# NANOTECHNOLOGY: AN EMERGING AND PROMISING TECHNOLOGY FOR WASTEWATER TREATMENT

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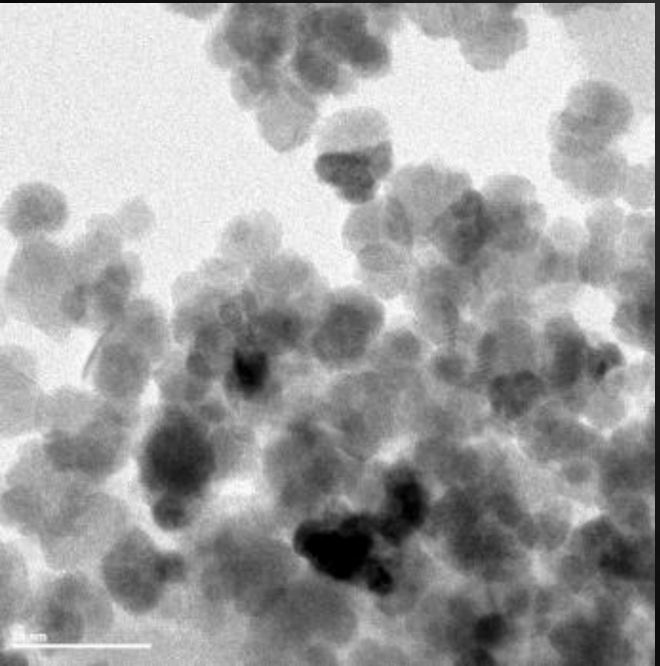

WATER ARABIA, 2015

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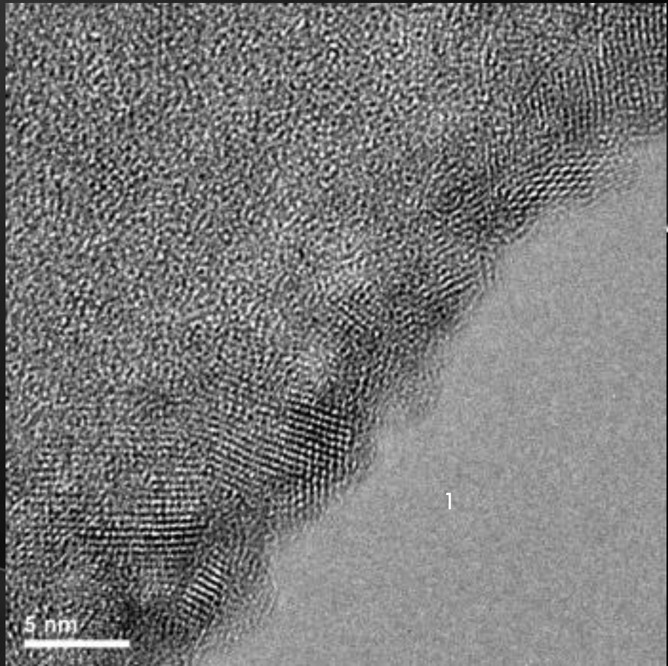
Le Meridien, Khober, KSA



# Outline

- Why nanotechnology (NT)?
- NT for wastewater in the context of Kingdom
- Nano for different treatments
- Applications:

--- Industrial dye degradation by $TiO_2$

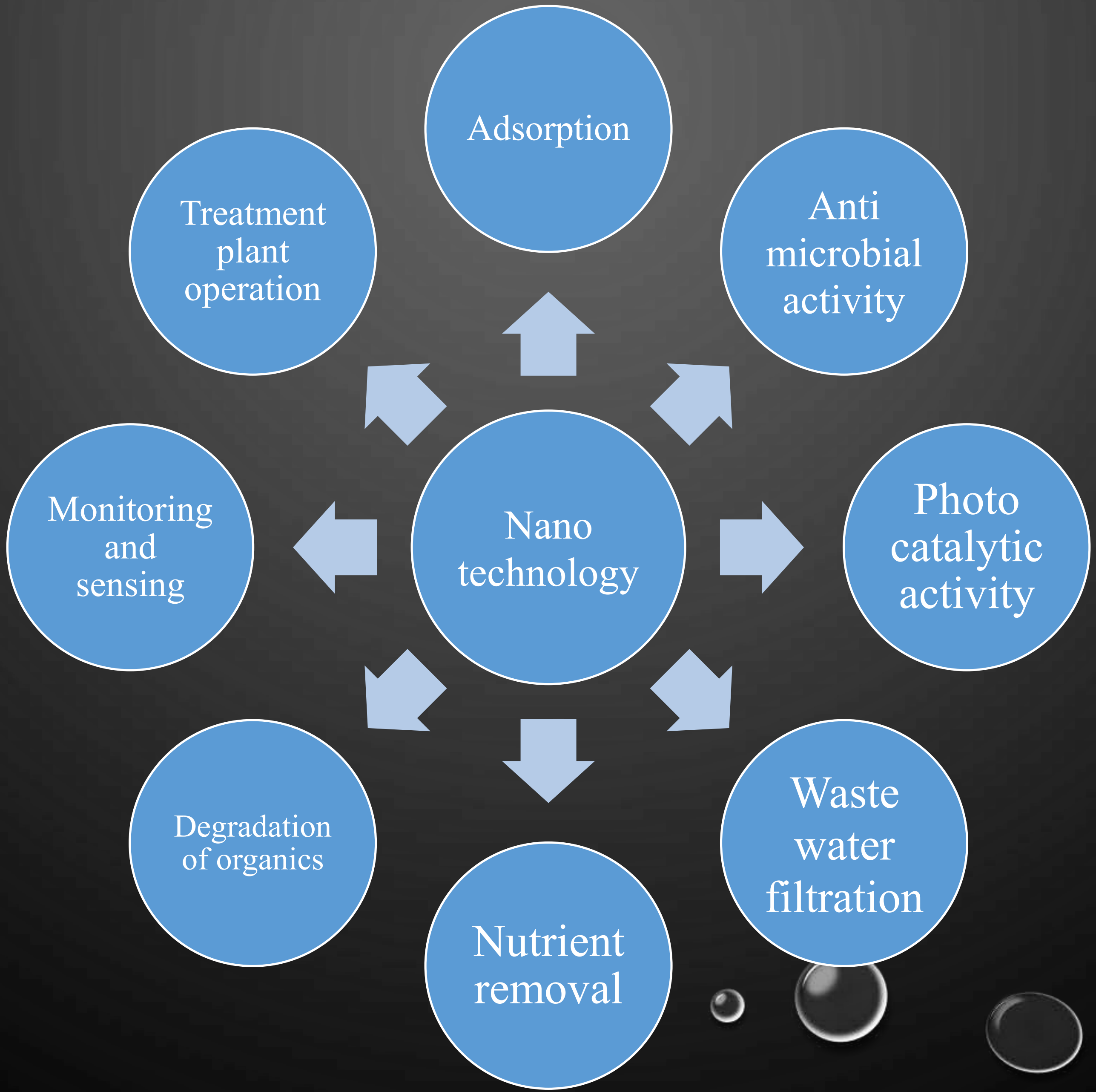
--- Antimicrobial properties of nanoparticles (NPs)

- Challenges in NT
- Societal and health impact
- Acknowledgement

# Why nanotechnology (NT)?

| | | | | | |
|---|---|---|---|---|---|
| High surface area | Possible to tune the properties of the nanoparticles | Can increase competitive-ness among the wastewater treatment technologies | Environmental performance can be improved by increasing efficiency and reducing pollutants | Can take the lead in wastewater treatment technologies by deducing the knowledge gap | Cost-effective-ness |

# NT for wastewater in the context of Kingdom



# Nano for different treatments

| Applications | Nanoelements |
|---|---|
| Adsorption | $TiO_2$; CNT; $Fe^0$; |
| Antimicrobial activity | $TiO_2$; MgO; ZnO; nAg; CNT; Chitosan; $Fe^0$; $Al_20_3$; Fullerene; |
| Photocatalytic activity | $TiO_2$; ZnO; CNT; Fullerene; |
| Wastewater filtration | $TiO_2$; CNT; $Fe^0$; nAg; Graphene; |
| Nutrient removal | $TiO_2$; $Fe^0$; |
| Degradation of organic | $TiO_2$; $Fe^0$; CNT; |
| Monitoring and sensing | CNT; Quantum dots; nAu; |
| Treatment plant operations | $TiO_2$; ZnO; CNT; |

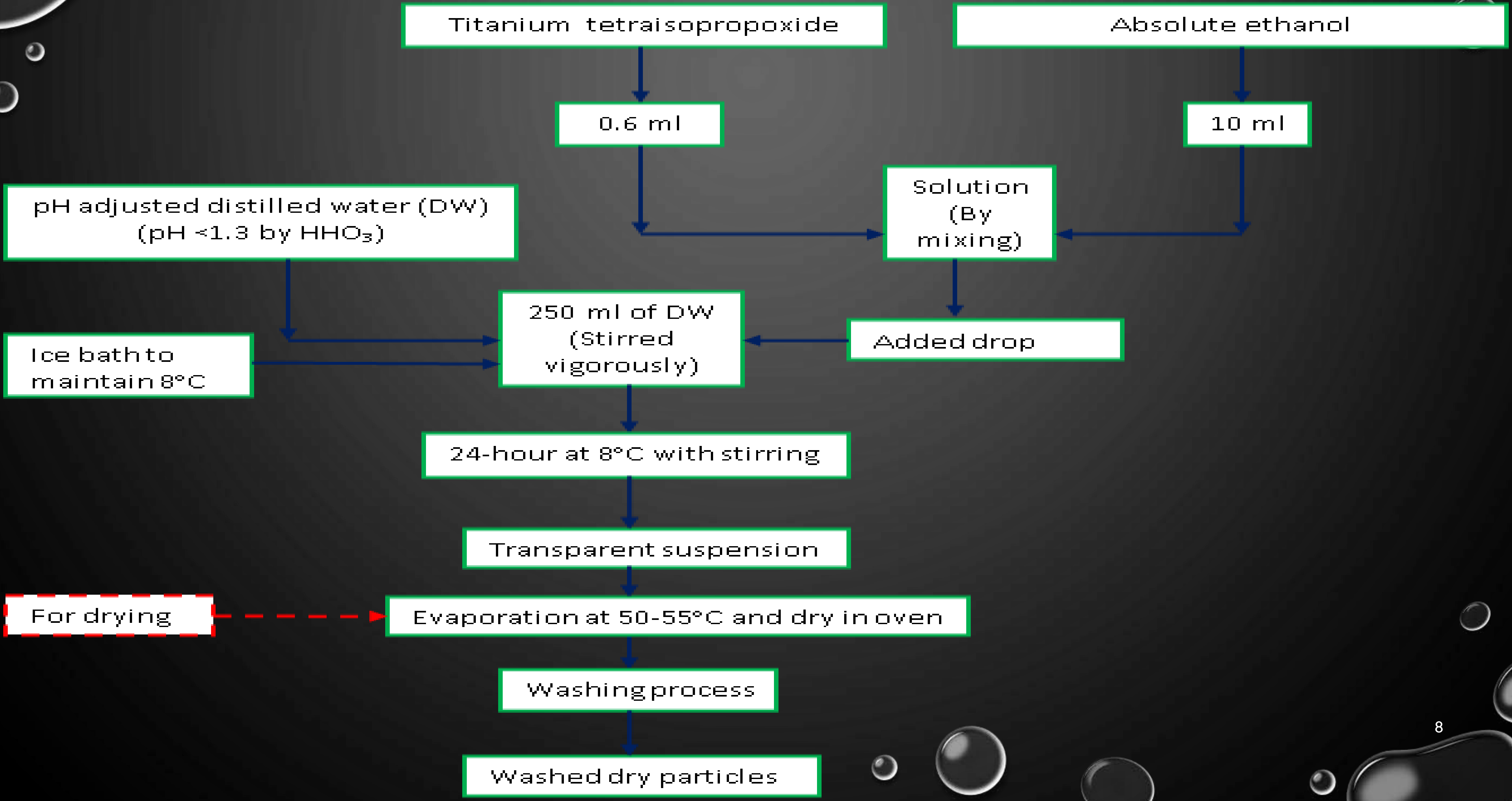
# Applications:

- Industrial dye degradation by $TiO_2$
- Antimicrobial properties of nanoparticles (NPs)

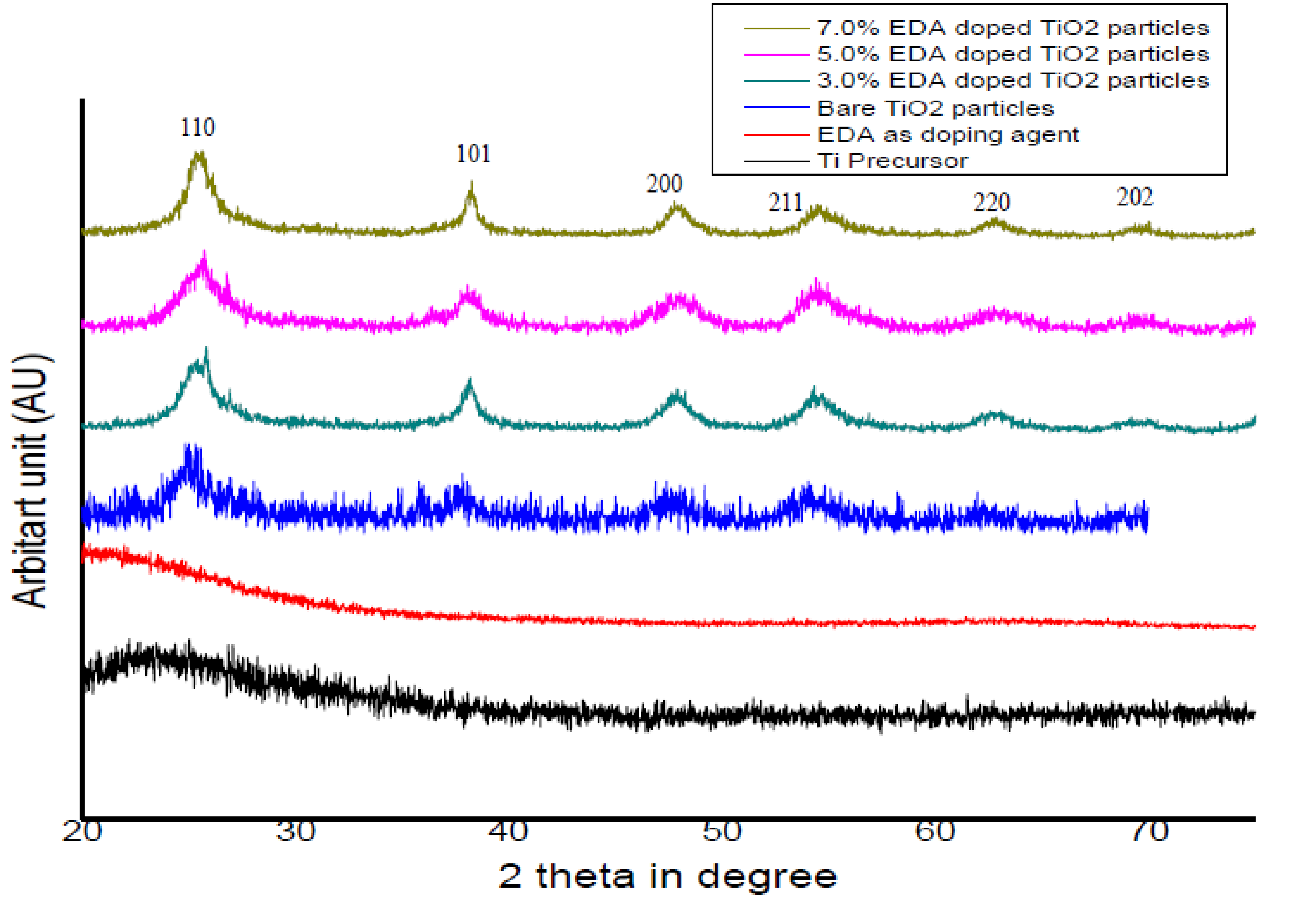
# Why $TiO_2$ for industrial dye degradation?

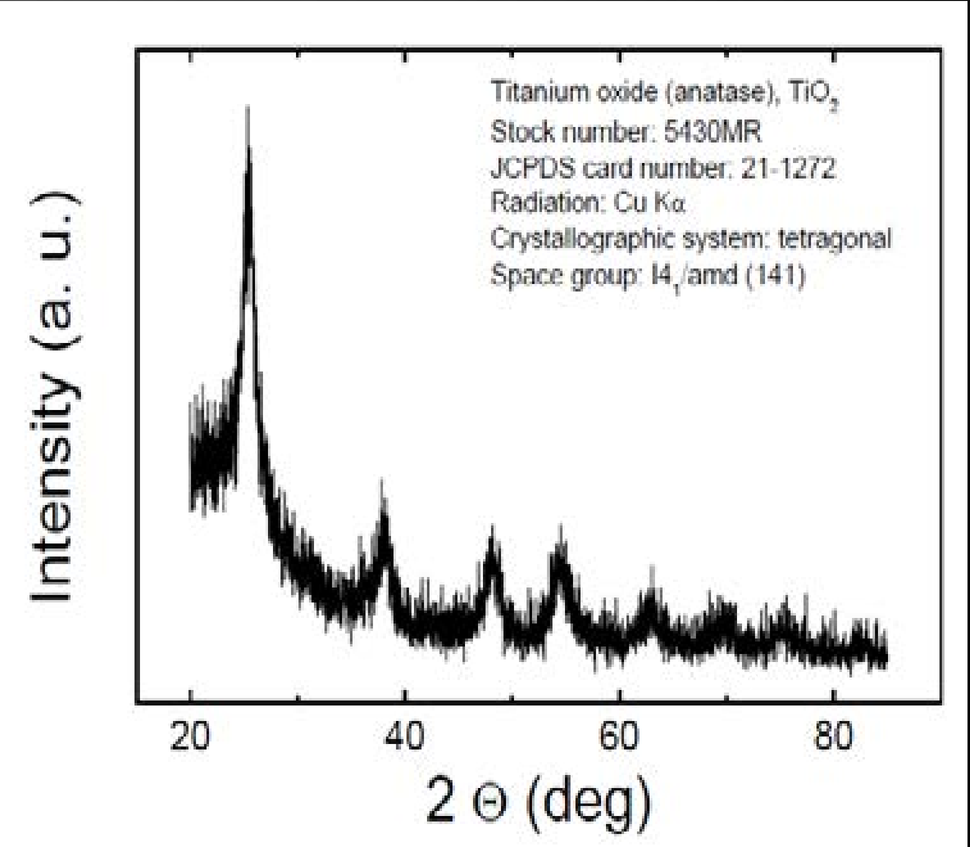
| | | | | | | |
|---|---|---|---|---|---|---|
| Low cost | Non-toxic | Particle stability | Anti-microbial properties | Environmental friendliness | Heavy metal adsorption | Generate ROS to inactivate virus & bacteria |

# $TiO_2$ synthesis for Photocatalytic activity

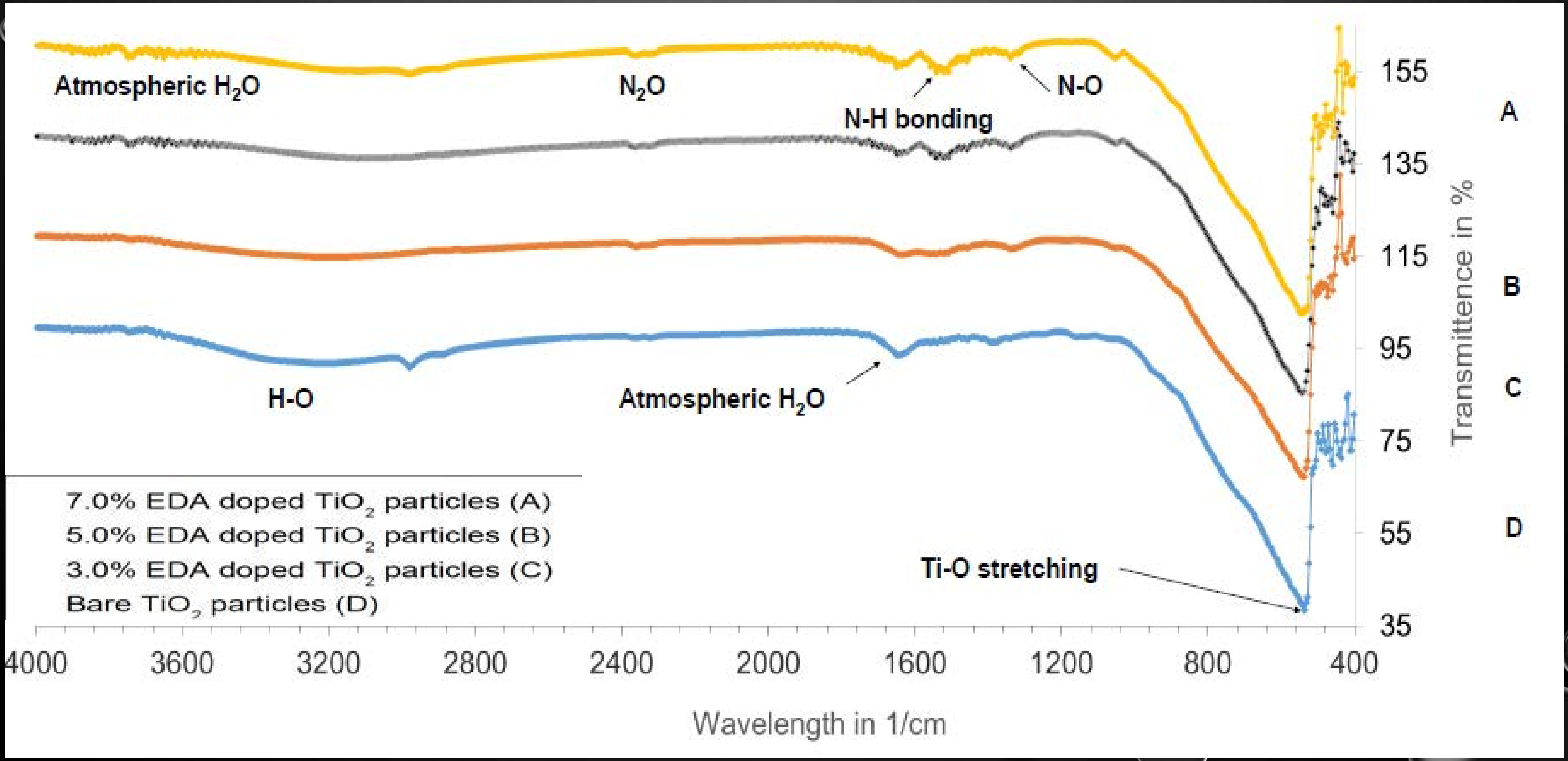


# XRD pattern for synthesized $TiO_2$ Anatase ($2\Theta$ at 25.5; 38.5; 48.2; 54.4; 62.4)



# FT-IR Spectra for synthesized $TiO_2$ (N-H bonding around 1500/cm)



# Industrial dye degradation by $TiO_2$

| EDA concentration (% v/v) | MB photo-degradation efficiency |
|---|---|
| Bare $TiO_2$ particles | 58.14% |
| 3.0% EDA-$TiO_2$ | 92.88% |
| 5.0% EDA-$TiO_2$ | 83.68% |
| 7.0%EDA-$TiO_2$ | 92.70% |

# Antimicrobial activity by nanoparticles (NPs)

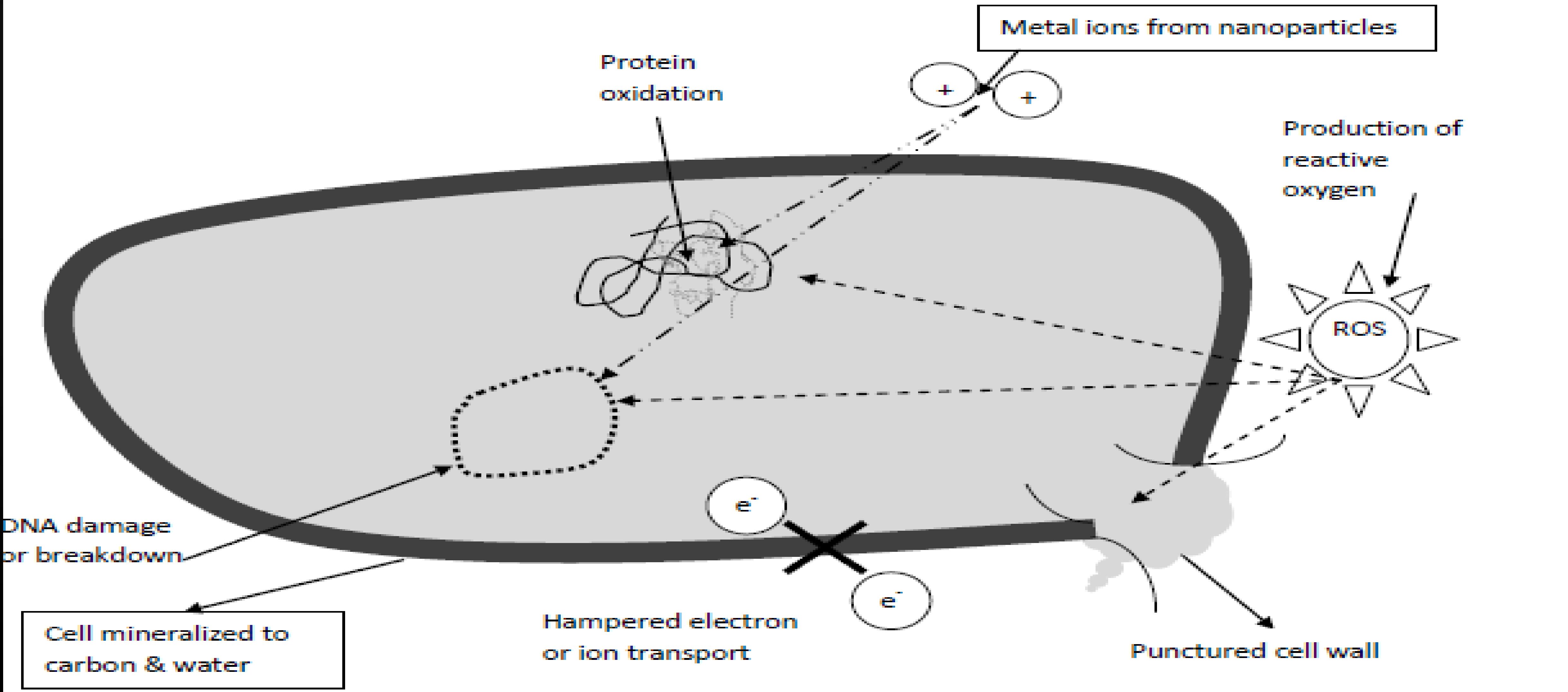



Figure 1: Bacteria cell damage by generated ROS (adapted from Li et al. 2008; Huh & Kwon, 2011)

# Antimicrobial activity by NPs

**Table 1**

The efficiency of $TiO_2$ NPs as antimicrobial agent.

| Elements | Properties | Irradiation process | Matrix | Inactivation efficiency | Ref. |
|---|---|---|---|---|---|
| $TiO_2$ powder (Degussa P-25) | Surface area 60 $m^2/g$ | Solar light (1660 $\mu E\ s^{-1}\ m^{-2}$) & dark | Drinking water | *E. coli* (99.97% in light after 60 min; 99.96% in dark after 60 min) Initial $TiO_2$ conc. 1.0 g/l & initial *E. coli* conc. $10^6$ CFU/ml | Wei et al. (1994) |
| $TiO_2$–$Fe_2O_3$ composite | Particle size 10 nm; Surface area 168 $m^2/g$; | UV (11 W; Wavelength 253.7 nm) | Drinking water (pH-7.0) | *E. coli* (99.9% after 1 min.) Initial $TiO_2$ conc. 0.2 g/l & initial *E. coli* was $10^7$ CFU/100 ml | Sun et al. (2003) |
| $TiO_2$ powder (Degussa P-25) | Surface area 60 $m^2/g$ | UV (18 W; Wavelength 300–420 nm; $7.9 \times 10^{-6}$ einsteins/l/s) | Drinking water (pH-7.1) | MS2 Phage, a virus species (88.78% after 120-min) & *E. coli* (99.43% after 120-min.) Initial $TiO_2$ conc. 1.0 g/l & initial *E. coli* conc. $6.4 \times 10^5$ CFU/ml; MS2 same. | Cho et al. (2005) |
| $TiO_2$ film | Particle size 8–10 nm; Surface area 147 $m^2/g$ | UV ($2 \times 15$ W; Wavelength 365 nm; 3.48 $mW/cm^2$) & Dark | Wastewater | MC-LR (100% after 150-minute; 24% after 180-minute); *E. coli* (100% after 120-minute) Initial $TiO_2$ conc. 62.2 $\mu g/cm^2$ of film & initial *E. coli* conc. $10^6$–$10^7$ CFU/ml) | Choi et al. (2006) |
| $TiO_2$ & N-doped $TiO_2$ (Doped by Ethylenediame & Ethanolamine) | Particle size 10 nm; Surface area 80–120 $m^2/g$; | Solar light (10 $W/m^2$) | Synthetic wastewater (pH-7.2) | *E. coli* (99.99% by $TiO_2$ after 120-min.; 100% by $TiO_2$-N-Ethylenediame after 120-min.; 99.9999% by $TiO_2$-N-Ethanolamine after 120-min.) Initial $TiO_2$ conc. 0.1 g/l & initial *E. coli* conc. $8.9 \times 10^8$ CFU/ml | Liu et al. (2007) |

# Antimicrobial activity by NPs

**Table 2**
Antimicrobial efficiency of nAg, CNT and ZVINP.

| Elements | Properties | Matrix | Inactivation efficiency | Ref. |
|---|---|---|---|---|
| Ag-Zeolite | | Water | *E. coli* (99.7% after 30 min); Ag-Zeolite conc. 100 mg/ml and *E. coli* conc. 2.2 × $10^7$ CFU/ml | Matsumura et al. (2003) |
| n-Ag | Particle size 12 nm; Surface area 158 $m^2$/g | Water | *E. coli* (99.0% after 30 min); n-Ag conc. 50 μg/ml and *E. coli* conc. $10^8$ CFU/ml | Sondi and Sondi (2004) |
| n-Ag | | Water | *E. coli* (99.93% after 24 h); *B. subtilis* (99.99% after 24 h); n-Ag conc. 100 μg/ml | Yoon et al. (2007) |
| SWNT | 5 μm | Water | *S. typhimurium* (99.997% after 1 h); SWNT conc. 100 μg/ml and *S. typhimurium* cell $10^8$ CFU/ml | Yang et al. (2010) |
| SWNT | | Water | *E. coli* K12 (73.1 ± 5.4%, 79.9 ± 9.8% and 87.6 ± 4.7% inactivation after 30, 60 and 120 min of incubation time, respectively) | Kang et al. (2007) |
| SWNT and MWNT | | Water | *E. coli* K12 (79.9% and 25% after 1 h by SWNT and MWNT respectively); NT conc. 5 μg/ml and *E. coli* conc. 5 × $10^7$ CFU/ml | Kang et al. (2008) |
| SWNT and MWNT | SWNT (Diameter 1.2 nm; Length 17.8 μm); MWNT (Diameter 17.4 nm; Length 77 μm) | Water | *E. coli* (87% after 1 h); *P. aeruginosa* (80% after 1 h); *S. epidermidis* (66% after 1 h); *B. subtilis* (16% after 1 h); NT conc. 0.1 μg/ml and Bacteria conc. 2 × $10^6$ CFU/ml | Kang et al. (2009) |

# Challenges in NT

- Particle agglomeration
- Reducing particle surface area
- Bulk commercial production
- Practical applications
- Utilization of exceptional physical, chemical and mechanical properties
- NPs may have less toxicity than micro or bulk size particles

# Societal and health impact

- Nanotoxicity: About 400 reported toxicity and ecotoxicity
- Public awareness
- Nanocontamination
- Can effect human cells
- Recovering of nanoparticles or nanomaterials from the environment

# Acknowledgement

Thank you

Question!!