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Research paper

Review of nanotechnology value chain for water treatment applications in Mexico

Rafael Castañeda Olvera [a,*], Sein León Silva [b], Eduardo Robles-Belmont [c,d], Edgar Záyago Lau [a,e]

[a] Academic Unit in Development Studies, Autonomous University of Zacatecas, Zacatecas, Mexico
[b] Program in Science, Technology and Society, CINVESTAV, Zacatenco, Mexico
[c] CINVESTAV, Zacatenco, Mexico
[d] National Autonomous University of Mexico, Mexico
[e] Multidisciplinary Program Coordination, CINVESTAV, Zacatenco, Mexico

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Abstract

Nanotechnologies are part of a new industrial platform with the capability to surpass existing tech-intensive systems for water treatment. Accordingly, many countries apply nanotechnology-based processes to solve problems associated with water. The authors of this article review the state of nanotech applications for water treatment in Mexico. To this purpose, they follow the trajectory of the nanotech package; from research and development to its commercialization. The study encompassed several stages: a bibliometric analysis (publications), a database with all the research groups looking at this issue, a catalog of all related patents and, finally, an overview of Mexican nano-companies in the water sector.

Keywords: Nanotechnologies; Water treatment; Value chain; Water deprivation

1. Introduction

Water-related problems are a persistent global issue. Various factors, such as population growth, urbanization, and industrialization (associated with an increase in production and consumption), have continually stressed hydrological resources [1]. The increasing use of fertilizers and chemical materials is another factor that has contributed to the eutrophication of rivers and the generation of dead zones in different habitats [2]. The mismanagement of wastewater as well as the lack of public policies complicated the scenario [3]. It is, therefore, a complex and multidimensional problem. Faced with this situation, researchers developed new technologies to ease the pressure on this limited natural resource.

Mexico is the eleventh largest economy in the world and an emerging industrial power. Water, for both economic and social reasons, is an important yet scarce resource despite making up about 71% of the earth's surface. The need to find effective solutions to control the contamination of water for industrial, agricultural and household activities is a key issue for the country's development. Despite being a matter of concern, water scarcity and pollution have not been successfully addressed by the Mexican government.

According to the National Water Commission (CONAGUA), 7 of the 13 hydrological-administrative regions in which the national territory is divided suffer a high degree of water stress. The one that corresponds to the Valley of Mexico, where a great part of the industrial activity of the country concentrates, experiences very high stress.[1] A significant imbalance exists between the average natural availability and the demand for potable water. 77% of the national population is concentrated in regions where only 31% of viable water sources are available for use. This is supported by data from the Water Advisory Council, which asserts that 2/3 of our territory is considered arid or semi-arid, and almost 80% of the country's

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All authors contributed equally to this work.
* Corresponding author. Autonomous University of Zacatecas, P.O. 98000, Zacatecas, Mexico. Tel.: +52 5532284775.
E-mail address: rafaelcastaneda10@yahoo.com.mx (R.C. Olvera).

[1] Cfr. http://recsa.mx/reportes_recsa/reportes/Reporte2.pdf.

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population is concentrated within that territory.[2] In the medium- and long-term, the cost of providing drinking water to citizens, industry and the countryside will increase significantly. CONAGUA estimates show that there is an overexploitation of the underground reserves that currently supply more than 28% of the demand. In the Valley of Mexico an increase of 2.6 million inhabitants is expected by the year 2030 [4].

This is an opportunity awaiting resolution. Nanotechnologies (NTs) are portrayed as the solution to many problems, among them, water scarcity and pollution. The technological power of NTs occurs at the nanoscale (1×10^{-9}), where nanomaterials behave differently from their bulkier counterparts. At the nanoscale, different physicochemical properties are exhibited, which makes them suitable for several applications involving water, including desalination, purification and remediation. Nanomaterials could provide solutions to adsorption, catalysis, disinfection and water cleaning [5].

There is a considerable lacuna in the academic literature about what is being done in the country regarding research and development (R&D), commercialization and consumption of nano applications for water. Our aim is to fill that void with actual data. The information would be of interest to government officials, researchers, students, and other agents, such as non-governmental organizations (NGOs), companies, decision-makers and other actors. To that end, we study the nanotech value chain to identify relevant areas where NTs may contribute to solutions.

In order to fulfill the objectives of the project, we had to overcome several challenges. The most important was the dispersion of data. Mexico lacks a national strategy in nanotechnology, specific public policy or an institution in charge of following nanotech developments, especially in terms of commercialization. Having basic data on any given issue is central to the design and implementation of a specific policy. We therefore decided to tackle the lack of information related to nano applications for water in Mexico.

2. Nanotech development in Mexico

According to prior studies based on bibliometric research, which contemplates patents, companies, human resources and infrastructure, Mexico ranks second in Latin America, after Brazil, in the development of NTs [6–8]. Nevertheless, there are no data related to R&D, commercialization and consumption of nano-applications for water. There is some information drawn from isolated initiatives that provide a panorama of what is happening with NTs in this country. For instance, the Ministry of the Economy, in partnership with the Center for Advanced Materials Research (CIMAV), carried out an extensive study on NTs in Mexico [9], and illustrated that between 1998 and 2004 the Mexican government, through the National Council of Science and Technology (CONACyT), supported a total of 152 research projects worth $14.4-million. Takeuchi and Mora [10] added to this amount and estimated the total funds for nano R&D (between 2006 and 2009) at roughly $60-million. There are a series of agreements between Mexican institutions and research centers with international organizations to cope with the lack of funding. That strategy generated investments of up to $60-million [9].[3]

As a subsection of the National Development Plan for 2007–2012, the National Expenditure on Science and Technology and Innovation (GNCTI) was inaugurated. The aim of the GNCTI was to endorse the development of new knowledge, including nanotechnology [11]. CONACyT reported that the number of projects with funding grew by 5% in the last 5 years, with the greatest increase (6.9%) in the 2013–2014 period. The GIDE/GDP ratio in 2014 ranked Mexico above the Latin American average (0.54% versus 0.29%); only below Brazil and Argentina (1.21% and 0.58%, respectively), but much lower than the OECD average (2.37%) [12].[4]

As a reflection of the economic inequalities, research is highly concentrated in Mexico. Almost 90% of the GNCTI is concentrated in four institutions: the National Autonomous University of Mexico (UNAM) (52.9%), the Center for Research and Advanced Studies of the National Polytechnic Institute (CINVESTAV) (13%), the National Polytechnic Institute (IPN) (10.1%) and the Metropolitan Autonomous University (UAM) (9.8%).[5] In general terms, nanotechnology development in Mexico has been concentrated into three areas of interest: creating research networks, national laboratories and industrial clusters [13]. Yet there is little information regarding specific areas of application for NTs and very scarce information on water applications. Therefore, we implemented a methodology to try to uncover as much information as possible from the nanotech water value chain in the country.

3. Methodology

Our data were concentrated in three areas of application (according to the final use of the water): remediation and purification; detection and filtration, and desalinization. We decided to employ these categories after reviewing specialized literature on the matter [14–18]. We acknowledge that all those procedures are implemented, sometimes simultaneously or in combination, but the classification was created to detect the potential use of the water and not the technique (procedure) in

[2] Cfr. http://www.aguas.org.mx/sitio/index.php/panorama-del-agua/agua-en-mexico.

[3] For example, the Cluster of Innovation in Nanotechnology in North America was created under an agreement between the University of Arizona, CIMAV and CONACyT [21].

[4] It should be noted that this report considered the reformulation of the Frascati Handbook, through the Organization for Economic Cooperation and Development (OECD): "*Research and experimental development (R & D) comprise creative and systematic work undertaken in order to increase the stock of Knowledge – including knowledge on humankind, culture and society – and to devise new applications of available knowledge*" (p. 44) [12].

[5] For further details, see the statistics provided annually by CONACyT's Integrated Information System on Scientific Research, Technological Development and Information (SIICYT), at: http://www.siicyt.gob.mx/index.php/estadisticas/indicadores.

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