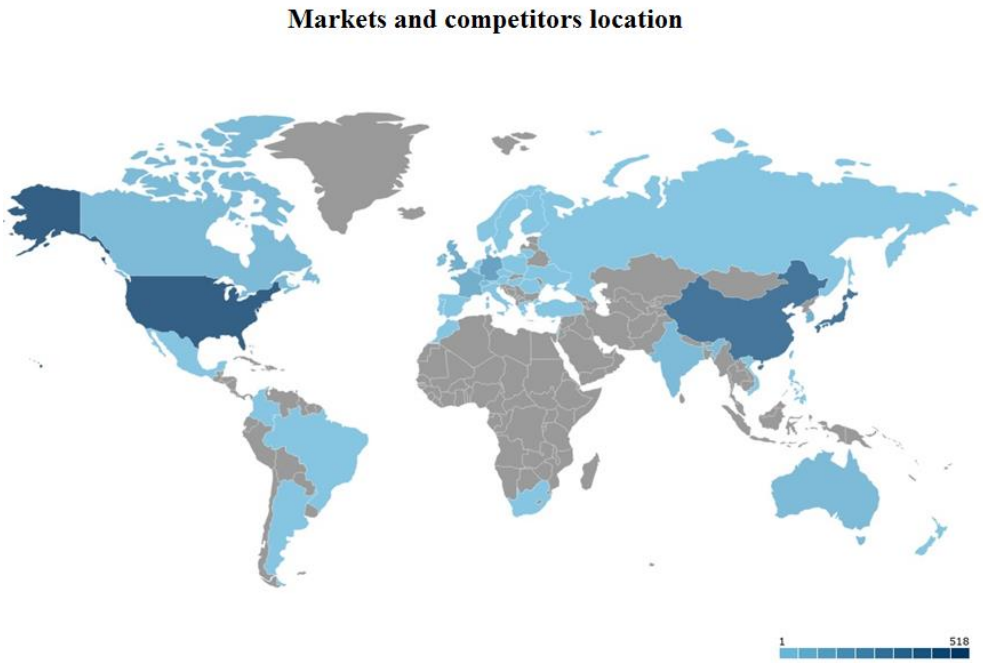

Figure 9: *Illustrative map of the patent protection strategy in force in the field of dosimetry in several national offices, with regions highlighted by the number of patents filed.*

The map presented in Figure 9 provides information about the markets considered strategic both for consumption and for R&D and, therefore, that need to be protected, such as those of companies' origin, especially countries in Europe, Japan, China and the United States. Of the thirty companies and institutions holding patents in dosimetry initially identified, thirteen are Japanese (JP) and nine are from United States of America (US). Among the other countries listed are France (FR) and South Korea (KR) with their public research institutes, universities in Russia (RU) and China (CN), as well as Germany (DE) with the Siemens, Sweden (SE) with the Elekta and Taiwan (TW) with the Hon Hai Precision Industry.

The Figure 10 shows a more specific view of the interest of each patent holder for international markets. It is confirmed that Japan is a major R&D center in dosimetry, as all the holder companies file patents in their national office. The companies with the broadest coverage are Axcelis

Tecnhologies and Elekta, in addition to the French research institutions CEA and CNRS. These data confirm the strong impact and blocking power of Axcelis Technologies, already evaluated by the number of citations and volume of patents and, now, by the strategy of protecting its inventions in the international R&D scenario.

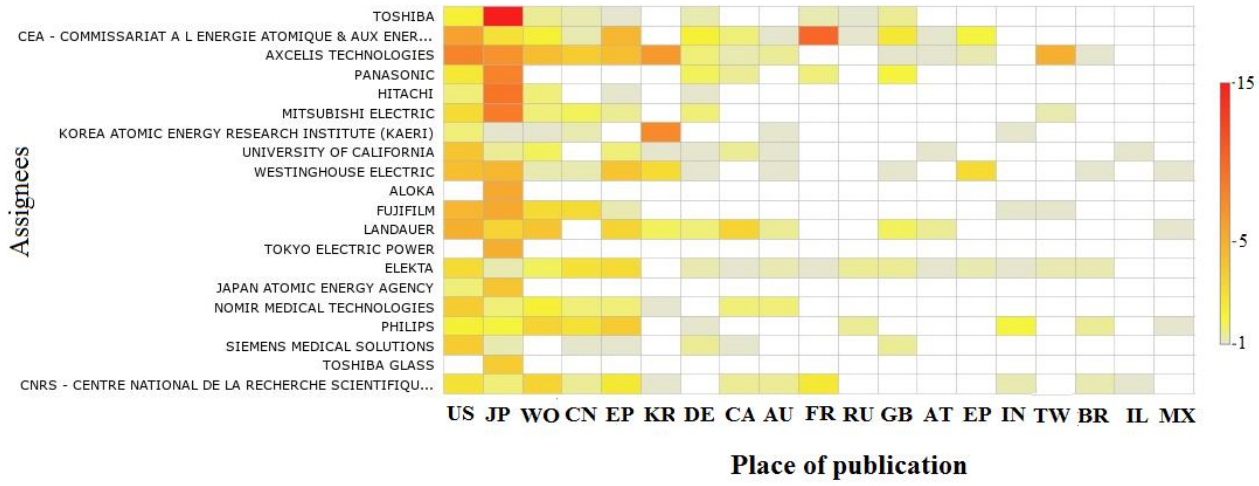

Figure 10: *Volume of patents filed by national offices.*

With regard to the Brazilian market, there is interest shown by the following assignees: Axcelis Technologies, Westinghouse Electric, Elekta, Philips and CNRS. In Brazil, the semiconductor production chain is still in its infancy, with initiatives concentrated in universities, which would not justify the protection of its market by Axcelis Technologies [43]. On the other hand, with regard to ion implantation technology, a technique used in semiconductor doping, in addition to other applications, it is developed in Brazil both in the context of universities and in research institutes, such as the Instituto Nacional de Pesquisas Espaciais (INPE) [44.45].

Westinghouse Electric worked in partnership with Indústrias Nucleares do Brasil (INB) and Korea Nuclear Fuel Company (KNFC) to jointly design an advanced fuel element for use at the Angra I nuclear power plant [46]. With regard to dosimetry, we have, for example, a patent filed by Westinghouse Electric in Brazil in 2011, describing a method for monitoring the distribution of energy within the core of a Pressurized Water Reactor (PWR) and a method for calibrating detectors external to the core in a PWR reactor [47]. With the bankruptcy of Westinghouse Electric,

Toshiba completed its acquisition in 2006 to own and market the company's PWR technologies [40]. Within nuclear applications there is an established and well-structured cooperation between French public research organizations and Brazilian institutes and universities, such as between the CNRS and the Instituto de Radioproteção e Dosimetria (IRD), justifying patents filed in both national offices [48].

Elekta established its own subsidiary in Brazil in 1998 to serve Brazilian and other Latin American markets [49]. Interaction between the companies Philips and Elekta was demonstrated, through exchanges of quotes shown in Figure 7 and, in Figure 10, they appear together protecting the Brazilian market. The association between the two occurred in 2012, through the establishment of a research consortium for the combined production of equipment for the treatment of cancer, linear accelerator associated with magnetic resonance, which seems to indicate the market they intend to simultaneously protect in Brazil [25-28], [50]. Returning to Figure 4, it is observed that both Philips and Elekta started a sequence of patent filings in the area of dosimetry that evolved between 2011 and 2015 simultaneously.

In fact, Philips filed a patent with the Brazilian national office in 2011, and was published in 2020, bringing in the abstract a basic initial description of a dosimeter for measuring absorbed dose in an individual during MR-guided radiotherapy [51]. A reading of this patent allows us to exemplify the protection strategy regarding the development in R&D, technological segments subject to competition in Brazil, in the area of radiation dosimetry. The title of the patent refers to both the dosimeter as therapeutic apparatus and product software. As the title itself suggests, it describes a dosimetric system and also a therapeutic proposal, involving a computer program, that is, the detailed description of the invention involves both dosimetric materials and data processing. It includes both chemical dosimeters and, in another embodiment, a pillow with sensors placed inside and mixed polystyrene balls. It also describes other conformations for dosimeters such as being a blanket. It claims protection for the therapeutic device itself and also for the computer program associated with the processing and post-processing of the images obtained by MRI.

Thus, if we think that Brazil does not have a company producing MR equipment or equipment for radiotherapy treatment, the need demonstrated by Philips to require protection for an invention in this technological segment can be questioned. However, a more detailed analysis of the patent allows us to verify the great scope of the claim and how it also affects national productions in

dosimetric materials and information technology, digital communication. Therefore, it is observed that, in fact, the patent filed by Philips restricts the use of inventions potentially produced in Brazil for similar functions and, likewise, this assessment can be followed by other similar examples.

4. CONCLUSION

The search for information on the field of application of R&D knowledge in dosimetry through the study of patent families resulted in the configuration of a diversified scenario, with regard to the breadth of the markets involved. It presents clusters of companies that act globally and simultaneously in the fields of medical applications and power generation in nuclear reactors as main actors. Among the main ones are Toshiba, Hitachi, Mitsubishi Electric, Philips, Fujifilm and Landauer. More specifically in medical applications, the Swedish Elekta stands out, which, in partnership with Philips, has developed inventions aimed at radiotherapy treatment, associating linear accelerator and magnetic resonance, seeking to protect several national markets, including the Brazilian one.

Regarding public research bodies and institutes, we have the participation of the French centers CEA and CNRS, the Japanese Tokio Electric Power and Japan Atomic Energy Agency, in addition to the Korean KAERI. Some of the pioneers in dosimetry withdrew from the sector, either because they were acquired by others , such as Westinghouse Electric (incorporated by Toshiba) and Aloka (incorporated by Hitachi), or because of the option for other markets, such as Panasonic and to Siemens. The aggressive performance of Axcelis Tecnhologies stands out, involving a significant number of patent families and broad protection in the international market, pointing to ion beam dosimetry as a technological trend.

Through the analysis of citations, a good confluence of interests between public institutes and private companies can be observed, signaling a field with good convergence of studies. It is, therefore, a strategic field for directing research and development of technologies, since it presents itself as a global interest, with difficult competition, which involves highly active actors, generating impact in various fields of knowledge and technological segments

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