

## **Iran's Research Capabilities in Water Treatment Using Nanotechnology**

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### **ABSTRACT**

Nanotechnology by presenting appropriate solutions for water and wastewater treatment can play a constructive role in compensation the lack of water and protection the environment. This article presents Iran research capabilities by surveying university theses and published articles of Iran. By quantitative study, the share of water-related researches (theses and articles) among all nanotechnology researches in Iran is obtained. Then the annual trend of the number of theses and articles and active universities in this area are obtained. Finally the trend of researches and active fields of each branch are identified.

The results show an increasing trend in the number of country's theses and scientific articles. Also it is cleared that more than 75% of activities have allocated to four branches of Chemistry, Chemical Engineering, Environment and Materials Engineering. Tehran University, Iran University of Science and Technology and Tarbiat Modares University are most active universities of the country in this field. Finally, different methods of treating waste water, which have been investigated in Iran, are presented. With the study of researches from forty universities of the country, is cleared that more than twenty kinds of nanoparticles and ten kinds of nanofiltration membranes have been synthesised and used for water treatment. Bringing these researches from laboratory to industry is the most important step to solve the problems due to lack of water, wastewater infiltration and environmental protection.

### **1 INTRODUCTION**

Lack of fresh water is one of the most important issues in the world. In our country with regard to the lack of fresh water resources it's one of the important issues, too. Because of the lack of healthy water, using modern technologies for water and wastewater treatment is necessary. In recent years, Nanotechnology by presenting appropriate solutions for water treatment can play a constructive role in compensation the lack of water and protection the environment (Smith A, 2009).

In Iran the Ten-Year strategic plan for nanotechnology development (Future Strategy) has been started since 2006. Water and Environment (Water filtration and Desalinate) is one of the five priorities in this plan (Web 1). Survey of scientific researches in this field of technology is one of the effective tools for investigation of nanotechnology development trend in water treatment area.

According to Future Strategy plan, all of nanotech-related researches, have been done by Iranian researches are supported by Iran Nanotechnology Initiative Council (INIC) and the information of these researches are gathered in INIC's databases (Web 2).

Assembly of all the graduate thesis and scientific articles in these databases makes it possible to observe and investigate the country's research in this technology.

In this article, all nanotechnology theses and articles in INIC databases are analyzed. First the appropriate keywords for applications of nanotechnology in water treatment are searched. Then active universities and various fields in water treatment are introduced. With this study, the status of each division is analyzed.

## 2 SEARCH METHOD

Nanotechnology presented different methods to water treatment that are divided in three main divisions including; refining drinking water, wastewater infiltration and industrial wastewater infiltration (Smith A, 2009).

The keywords used to extract water-related theses and articles from INIC databases are shown in Table 1.

Table1. Water related keywords.

Independent word	Dependent words
Water	Salt, poor, clean, drinking
Water	Treatment, waste, ultra pure, monitoring
-	Heavy metal, nano membrane, Biological contaminants, Biological agents, nano filtration
Removal	lead, arsenic, uranium, mercury, toxic chemicals, cyanide, organics, antibiotics, Chloroacetic acid, PBDEs, low molecular weight

These keywords are chosen in a way to contain related theses and articles completely. After election of appropriate keywords, each the words, in a separate, accompanied by a dependent word or in combination of other words, as well as some other special expressions in title and abstract of theses and articles are searched. All of abstracts are studied and non-related cases are eliminated.

Due to this method, 131 theses (110 MSc and 21 PhD) and 32 articles are found in the field of water treatment using nanotechnology (The articles are listed in the reference). Note that, these data are updated until 5 November 2009.

## 3 QUANTITATIVE STUDY

Total number of the theses recorded in INIC databases to 5 November 2009, were 3504 (2862 MSc and 642 PhD). As it mentioned above, 131 (3.7%) of them theses are related to water treatment. In recent years, total numbers of theses related to water treatment, increased rapidly from one thesis in 2004 to 53 theses in 2008. Also 1834 articles are recorded in the databases that 32 (1.7%) of them are related to water treatment. Total numbers of articles related to water treatment increased rapidly from one article in 2003 to 12 articles in 2009 (Figure.1).

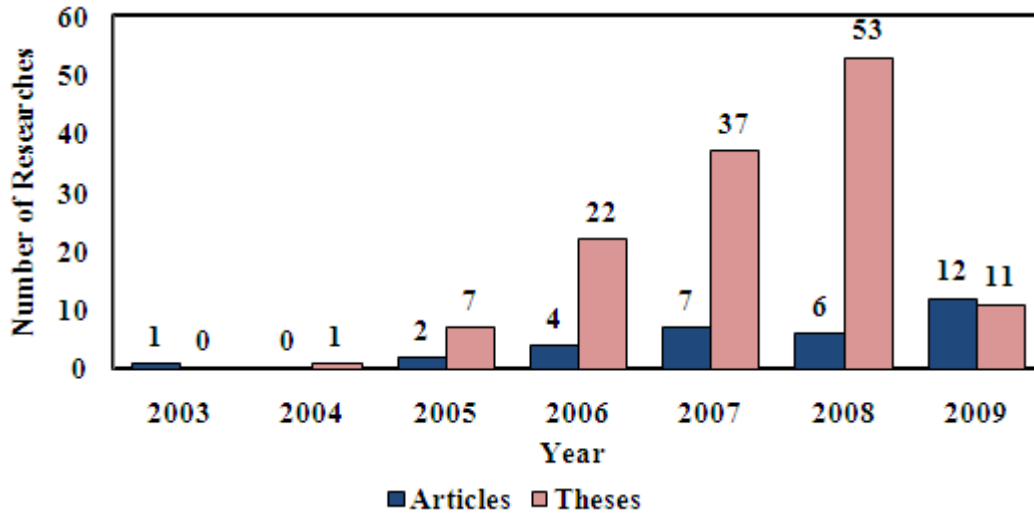


Figure1: theses and articles related to water treatment from 2003 to Nov. 2009.

#### 4 STUDY OF ACTIVE ACADEMIC FIELDS

Results show that four fields as Chemistry with 53 theses (40% of all), Chemical Engineering with 22 theses (17%), Environment with 15 theses (11%) and Materials Engineering with 9 theses (7%) are effective fields in water treatment. In the articles also it is cleared that Chemistry, Chemical Engineering and Materials Engineering play the most important role in this field. Chemists with 12 articles (37%) are at the top. Chemical and Material Engineers with 7 and 5 articles are in 2th and 3th rank, respectively (Figure 2).

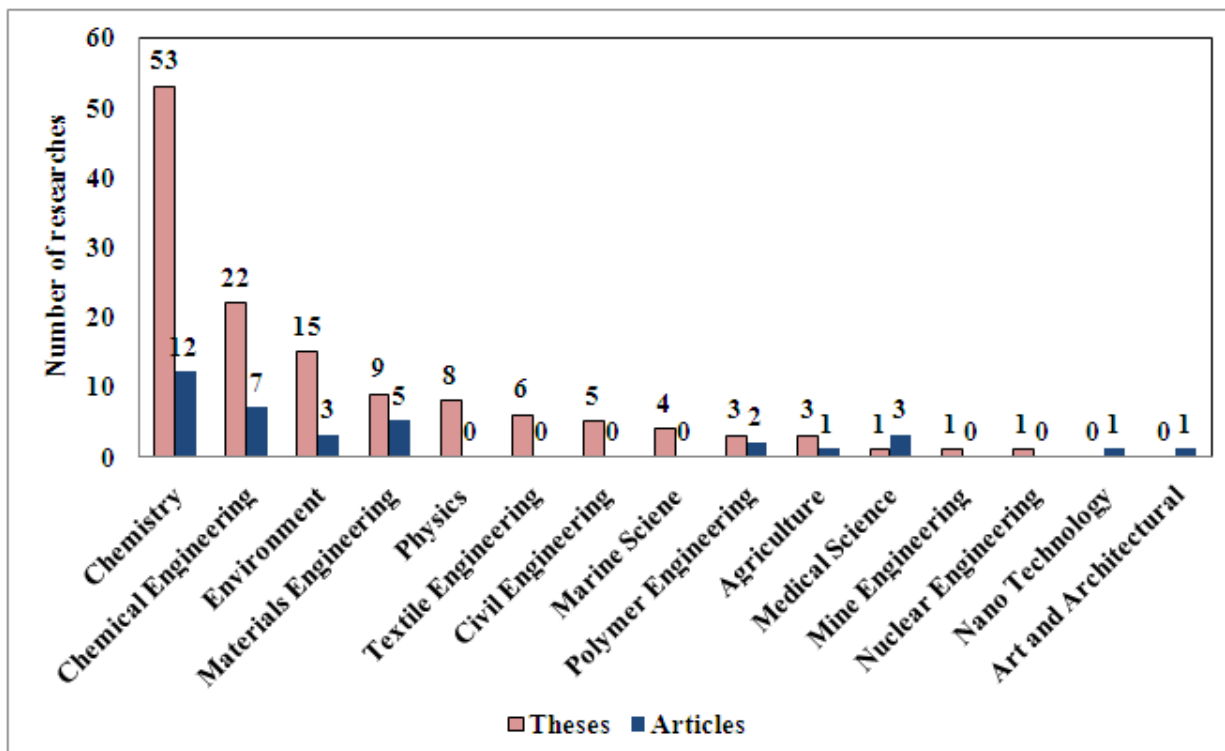


Figure2: number of theses and articles in each academic field

It should be attended that some articles in division of Figure 2 have been done interdisciplinary. For example, a case maybe defined based on chemistry but part of it done by chemical engineers. In such cases to every of these two fields an article is added. Figure2 shows numbers of theses and articles in different academic field.

## 5 ACTIVE UNIVERSITIES OF COUNTRY

Results show that 40 universities have theses or article in this field. Among them University of Tehran, Iranian University of Science and Technology (IUST), Tarbiat Modares University and Tabriz University are the most active. IUST, Tehran Medical Science University and Tarbiat Moallem University, by 6, 3 and 3 articles have the most articles among Iran's universities, respectively. First 15 universities are shown in Figure 3.

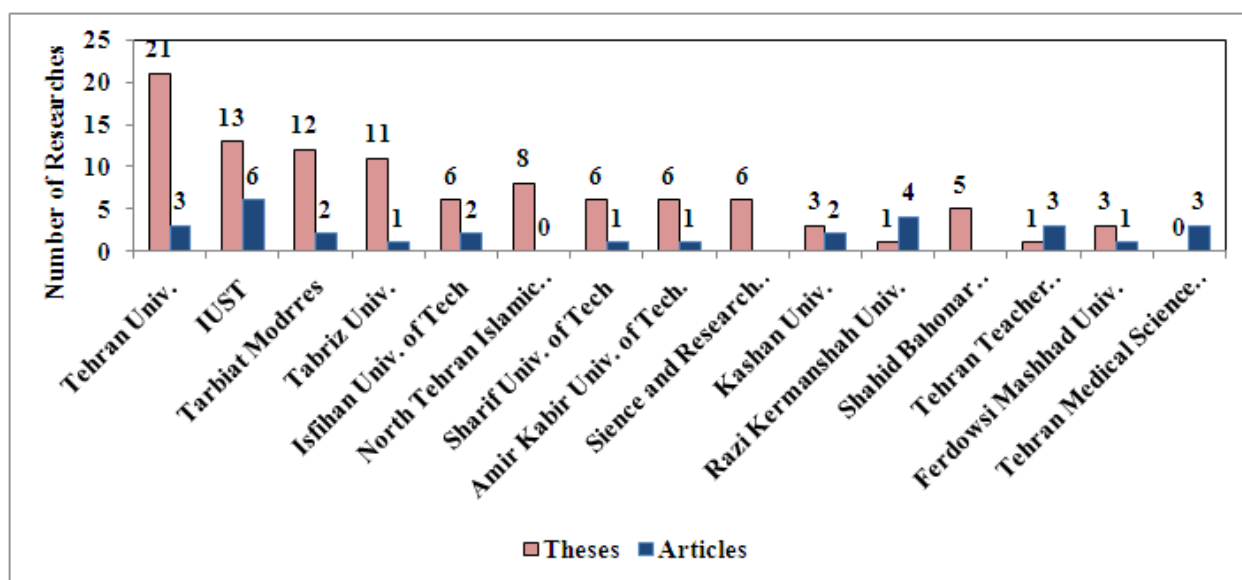


Figure3: numbers of theses and articles of active universities of Iran

15 articles (47%) of these 32 articles have been published as cooperation between universities; 12 of them as a scientific cooperation between domestic universities and 3 articles as scientific cooperation with foreign universities. Two articles are the results of cooperation between IUST and Department of Materials Engineering of University of British Columbia and the other is published by University of Kashan and Laboratoire de Genie of Universite Paul Sabatier (France).

## 6 METHODS OF INFILTRATION

Different methods of wastewater treatment are summarized in 3 main categories:

- A- Adsorption:** In this method, pollutants from wastewater absorb using a suitable absorbent.
- B- Nano Filtration:** Nano filtration is a membrane process that is between reverse osmosis and ultra filtration.
- C- Photocatalysis oxidation:** in general, process of advanced oxidation includes all processes that produce active hydroxyl radicals and cause to decompose most of pollutants completely.

### **A- Adsorption**

Adsorption mechanism is used to remove pollutions of water using different kinds of material with nanopores. All kinds of zeolite and active carbon with nanopores are examples of such materials that are able to absorb heavy metals and colours. Iron nanoparticles are used, due to their strong magnetic properties. In this methods often try to use cheap absorbents.

With study of theses is specified that in 56 theses (43%) and 5 articles (16%) wastewater treatment is done using nanoparticles produced by adsorption mechanism. Among these absorbents, role of ion exchange absorbent like zeolite is noticeable.

### **B- Nanofiltration with nanomembranes**

Nanomembranes include production of membranes and using them in water treatment. In 42 theses (32%) and 18 articles (56%) production of nanofiltration membranes in wastewater treatment are studied.

Most of these researches are investigated synthesis and analysis of membrane and its properties. Among these membranes, nano membranes that made by titanium had excellent results. Titanium reinforces the nano membrane capabilities because of its photocatalytic properties. Notice that most of these membranes are produced by sol-gel method. In this kind of membranes in addition to filtration, photocatalytic mechanisms are used to eliminate organic pollutions.

In other group of researches, zeolites are used to infiltration. Due to nanoscale and sub-nano scale pores, zeolites can be used as nanofilter in water treatment. Zeolites are grouped in two categories, natural and synthetic, that it found as mineral in the nature (In Iran, it mines in the Aftar region of Semnan province).

### **C- Photocatalysis Oxidation**

Photocatalysis oxidation is a process which uses different wave length of light and an element with Photocatalysis capability to act oxidation in a catalysis process. Using elements with Photocatalysis capability can eliminate all biological pollutions such as all kinds of bacteria and micro organs, pollutions of colour and surfactant can be done. Products of this process are water (H<sub>2</sub>O) and Carbon Dioxide (CO<sub>2</sub>) in best situations. Titanium Oxide is one of the suitable compounds for Photocatalysis (in addition of Titanium Oxide, silver Oxide and Zinc Oxide are used, too). Deposition of Titanium Oxide on different substrates is used in different membranes to eliminate organic and biological pollutions.

In 32 theses (24%) and 5 articles (16%) wastewater infiltration is studied using advanced oxidation processes. In a thesis elimination of organic pollutions using Catalysis Wet Air Oxidation (CWAO) is shown good results.

## **8 PRODUCTS**

Our study shows that more than 20 kinds of nanoparticles and 10 kinds of nanofiltration membranes are produced in laboratory-scale and then are used for wastewater treatment. Among these nanoparticles Titanium Dioxide is studied widely.

Nano silver is another nano particle that is used frequently. Silver is one of the effective elements in preventing grows of bacteria. Researches show that this element can obviate more than 650 such bacteria in less than a few minutes. Decrease in particle size increases ability of this element and in nano scale reaches to maximum capability.

Also, a large number of theses are produced nano filtration membranes and then used them to wastewater infiltration. Nano filtration membranes are recent advances in membrane technology. These membranes are more effective (usually about 10 times) than reverse osmosis membranes. Investigation costs and energy consumption which they need are less than the reverse osmosis membranes. These advantage make them a suitable choice for researchers.

## 9 CONCLUSION

In this article, I.R of Iran research capabilities in water treatment using nanotechnology in two forms of theses and scientific articles are studied. First, scientific centres related to water treatment using nanotechnology are surveyed until to 5 November 2009 and data of 131 theses and 32 articles are collected. By studying annual trend is cleared that the number of theses increased rapidly and reached from 1 thesis in 2004 to 53 theses in 2008 and the number of articles from 1 article in 2003 reached to 12 articles in 2009 (10 months). After that by ranking universities and higher education centres based on the number of theses and published articles, the most active centres identified. University of Tehran, Iran University of Science and Technology and Tarbiat Modares University had done most of the researches in this field. On the other hand, it is cleared that a Canadian university and a French university had scientific cooperation with Iranian universities.

Collected data indicates that more than 20 nano particles and 10 nano filtration membranes are produced in laboratory scale and are studied in water and wastewater infiltration. Also using nano membrane is the most active part in water infiltration (56%). Organization and definition routes with regard to the needs of using this technology, with consult of active researchers of this field is necessary. Using these products in water industry of country is the next activity of Iran Nanotechnology Initiative Council in using this technology in water treatment.

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