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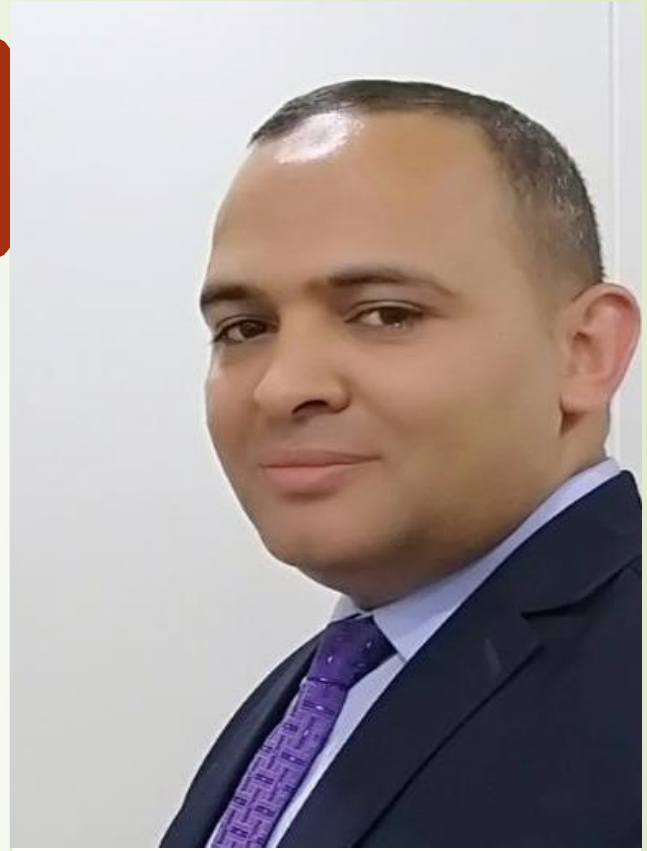
Nanoparticles for Environmental Applications

By/ Ahmed Hasham

4/21/2021

About the presenter

- Member of the Board of scientists Egypt.
- Member of Scientific Professions Syndicate.
- Member of the Arab Society for experts and Safety Professionals.
- Member of the International Association of Engineers.
- Expert in water and wastewater treatment technologies.
- Certified trainer in the water treatment field.
- Certified trainer in the Quality Management Systems field.
- M.Sc. of Environmental Chemistry – Ain Shams University.
- Ph.D. candidate in Inorganic and analytical chemistry. Suez Canal University- Egypt.



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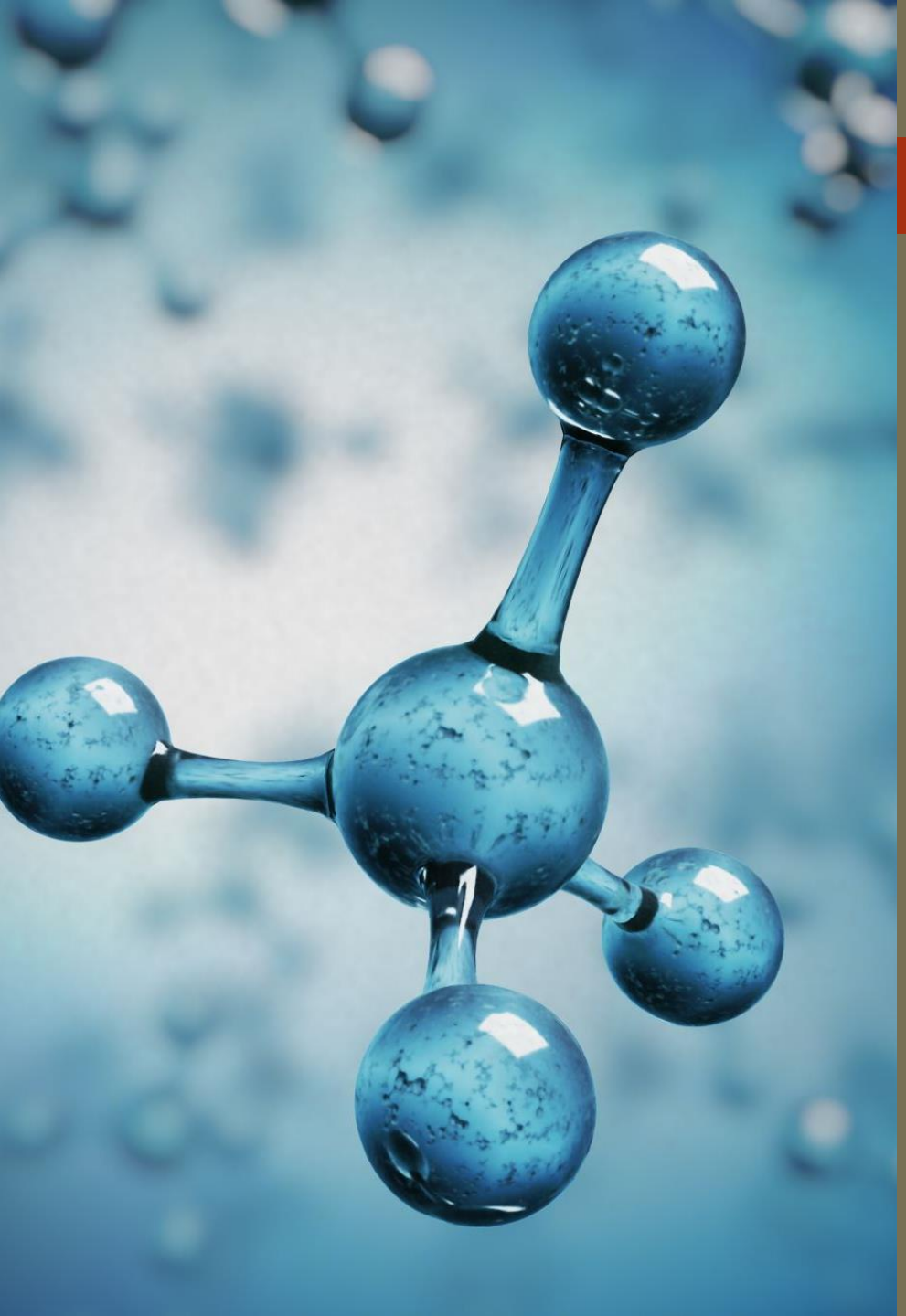


Contents

- Nanotechnology definition.
- Nanotechnology market.
- Natural Nanomaterials
- Common preparation methods.
- Common characterization methods.
- Trend of Nanoparticles for environmental applications.
- Examples from current applications

Nanotechnology Definition

- The understanding and control of matter at dimensions between approximately 1 and 100 nm, where unique phenomena enable novel applications. *

- Nanoparticles are sub-nanosized colloidal structures composed of synthetic or semi synthetic polymers

* National Nanotechnology Initiative (NNI).

Nanotechnology Market

- The nanotechnology is a promising market.
- It is expected to grow by 30 percent annually in the recent decade.
- This growth will enhance the individual's awareness of the nanotechnology impact on the world.

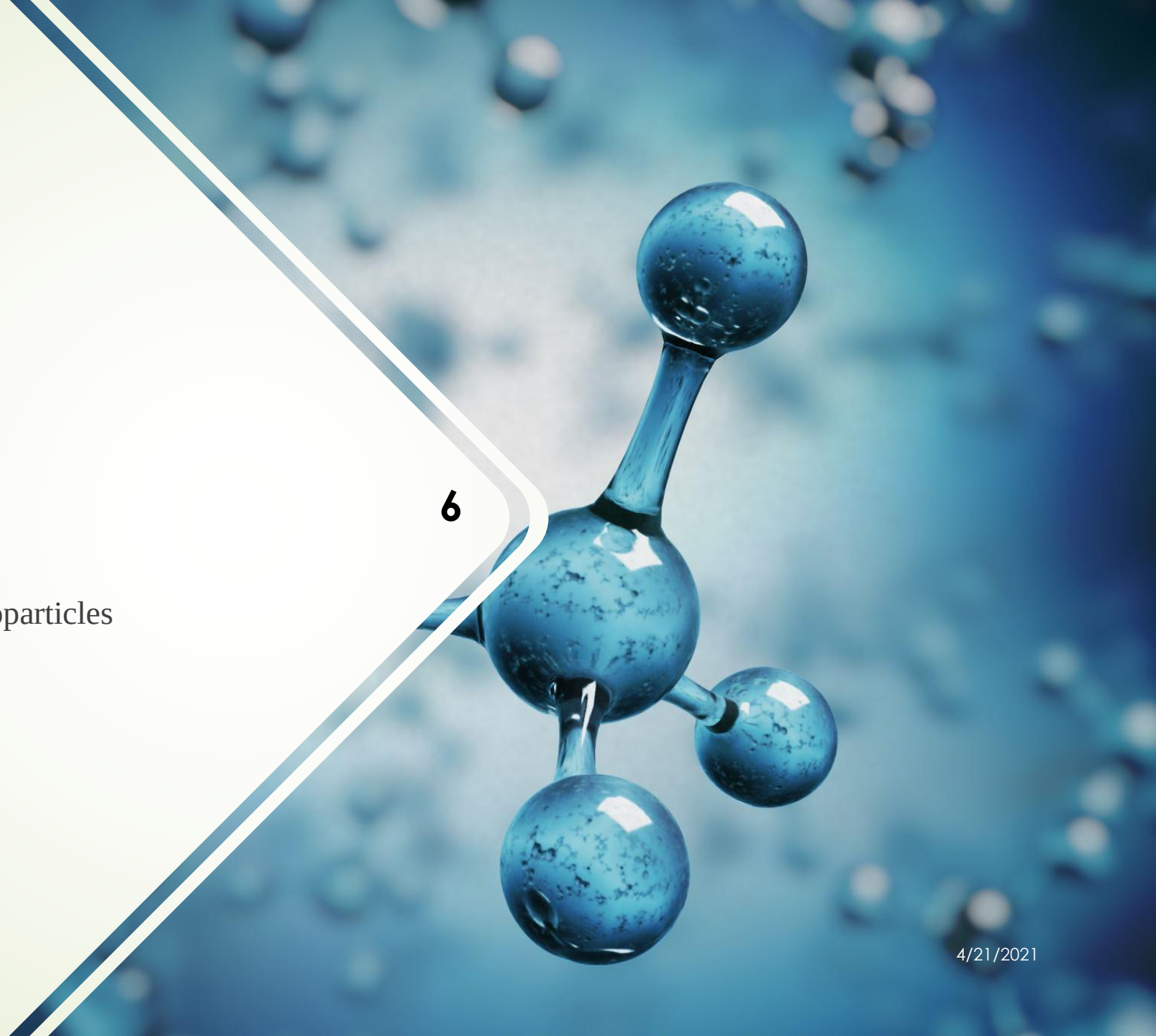
Nanoparticle's characterization

Chemical / Physical Characterization:

- Size and surface Morphology
- Specific Surface Area
- Surface Charge
- Density
- Molecular weight Measurements of Nanoparticles
- Kinetic Study
- Stability of Nanoparticles

Biological Characterization

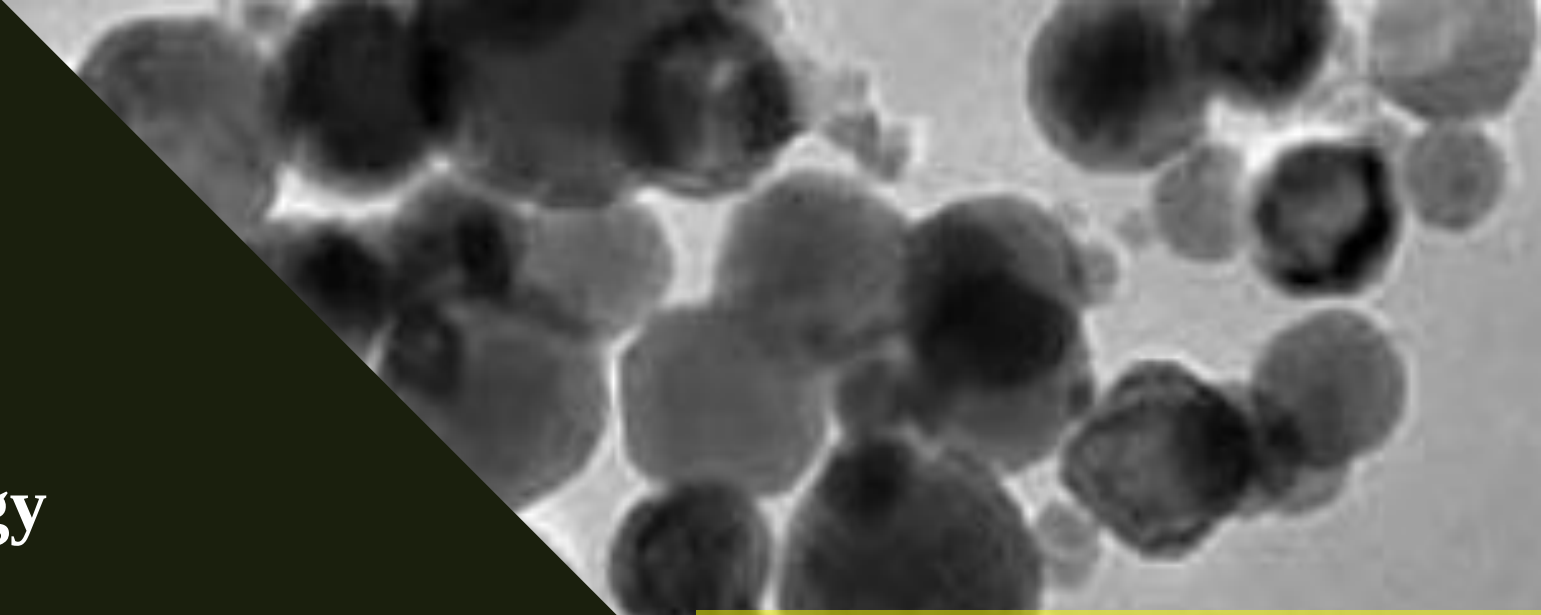
- Compatibility studies
- In-vitro Release Studies



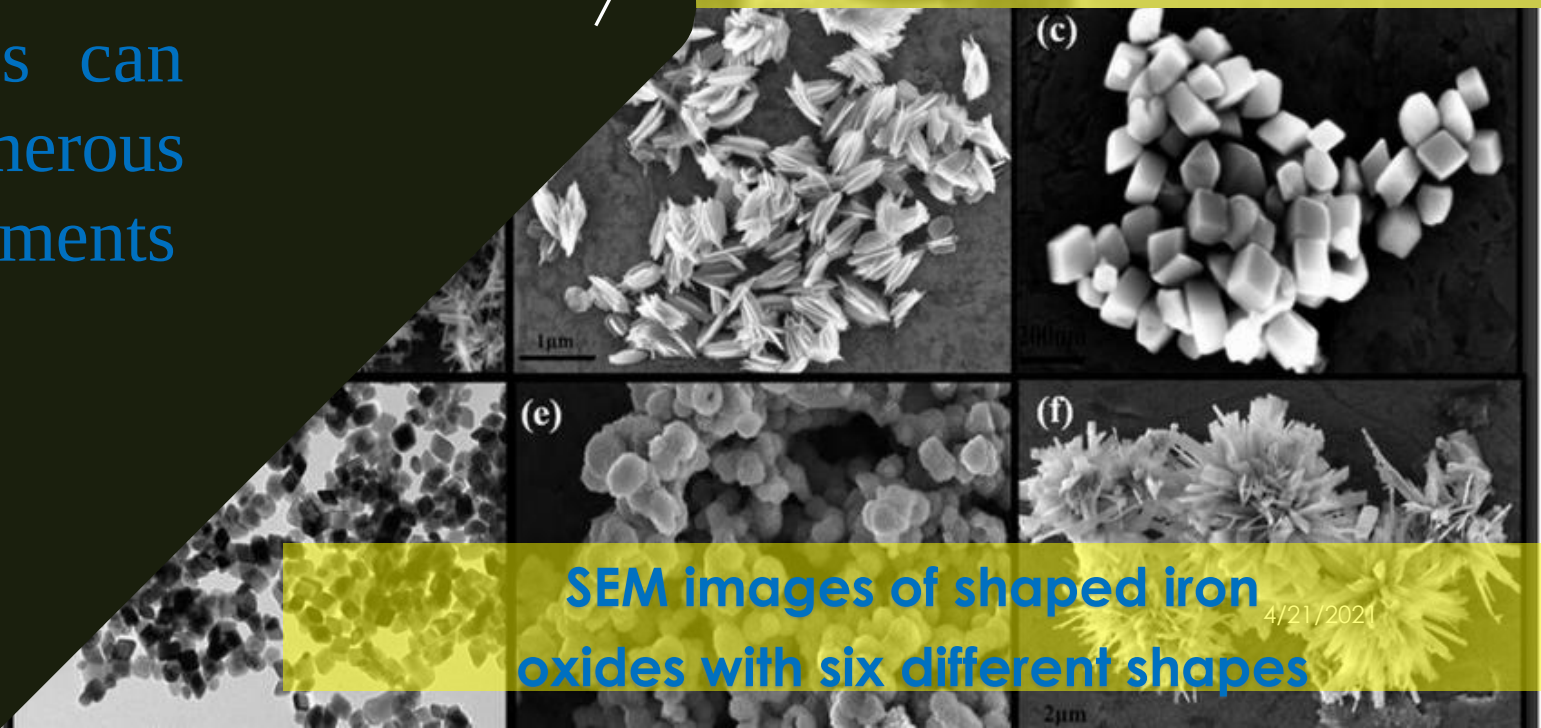
Nanoparticle's characterization

Size and surface Morphology

The particle size and size distribution of nanoparticles can be determined using numerous commercially available instruments



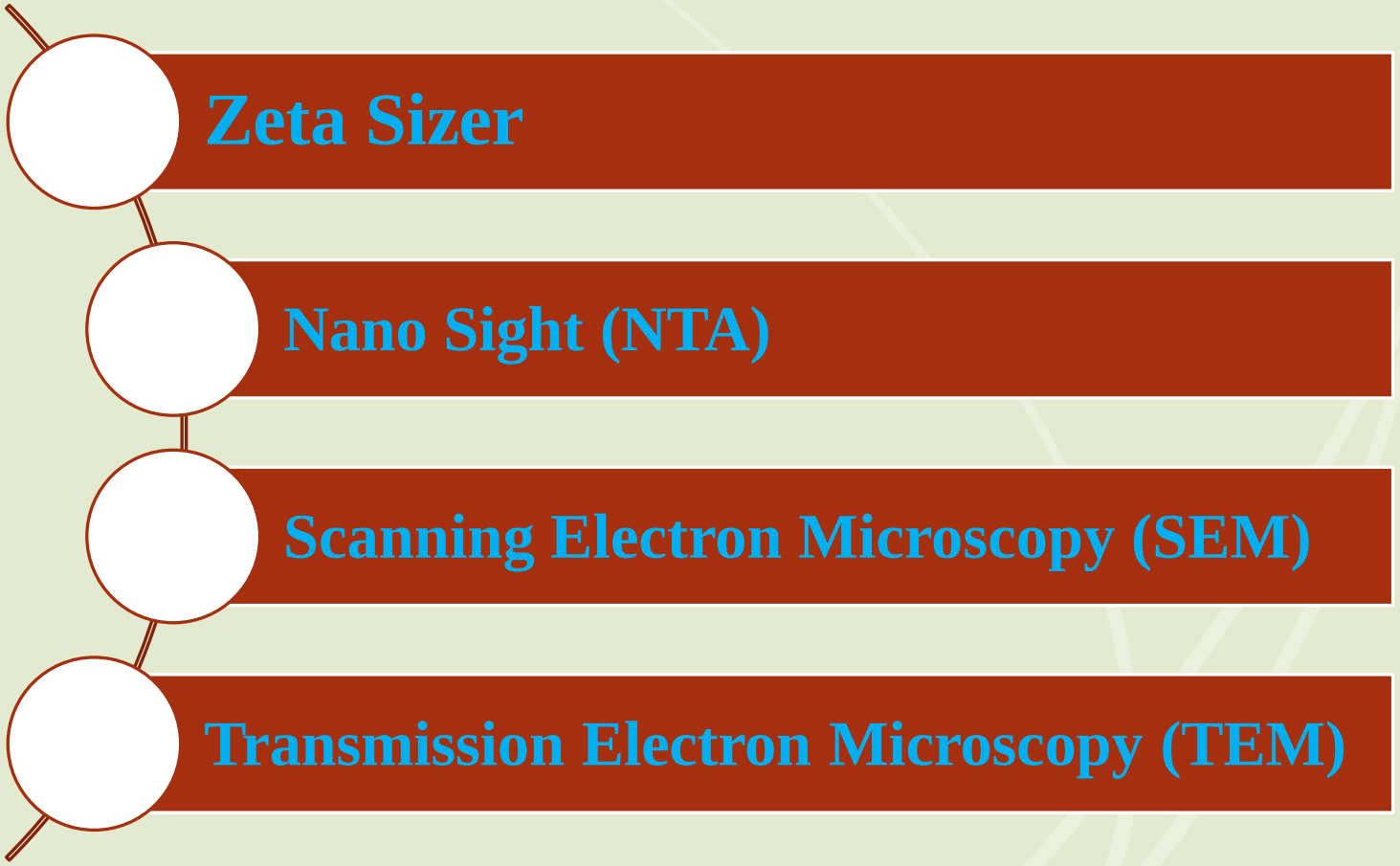
TEM image



SEM images of shaped iron oxides with six different shapes

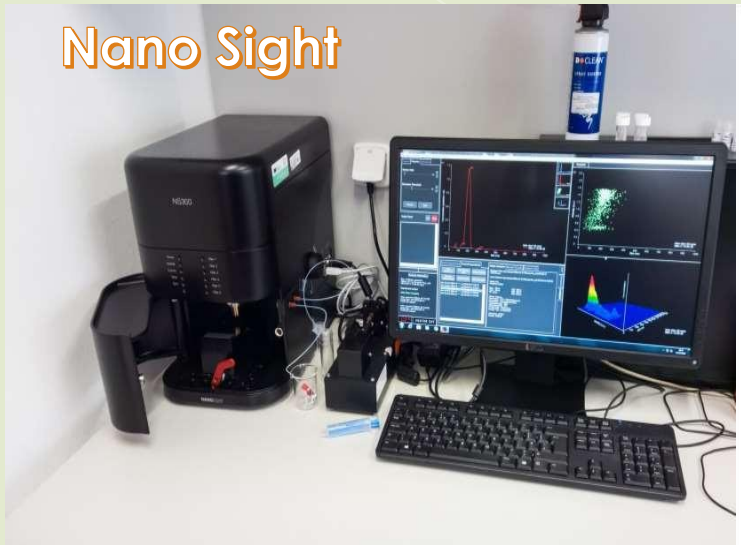
Examples for devices can be used for particle size determination:

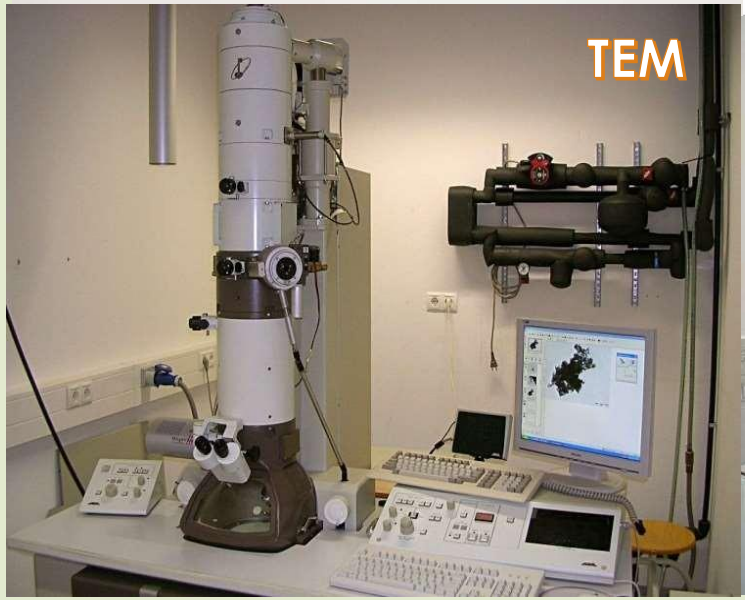
Nanoparticle's characterization



Nanoparticle's characterization

Examples for devices can be used for particle size determination:

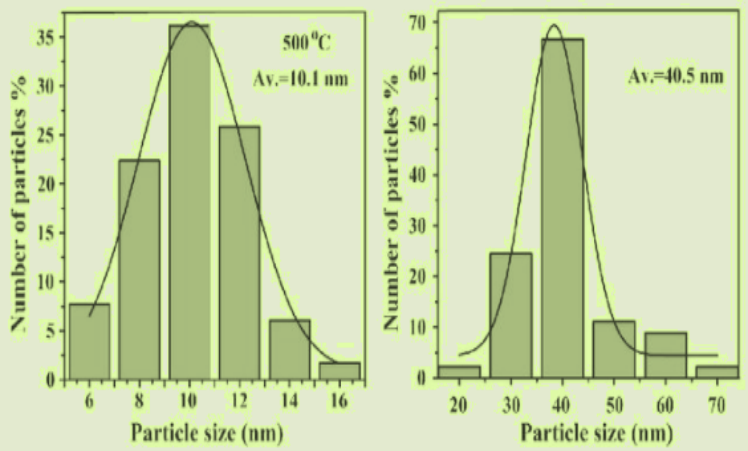


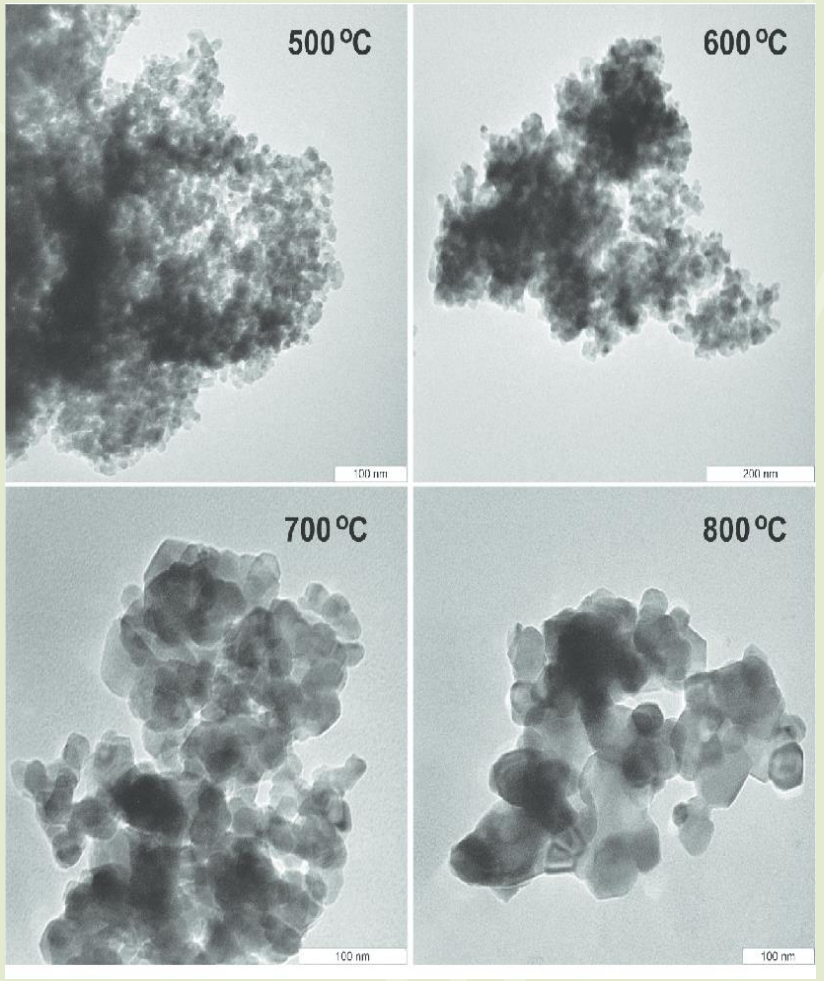


Morphology

- The shape, surface morphology commonly determined by SEM and TEM.

Nanoparticle's characterization





Transmission electron microscopy (TEM) images of TiO2 nanoparticles at different calcination temperatures and the size distribution histogram

Nanoparticle's characterization

Brunauer Emmett Teller (BET)

- Gas adsorption or Nitrogen adsorption.
  - Measure the specific surface area of nanoparticles including pore size distribution.
  - Determine porosity.

Nanoparticle's characterization

Surface Charge

The colloidal stability is analyzed through zeta potential of nanoparticles.

This potential is an indirect measure of the surface charge.

Zeta potential:

The Zeta potential value that ranges from:

±0 - 10 mV shows a highly unstable colloid.
±10 - 20 mV shows relatively stable colloid.
±20 - 30 mV shows moderately stable colloid.
± 30 mV shows highly stable colloid.

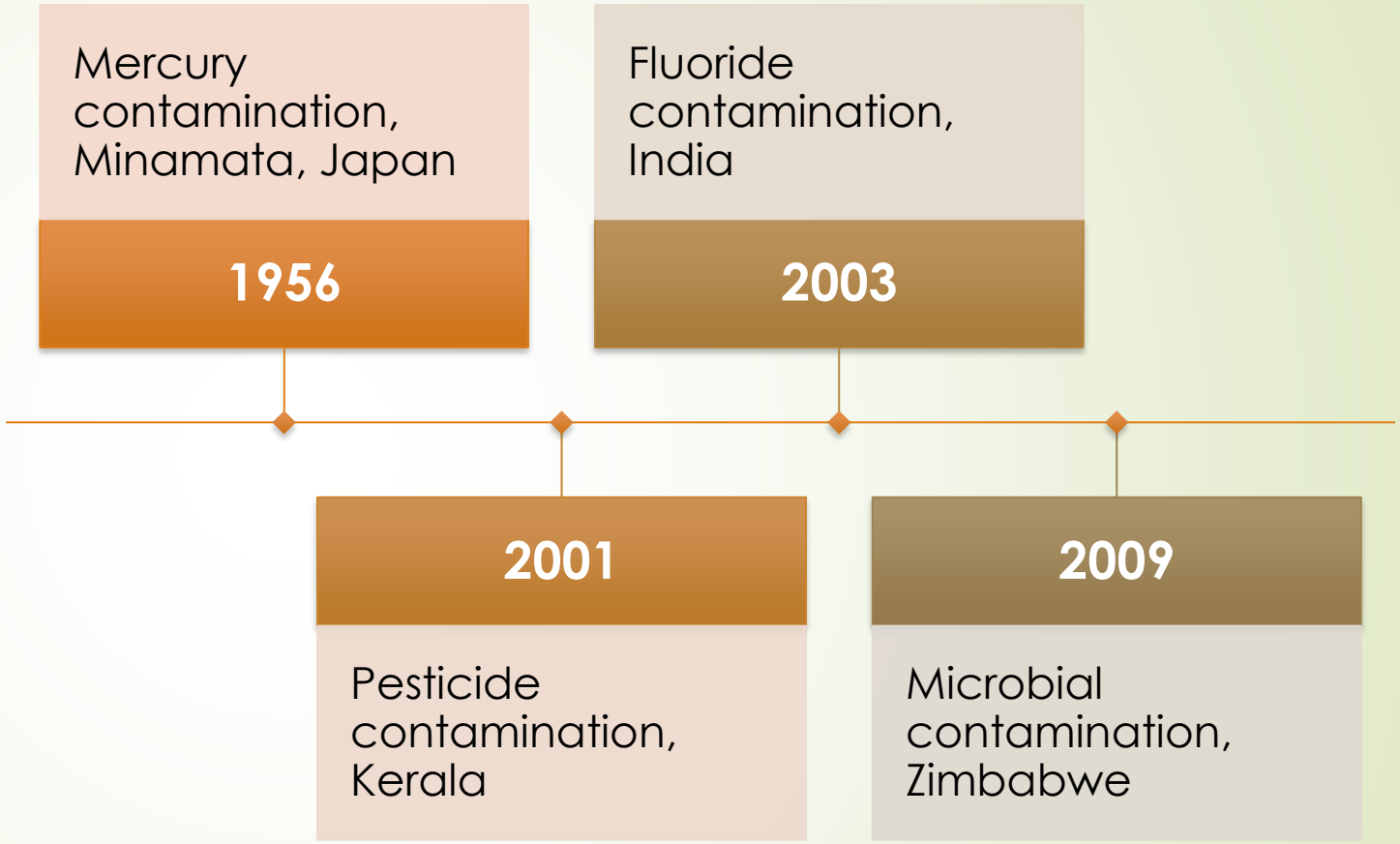
CONVENTIONAL WATER / WASTEWATER TREATMENT METHODS

- Coagulation
- Chlorination
- Flocculation
- Lime softening
- Ozonation
- Membrane separation processes
  - etc ....

Why is research still going on?

- Day to day Change in water /wastewater composition
- Requirement of stable methods
- Requirement of economical methods
- Requirement of effective methods
- Search for reliable methods

UNSOLVED TECHNOLOGY PROBLEMS..



Benefits of using Nanotechnology in Water and Wastewater Treatment

Increased effectiveness

contaminants could be more effectively removed , contaminants that were previously impossible to remove could now be removed, because of the expand specificity of nanotechnology and the advancement of smart filters tailored for utilization.

Simplification

nanotechnology could radically reduce the number of steps , materials and energy required for water treatment , making it simpler to implement widely in rural areas.

Reduced cost

significant introductory investment would be required to incorporate or switch to nanotechnology-based water treatments.

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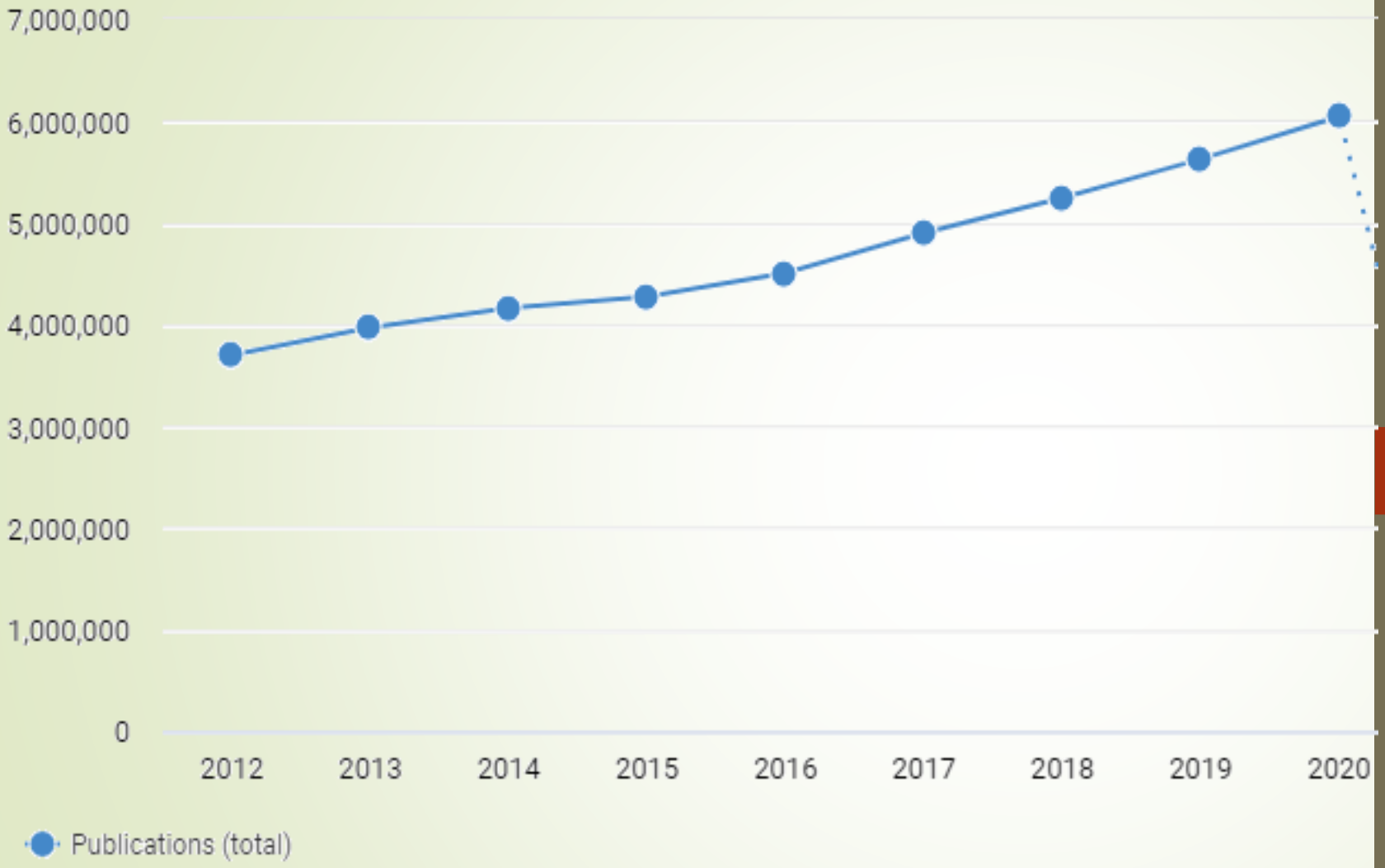
Nanoparticle's Benefits



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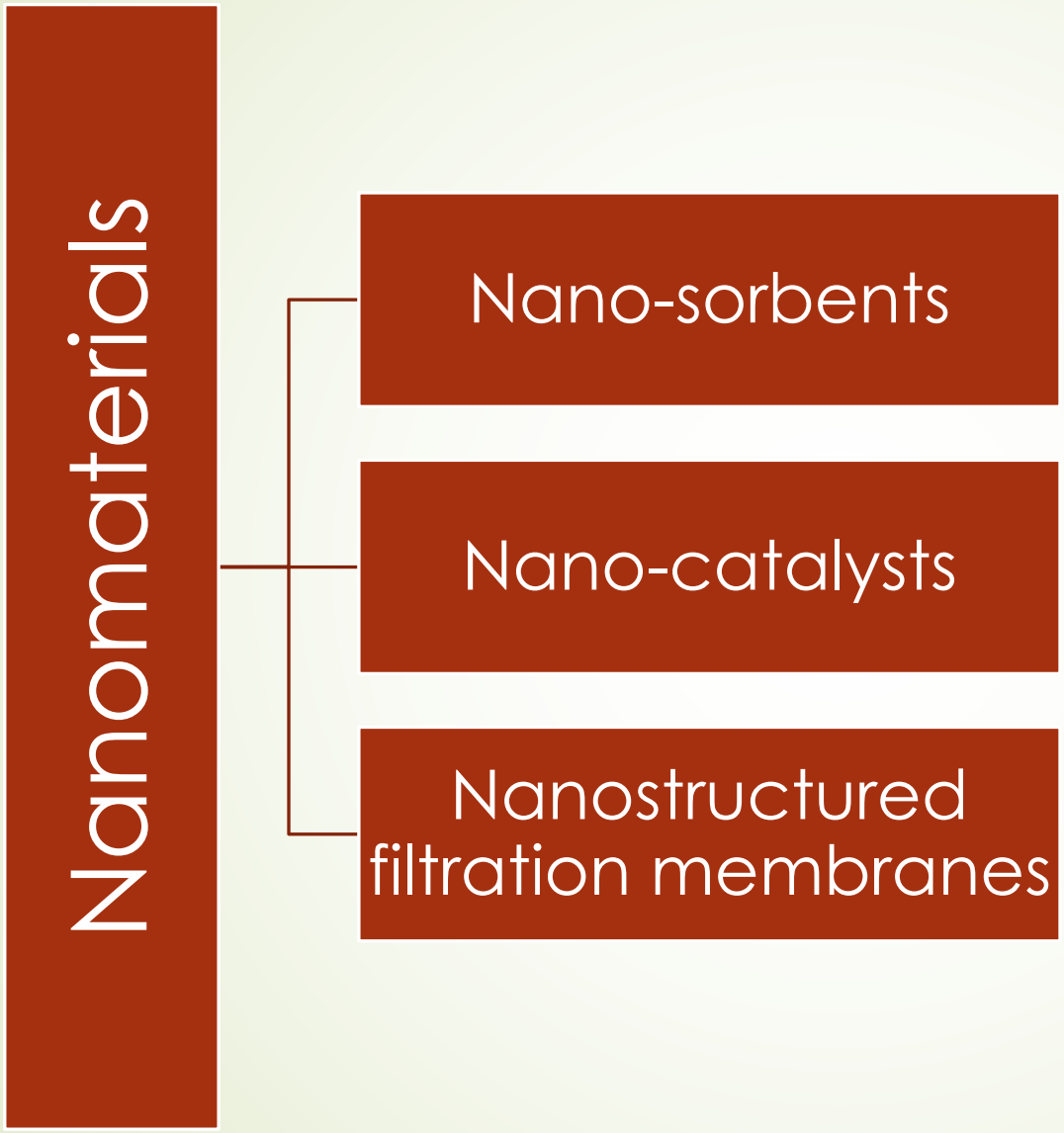
Nanoparticles in Environmental applications researches

Nano-remediation

The use of nanomaterials to remedy environmental hazards can be called "**nano-remediation**". Nanotechnology has reformed almost all fields of science and engineering, and remediation of the environment is no exception.

Nanoparticles (< 100 nm) with a high surface-to-volume ratio have a large reactive surface area compared to bulk materials and play an important role in the remediation of the environment



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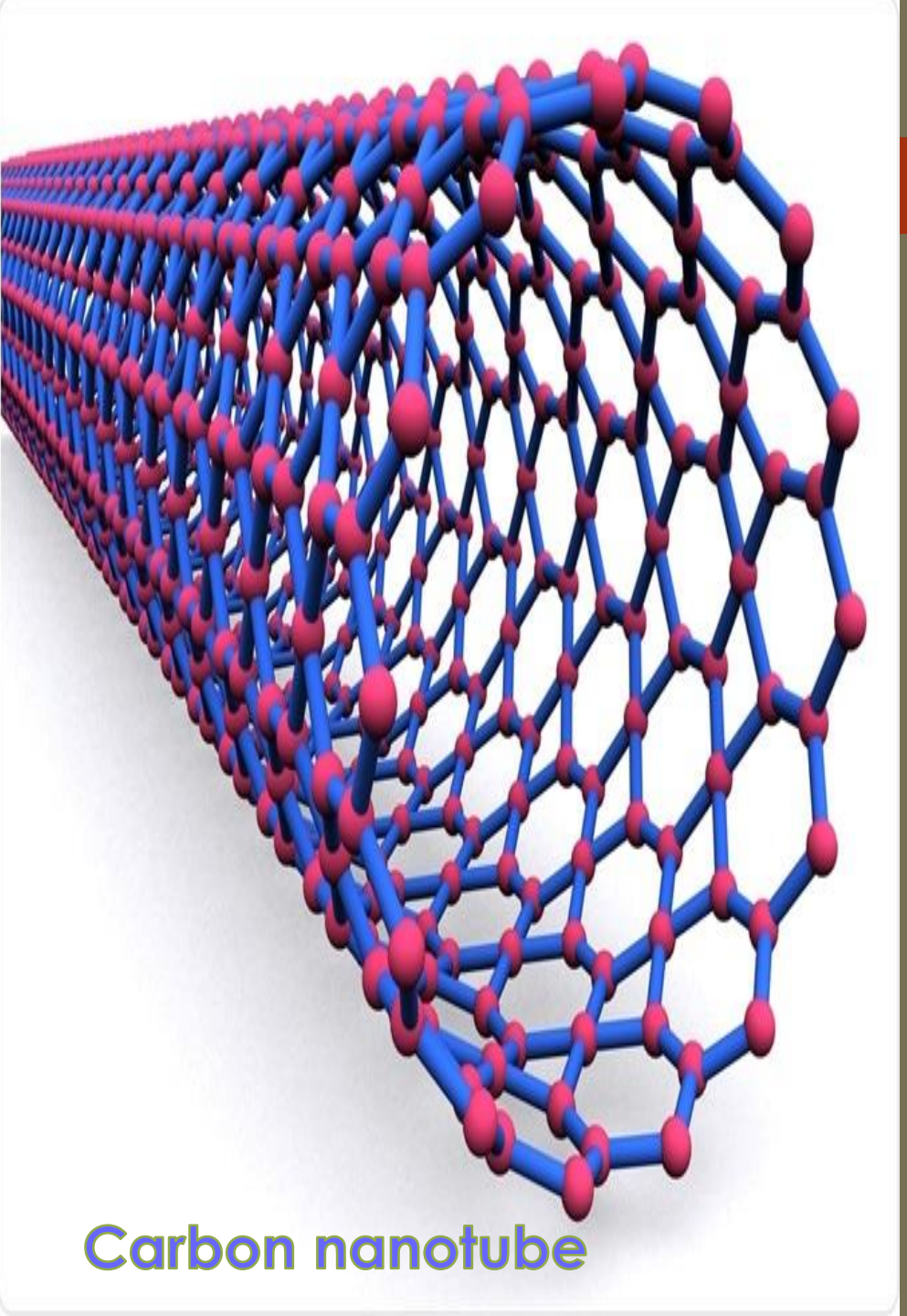
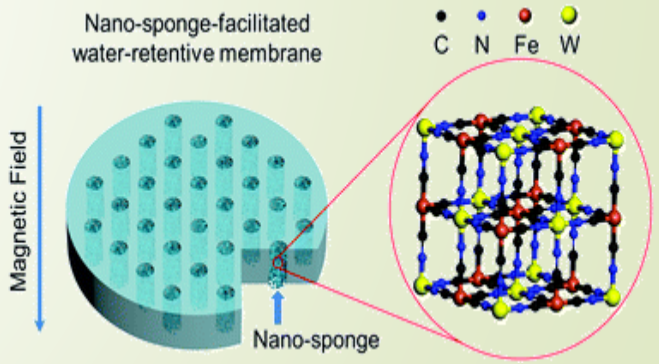
Categories of Nanomaterials utilized for water treatment



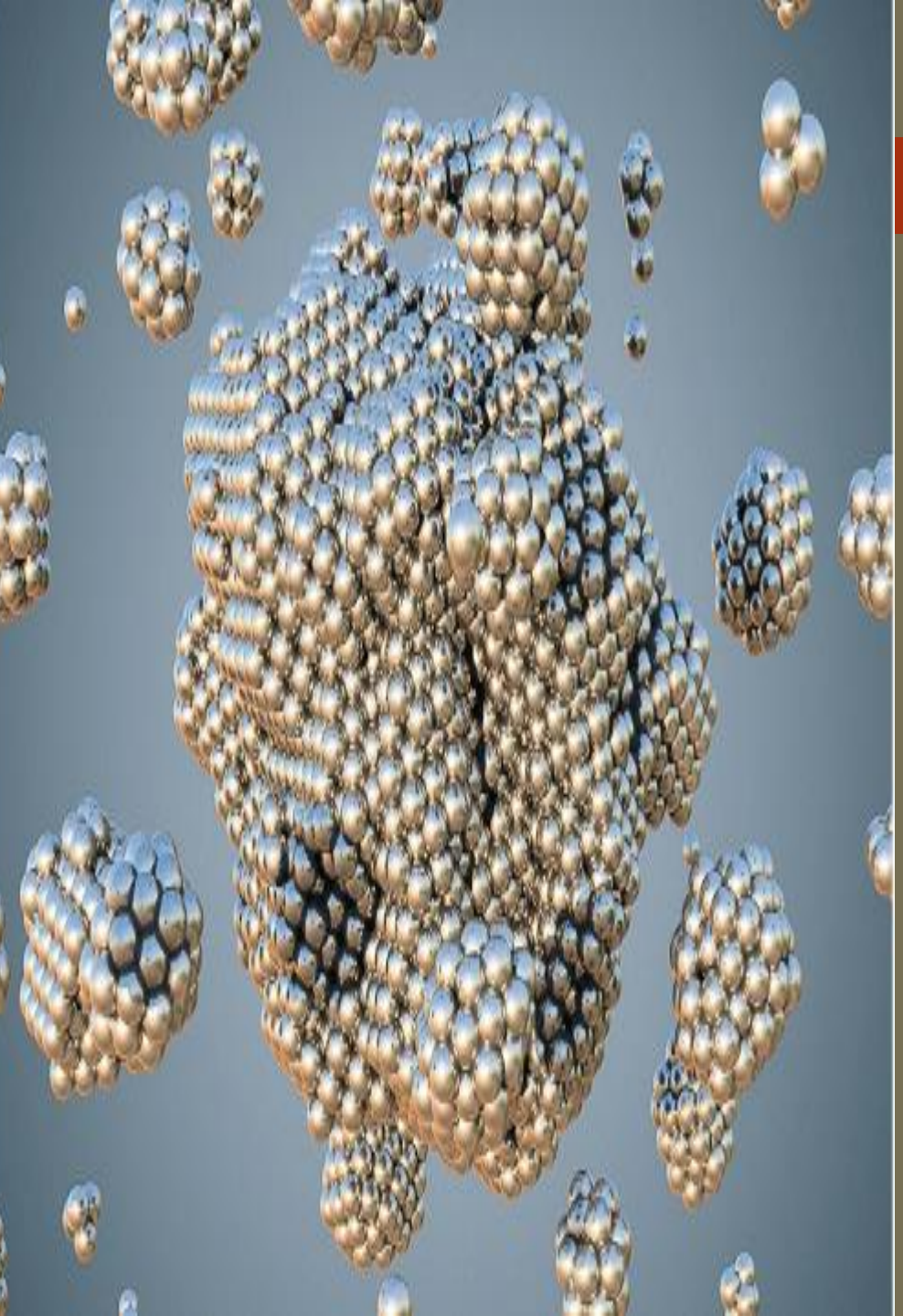
Carbon nanotube

Nano-sorbents

- Nano-sorbents are nanosized particles onto which some inorganic and organic molecules could be absorbed.
- Several nano have been synthesized tested for their application in water treatment.
- Examples:
  - Carbon nanotubes,
  - Metal nanoparticles,
  - Nano-sponges
  - Zeolites

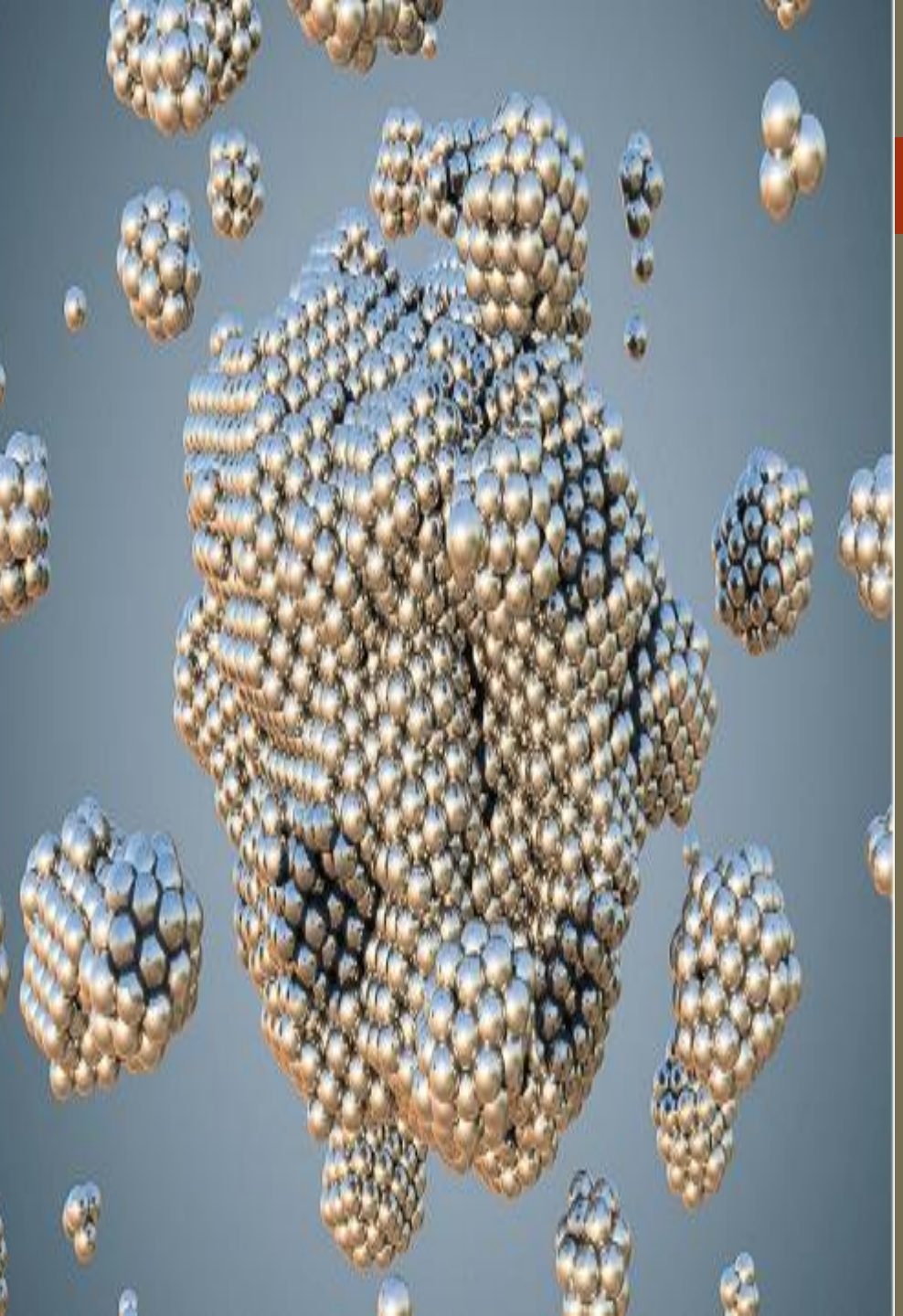


Nano-sorbents



Nano-catalysts

- These are mostly zero- valent metallic nanoparticles that have solid catalytic properties.
- These nano-catalysts can also be bimetallic to enhance the catalytic properties.
- Nano-catalysts catalyze basically the reduction of metal ions in solution and can catalyze de-chlorination of chlorinated organic pollutants.



Nano-catalysts characteristics

Nano-catalysts

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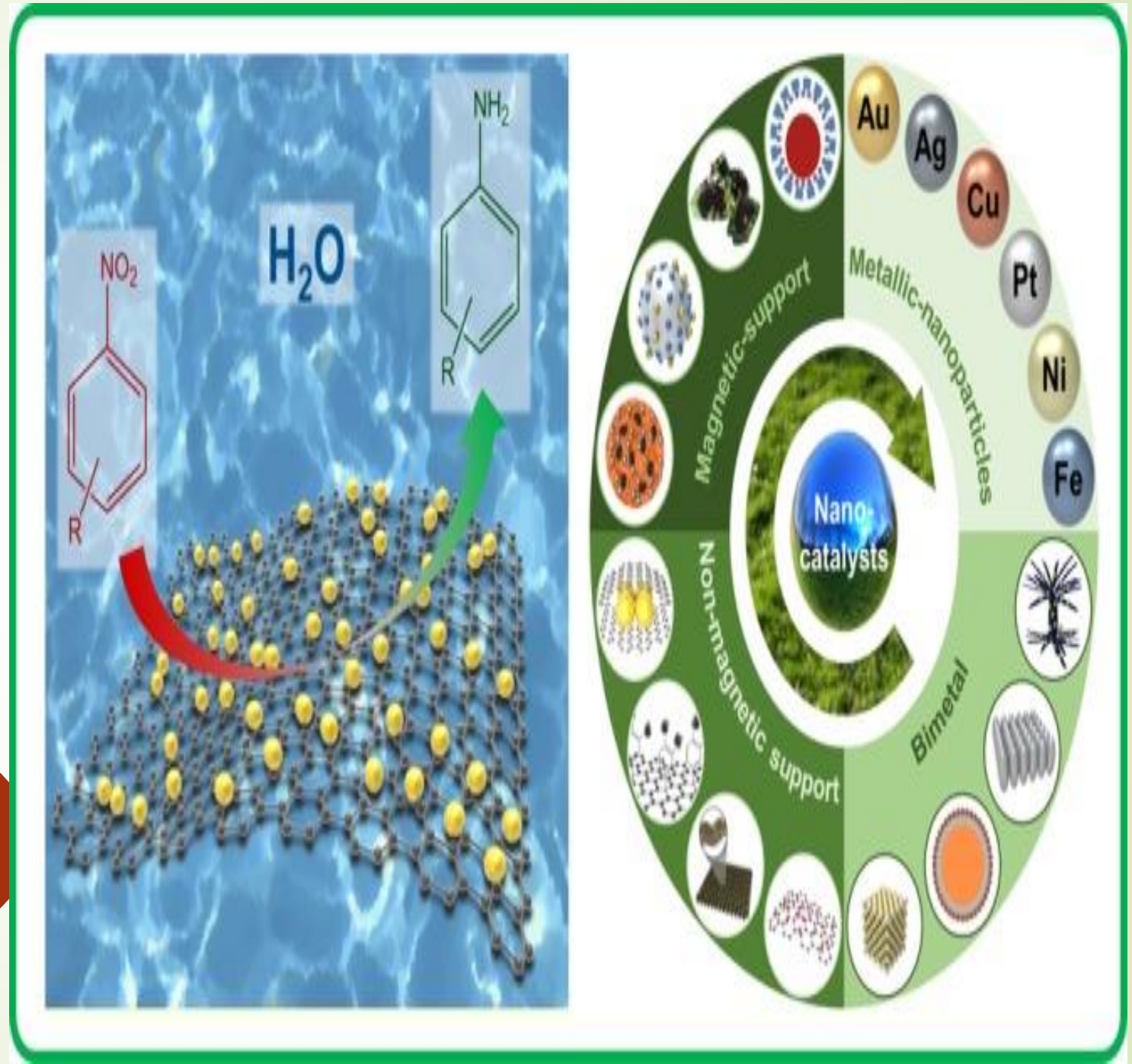
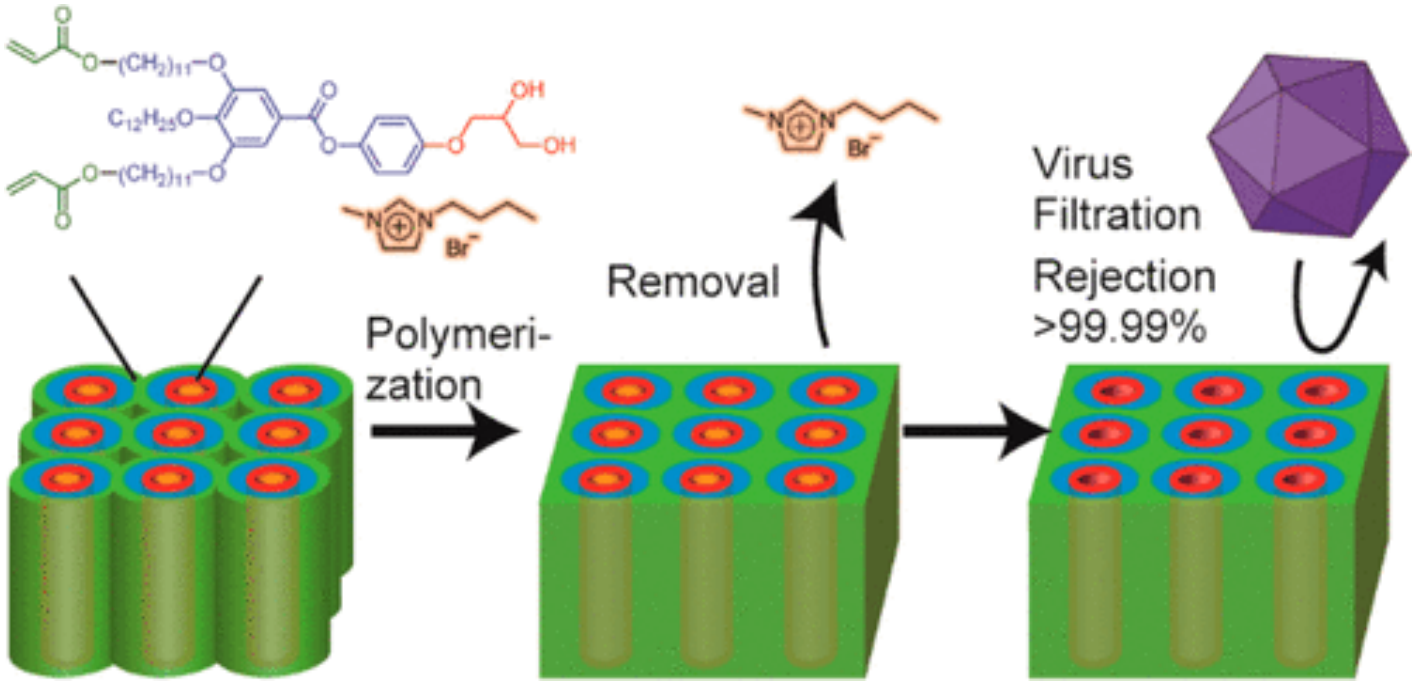
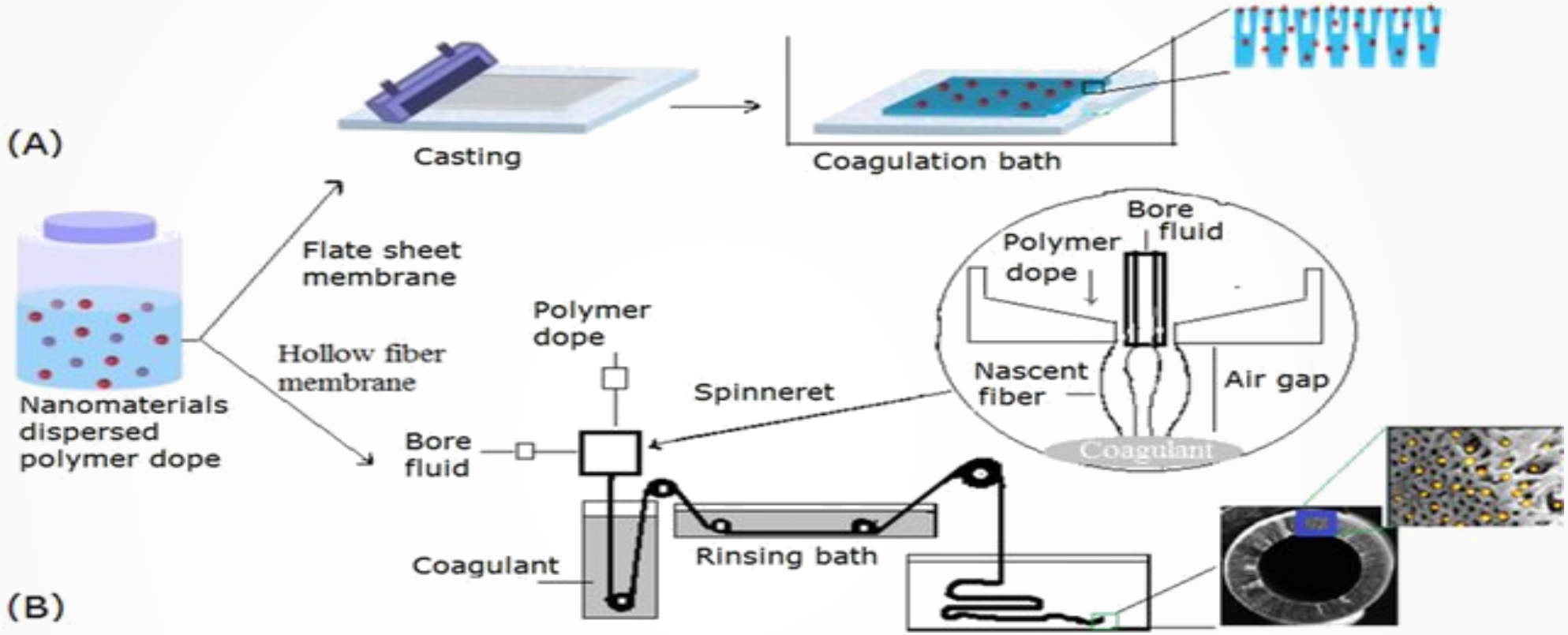


Nanostructured filtration membranes

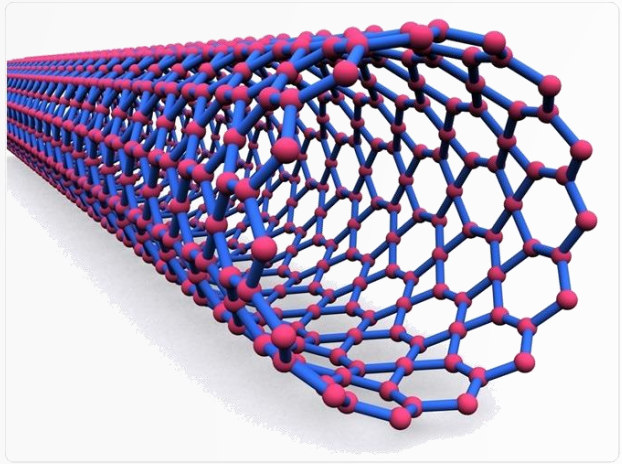
- nanostructures filtration membranes are polymeric permeable membranes that have nanosized pores.





Nanostructured filtration membranes fabrication

Examples of applications in Environmental applications



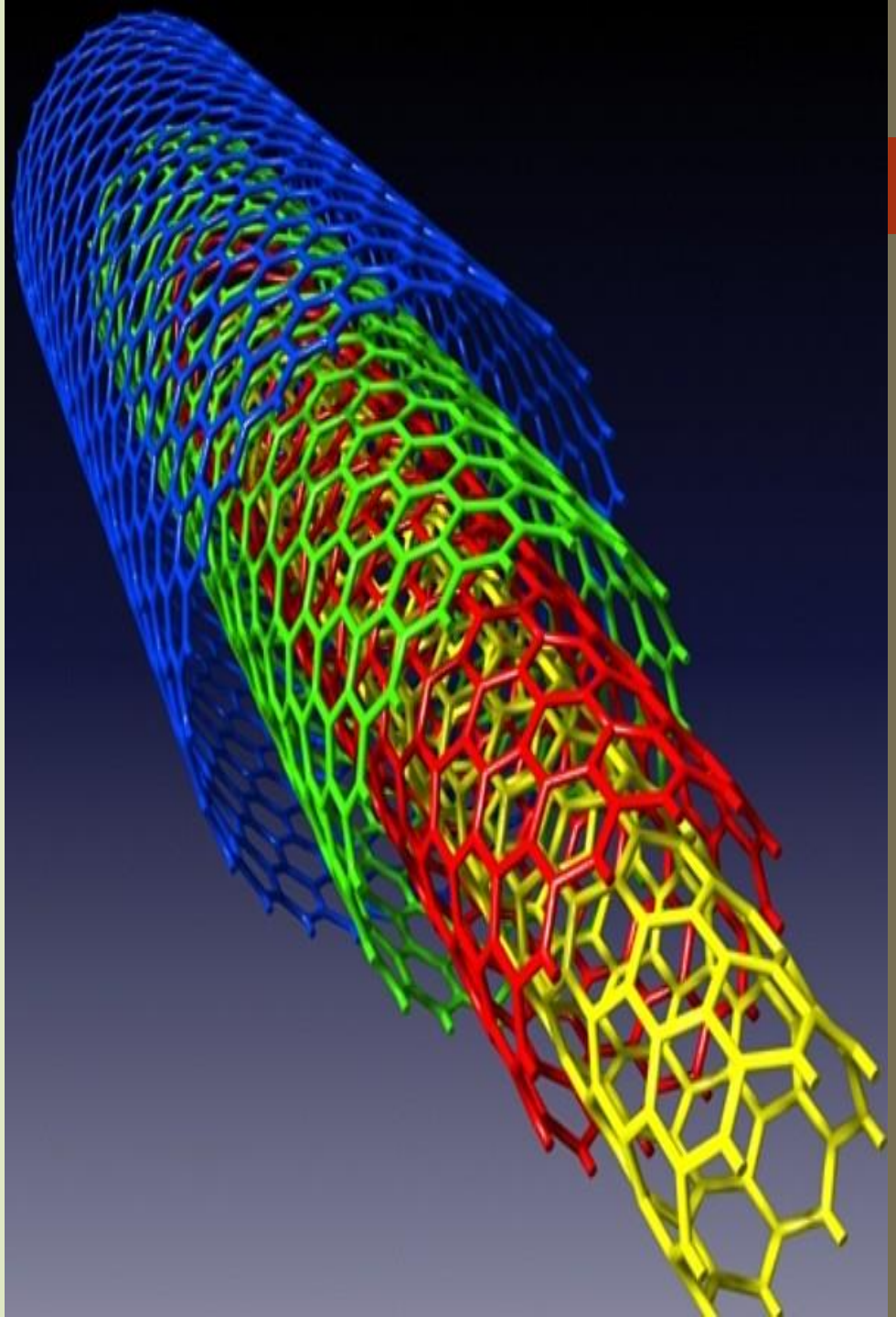
Carbon Nanotubes

The unique properties of Carbon Nano

- **High strength**
- **Resistance to acidic and basic media**
- **High surface area**
- **Good thermal, electrical, and conductive properties**
- **Novel structure with extra -ordinary properties.**

The CNTs consist of very thin honeycomb structures of graphene sheets rolled up in **cylindrical** shape with **a few nanometer diameter** and many micron or even centimeters length.

- **Single walled CNTs (SWCNTs)**
- **Multi-walled CNTs (MWCNTs)** distinguished by the layer's numbers.



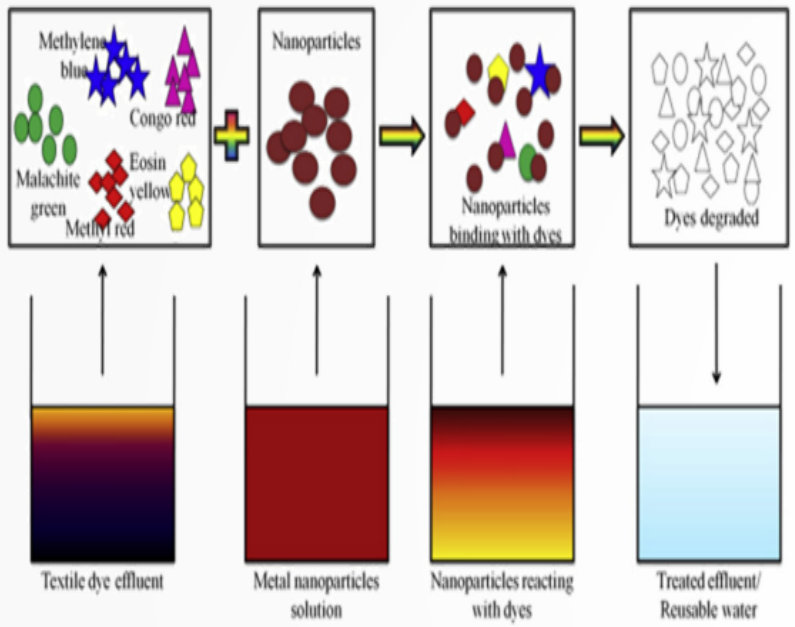
Examples of CNTs applications

- Various organic pollutants adsorption.
- Heavy metals adsorption.
- Control microbial pathogens.
- They are not strong oxidants and relatively inert in water resulting in avoiding the formation of carcogenic disinfection byproducts (DBPs).

Other applications

- DYES DEGRADATION
- MERCURY DETECTORS
- NITRATE, AND PHOSPHATE REMOVAL
- HEAVY METALS REMOVAL
- ANTIMICROBIAL

Examples of applications - DYES DEGRADATION



- The dyes, in most cases based on organic compounds with AZO bond (R–N=N–R′) that flow discharging into canals and rivers and other water bodies.
- Using the enhanced photocatalytic property of metal nanoparticles, these dyes could be degraded before exposure to the atmosphere.
- Nano-silver compounds achieved around 75% dye degradation in the presence of solar exposure after 8 hours as contact time.

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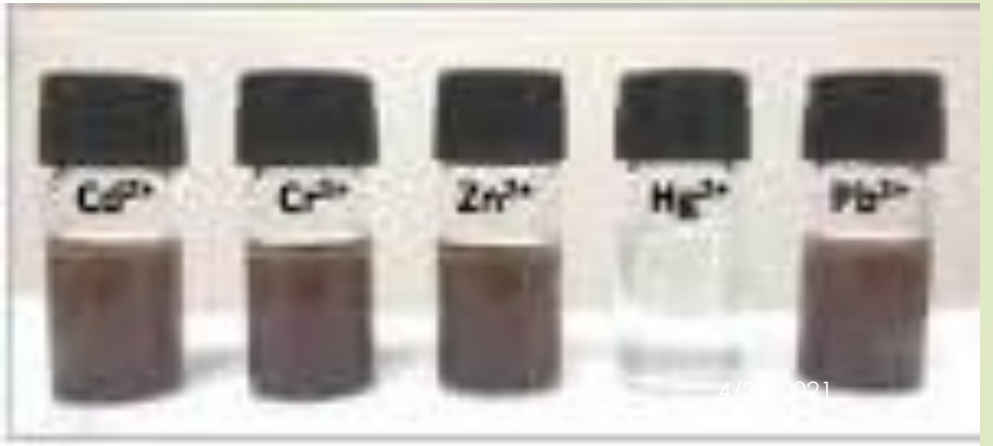
Dyes Degradation

Examples of applications - silver nanoparticles as mercury detector

- During 2015 silver nanoparticles was used as green synthesized suspension for colorimetric detection of Hg^{2+} . The dark brown suspension of nano silver was only decolorizing by Hg^{2+} contrariwise Cd^{2+}, Pb^{2+}, Zn^{2+} , Cr^{3+} not affect the color of the dark brown suspension of nano silver.



Examples of applications - NITRATE, AND PHOSPHATE REMOVAL

NITRATE, AND PHOSPHATE REMOVAL

Nano-composite was prepared from chitosan and Fe_3O_4/ZrO_2 under mild conditions.

The nanocomposite had the ability to adsorb both nitrate and phosphate.

The maximum adsorption process fitted well to the pseudo-first-order kinetic rate model, and the mechanism involved simultaneous adsorption and intraparticle diffusion.

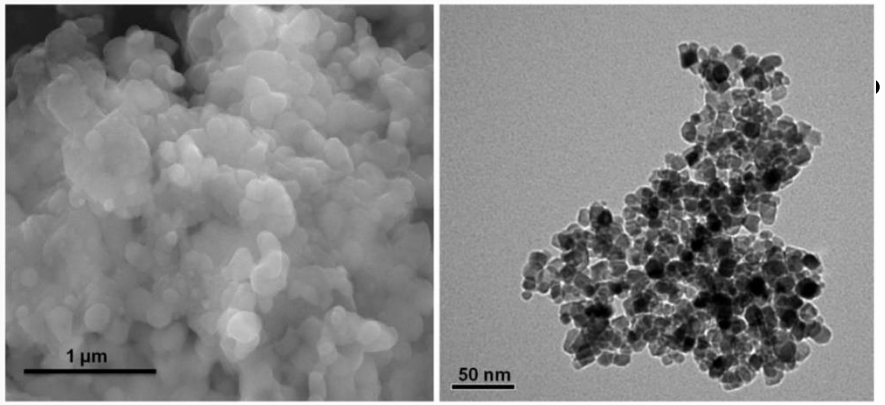
Examples of applications - HEAVY METALS REMOVAL

➨HEAVY METALS REMOVAL

- The commonly used nanoparticles for the wastewater treatment are made of alumina, cadmium sulfide, cobalt ferrite, copper oxide, gold, iron, iron oxide, iron hydroxide, nickel oxide, silica, titanium oxide, zinc oxide, zinc sulfide, zirconia, and some alloys.

- Most notably, ZnO hollow nanospheres and ZnO nanoplates showed complete removal of Cu(II) in binary compound solutions.

Examples of applications - HEAVY METALS REMOVAL



- A novel adsorbent, titanium dioxide nanowire (TiO_2), is prepared using hydrothermal methods and subsequently used for the removal of heavy metals.
- Some studies were tested the potential of using the TiO_2 nanowire to remove residues of heavy metals such as (Pb^{2+}, Cu^{2+}, Fe^{3+}, Cd^{2+}, and Zn^{2+}) from contaminated water.
- Due to its magnetic nature, TiO_2 nanowire is an exceptional adsorbent material. The highest efficiency of absorption was 97.06 % with Pb^{2+}

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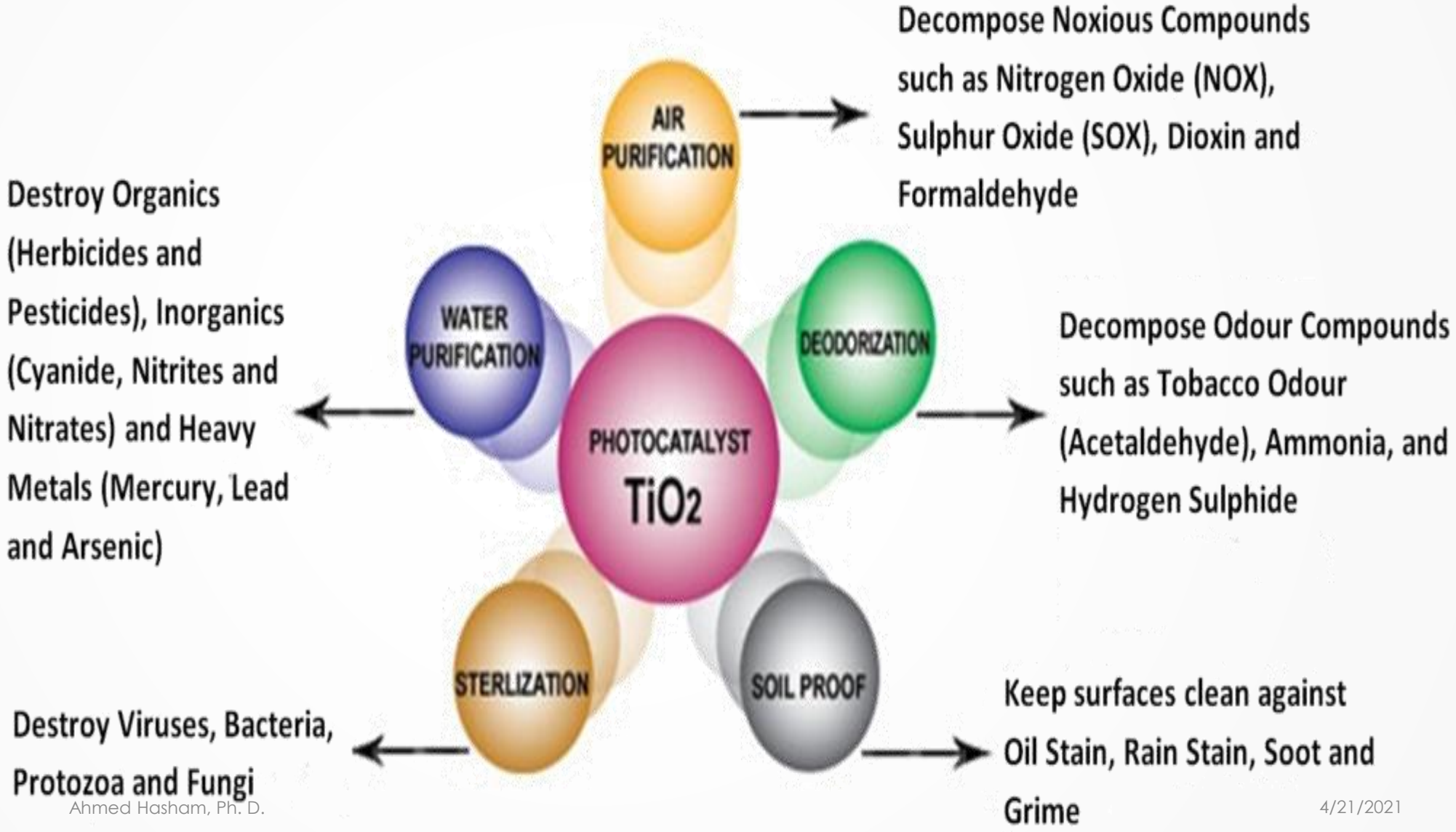
HEAVY METALS REMOVAL

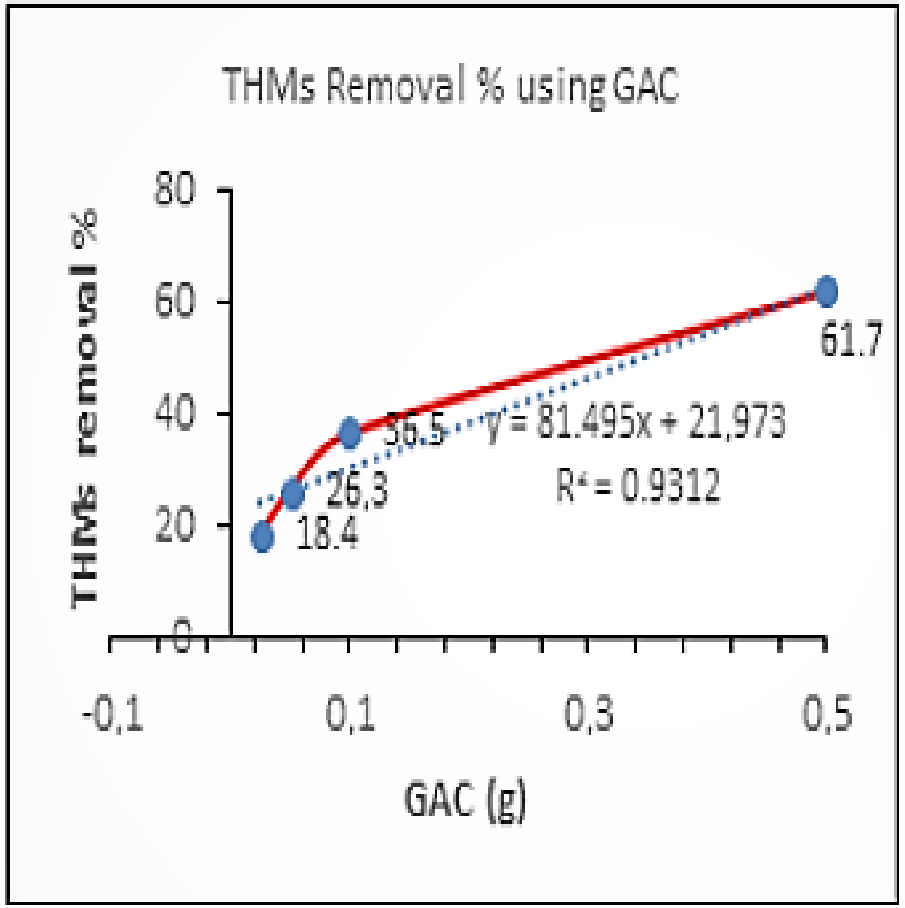
Examples of applications – TiO_2 Nanoparticles

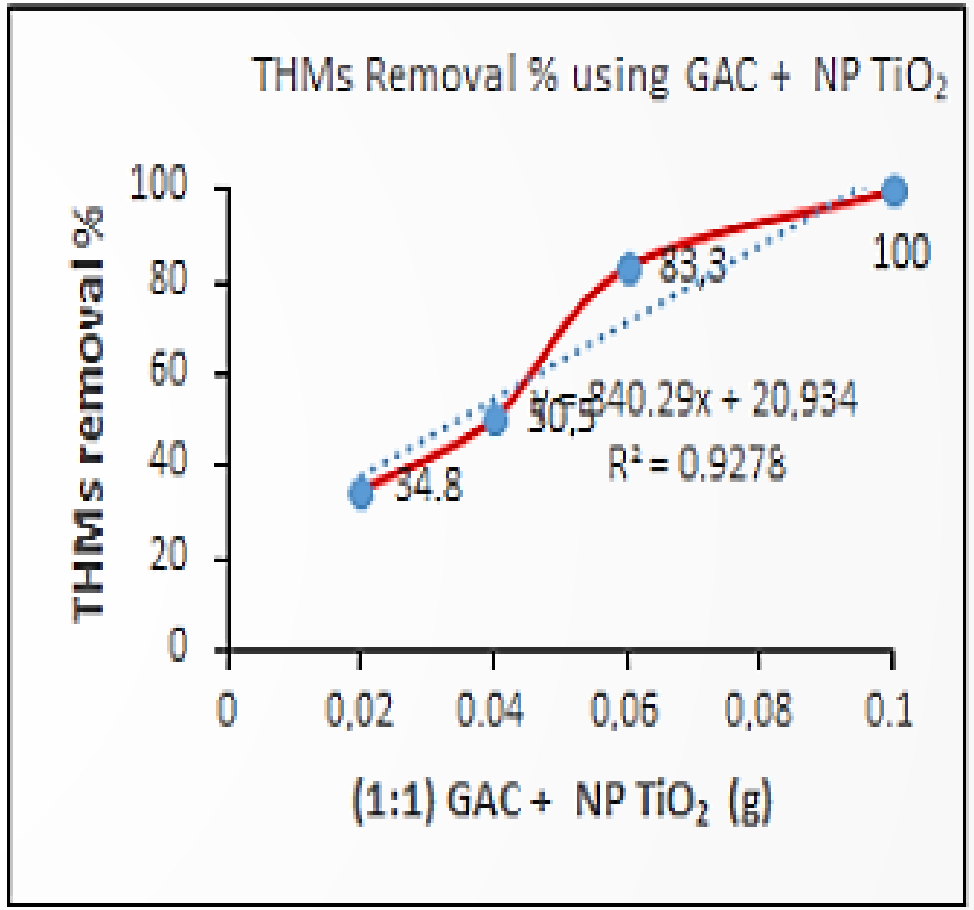
TiO_2 Nanoparticles



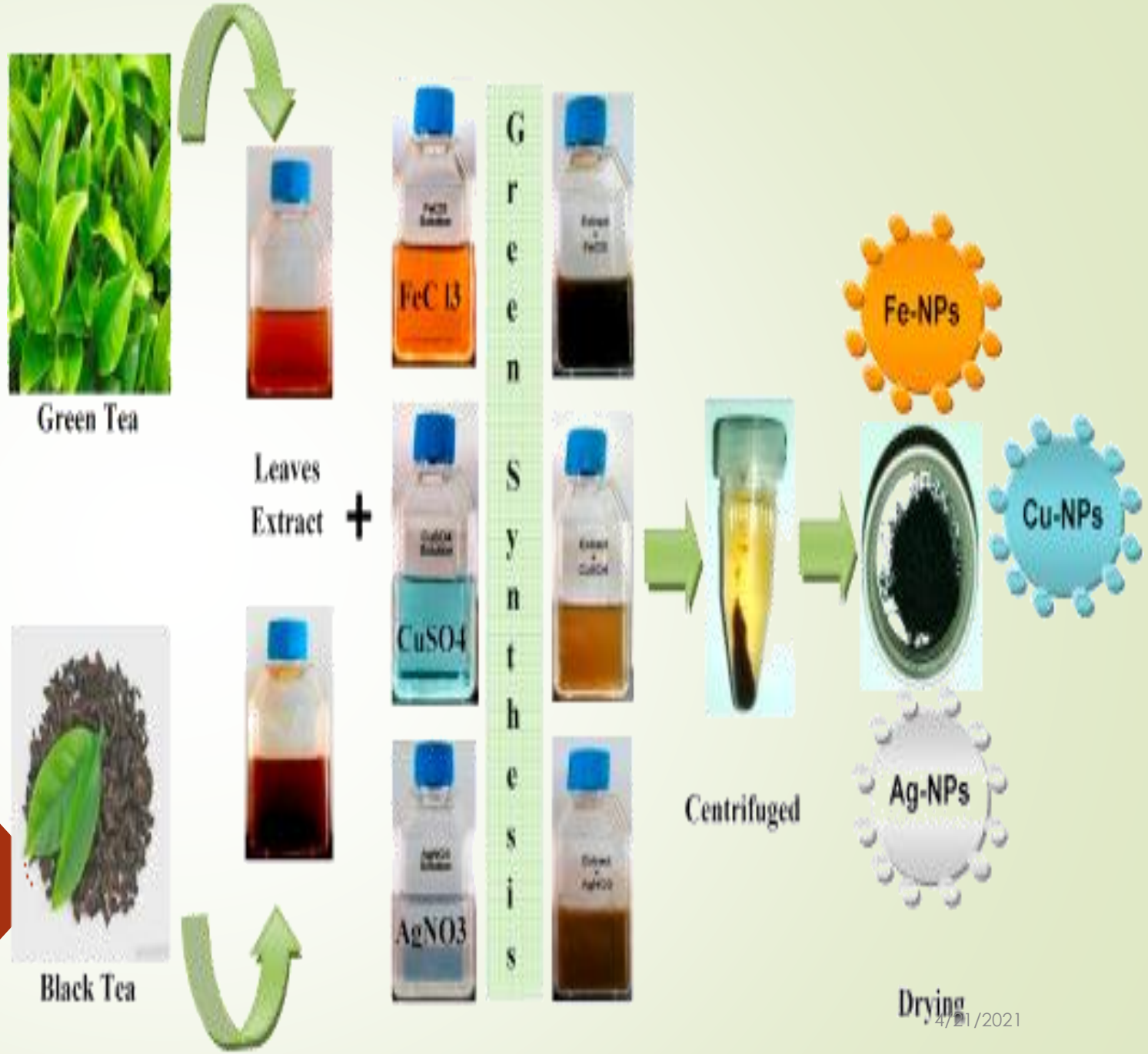
Examples of applications – DBPs Removal

DBPs Removal Using TiO_2 nanoparticles

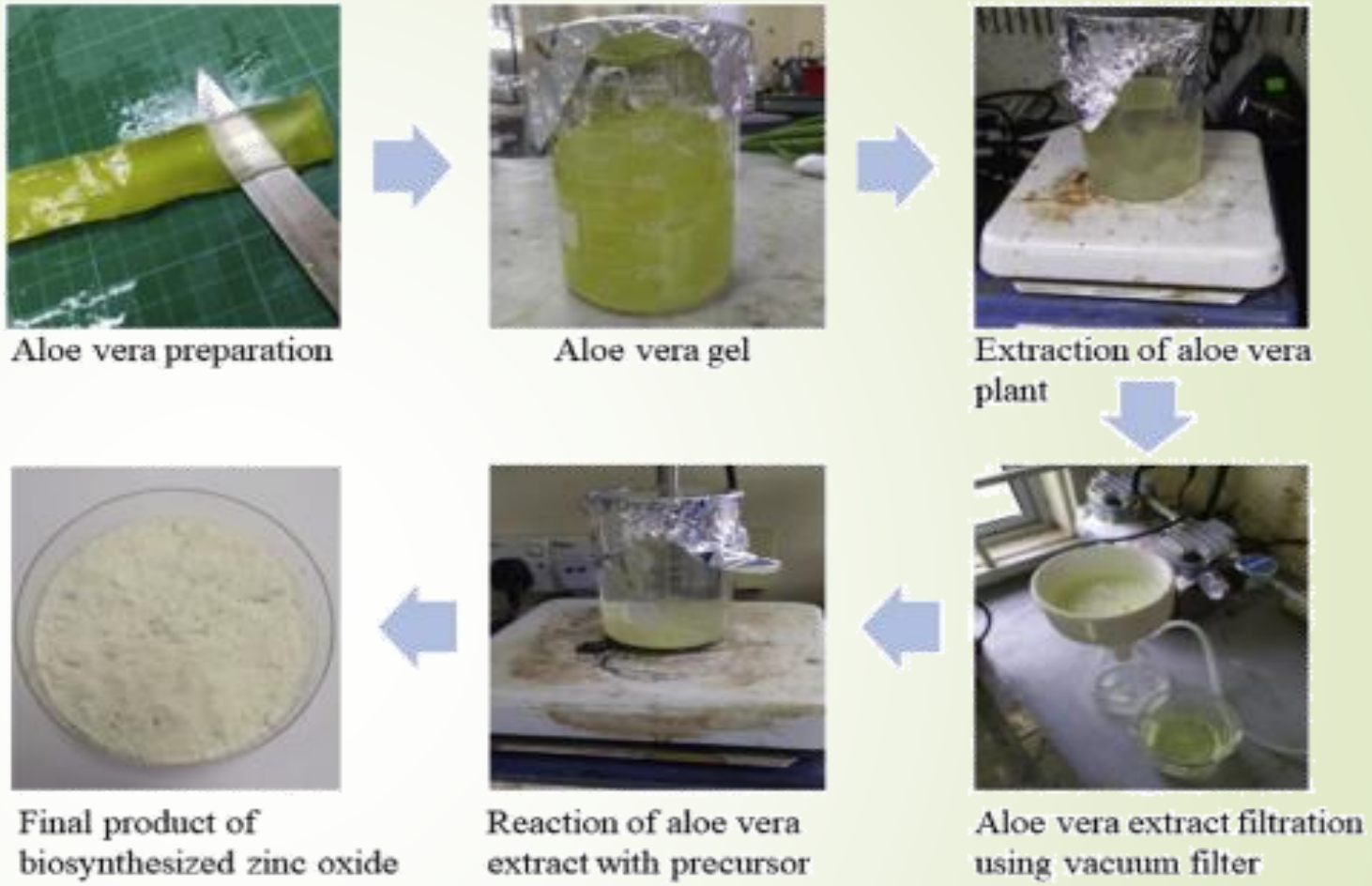




Easy green synthesis for Nanoparticles



Easy green synthesis for ZnO Nanoparticles



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7- https://www.mdpi.com/2079-4991/10/4/766/htm
8- https://jnanobiotechnology.biomedcentral.com/articles/10.1186/s12951-018-0408-4
9- https://www.sciencedirect.com/topics/engineering/green-synthesis

Articles & Software

Handbook

Nanomaterials and Nanocomposites: Synthesis, Properties, Characterization Techniques, and Applications

Green Metal Nanoparticles: Synthesis, Characterization and their Applications

ImageJ Software:

https://imagej.nih.gov/ij/download.html

Thanks for listening