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Impact of nanotechnology on urban sustainability;

Introduction of concepts and assessment of an idea

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Abstract

Nanotechnology is considered pervasive enabling technology, resulting in novel applications of nanomaterials that promise radical improvements in various spheres of life (Dhingra, Naidu et al. 2010). It is all about getting more function on less space, emphasizing on clean technology, using renewable energy and also facing facts about years of massive industrialization. It has the potential to make a big impact on sustainability. Today, Sustainability is the biggest challenge that human face. The main issue is, to be sufficiently intelligent not to destroy the fundamentals on which our life and our ecosystem are based on while improving quality of human life**.** Awareness from new technologies and their effect will help in this issue. Nowadays, nanotechnology has been reviewed in most sciences but the technology less has been introduced to urban planners or its usage had not been significant. The aim of this paper is to identify this technology and its role on the urban sustainability. The method used for this purpose was an analysis of data gathered through library study, so, first the concept of nanotechnology and its main ideas have been represented while simultaneously the concept and indicators of urban sustainability have been reviewed. After that, applications of this new technology in environmental sustainability have been expressed. Then to indicate clearly applications of this new technology in urban area an idea was represented and analyzed; Nanocity. In the result of analyses it has been indicated that nanotechnology with its advantages, and disadvantages can change urban environment in order to achieve sustainability but in cities it should be considered logically not idealistically besides social and cultural dimensions. Also its harmful effects on the environment should be considered. Potential solutions are seen in the form of greener nanosynthesis methods, which are called ―Green Alternatives.

Key words: Nanotechnology, urban sustainability, Nanocity, assessment.

1. Introduction

Many novelties are discovered as a result of the scientific research and the continuous development in the field of technology. This helps create a better life for mankind. It

would be difficult to deny the potential benefits of nanotechnology and stop development of research related to it since it has already begun to penetrate many different fields of research.

Nanotechnology and nanoscience got started in the early 1980s with two major developments: The birth of cluster science and the invention of the scanning tunneling microscope. This development led to the discovery of fullerenes in 1985 and carbon nanotubes a few years later. In 2000, the United States National Nanotechnology Initiative was founded to coordinate Federal nanotechnology research and development (Dhingra, Naidu et al. 2010).

Nanotechnology can be developed using guidelines to insure that the technology does not become too potentially harmful. As with any new technology, it is impossible to stop every well funded organization which may seek to develop the technology for harmful purposes. The coming decades are expected to witness an enormous, amazing breakthrough in this technology**.**

The present paper casts light on the recent remarkable development in discovering a novelty in the field of technology, which has led to the emergence of nano technology, which has become connected with our daily life and our living environment. According to noticeable advantages of this technology, it has been reviewed in most sciences but in urban science it has not been clarified appropriately yet. The aim of this paper is to identify the role of this technology on the urban environment and its application in creating sustainable city. For achieving by this, the paper is divided into three main parts, which review the topic of nanotechnology and cities sustainability in a serial scientific, method. The first part discusses the definition of the word nanotechnology and what nanotechnology had introduced to man, and its effects on environment also the present-day urban experts thought. Definition of urban sustainability indicators and review of how this technology can make impact on all dimensions of sustainability through its four general concepts have been presented then. Finally in this part an idea refers to urban issues have been introduced.

At the end part evaluation of principles and visions expressed in idea of Nanocity by urban sustainability indexes had been done. Finally evaluation of Nanocity as a theory given for urban sustainability achievement, led us to significant results for using nanotechnology in contemporary cities.

2. Data and Material

2.1. Nanotechnology and Fundamental concepts

Nanotechnology, shortened to "Nanotech", is the study of the control of matter on an atomic and molecular scale in the length scale of approximately 1 -100 nanometer range(INIC 2010). But it is important to know that Nano-technology is not only about nano-particles. it is also about; New “non-nano” materials with potential high impact of ESH/sustainability, new manufacturing tools and processes, novel properties, creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size, sustainability challenges due to increased use of: water, energy, materials(Schrader 2008).

Today we encounter third generation of nanotechnology. First generation was up to~2001: which was about passive nanostructures; nanostructured metals, polymers, ceramics, catalysts, composites. The second generation ~2010: It was about active nanostructures; transistors, targeted drugs and chemicals, fuel cells, solar cells, and the third generation from Now: 3-D nanosystems and systems of nanosystems; various assembly techniques, networking at the nanoscale and newarchitectures, biomimetic materials, novel therapeutics (Karn 2005). It seems that the third generation has been more dealt with environmental and urban subjects.

Fundamental concepts: Areas of physics such as nanoelectronics, nanomechanics and nanophotonics have been evolved during the last decades to provide a basic scientific foundation of nanotechnology.

A. Larger to smaller: a material perspective: A number of physical phomomena become pronounced as the size of the system decreases.

B. Simple to complex: a molecular perspective: Modern synthetic chemistry has reached the point where it is possible to prepare small molecules to almost any structure.

C. Molecular nanotechnology: a long-term view: Molecular nanotechnology is a term given to the concept of engineered nanosystems (nanoscale machines) operating on the molecular scale. It is especially associated with the concept of a molecular assembler, a machine that can produce a desired structure or device atom-by-atom using the principles of mechanosynthesis(Hemeida 2010).

2.2. Urban sustainability and it's indicators

After defining the concept and indicators of urban sustainability here nanotechnologies' principles that support sustainability will be reviewed.

Sustainability is equity and harmony extended into the future, a careful journey without an endpoint, a continuous striving for the harmonious co-evolution of environmental, economic and socio-cultural goals. A sustainable city is one which succeeds in balancing economic, environmental and socio-cultural progress through processes of active citizen participation. It is a continuous invention of new opportunities, resembling youth itself, a capacity for innovation which is a non-depletable resource, a permanent thirst for the unknown, the search for something better(Mega and Pedersen 1998).

Therefore because nanotechnology is a new novel approach and also has ideas about using non-depletable resources, so it is in correspondence with concept of urban sustainability.

But if sustainability is a coherent policy goal, it must be possible to measure whether we are moving towards it. So sustainability indicators can be used as tools for quantifying sustainability performance

The "Charter of European Cities and Towns: Towards Sustainability" express these indicators as a tool for measuring sustainability; global climate, air quality, acidification, ecosystems toxification, urban mobility or clean transportation, waste management, energy consumption, water consumption, nuisances, social justice ,housing quality, urban safety, economic urban sustainability, local heritage, green and public spaces, citizen participation, unique sustainability(Mega and Pedersen 1998).

Also Istat[1] experience in developing urban environmental indicators for major cities of Italy reach to below result as indicators.

Urban Transport indicators, Air, Noise indicators, Energy indicators, Water indicators, Waste indicators, Green areas indicators(NSII 2001).

2.3. Nanotechnology and sustainability

Nanotechnology has the potential to make impact on sustainability. It is all about getting more function on less space. Nanotechnology contributes to make energy conversion and energy storage more efficient or improve product durability by below properties.

- **More for less:** Efficiency and getting more with less is essential for sustainability. Nanotechnology is also about integrating disciplines and building a cross disciplinary research community. New solutions to replace non-renewable energy based technologies and minimize their impact on the environment will need this cross disciplinary approach. Nanotechnology can contribute to make energy conversion and energy storage more efficient or improve product durability(Bacsa 2007).

[1] The National Institute of Statistics is the main supplier of official statistical information in Italy

- **Nanotechnology and clean technology:** CleanTech has become a word that is increasingly gaining attention since sustainability is an issue in the context of global warming, climate change and increasing cost of primary natural resources. The issue of sustainability has clearly caught the interest of the economic world. Any new technology is however expensive at the beginning but increasing energy cost and the cost of other natural resources make alternative energy sources and intelligent solutions more cost competitive while mass production of the new technology help to drive costs down(Bacsa 2007).
- **Energy and big things start small:** One of the main issues about sustainability is the way we use energy. We use mostly non-renewable energy. The main demand of sustainable technology is that it makes a radical shift towards the use of renewable energy. There is plenty of sun energy shining on us and we have yet to learn how to make use of it. How can energy conversion and energy storage be improved? How can energy consumption be reduced through intelligent design? We could imagine a system where mechanical energy is converted into electrical energy, stored as chemical energy and is recovered on demand. The roofs of our buildings could be covered with solar panels or collectors to convert sun light into thermal or electrical energy. Sun collectors combined with a Sterling engine show promising results. Electricity might soon flow in the installations of our house in both directions.(Bacsa 2007)
- **Facing facts:** It is not enough that a scientist makes a discovery when industry is based on non-renewable natural resources; it is not enough to design new products without knowing what is going to happen to it at the end of its lifetime. Today, Sustainability is the biggest challenge that humans face. It is not a question of getting more comfort and to live longer. The question is: Are we sufficiently intelligent to not destroy the fundamentals on which our life and our eco system are based on(Bacsa 2007). It is enough to take a look at certain numbers to see that sooner or later we have to face the sustainability problem in all our undertakings.

But it has been said that nanotechnology is also about Sustainability challenges due to increased use of water, energy and materials, so, using this new technology awarnessly will help solving this challenges. So it is important to know essential technology challenges of the society today and in the future are: Environment/Climate, Efficient use of resources, CO2-Prevention, Energy; Conversion, Storage, Efficient use, Mobility, Nutrition and Health(Krüger 2009) and how nonotech will help them? There are two possible approaches to address technology challenges in the society:

1-Optimized use and combination of existing established technical solutions

2-Develop new technology options for relevant applications(sustainability)(Krüger 2009)

By choosing second approach - choosing nanotechnology to achieve sustainability – the challenges could be answered. It has been expressed that technology confront challenges in society and there are two approaches for us to use them, from now in this paper the second approach is admitted, nanotechnology as a new technology option for achieving sustainability as relevant applications.

Nanotechnology issues of sustainability come in below table through its potential and fundamental concepts (Table 1).

issues	sub category
Energy	Conversion, Transport, Storage, Saving
Resources	Efficient use, Catalysis, Corrosion, protection
Health Recovery	Drug delivery**,** Controlled release**,** Diagnostics.
Nutrition	Plants / Crops, Clean water.
Communication/ Information	Data storage, Data processing, Displays.

Mobility	Ground transportation, Aerospace, Marine
Environment/Climate Decontamination	Air, soil, water, renewables

Table1. issues of sustainability, which nanotech support them. reference: (Krüger 2009).

There is no doubt that nanotechnology has great potential to bring benefits to society over a wide range of applications, but it is recognized that care has to be taken to ensure these advances come about in as safe a manner as possible(Hemeida 2010). There has been much debate on the future of implications of nanotechnology. Nanotechnology has the potential to create many new materials and devices with wide-ranging applications, such as in medicine, electronics, and energy production. On the other hand, nanotechnology raises many of the same issues as with any introduction of new technology, including concerns about environmental impact of nanomaterials, and their potential effects on global economics, as well as speculation. These concerns have led to a debate among advocacy groups and governments on whether special regulation of nanotechnology is warranted(Dhingra et al. 2010).

James Hutchison, director of the Safer Nanomaterials and Nanomanufacturing Initiative (SNNI), which is the leading green nanotechnology effort in the world, suggests an evolving approach towards nanotechnology Environmental Health and Safety (EHS) research in three phases.

1. Studies of nanomaterial implications.
2. Coordinated applications and implications research.
3. A green nanoscience approach to material and process design to eliminate hazards throughout the material's life cycle(Dhingra et al. 2010).

Potential solutions are seen in the form of greener nanosynthesis methods, which is called Green Alternatives, and assessment frameworks that combine life cycle and risk assessment.

2.4. Nanocity

Nanocity claims all good criteria of third Millennium- from nanotechnology to sustainable urban form- and tries to represent an ideal pattern of sustainable city for the 21th century(Hejazi and et.al 2010).

Nanocity spans 11138 acres of flatland located just beyond the foothills of the Himalayas. It is less than 25 kms east of Chandigarh and just over 200 kms north of Delhi. Two seasonal rivers form the eastern and western borders of the city and two streams trickle within its boundaries. It is well connected by National highway- 73 and State highway-1. It is a public/private partnership between Sabeer Bhatia Group and the Haryana State Government. The vision is to develop a sustainable city with world class infrastructure and to create an ecosystem for innovation leading to economy, ecology and social cohesion.

2.4.1. Design principles

Nanocity has been designed on the principles of(Bahtia 2006):

1) **Greencity:** Uses context as opportunity, promotes a lush and shaded climate-sensitive environment, encourages the expansion of local natural systems, and advances ecologically intelligent and sustainable design. Half of the land will thrive as a green open space. Grassy frontages, green belts, courtyards, walking trails and public parks will contribute to the all – natural vibrancy of the city. The urban infrastructure will be ecologically intelligent and sustainable by outfitting the buildings with energy efficient systems and renewable energy sources.

2) **Flexcity:** Creates an adaptable and evolving framework that is flexible over time, responds to changing needs, and adjusts to future uses and patterns of growth. A city will not reach its full potential overnight and for this reason, Nanocity has been planned to emerge in incremental phases. This will ensure the completion of high-quality, dependable infrastructure. This gradual method of build-out will also allow the city to be flexible and responsive to new conditions and changing needs over time.

3) **Complexcity:** Proposes a city of mixed use districts, encourages a dynamic sequence of neighborhoods and open spaces, defined unique nodes of density and character, and linked by efficient systems of transportation. Nanocity will provide diverse, hybrid spaces that cultivate creativity through their unique nodes of character. This will be evident in the different types of residential options and housing accommodations available. The function of each district will determine its spirit.

2.4.2. Master plan

Master plan of nanocity is based on below cases(Bahtia 2006):

- City of parks and public open spaces: Parks and open spaces, help facilitate healthy living and create positive social environment that give citizens a sense of belonging. They are community development tools and the lungs of a city In NANOCITY, 50% of the land is earmarked for development of parks and upkeep of open space.

A park will be less than a five minute walk away from any starting point in the city. These parks will host various outdoor leisure opportunities. It has been announced that Nanocity will foster an urban atmosphere on an eco-island of living landscape. **

- City of comprehensive state of the art transit:

The pedestrian has priority in Nanocity. To dissuade "car culture", a state of the art public transit system has been envisaged. Nanocity's Bus Rapid Transit (BRT) system will consists of a main loop connecting the entire city. There are secondary loops, neighbourhood loops with transferstops and regional transit centers to increase the efficiency of mass transport. Each residence will be within a five minute walking distance from every starting point in the city. If one has to journey by car, two wheelers & other automobiles, there are lanes that are specifically meant for them thereby making the journey safe and comfortable

- City of inclusion: It takes a village to build a city. Local villagers will be encouraged to gain employment through local construction projects and live in the builder's town. These towns will provide technical training, low cost housing, electricity, safe drinking water and education to children.
- City of sustainability and sustenance: Global warming and climate change make the contemporary urban agenda a global one. Nanocity will preserve the naturally existing resources of the land. The city will be outfitted with a dual distribution piped water system to separate drinking water from reclaimed greywater used for non-potable purposes. Living machine technology will provide Nanocity with the capacity to convert wastewater into odor-free drinking water. Half of the energy used in the city will come from renewable sources viz: wind, solar and photovoltaic technologies. Buildings will use climate responsive design techniques such as sun shading, cross ventilation and direct evaporative cooling. At least 70% of the city's waste will be recycled or composted.
- High density nodes: The high density nodes have been located in areas which will minimize the impact of dense development on surrounding neighbourhoods. The city has been divided for even and sustainable development into four high density nodes viz : technology and ecology region, research and development, knowledge and innovation and international communication and exchange regions.

- City of economic opportunity: The urban structures in Nanocity has been developed as mixed-use buildings, with the street level devoted to business and trade and the upper floors allocated for residential use. The mixed-use derives from the notion of creating a market of mutually complimentary and supportive services and activities.

The city has been divided into four districts viz: IT, University, Airport and Biotech districts for administrative control.

Innovation is the motivation for Nanocity's four districts. It will generate a vast quantity and variety of employment opportunities in the state of Haryana. These concentrated areas will be urban agglomerations of residential, commercial, business, institutional and industrial infrastructure. The districts will house a number of unique neighbourhoods and will be connected through a comprehensive system of roads and public transit options.

3. Research Methodology

In this paper starting from general questions like what are nanotechnology and its concepts? Then narrowing down and focusing on one specific aspect of its effect on urban environment, and representing two ideas refer to this technology in urban subjects, where we can observe and analyze this aspect. At last, we conclude and generalize the results to the practicable and real world.

The method of this research is based on the analysis of documents. Data gathered through library study and others' practice documentary analysis for collecting background information. Finally, analysis of the idea of nanotechnology for urban environment to indicate clearly its applications and evaluation of it by indicators of urban sustainability.

We choose a collection of general indicators given by charter of "Towards Sustainability" and ISTAT to check the correspondence of Nanocity as an idea of Nanotechnology for urban environment to urban sustainability. It is noticeable that because quantitative and statistical studies were not possible, analyses in this paper are descriptive so indicators evaluated qualitatively with theoretical basics represented for Nanocity.

There are some subindicators extracted from charter of "Towards Sustainability" which make process of recognition and evaluation easier.

4. Results and Analysis

After defining concepts and ideas, collection of general indicators given by charter of "Towards Sustainability" and ISTAT had been used to check the correspondence of Nanocity as an idea of Nanotechnology for urban environment to urban sustainability. For each indicator, there are some subindicators which help process of recognition and assessment.

urban sustainability		Nanocity
indicator	Subindicators	
global climate	Contribution of cities to the change in the global climate.	✓
air quality	Number of days per year on which alarm levels are exceeded and traffic circulation is stopped.	✓
urban mobility or clean transportation	use of environment-friendly means of transport	✓
waste management	Waste disposed of by incineration; waste reused or recycled.	✓
water consumption	The total amount of water extracted; Water from recycling.	✓
energy consumption	Consumed energy according to the source of production	✓
nuisances	Improvement of environment by reduction of noise and …	✓
social justice	Reduction of the percentage of the excluded and marginalised population, vulnerable groups.	-
housing quality	percentage of people affected by lack of housing or poor housing	✓
urban safety	Population affected seriously by crime or traffic accidents.	-

green and public spaces local heritage	The surface of green spaces, the surface of heritage spaces and the surface of public spaces per inhabitant.	✓
citizen participation	The percentage of the population active in local elections and participating in associative life.	-
unique sustainability	The degree to which unique factors or events lead to urban sustainability with its all dimensions.	-

Table2. Correspondence of urban sustainability indicators to Nanocity.

In result of analyses it seems that Nanocity can reach urban sustainability in most dimensions, but it is obvious that sustainability could be achieved in all dimensions. Only claim of nanotechnology and urban sustainability indexes such as new energy resources cannot reach sustainability. Although this idea includssome aspects of urban sustainability, but it did not consider citizens participation and unique identity for city. These two recent indicators cannot be achieved suddenly they need time which is not considered in Nanocity idea.

Nanocity is not based on specific theory and philosophy(Hejazi and et al 2010). It is an ideal opinion which its occurrences and progress as expressed is not predictable. In addition Nanocity seems to be preoccupied by nanotechnology, but we should be aware of its disadvantages. Finally, Nanocity it is an experience teaches us using nanotechnology to reach saving time and efficiency in achieving urban sustainability.

5. Conclusions

Nanotechnology is a very powerful new approach that will change our industries and our lives. We have a very small window right now to bring up this technology responsibly and sustainably—to learn from past mistakes and concurrently look at the possibility of harmful implications as we benefit from the applications .It's an opportunity too important to neglect(Karn 2005).

This paper has led to promising results for a better future for urban experts to access sustainability. These results appear in designing, for cities have been built based on this technology. It has its effects on the building materials, decoration and energy. So besides controlling environmental effects of Nanotechnology it should be considered that idea of Nanocity can not be realizable idealistically. Technology should be under domination of society, serve it and be used gradually. It is noticeable to know logical using of this new technology in our cities will help achieving sustainability faster and easier. Finally, among Nanotechnology's idea in Nanocity below item in a logical framework can be used in contemporary cities; new low consumption technology matches with a new energy system, dynamic advanced industry which their environmental and social effects are under control, consideration of green open spaces, flexibility and providing creativity context in the community.

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