Nanoparticles in the Environment; Tiny Size, Large Consequence
WHAT IS IT?

- The manufacture of extremely small particles (atomic particle size) for uses in medicine, cosmetics, agriculture, electronics, etc.
- **Nano** – Greek word for dwarf
- **Nanotechnology** deals with particles the order of a nanometer in size
- 1 nanometer = 1 billionth of a meter or 0.0000000001 meter
- A human hair is between 17,000 and 180,000 nanometers
History of Nanoparticles

Although nanoparticles are associated with modern science, they were used by artisans as far back as the ninth century in Mesopotamia for creating a glittering effect on the surface of pots.

1959 – Richard Feynman – “There’s Plenty of Room at the Bottom” Feynman had described a process by which the ability to manipulate individual atoms and molecules might be developed, using one set of precise tools to build and operate another proportionally smaller set, so on down to the needed scale.

1985 – Carbon Fullerene accidently discovered by Harry Kroto, Richard Smalley, and Robert Curl, who together won the 1996 Nobel Prize in Chemistry. These are carbon rich grains expelled by old stars such as R Corona Borealis. The result of this collaboration was the discovery of C_{60} and the fullerenes as the third allotropic form of carbon. Subsequent discoveries included the endohedral fullerenes, and the larger family of fullerenes the following year.

Fullerenes were named after the architect, Richard Buckminster Fuller. Spherical shapes are called Buckyballs.
Types of Nanoparticles

- Lipids Based NPs (Cubosomes, Liposomes, etc.)
- Metallic NP's
- Carbon Nanotubes
- Polymeric nanocarriers
- Polymer Micelles
- Dendrimers
Surface Area to Volume Ratio

- Carbon nanoparticles have a HUGE surface area and a very tiny volume
- Materials can be developed from the bottom up or top down
- The higher the SA:V; the stronger, more stable and durable the nanomaterial
- Materials may change optical, physical, chemical, biological, or electrical properties at the nanoscale level.
Materials obey different laws of physics as they approach the atomic scale

- Gold changes color in the nanoscale
- Zinc Oxide appears clear
- Boiling temperatures change
- Gravitational forces become negligible
- Electromagnetic forces become dominant
Nanoscale properties

- Makes material stronger, more durable
- Makes chemical and biological reactions easier
- Can attach enzymes, metal ions, etc., to nanomaterials for more effective use and delivery
Small size is ideal for medicine

- Red blood cells are 7,000 nm
- Good candidate for cancer detection
- May be used for drug delivery
Applications Of Nanotechnology

Applications of nanotechnology in the different field can be summarized as follows:-

1- **Nanomedicines**: Drug delivery, medical devices, tissue engineering.
2- **Chemicals and cosmetics**: Nano-scale chemicals and compounds, paints & coating.
3- **Environment and energy**: water and air purification filters, fuel cells & photovoltaics.
4- **Scientific tools**: microscopes and scanning tunneling microscope.
EVERYDAY USES OF NANOTECHNOLOGY

National Nanotechnology Day (Oct. 9) is a yearly event in the U.S. to celebrate the tiny tech. Here, we take a look at various consumer products that utilize nanotechnology and the chemistry behind them.

**WHAT IS NANOTECHNOLOGY?**

- **SALT GRAIN**: 100,000 nm
- **NANOPARTICLES**: 1-100 nm

Nanotechnology involves the applications of nanoparticles, which are collections of atoms or molecules less than 100 nm across. Because of their small size, the particles have properties that can differ from those of larger amounts of the same material.

**ANTIMICROBIAL USES**

- **Damage Cell Wall**
- **Inhibit Protein Replication**
- **Cause Cell Death**

Products such as bandages, soaps, and surgical implements use silver nanoparticles for their antimicrobial effects. However, the particles’ effectiveness in some applications has been questioned, and the materials may cause environmental problems.

**SUNSCREENS**

- **ZnO**: Blocks UV-A, UV-B
- **TiO₂**: Blocks UV-A, UV-B

Many sunscreens contain titanium dioxide and/or zinc oxide nanoparticles because the materials can absorb UV radiation. Titanium dioxide also finds use in some foodstuffs as a whitening agent.

**CLOTHES**

- **Silver**: Antimicrobial
- **Silica**: Water-repellent
- **TiO₂/ZnO**: UV-absorbing
- **Antimony-doped Sb:O³⁻**: Antistatic

UV-absorbing titanium oxide and zinc oxide nanoparticles can be incorporated into clothes to prevent sunburn and sometimes to act as antistatic agents. Silicon dioxide nanoparticles can prevent stains and help clothing repel water.

**SPORTS EQUIPMENT**

- **Carbon Nanotubes**
  - 100 TIMES AS STRONG AS STEEL
  - ONE-SIXTH THE WEIGHT OF STEEL
  - AS STIFF AS DIAMOND

Sports equipment such as tennis rackets and bicycles are sometimes built using nanomaterials including carbon nanotubes. The nanotubes improve strength and durability and decrease weight. Titanium nanoparticles can also be used.

**QUANTUM DOTS**

- **Cadmium Selenide**: Zinc Sulfide
- **Various Ligands**: Increasing Particle Size

Quantum dots, which are nanoparticles of semiconductors such as cadmium selenide, absorb light of one color, such as blue light, and emit it as another depending on particle size. The particles are more energy-efficient than light-emitting diodes.

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Future Uses

- Self-assembling/robotic materials
- Computers billions of times faster
- Space Travel
- Medical
- Food syntheses
More than 1,200 companies, universities, government laboratories, and other organizations across all 50 U.S. states and in the District of Columbia that are involved in nanotechnology research, development, and commercialization. This number is up 50 percent from the 800 organizations identified just two years ago.
Uses in the Environment

- Water Filtration
- Disinfection
- Water/Soil Remediation
- Energy Efficiencies
Nanoparticles Adverse Impacts

- Nanoparticles may be more toxic than micron-sized particles
- Nanoparticles may translocate to other organs in the body
- Nanoparticle may enter the brain through inhalation through nasal neurons
- Toxicity to cells may be modified to reduced by coating the particles
- Buckyballs may cause cellular damage in young fish (largemouth bass)
- Copper nanoparticles can cause gill injury and acute toxicity on aquatic biota
- Test show that nanoparticles can damage human DNA increasing cancer risks
How Nanoparticles get in the Environment

**Auto Traffic**
- Palladium and Platinum NPs (catalytic converter)
- Battery waste (electric cars)
- Fine carbon particles (exhaust, tire wear)

**Combustion**
- Soot/carbon black
- Fly ash
- Fullerenes/carbon nanotubes

**Mining**
- Fine metal and metal oxide particles

**Energy Generation**
- Quantum dots (solar cells)
- Metal oxides (solar cells, batteries)

**Laundry**
- Silver NPs (antibacterial fabrics)
- Metal oxide NPs (UV-proof fabrics)

**Medicine**
- Silver NPs (antibacterials)
- Gold NPs (therapeutics)
Nanoparticle Exposure

DISEASES ASSOCIATED TO NANO PARTICLE EXPOSURE

- Neurological diseases: Parkinson's disease, Alzheimer's disease
- Asthma
- Bronchitis
- Emphysema
- Cancer
- Atherosclerosis
- Vasoconstriction
- Thrombus
- High blood pressure
- Arrhythmia
- Heart disease
- Death
- Diseases of unknown etiology in kidneys, liver
- Podoconiosis
- Kaposi's sarcoma
- Autoimmune diseases dermatitis

Exposure → Model System → Mechanism? (including uptake/association/proximity) → Viability? → Changes Cell Function?

- Yes → Non-Toxic
- No → Toxic
Impacts of Silver Nanoparticles on Wastewater Treatment

- **Silver nanoparticle** aka AgNP or nanosilver - excellent antimicrobial agent in many consumer products.
- Includes fiber coatings, detergents, plastics to prevent bacterial and fungal growth.
- Nanosilver released enters the wastewater treatment plant via laundry and other washing activities.
- Tests show that at a concentration of 0.4 mg/l of Ag mixed with AgNP inhibited the growth of nitrifying bacteria in wastewater activated sludge process.
- Study suggests that accumulation of silver in activated sludge could have a detrimental effect on ammonia removal in the wastewater treatment plant process if silver concentration exceeds a threshold value of 0.1 mg/L.
It’s everywhere – application of Nanosilver
Nanotechnology Needs

- Responsible development of nanotechnology methods
- Developing a sound EHS Research Strategy and Monitoring Program
THE TRUE SIGN OF INTELLIGENCE IS NOT KNOWLEDGE BUT IMAGINATION.

Albert Einstein
German Theoretical-Physicist
(1879-1955)

In thinking about nanotechnology today, what's most important is understanding where it leads, what nanotechnology will look like after we reach the assembler breakthrough.

K. Eric Drexler
American Scientist