RESEARCH ARTICLE

Construction nanoparticles imported into the environment in recent years in Iran

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ABSTRACT

In this paper, the quantities of nanomaterials used in the construction industry in Iran in recent years have been estimated. Then the amounts of nanomaterials in different environments of water, air, soil, and municipal wastewater from 2015 to 2019 in Iran have been estimated. The results show that during these few years, the amount of nanoparticles imported has been more than its production. This study shows that the highest concentrations of nanoparticles in different environments are SiO_2, TiO_2, Fe_2O_3, and carbon nanotube, respectively. The concentration of TiO_2 nanoparticles, carbon nanotubes, and Fe_2O_3 in different environments has increased with a gentle slope during five years. This could be due to the increasing use of these nanoparticles in the industry without control and the lack of appropriate filters to prevent nanoparticles from entering the environment. The results of this study show that during five years, the concentrations of SiO_2, TiO_2, carbon nanotube, and Fe_2O_3 nanoparticles have increased by about 4%, 30%, 28%, and 45% in water and %11, 16%, 27% and 29% in air, respectively. Also, their concentrations in soil % were 23, 18%, 43%, and 52%; and in municipal wastewater %30, 27%, 37%, and 61%, respectively.

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INTRODUCTION

Nanotechnology means understanding and controlling matter at the nanoscale, in dimensions approximately between 1 - 100 nanometers, where unique phenomena allow new applications [1]. The prefix “nano” means 10^{-9} or one billionth. There is a wide range of production systems that can change the shape, morphology, size, composition, and crystal structure [2-4]. The two standard production approaches used are: “bottom-up” and “top-down”. In the bottom-up approach, complex structures are produced through the build-up of atoms or molecules [5-9]. While in the top-down approach, nanostructures are built from their macroscale counterparts without atomic-level control [10]. Today, nanotechnology offers the potential to create better materials with advanced properties for use in a variety of applications. When the dimensions of a substance are changed from macro to micro and then to nano, fundamental changes in the properties of the material occur [11, 12]. Nano products are used in various industries such as cosmetics, construction, electronics, and medicine [13]. The building and construction industry is one of the main consumers of nanoparticles in the world, which includes cement, concrete, glass, tiles, and so on. By combining nanoparticles and traditional building materials, exceptional properties can be achieved for the construction of long-span and super high-rise systems [11]. From an environmental point of view, climate change and the shortage of fossil fuels have led to increased interest and use of modern developments and new

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materials in various parts of the building with the aim of saving. In the meantime, the environmental and health hazards of these materials in the production, use, and recycling stages should be considered. Therefore, the need to study the life cycle of nanomaterials, especially in the construction sector, is increasingly felt. However, limited research is available on the long-term effects of nanomaterials on the environment and human health. Long-term adverse effects may be due to long-term exposure to nanoparticles, as well as the use of products containing nanoparticles [14]. The benefits of nanomaterials in construction materials have led to the elimination of their environmental hazards as environmental contaminants. This emphasizes the need for risk assessment and regulatory guidelines to ensure the safe use and disposal of nanoparticle-containing products [15].

Carbon nanotubes (CNTs) can dramatically improve mechanical durability by gluing concrete mixes, cementitious agents, and concrete aggregates to prevent crack propagation [16-18]. The Incorporation of carbon nanotubes as cracking bridges in ceramics can increase their mechanical strength and reduce their fragility, as well as improve their thermal properties [19-22].

SiO_2 and Fe_2O_3 nanoparticles (NPs) can be used as fillers to pack pores and reinforce concrete [17, 23]. Combining them with fly ash as an alternative to cement can also increase the mechanical properties of concrete [23]. Doping or coating with SiO_2 and TiO_2 NPs improves the performance of window glass, paving, walls, and roofs. The use of silica nanoparticles inside windows acts as an anti-reflective coating and leads to energy savings [24]. TiO_2-coated glass, walls, and roofs act as an antibacterial and self-cleaning agent to clean surfaces under solar irradiation [25,26]. In addition to its antibacterial properties by light, the super hydrophilic property of TiO_2 prevents the accumulation of dust on windows [27].

Nanoparticles released from construction materials can create toxicological risks for microorganisms as well as higher organisms through various mechanisms. Carbon nanotubes pose risks such as pulmonary toxicity, inflammation, fibrosis, and cell wall damage [28-31]. TiO_2 irradiated with UV light or sunlight produces ROS, which causes inflammation, cytotoxicity, and DNA damage in mammalian cells [32, 33]. SiO_2 NPs have been reported to exert carcinogenic activity [34]. Exposure to nano-sized SiO_2 triggers lipid peroxidation and membrane damage in human lung cancer cells [34] and induces tumor necrosis genes in rats [35].

Undoubtedly, future research trends will lead to the production of greener, lighter, less hazardous, stronger, and cleaner building materials that, in addition to having such properties, have less adverse effects on the environment and are also effective in reducing energy consumption. In this paper, an attempt has been made to estimate the amounts of nanomaterials used in the construction industry in Iran in recent years. Then the amounts of nanomaterials imported in different environments of water, air, soil, and municipal wastewater from 2015 to 2019 in Iran are estimated.

MATERIAL AND METHODS

The study used a quantitative survey method as the data collection procedure to achieve the objectives. The respondents were selected based on purposive sampling and generally, they represent the various social groups in the country. The statistical population of the present study consists of reputable companies and factories active in the field of nanomaterials in Iran and 45 companies and factories have been selected as the statistical population. Before the actual data collection, a pilot test was performed to ensure the observational categories themselves are appropriate, exhaustive, discrete, unambiguous, and effectively operationalize the purpose of the research. The nanomaterials studied include nano-silica, titanium dioxide nanoparticles, carbon nanotubes, and iron oxide nanoparticles. After determining the total values of each nanoparticle or nanomaterial in each year and determining the life cycle of each nanomaterial, the values entered into different environments of water, soil, air, and wastewater are determined.

RESULTS AND DISCUSSIONS

This section provides information on each of the NPs used in the construction industry that has been used in Iran in recent years. This information is related to some of the most important manufacturing or import companies in the field of nano in Iran. From this evaluation, it can be found that large quantities of nanomaterials are produced and imported into Iran annually.

Nano silica

Fig. 1 shows the production and importation of

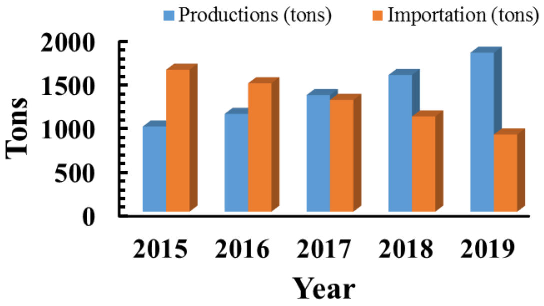

Fig 1. Quantities of SiO_2 NPs imported and produced by different companies from 2015-2019

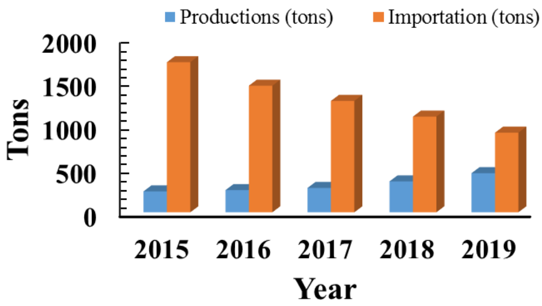

Fig. 2. Quantities of TiO_2 NPs imported and produced by different companies from 2015-2019

nano-silica (SiO_2) by domestic companies between 2015 and 2019. In addition to importations, some of these companies and factories also consume these NPs. In addition to universities and research institutes that produce small amounts of nano-silica, the most important companies producing nano-silica are Isatis, Padideh Shams Iranian, Silica Hamedan, Persian Silica, Sanat Avaran Vista, and Fadak Technology Complex. It can be seen from Fig. 1 that the production of nano-silica NPs has increased annually, which may be due to its widespread use in various industries. Nanosilica importers are mainly tile, glass, and concrete factories. Also, the import of nano-silica has decreased during these years, and this is due to the expansion of manufacturing companies and knowledge enterprises in the field of nano in Iran. The total quantity of silica NPs produced in Iran was 975, 1120, 1335, 1565, and 1820 tons; and the total quantity imported into Iran was 1625, 1470, 1280, 1090, and 884 tons from 2015 to 2019, respectively.

TiO_2 nanoparticles

The most important companies producing TiO2 NPs in Iran are Nano Vahed Sanat Persia, Namago, and *Pars Nanomaterials. Fig. 2 shows the production and importation of* TiO_2 *NPs by domestic companies between 2015-2019. As can be seen in Fig. 2, the production of this nanoparticle did not change much between 2015 to 2017, but after 2017, the production of* TiO_2 *NPs increased. Tile factories are the largest consumers and importers of* TiO_2 *NPs and this is due to the high self-cleaning properties of these nanoparticles and their application in the tile industry. In addition, imports of these nanoparticles decreased between 2015-2019. The total quantity of* TiO_2 *NPs produced in Iran was 240, 255, 280, 355, and 450 tons; and the total quantity imported into Iran was 1725, 1455, 1280, 1100, and 915 from 2015 to 2019, respectively. The results show that during these few years, the amount of imports of NPs has been more than its production.*

Carbon nanotubes

Carbon nanotubes are manufactured by a limited number of companies. The two major manufacturers are Pishro Structure Carbon Nanotechnology and Poya Nanopowder. Fig. 3 shows the total production of carbon nanotubes in Iran between 2015-2019. As can be seen in the Fig. 3, the production of carbon nanotubes increased between 2015-2019.

Carbon nanotubes are used to prepare self-healing and intelligent concretes as well as to increase the mechanical properties of concrete. Therefore, the two major importers of carbon nanotubes are Omran Soft and Fars Cement construction companies. Fig. 3 shows the amount of imports of carbon nanotubes by these two companies between 2015 to 2019. The increase in imports of carbon nanotubes shows that the consumption of nanotubes in the construction industry has increased rapidly in recent years. The total quantity of carbon nanotubes produced in Iran was 15, 25, 34, 35, and 46 tons; and the total quantity imported into Iran was 90, 105, 125, 140, and 150 tons from 2015 to 2019, respectively. The results show that during these few years, the amount of imports of nanoparticles has been more than its production.

Fe2O3 nanoparticles

Fig. 4 shows the productions and importations of iron oxide NPs by domestic companies, including Beton Plast Company, Dorostkar Trading Company, Zanjan Cement Company, and Kimia Company, Kimia Pajooh Afagh Kavir Company between 2015 and 2019. Unlike other nanomaterials, imports of iron oxide NPs have increased in recent years.

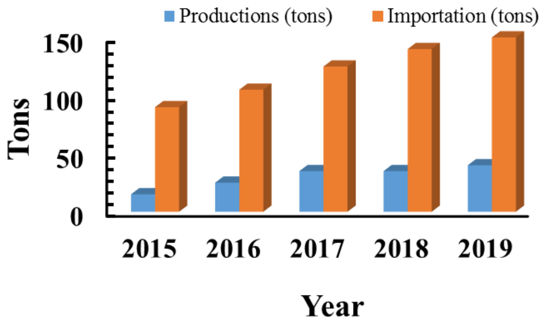

Fig. 3. Quantities of carbon nanotubes imported and produced by different companies from 2015-2019

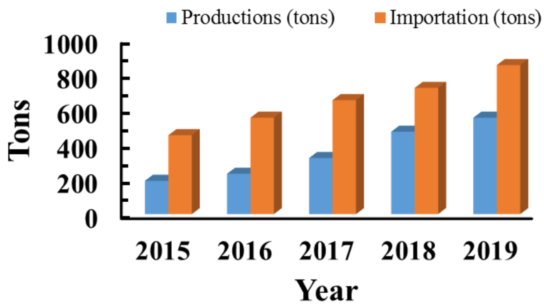

Fig. 4. Quantities of Fe_2O_3 NPs imported and produced by different companies from 2015-2019

The total quantity of Fe_2O_3 NPs produced in Iran was 190, 230, 320, 470, and 550 tons; and the total quantity imported into Iran was 450, 550, 648, 720, and 849 tons from 2015 to 2019, respectively.

The effect of nanomaterials on different environments

According to the production and importation of SiO_2, TiO_2, Fe_2O_3 NPs, and carbon nanotubes in Iran, the amounts of nanomaterials imported into the water, air, soil, and municipal wastewater can be approximated annually. Therefore, by determining the concentration of nanomaterials in the environment, the amount of their biological pollution can be estimated. Sun et.al [36, 37] estimated the production distribution and production volume of nanoparticles in Europe approximately. Data were obtained based on NP market projections, nanotechnology patent analysis, and direct NP production. Sun e.al [36, 37] calculated the fraction of nanoparticles that enter the environment at the stage of production, release, use, and average lifetime based on the degree of belief (DOB). Therefore, based on the results collected in this paper from the volume of nanoparticles produced and Sum's results, the percentage of nanoparticles entered into the environment is estimated.

Nanomaterials in suspension in water or other liquids can be discharged into the environment for domestic, urban, or industrial use. The nanomaterials are then transported towards wastewater treatment plants (WWTPs). The sludge from wastewater treatment in WWTPs is generally spread onto the soil. WWTPs, therefore, play an important part in controlling the dispersion of nanomaterials into the environment.

Fig 5 shows the concentration of different nanoparticles in water, air, soil, and municipal wastewater environments from 2015 to 2019 on a case-by-case basis. The highest amount entering the environment is related to water and the lowest is related to soil and wastewater. By installing special filters and recycling, the concentration of nanoparticles in the environment can be reduced; however, due to the small size of the particles, no filter has been made so far to remove all nanoparticles.

This study shows that the highest concentrations of nanoparticles in different environments are SiO_2, TiO_2, Fe_2O_3, and carbon nanotube, respectively. Fig. 5 shows that the concentration of silica NPs in different environments has increased slightly during five years. The concentration of TiO_2 NPs, carbon nanotubes, and Fe_2O_3 NPs in different environments has increased with a gentle slope during five years. This could be due to the increasing use of these nanoparticles in the industry without control and the lack of appropriate filters to prevent nanoparticles from entering the environment. The results of this study show that during five years, the concentrations of SiO_2, TiO_2 NPs, carbon nanotube, and Fe_2O_3 NPs have increased by about 4%, 30%, 28%, and 45% in water and %11, 16%, 27% and 29% in air, respectively. Also, their concentrations in soil % were 23, 18%, 43%, and 52%; and in municipal wastewater %30, 27%, 37%, and 61%, respectively.

To conclude, nanoparticles are already being introduced into the terrestrial and aquatic ecosystems, and the development of nanotechnologies will likely result in these additions growing, both in quantity and in diversity. Assessment of the future environmental consequences should take into consideration the nature and the scale of the sources, the transfer mechanisms and paths (atmosphere, runoff, direct discharge), the storage compartments (water, soil, sediment), the target species, and the effects

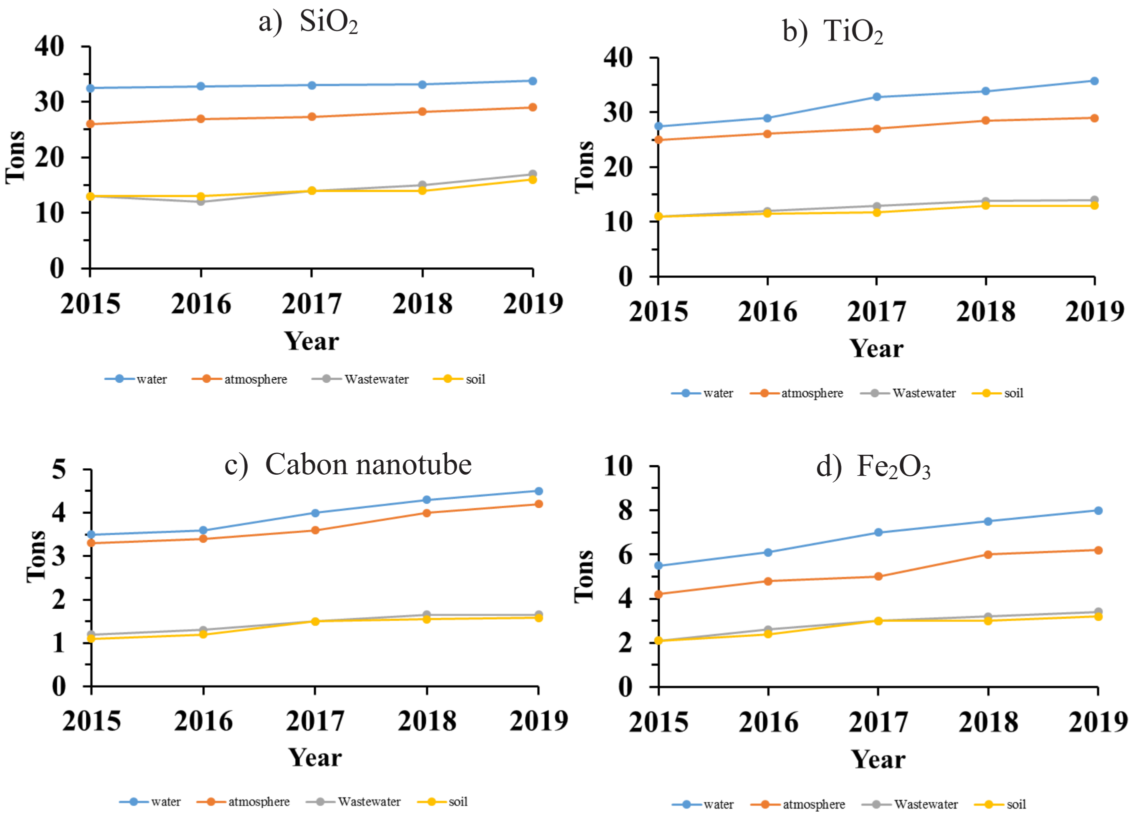

Fig. 5. Concentration of different nanoparticles in water, air, soil and municipal wastewater environments from 2015 to 2019

on the different populations exposed. By burning waste containing nanomaterials, they can enter the atmosphere. By using nano filters, large amounts of them can be prevented from entering the atmosphere.

CONCLUSIONS

The total quantity of silica NPs produced in Iran was 975, 1120, 1335, 1565, and 1820 tons; and the total quantity imported into Iran was 1625, 1470, 1280, 1090, and 884 tons from 2015 to 2019, respectively. The total quantity of TiO_2 NPs produced in Iran was 240, 255, 280, 355, and 450 tons; and the total quantity imported into Iran was 1725, 1455, 1280, 1100, and 915 tons from 2015 to 2019, respectively. The results show that during these few years, the importation of nanoparticles has been more than its production. The total quantity of carbon nanotubes produced in Iran was 15, 25, 34, 35, and 46 tons; and the total quantity imported into Iran was 90, 105, 125, 140, and 150 tons from 2015 to 2019, respectively. The total quantity of Fe_2O_3 NP produced in Iran was 190, 230, 320, 470, and 550 tons; and the total quantity imported into Iran was 450, 550, 648, 720, and 849 tons from 2015 to 2019, respectively. The results of this study show that during five years, the concentrations of SiO_2, TiO_2, carbon nanotube, and Fe_2O_3 NPs have increased by about 4%, 30%, 28%, and 45% in water and %11, 16%, 27% and 29% in air, respectively. Also, their concentrations in soil % were 23, 18%, 43%, and 52%; and in municipal wastewater %30, 27%, 37%, and 61%, respectively.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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