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Critical elements on nanotechnologies in Mexico

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— Abstract—

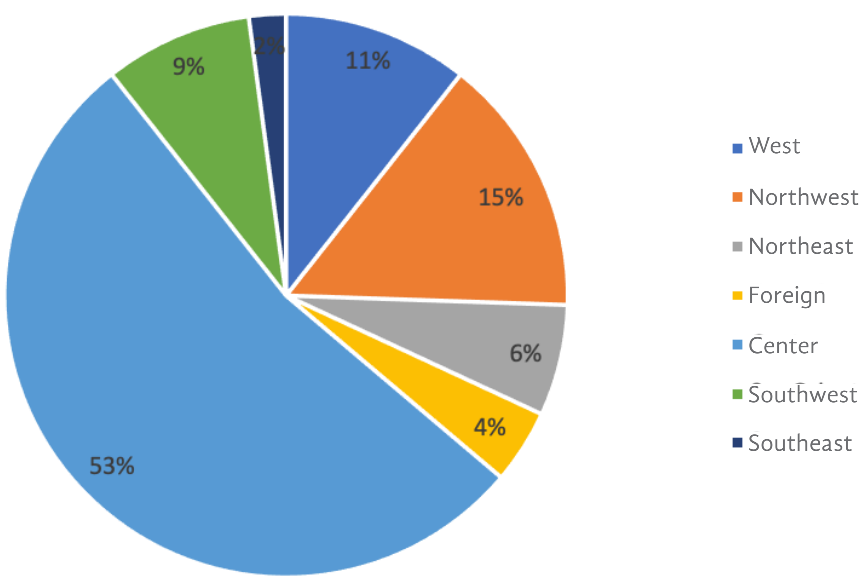
As part of the Conacyt-Ciencia de Frontera Project: A critical review of nanotechnologies development in Mexico, an exploratory electronic questionnaire was conducted on nanotechnology research for health/medicine in the country. The purpose was to examine the experts' perspectives and conduct in-depth individual interviews. Given the richness of the data and the global scope of the reflections, this text aims to present the results obtained and analyze the conditions of nanotechnologies in Mexico based on the responses. Among the main results was the generalized perspective on the need to have an updated inventory of nanotechnologies in Mexico, as well as the ignorance of researchers in some issues of standardization and regulation. Similarly, it was observed that the main investor in nanomedicine research is the State, with little collaboration from researchers with private initiatives.

Keywords:

Nanotechnologies; health; medicine; regulation; public policy.

At the end of 2021, as part of the Conacyt-Ciencia de Frontera Project 2019 No. 304320: *A critical review of nanotechnologies development in Mexico*, an exploratory questionnaire on nanotechnology research for health/medicine in the country was electronically surveyed. The purpose was to examine the topics and questions from a large number of answers, to improve it with the further purpose of conducting in-depth individual interviews. We have decided to present a systematization, given the richness of the results and the global scope of the reflections. The respondents were selected from the database of the aforementioned project on scientific publications on the topic from authors based in Mexico (Robles Belmont, 2021).

The methodology used was based on an electronic questionnaire consisting of 68 questions divided into six modules: the first of them requested information about the interviewee's profile, as well as some general data about the research carried out. Subsequent modules included the following topics: regulation, research and development, health and environmental risks, and major research areas. We obtained 47 responses from researchers, most of whom are working in the central area of the country (see Figure 1). After the survey, an analysis was carried out based on descriptive statistics of each of the modules mentioned, linking this information with the different regulations and documentation related to the topics addressed, as well as data from alternative sources to the questionnaire to reinforce the results obtained.



Note: Center: Mexico City, Mexico State, Guanajuato, Querétaro, San Luis Potosí. Northeast: Coahuila, Durango, Nuevo León. Northwest: Baja California, Baja California Sur, Sonora. West: Aguascalientes, Jalisco, Michoacán. Southwest: Hidalgo, Puebla. Southeast: Tabasco.

Although 4% of researchers live abroad, their research work is carried out in the national context.

Figure 1. Regional distribution of nanomedicine research in Mexico. Source: Own development based on the questionnaire on nanotechnology research in Mexico

The research covers different nanotechnology applications to the health/ medical sector, with different degrees of potential application. The distinction between basic science and applied science, which has gained strength since the middle of the twentieth century, has been in disuse in recent decades once the term technoscience has been consolidated and with it, the distinction between science and technology disappeared. However, the distinction was kept in the questionnaire because it is still preserved in official documents and is common among natural physical scientists (Roll-Hansen, 2017). However, the above will be referred to below on how the market pressure for rapid returns of capital invested in Research and Development is what distorts the distinction between basic and applied science, something that is a greater market in countries where financing is directly or indirectly private; something that does not yet happen in Mexico.

Of the respondents, 53% considered that their research corresponds to the basic sciences category while 34% to the applied science category; the rest stated that their research corresponded to both categories. In this regard, it is essential to mention that since 2019 Conacyt has sought to direct research toward areas of the scientific frontier that have a social impact. As this general orientation crystallizes in research projects, it is possible to modify the use of concepts such as basic or applied science. For business purposes the term basic science ceased to be attractive since the nineties; it is possible that for political-social purposes something similar happens, although under different strategic interests.

Most of the research has been carried out in groups (94%). Of those who answered that they conduct collective research, 62% said they work in teams of up to three people; 24% in groups of four to five researchers, and 14%, in six or more. The important participation of undergraduate students is striking: 97% of those who claimed to do research in a group included students of this educational level in their teams, something that could be further encouraged by integrating these practices flexibly into academic curricula, as is the case in other countries and universities.

In addition to this brief introduction, which includes the main findings of the first module of the questionnaire, the present text is divided into four sections. First, review information regarding the main areas of application and knowledge. The data obtained regarding the issue of regulation of nanotechnologies in Mexico are presented below. It then shows the results in terms of the production, research, and development of nanotechnologies in the country. Finally, there are some final considerations.

AREAS OF APPLICATION AND KNOWLEDGE

Nanotechnologies constitute a wide range of technologies characterized by manipulating matter at the atomic and molecular level, conventionally between 1 and 100 nanometers. The work's purpose on the topic is to explore the new functionalities that matter can manifest in that size and that are different from those known on the macro scale. It is an area of research with accelerated growth from this century and, in many cases, requires interdisciplinary participation, both because at the atomic level, the traditional differences between chemistry and physics are erased and between the living and non-living, as well as applications may require engineering involvement (High-Level Expert Group, 2004; Roco, 2003). Moreover, if we consider the potential risks to health and the environment as well, the social and human sciences play a significant role. For these reasons, identifying an area as health/medicine is not simple. It is, for example, the case that basic research on nanoscale material properties gives rise to its potential medical application, although the starting point did not go beyond knowledge of the effect of the combination of certain materials; "a solution searching for problems" (Wilsdon, 2004, p. 16).

It is not by chance that most of the answers place their research in more than one area of nanomedicines considering the multifunctionality of nanotechnologies. However, the sector that called for more responses is biopharmaceuticals, where the production of drugs with nanotechnology (including vaccines), delivery and release within the organism is located. Both aspects constitute a significant advantage of nanometric encapsulation of drugs and their release into specific organs or cells at appropriate times. 74% of the responses, which are not mutually exclusive, consolidated biopharmaceuticals as the area of greatest interest in nanomedicine research in Mexico. Meanwhile, between 40 and 47% of the responses combined research in *implants* with other topics, highlighting the sensors. Similarly, in the *instruments* area, interest in biosensors also stands out, and in the *diagnosis* area, the emphasis is on imaging.

It is noteworthy that almost half of all research options (47%) were inclined to consider the potential risks of nanotechnologies to health and the environment, a pending issue worldwide because, as we will see below, there is no legislation treating nanomaterials as new substances to regulate their control; most nanotechnology products are not labeled with the nano components they contain; there is no liability on the part of producers for adverse effects and there are no measures to control and monitor imports. Workers in companies that manufacture nanotechnology do not have information about it, due to ignorance and confidentiality clauses. Even less is known about the effects of nanoparticles on ecosystems. The general lack of knowledge on the subject of risks is reinforced by the postgraduate courses themselves in nanotechnology, whose programs tend to highlight the benevolent aspects of nanotechnologies, avoiding potential risks (Chemsec.org, s/f; ChemTrust, 2013).

Based on information obtained from the questionnaire, it is noted that only 36% of the replies indicated that there were projects in their institutions concerning the potential toxicity of nanoparticles existed. Considering that these are researchers in areas of health/medicine this percentage is not flattering.

Given that most respondents consider it important to have a national register of research and development, and of companies producing with nanotechnologies, an inventory can be considered; monitoring of production and marketing and developing regulatory measures are some of the pending issues in Mexico that could be supported by important nanotechnology research sectors, particularly in the heatlh area.

NANOTECHNOLOGY REGULATION IN MEXICO: RESEARCHERS' PERSPECTIVE

The regulation of materials is a recent policy in the history of the development of the chemical industry. Although the first measures in this area have been carried out in the United States and Europe since the 1970s, it was not until 2006 with the so-called European Union's regulation *Registration, Evaluation, Authorisation,* and *Restriction of Chemical Substances* (REACH) made significant progress. This regulation addresses the potential impacts of chemicals on human health and the environment and can be considered one of the most advanced worldwide.

Once in force, REACH faced a challenge: the status of nanomaterials. Since the eighties, it is known that several known materials manifest novel physicochemical properties when they are in nanometric size, for example, materials that are not reactive at a macroscale become reactive in nano size, while others that at the nanoscale are conductors or semiconductors are known to be insulators in a larger size. This is typical of the prevalence of quantum forces due to the greater relative external surface concerning its mass when the matter is in nanometric size. This functionality is the reason for the boom in the financing industry and the race to apply nanotechnologies in economic sectors since 2000 and globally (RS&RAE, 2004).

The challenge of REACH is that, as nanoscale matter manifests physicochemical properties different from macroscale, it is possible that it also develops different toxicology, a consideration that was pointed out by some scientists since the nineties. In the early 2000s, several environmental NGOs denounced the entry into the market of nanotechnology products without adequate toxicological analysis (ETC group, 2002); Already in 2004, a meeting of experts from the European Commission's Community Health and Consumer Protection warned about the risks and impossibility of transferring matter's properties on a macro scale to the micro scale (Community Health and Consumer Protection, 2004)[1]

In general, the properties of nanoscale materials are used in the industry quickly and extensively, but risks to health and the environment are not assumed with equal speed. In addition, the industry insists that macro examinations are sufficient and replicable for the nano size of matter (*e.g.* Foladori & Invernizzi, 2021). It is until the end of the first decade of the 21st century that the European Union begins to introduce some regulatory criteria for certain nanotechnology products (Figure 2).

Table 1

Overview of the main nanotechnology regulations in the European Union

Date	Subject	Title	Main regulations
2008, dic.	Food additives	On food additives	Pre-assessment, labeling
2009, Dec.	Cosmetics	On cosmetic products	Labeling
2011, Nov.	Food Products	On the provision of food information to consumers	Labeling
2011, Jan.	Food contact plastics	On plastic materials and articles	Previous evaluation Labelling
2012, June	Biocides	On the market and use of biocidal products.	Labeling and specific information
2015, Dec.	Food Products	On Novel Foods	Specific information
2017, Apr.	Medicine	On medical devices	Special requirement for authorization
2018, Dec.	REACH review	Nanoforms or nanosubstances	• Definition of nanoform and nanoform group • Requirement for new technical analysis • Report any nanoform • Incorporate downstream users into the report

Source: Foladori (2021)

Other countries such as China, Iran, Taiwan, Thailand, and the United States also have some regulations for nanotechnologies. This is not the case in Latin America, which chooses to leave voluntary standards on the characteristics and potential risks of nanomaterials in the hands of private or semi-private organizations (Anzaldo Montoya, 2022; Anzaldo Montoya & Foladori, 2022).

1 "Panel experts were unanimous in their view that the adverse effects of nanoparticles cannot be predicted (or derived) from the known toxicity of bulk material (Community Health and Consumer Protection, 2004, p. 11)."

In academia and research, there are controversies over the need to regulate nanomaterials; while in the industrial field, the position is one of systematic opposition because regulation is perceived as a commercial difficulty and an obstacle to economic benefit. So much so that regulatory policy advances very slowly while the market entry of nanotechnology products is increasing and practically without barriers (DTU Environment *et al*., n.d.; The European Consumer Organisation, 2013; Woodrow Wilson Center, 2017).

In Mexico, there is no register of companies that use nanocomponents to produce, nor of imports; nor are there any glimpses of any kind of regulation. On the contrary, the Ministry of Economy has joined the guidelines of the United States that are among the laxest (Foladori & Záyago Lau, 2014).

Given the uncertainty of the potentially toxic effects of nanoparticles and the rapid increase in commercialized products that incorporate them and circulate in international markets, a module on the subject was included in the questionnaire. The results of the four questions of the questionnaire relating to regulatory and governance issues of nanotechnologies are summarized below.

ON THE REGISTRATION OF COMPANIES WORKING WITH OR PLACING NANOMATERIALS ON THE MARKET

Some countries, such as France and Belgium, have established as a mandatory measure a register for companies (public and private) and research laboratories that buy, sell or handle nanomaterials either in their pure state, in combinations or incorporated into other products, and that involves the minimum amount of 100 grams per year of a substance that is considered to be in the nanoparticulate state (ChemSafetyPro, 2016)[2]. In this regard, the researchers were asked about the consideration of implementing a similar registry in Mexico.

More than 90% considered an equivalent registration important or necessary in Mexico; and only 4% of respondents answered that it was not necessary to establish a register where information on research, sale, and handling of nanomaterials is consolidated, similar to that of countries such as France, Denmark, Norway, Belgium, Sweden.

2 Refers to a "substance intentionally produced at the nanometer scale containing unbound particles, in aggregate or agglomerate form, of which 50% are quem particles in the size distribution of the number, have one or more external dimensions between 1 nm and 100 nm. (This minimum proportion may be reduced in individual cases where it is justified on grounds relating to environmental protection, public health, safety, or competitiveness. However, fullerenes, graphene flakes and single-walled carbon nanotubes with one or more of their external dimensions less than 1 nm should be considered as substances in the nanoparticulate state)" (European Commission, 2011).

ON THE LABELING OF NANOTECHNOLOGY PRODUCTS ENTERING THE MARKET

Some countries began labeling nanotechnology products at the end of the first decade of the century. In December 2008, the European Union imposed labeling of food additives, in 2009 of cosmetics, in 2011 of food and plastics in contact with them, and 2012 of biocidal products (European Commission, several years). Other countries such as Taiwan, Iran, Thailand (Karim & Munir, 2014), and New Zealand (EPA, 2012) are also labeling certain products with nanotechnologies. These measures have forced countries that export to these regions to label their products, including Mexico, where some companies are already doing so (*e.g.* Nivea in certain cosmetics).

It is argued that labeling allows transparency to the consumer, however, labeling does not imply that there is a prohibition on marketing. However, some products that were early labeled are on track to be banned because they contain several chemicals considered toxic (Bergeson, *et al*., 2022). There is widespread discussion about the usefulness of regulations such as labeling.

Following the international discussion, the questionnaire asks researchers if they consider it appropriate to establish a regulation on the labeling of nano components in marketed products. The majority (87%) are in favor of labeling.

One comment that stands out is about the difficulty of labeling products with nano-sized elements when the potential toxicity is debatable. Other comments concern whether the consumer has the conditions to evaluate what nanomaterials are. Place, for example, a label that explains that sunscreens contain "TiO2 Nano" or "ZnO Nano", it does not mean that the consumer knows the codes of the chemical elements, and although the indication appears in extensive (for example nano titanium dioxide), there is no guarantee that he knows the degree of health risk of this chemical element. This type of uncertainty happens with all the labeled elements, but it is still a controversial aspect.

In that sense, other comments indicate that, if the term "nano" is repeated on labels about the health risk, a negative association could be created around these products and even generate a rejection of scientific information. Some of the researchers surveyed are concerned about the possibility of hindering research and development in general, because of complaints arising from consumer appreciation of particular products. As can be seen, labeling is a highly debatable issue that requires an official position, something that will be accentuated by the foreseeable expansion of this type of requirement in the markets of affluent countries.

THE PRECAUTIONARY PRINCIPLE IN MEXICO

The Precautionary Principle was widespread internationally after its adoption at the 1992 Earth Summit in Rio de Janeiro (UN-GA, 1992). The principle states that when there are indications of the potential risk to health or the environment, precautionary measures must be taken, even when there is no conclusive scientific evidence. Several countries have recognized the principle, being party, for example, to the European Union's chemicals regulation (REACH) (European Union Legislation, 2000) and the strategy for nanotechnologies (European Commission, 2004).

The precautionary principle is based on the fact that toxicity analyses carried out in laboratories are never conclusive, due to several reasons, such as the fact that the analysis time is reduced since there are elements that are bioaccumulative and the manifestation of toxicity only occurs years or decades later; or the reduced number of variables that can be used, which contrasts with the thousands or millions that potentially intervene in a living being, or the impossibility of analyzing the impact on an ecosystem, etc. The European Union Environment Agency compiled two volumes with examples of chemical elements that were only regulated decades after their toxicity was reported and for not applying the precaution (EEA, 2002, 2013).

In the case of nanomaterials, the precautionary principle is particularly critical. Due to their large surface area in relation to their volume, nanomaterials are more reactive and this suggests that the impact on living organisms and ecosystems has unknown effects and eventually risk.

Mexico has signed several international conventions that accept the precautionary principle, such as the Convention on Biological Diversity and the Cartagena Protocol on Biosafety. It also participates in tribunals such as the Inter-American Court of Human Rights, where the principle is included (DOF - Official Journal of the Federation, 2020), as well as in the International Tribunal for the Law of the Sea where a specialized judge has been appointed. At the domestic legislative level, this principle is part of the Law on Biosafety of Genetically Modified Organisms and the decree on glyphosate (DOF - Official Journal of the Federation, 2020); and has been used by the Supreme Court of Justice (Precautionary Measure -Transgenic Maize-, 2021).

Based on the above considerations regarding the precautionary principle, the researchers were asked about the relevance of the precautionary principle being used in Mexico to regulate nanoparticulate materials. In this regard, 85% of the responses were in favor of incorporating the principle into the regulation of nanotechnologies in Mexico. 6% were strongly opposed; some were on the basis that the precautionary principle is not based on scientific evidence, that is, laboratory analysis; or that it could hinder research and development.

Among those who supported the incorporation of the precautionary principle, there were some conditioning comments. It was noted, for example, that there is uncertainty about the definition of nanoparticle, which may lead to the application of the principle to materials that do not exhibit properties different from macroscale materials. Caution was also expressed about bureaucratization, which regulatory measures may entail.

NANOTECHNOLOGIES: VOLUNTARY STANDARDS AND/OR OFFICIAL REGULATION

Industrial standards arise from the need for the raw material to conform to criteria of quality and homogeneity for its trade. This need increased with globalization during the eighties and nineties, when industrial standards grew, such as those of the International Organization for Standardization (ISO), pushed by large corporations to promote free trade and reduce trade barriers. As they grow, they overshadow any kind of mandatory state regulation (OECD & ISO, 2017).

In 2005, ISO created the Technical Committee 229 (ISO TC-229) dedicated to nanotechnologies, to date it has published about 100 norms or standards on the subject. For their part, the National Committees reproduce those standards with minimal adjustments. In Latin America, several countries (Brazil, Mexico, Colombia, Peru, Argentina, Costa Rica, and Chile) have a national committee and have begun to reproduce nanotechnology standards (Anzaldo Montoya & Foladori, 2022).

Mexico adopted the standards on nanotechnologies in 2013, when the Ministry of Economy absorbed the standardization work that had been developed by the Mexican Institute of Standardization and Certification, A.C. and instead created the Technical Committee for National Standardization in Nanotechnologies (CTNNN) under the coordination of the National Metrology Center (CENAM). It should be noted that the latter is not a regulatory body, so the standards issued are voluntary. To date, Mexico has published 19 such standards on nanotechnology (ISO NMX-R) (Anzaldo Montoya, 2022).

One of the questions asked in the regulation section was about the consideration of whether complying with NMX standards for nanotechnology made regulation of nanotechnologies unnecessary in Mexico. The results show a lack of knowledge and understanding on the subject: 23% of respondents said they did not know about standardization and regulation, while 40% do not recognize the difference between a voluntary standard and a mandatory regulation. This suggests that a policy to inform nanotechnology researchers about some legal aspects may be important. As for the answers of "yes" and "no" in a forceful way, they reflect a percentage of 30% for each option.

The regulation of nanotechnologies is under discussion worldwide; an example of this is the updating of the regulations on chemical materials in the European Union and China, which seeks to include special chapters on nanotechnologies differentiating them from their same elements in macro size (Foladori, 2021). Nanomaterials can develop particular toxicities, both for humans and the environment, so specific regulation is considered necessary and, therefore, it is important to have the opinion of researchers and experts in the field.

PRODUCTION AND ENTERPRISES: RESEARCH AND DEVELOPMENT

The section on production and enterprises, research, and development include questions concerning the relationship of researchers with companies. In the same way, information was requested on raw materials and their origin, as well as on the technical equipment used.

40% of the researchers surveyed do not register collaboration with companies or other research centers. If we add to this percentage 26% who admit not knowing if there are such agreements in their center/project, it is assumed the need for public policies that induce institutional linkage and interdisciplinary work that allows research to be approached from different perspectives, including networks that provide external financing to the state and international agreements. The above concern is reinforced if we consider that 53% of research is directed to basic science, an area that does not generate greater interest on private companies due to the uncertain or long-term outcome. The tendency of private companies and corporations is not to direct basic research, but to follow up on the new start-ups that are successful to associate or buy or control them through conditional credits, thus avoiding investing in research stages of high financial risk (Tsarouva, 2022).

This is of great relevance considering that the latest UNESCO report, with data from 2018, indicates that Latin America invests about 0.6% of its GDP in Research and Development, a percentage lower than the previous measurement of 2015. Mexico's investment is even lower: by 2018 Mexico only reached 0.3% of GDP, even though the goal was to reach 1%. In contrast, developed countries invest around 2% of their GDP and some up to 3%. (Unesco, 2021). According to the same report, 78% of research and development expenditures in Mexico come from public sources, while private financing does not reach 18%. This differs from other countries in the region, such as Brazil, where the private contribution was 48% (Unesco, 2021).

The survey highlights in a previous section that almost 66% said that their research had funding, being that 52% of it was with public resources (mostly from Conacyt), following the pattern of Mexico where the National Expenditure on Science, Technology, and Innovation (GNCTI) is composed mainly of public resources. In 2019 it was 89% (Conacyt, 2019). Only 10% said their research was supported by the private sector, just as only 13% of respondents said they were researching in collaboration with a private company. This is practically the norm in Latin America, where private companies do not invest in Research and Development.

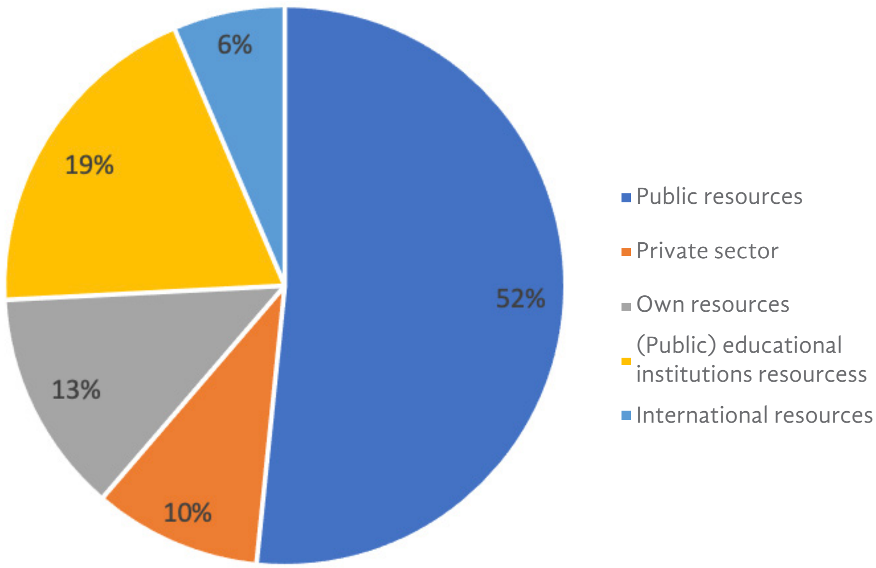


Figure 2. Sources of funding for nanomedicine research. Source: Own development based on the questionnaire on nanotechnology research in Mexico

Likewise, 34% of the responses register participation with other centers or companies and are distributed in equal percentages between public research centers and private companies. The public centers and universities with which some type of collaboration is mentioned are three Conacyt centers (CIDETEQ, CIATEJ, and IPICYT) and five universities (UNAM, IPN, UAQ, BUAP, and UASLP). Only one case was reported to be linked with a foreign public research center.

As for investigations with business collaboration, the information is briefer, since some responses indicate that they cannot disclose the names of the companies with which they work because of confidentiality agreements in the contracts. This type of contract can be considered an obstacle for the government to follow up on investigations with business collaboration in the country.

On the other hand, most ongoing research projects require nano-raw material. The production of this type of material for commercial purposes has been concentrated in large chemical corporations worldwide. Particularly in the case of carbon elements (*e.g.* nanotubes, fibers) and oxides (*e.g.* titanium, zinc, aluminum). There is little systematized information globally, and estimates by output vary significantly between sources. A report by the European Commission in the early 2010s noted the following nano substances with new properties such as those with the highest volume of production worldwide: aluminum oxide, barium titanate, titanium dioxide, zinc oxide, cerium oxide, and carbon nanotubes (European Commission, 2012).

Some of the nano raw material requires sophisticated laboratories to produce them for industrial purposes, hence the trend toward global concentration (Scientific, 2008). The cause of this is the sophistication of the technology used, which for commercial purposes of mass production must result in exactly homogeneous products, for which there are few facilities, but it is also important to consider that the rise of nanotechnologies occurs at the beginning of the first decade of the century, when the degree of concentration of capital worldwide, after the nineties, was much higher than in previous decades and marks the difference with other technologies such as biotechnology of the eighties, in which capital did not have that degree of concentration (Foladori, 2018). Thus, for example, around 2010, estimates of the production of carbon nanotubes for commercialization worldwide recorded 66% concentrated in four chemical corporations (Patel, 2011).

Basic research may require a small amount of raw material and not necessarily with the same standards of homogeneity as that intended for industrial marketing. But, the fact that it is the starting point for research and a highly demanded resource at the international level, must be considered in terms of long-term science and technology policy. Since Mexico is the world's leading producer of silver, a diagnosis of nanotechnologies carried out by CIMAV in 2008 suggested that Mexico could become an international producer of nanosilver, a substance highly demanded in research and industrial production with nanotechnologies (CIMAV, 2008)[3].

The answers to the questionnaire place metals and alloys as the most used nano raw materials (30%), followed by polymers and dendrimers with 22% and ceramic materials with 14%: with these three types of materials 66% of the total is reached. It is necessary to remember that the question refers only to the type of raw material and not to the quantity, so it may happen that another type, with fewer users, registers higher annual volumes.

In the same way, information was obtained on the origin of the main raw material. 16% claim to have their own manufacture, but some of them combine it with purchases in the national and international markets. When

3 For the interested reader, the Conacyt project registered companies that use nanotechnology by economic sector, and its headquarters are georeferenced (Arteaga Figueroa, 2022). In some cases, it is possible to assume the main nanomaterial they use based on the product they launch on the market.

it comes to a single origin, 32% indicate international purchases and 13% consumption in the domestic market. Likely, these differences are closely associated with the type of raw material, even so, the dependence on the foreign market is significant. This situation occurs in most countries given the degree of concentration of nano raw material production as indicated above. This is exemplified by the responses included by the selling company, 75% of which correspond to purchases from Sigma-Aldrich.

Regarding the equipment used, most of the most valuable equipment is foreign-made, which is a reflection of financial and technical dependence. In this last aspect, 65% of the responses indicate that the equipment requires qualified foreign personnel for its maintenance. It is worth noting that, in other non-core countries, such as Iran, the government invested not only in research and development of nanotechnologies but also in sophisticated equipment, and today they have an important international market to which they sell.

FINAL CONSIDERATIONS

The introduction of new technologies is a daily occurrence worldwide, given the degree of historical accumulation of knowledge and technological development. This puts countries in the dilemma of how to assume global trends that are practically impossible to avoid together with the orientation towards national interests and safeguarding potential harmful effects on both human health and the environment.

The case of nanotechnologies in health/medicine, which was the subject of this work, exemplifies the previous dilemma. On the one hand, there is already a wide range of benefits that nanotechnologies can offer when applied in the sector. On the other hand, the potential risks of these and other applications are only superficially reduced. The pressure of the market to transform techno-scientific innovations into economic benefits makes it difficult for any public policy to seriously consider this type of dilemma. Countries that have fewer resources and experience to evaluate the products that enter the world market each year and that have novel chemical elements have the possibility of replicating what the most advanced countries do in terms of materials regulation. This has been the case of nanotechnologies in Mexico and Latin America, but not in terms of regulation but of voluntary codes as is of interest to large global corporations.

It is worth noting that most of the responses to the questionnaire are in favor of considering the risks of nanotechnologies and regulations in this regard, although at first glance the research projects do not include any type of requirement in terms of literature review regarding potential risks of the products with which they work. It would be worthwhile for universities and laboratories to update the safety practices of their researchers against the manipulation of nanomaterials and derivatives.

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