1-D and 2-D Carbon-Iron Nanohybrids Prepared with Ultrasonic Spray Pyrolysis for Cr (VI) Removal

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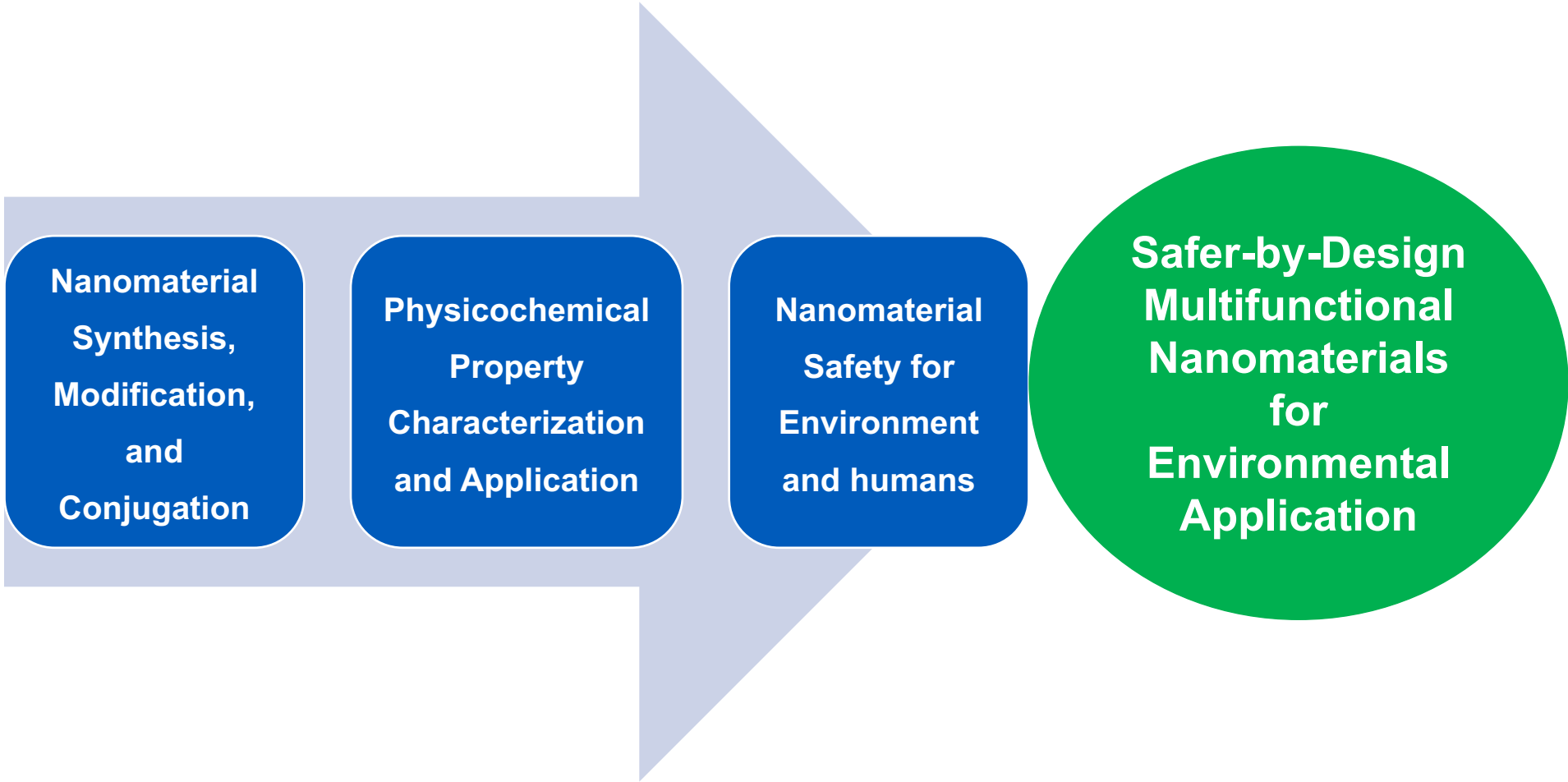
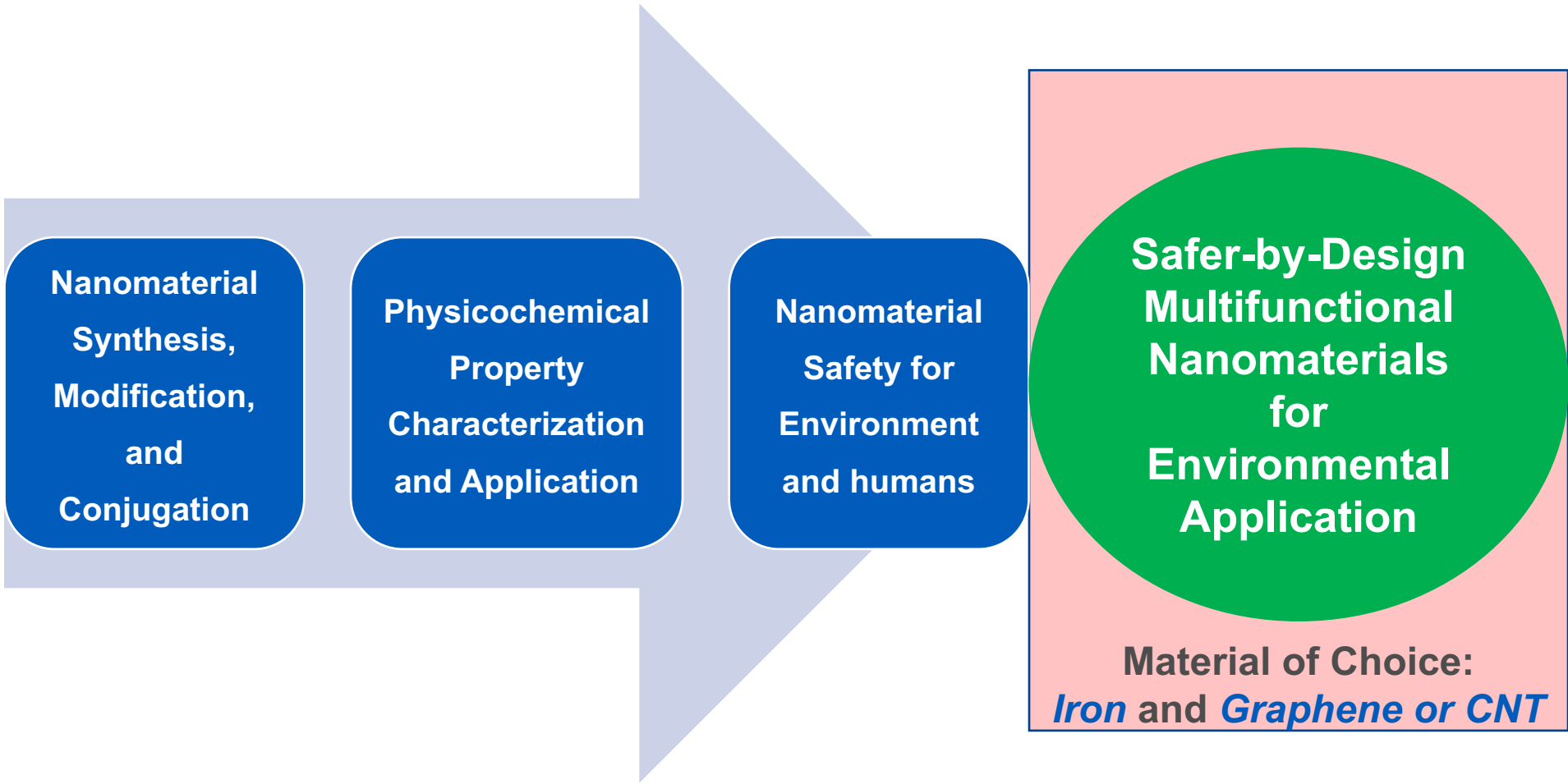

Nanomaterial Synthesis, Modification, and Conjugation
Physicochemical Property Characterization and Application
Nanomaterial Safety for Environment and humans
Safer-by-Design Multifunctional Nanomaterials for Environmental Application


Nanomaterial Synthesis, Modification, and Conjugation
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Safer-by-Design Multifunctional Nanomaterials for Environmental Application
Material of Choice:
Iron and Graphene or CNT

Environmental Application of Iron Nanoparticle

- In 2010, world market for environmental application of nanomaterials was ***$6 Billion***
- Fe NP (mostly nano zero valent iron, nZVI) is the most used engineered nanomaterial for in-situ soil and groundwater remediation
- High ***redox activity*** & ***adsorptive capacity*** enable Fe NPs to remove heavy metal and organic contaminants
- Applied to ***77 pilot & field scale*** sites worldwide (2014)
- Applied also in pilot wastewater treatment plants

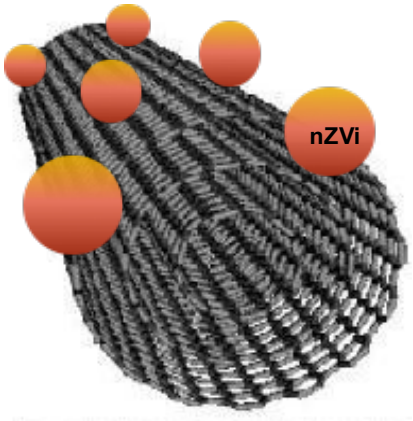
Pilot scale iron nanoparticle based ground water remediation plant through injection well

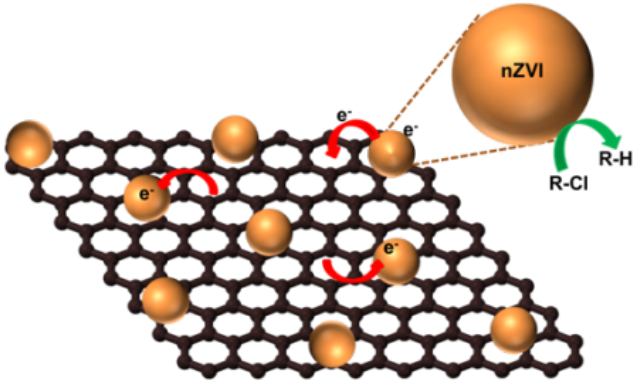
Limitations to Reactivity and Need for Solid Supports

Fe NPs ***agglomerate*** due to van der Waals and magnetic attraction forces, ***decreasing reactivity and adsorption***

1-D ***carbon nanotube (CNT)*** and 2-D ***reduced graphene oxide*** (rGO) are good solid supports

- Large ***accessible specific surface area***
- High ***electron mobility***
- Mechanical durability
- High ***contaminant adsorption***





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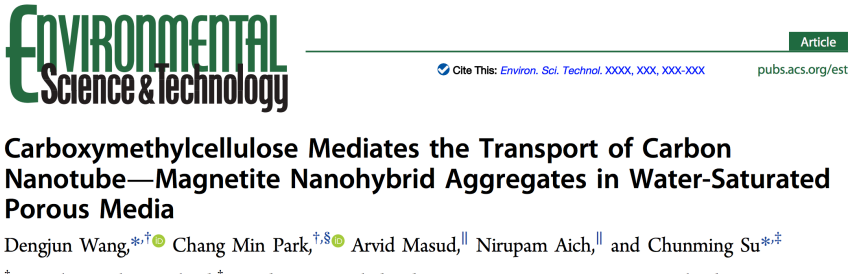

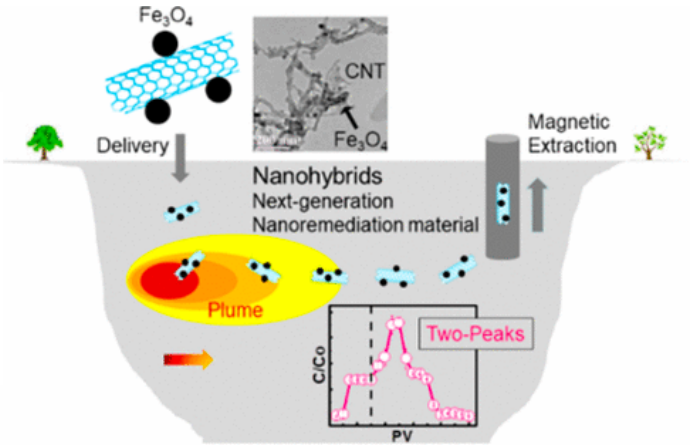

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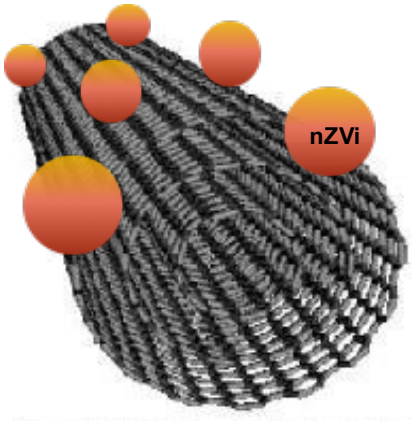
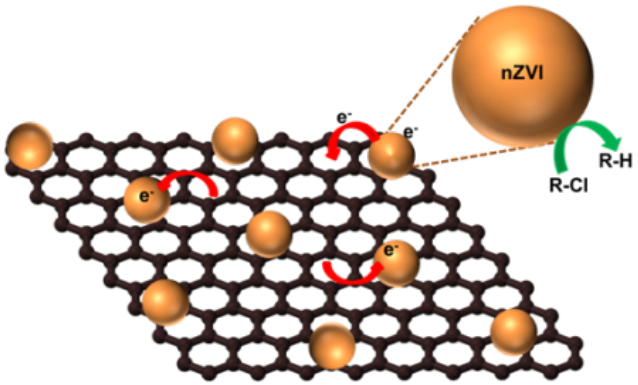
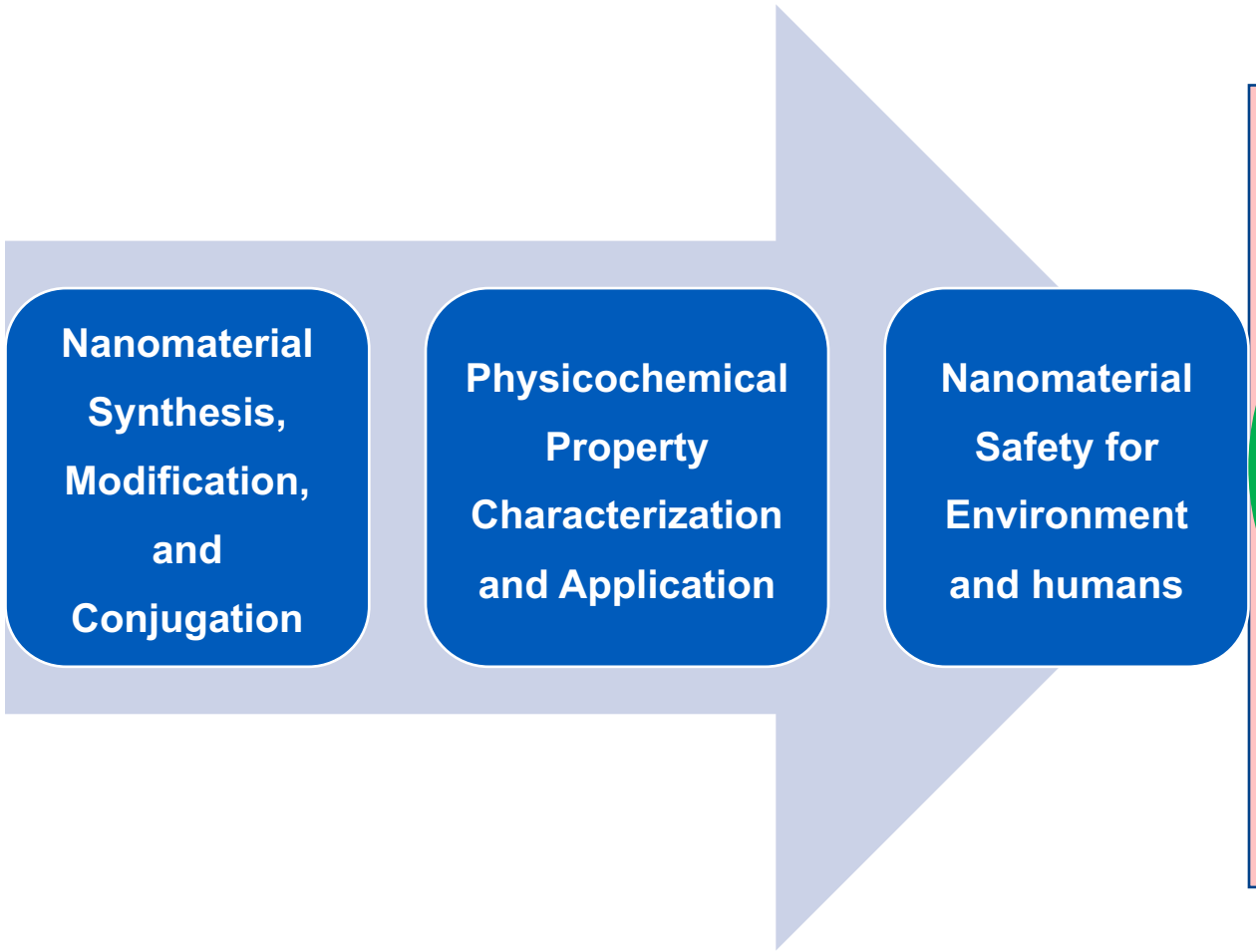
Comparison of Fe-CNT and Fe-rGO
Effect of Shape of Carbon Nanomaterials







Safer-by-Design Multifunctional Nanomaterials for Environmental Application

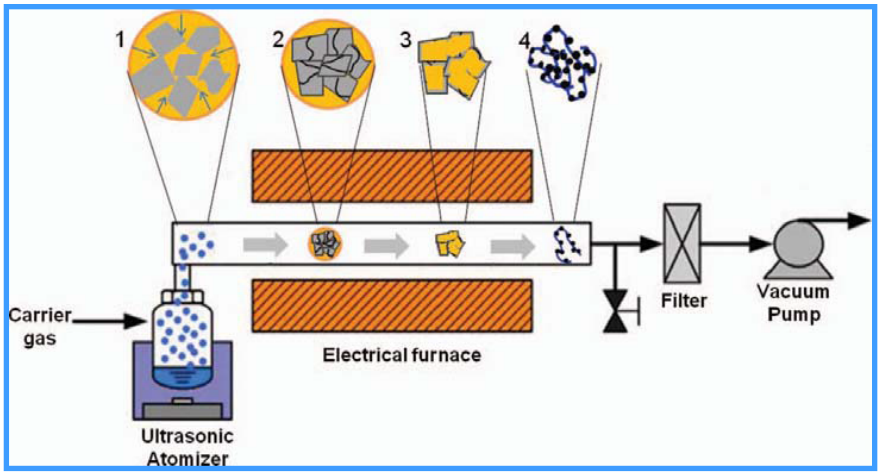
Process of Choice:
Ultrasonic Spray Pyrolysis

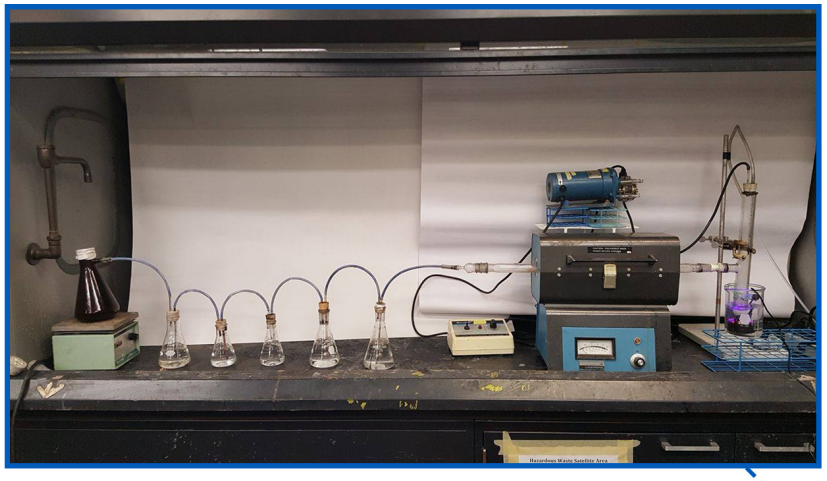
Synthesis of Fe-Carbon Nanohybrids

- ***Wet Chemistry*** based methods are conventional
- ***Chemical reduction of iron salts*** onto oxidized CNT or graphene oxide (GO)
- Some methods require ***hazardous reducing agents*** (hydrazine, benzene)
- Require ***extensive reaction time*** (up to 24 hours)
- Limited by ***scalability***

Ultrasonic Spray Pyrolysis (USP)

- ***Aerosol*** based process
- ***Fast:*** reactions happen in matter of seconds
- Thermal reduction: so ***No hazardous reagents***
- Continuous, one-step, and ***Scalable*** process





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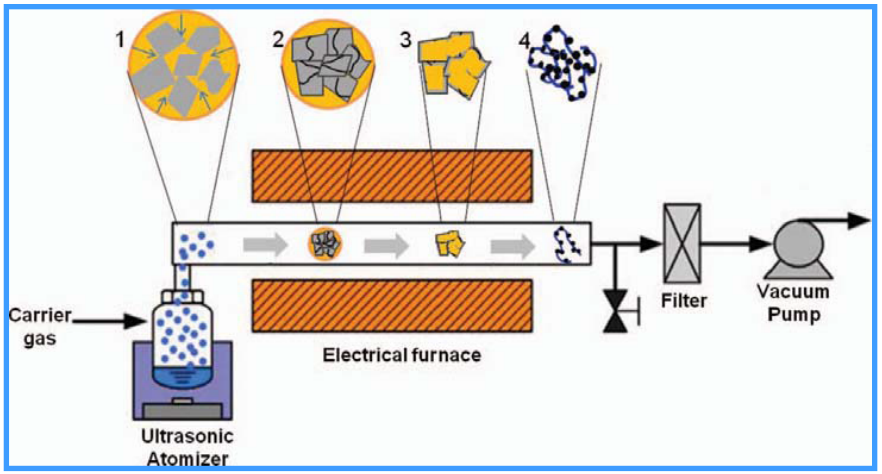
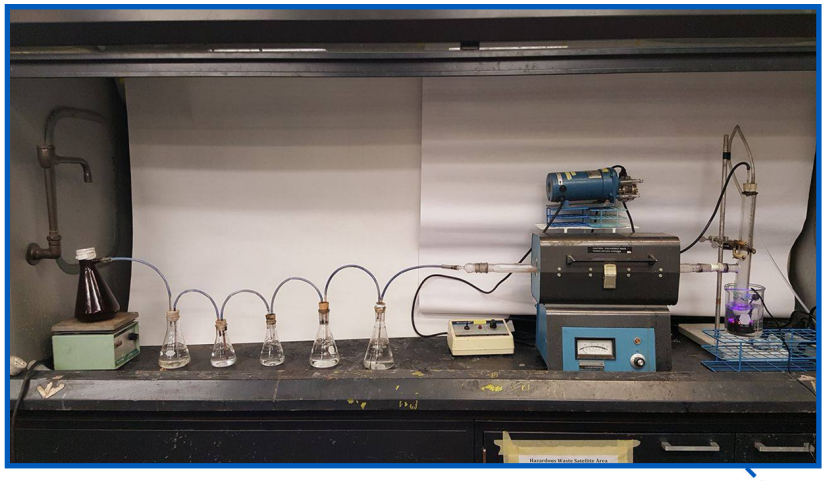
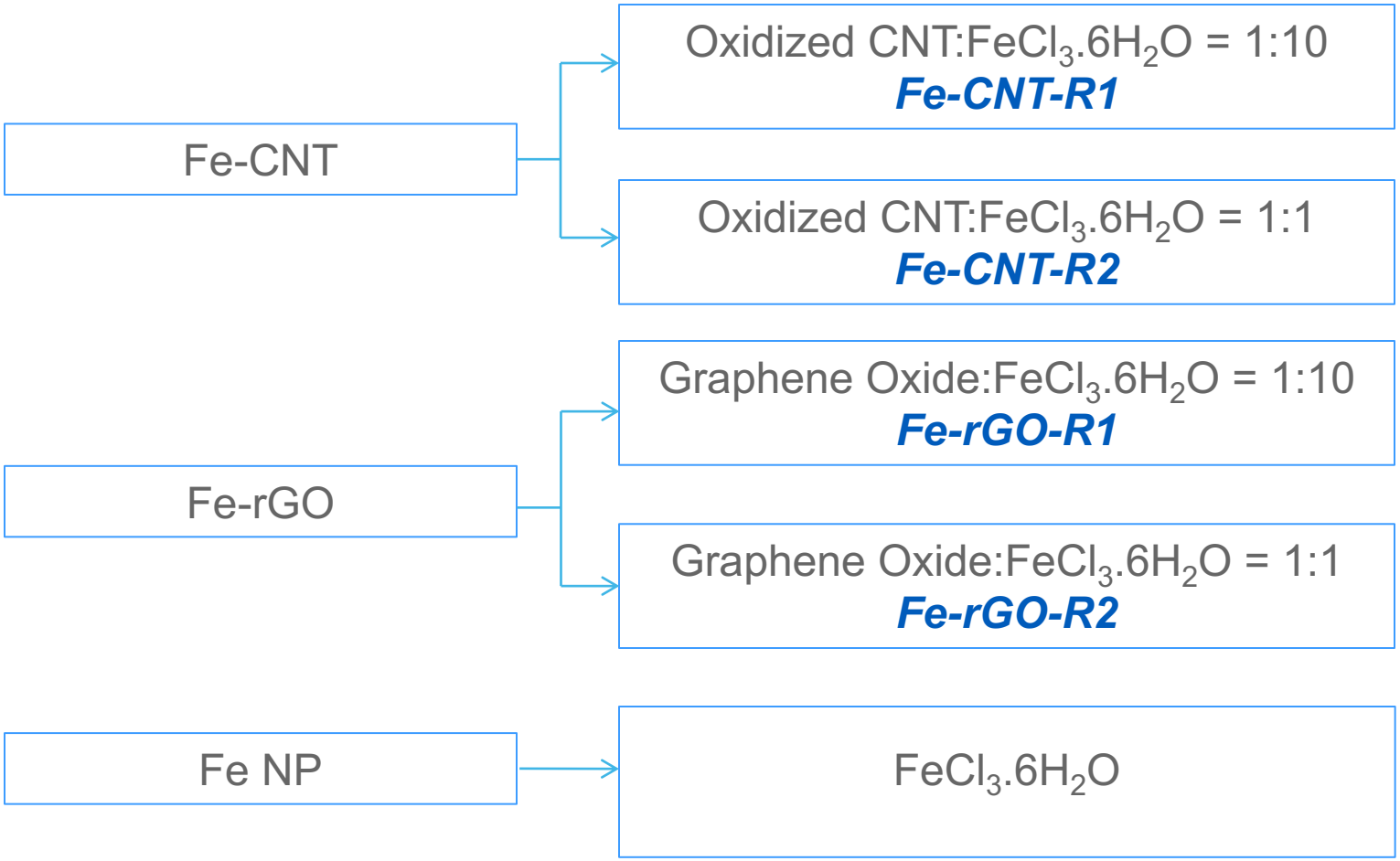
No study on USP-derived Fe-CNT or Fe-rGO for *pollutant removal*



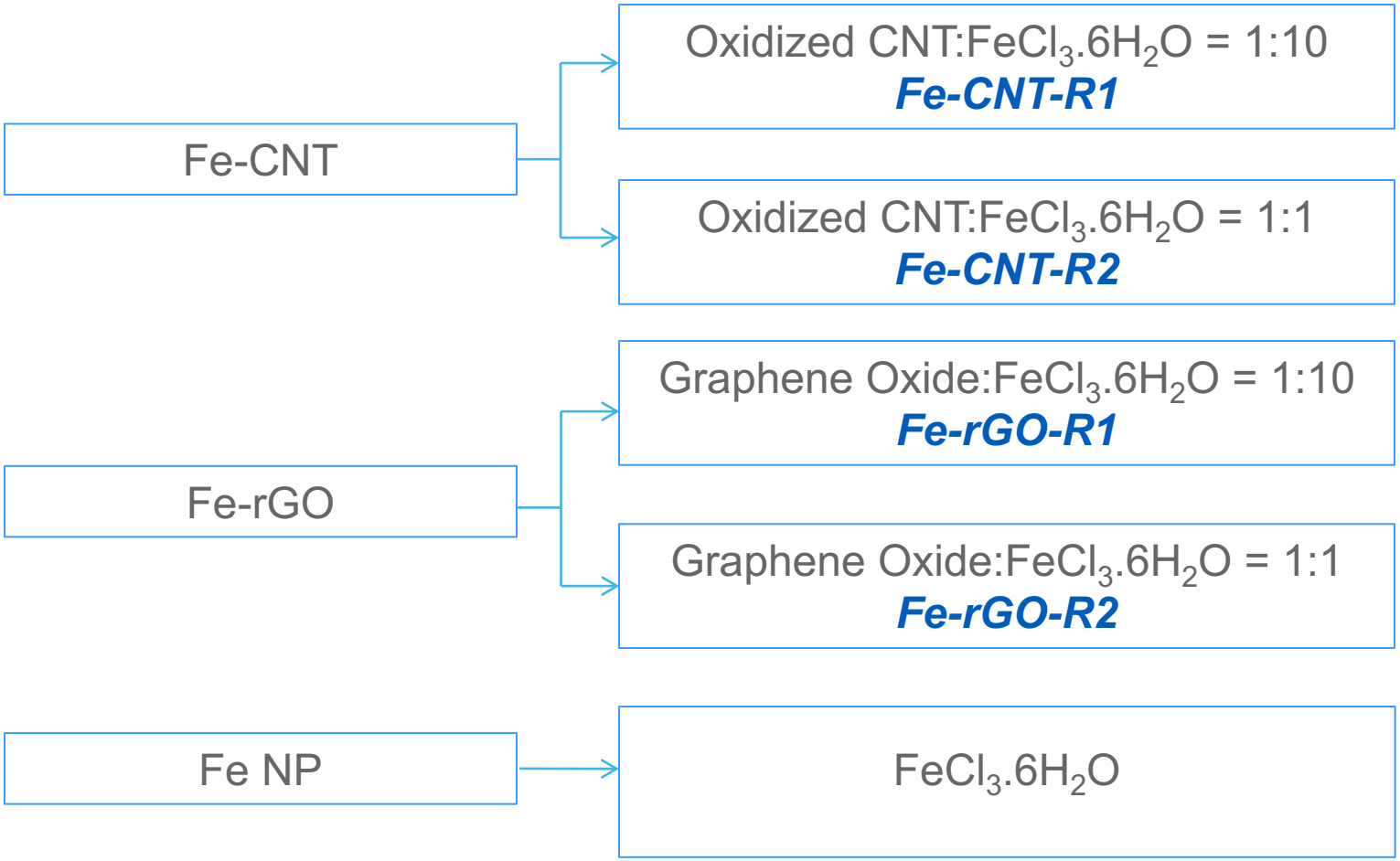


Nanohybrid Types and Relevant Precursors

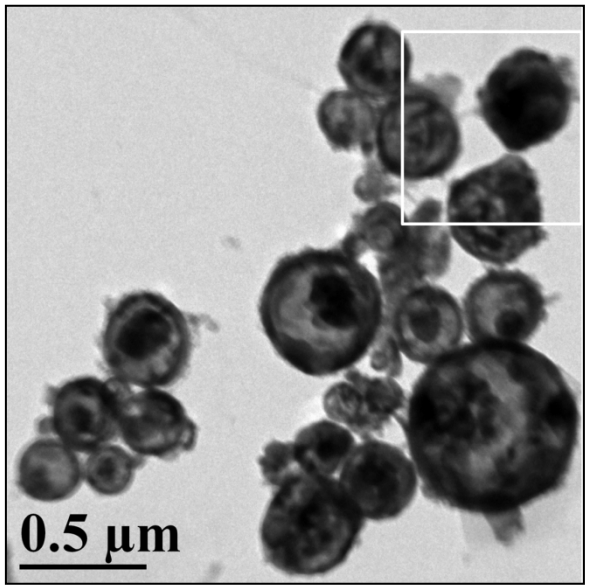


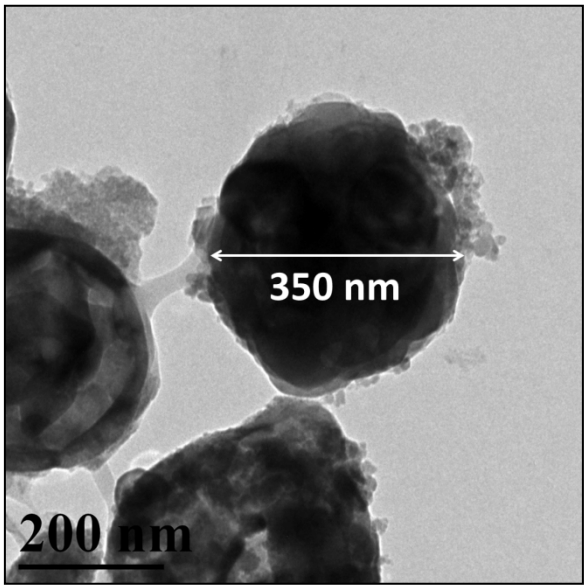
Nanohybrid Types and Relevant Precursors

R1: High Fe Content and Low Carbon Content



High Resolution Transmission Electron Microscopy Image

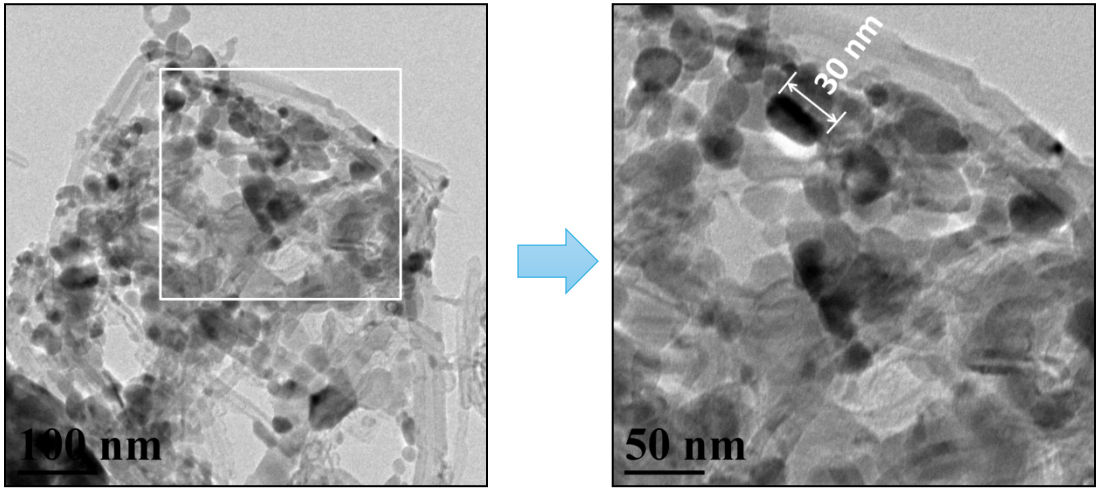




Fe NP

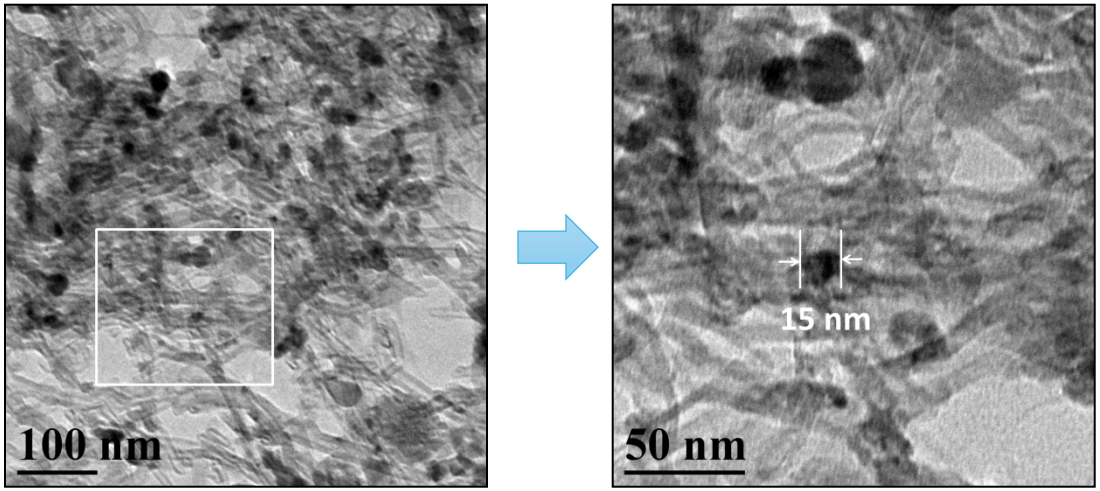
Size range:
200-500 nm

High Resolution Transmission Electron Microscopy Image



Fe-CNT-R1

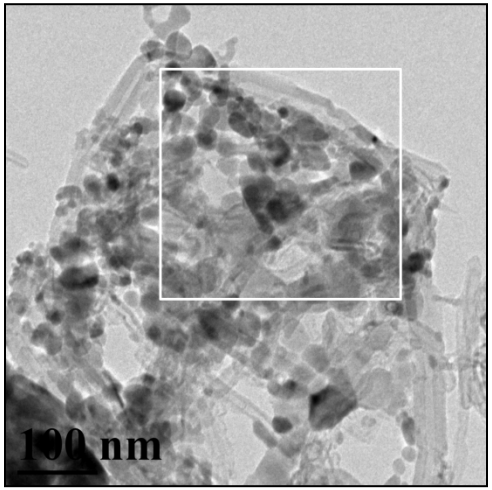
Size range:
20-50 nm

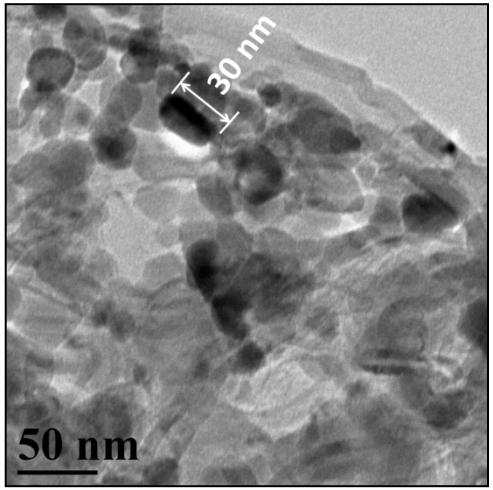


Fe-CNT-R2

Size range:
10-25 nm

High Resolution Transmission Electron Microscopy Image

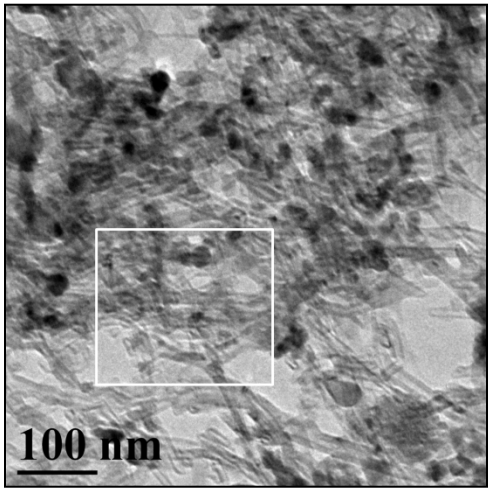


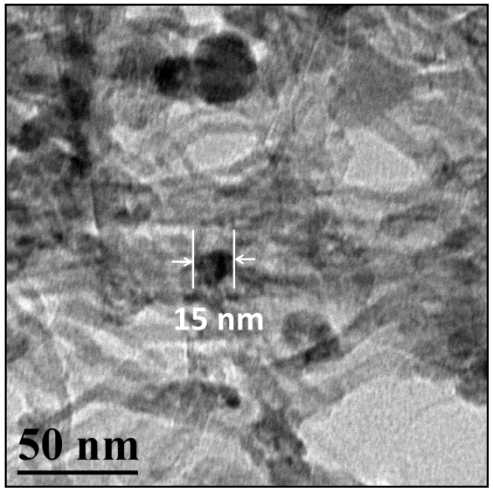


Fe-CNT-R1

Size range:
20-50 nm

CNT gets more bundled in USP





Fe-CNT-R2

Size range:
10-25 nm

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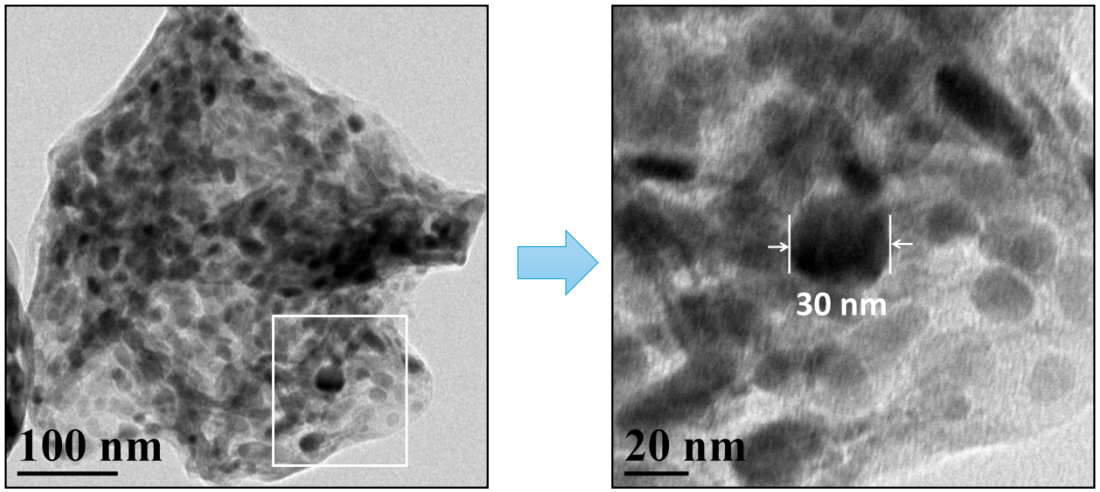
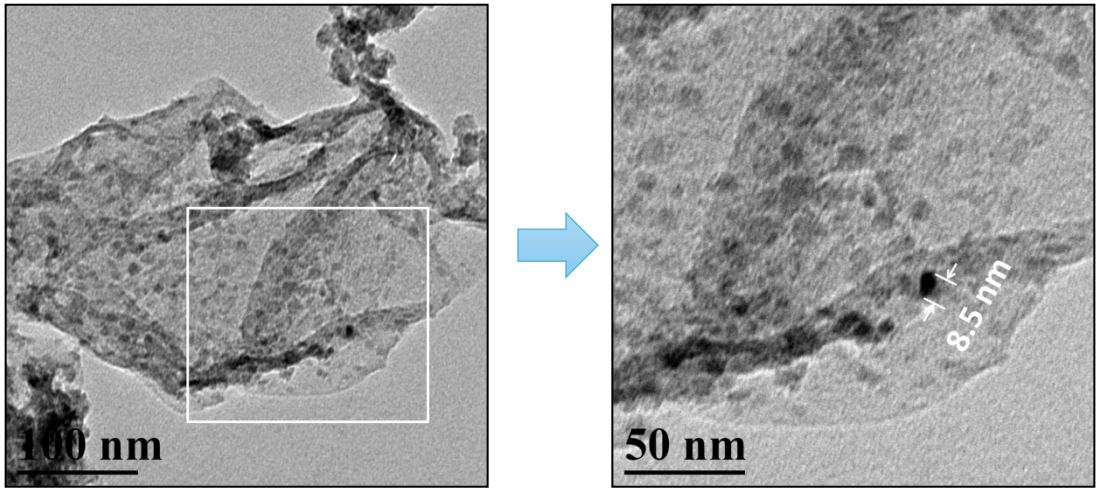


Fe-rGO-R1

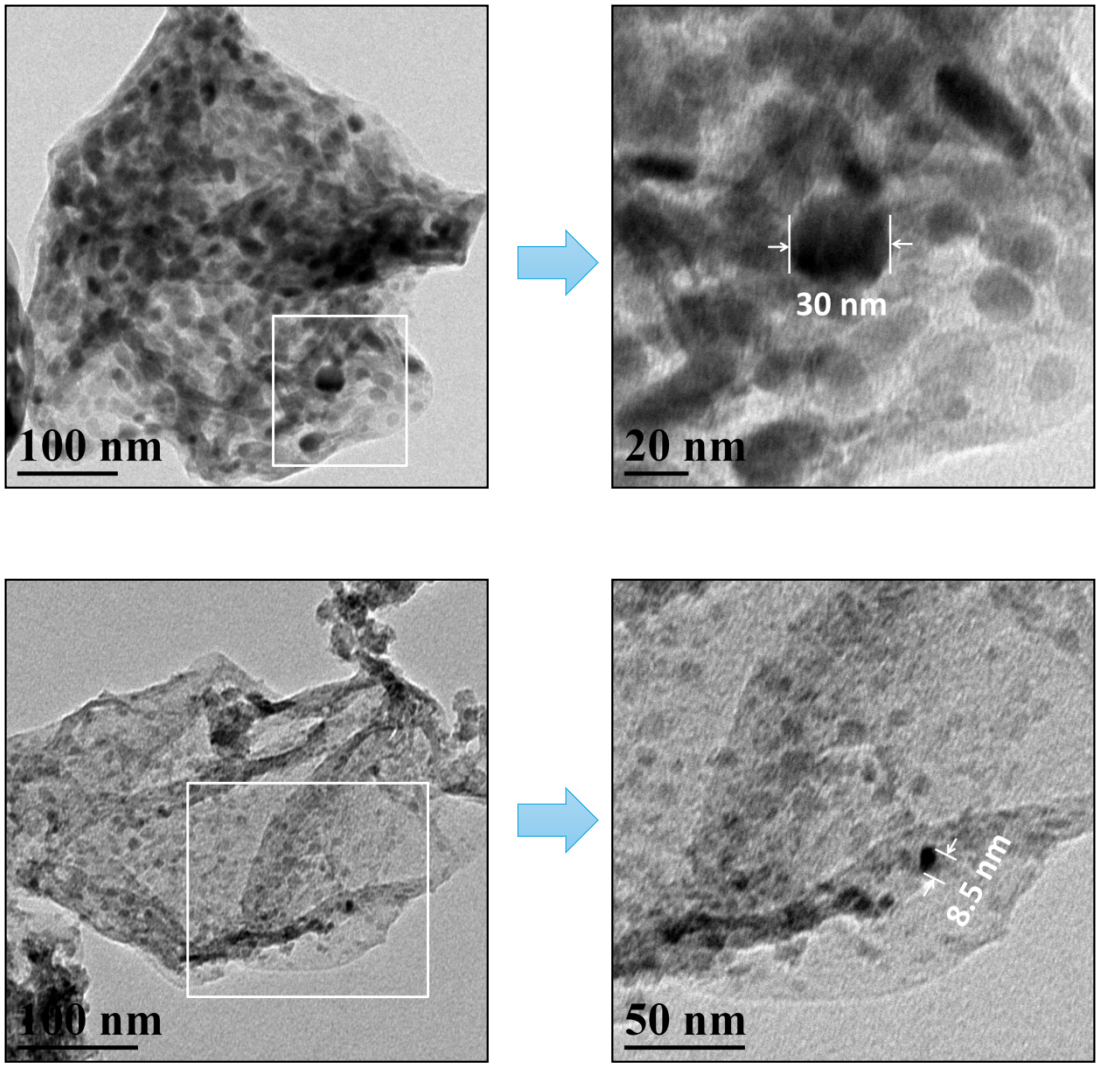
Size range:
20-50 nm



Fe-rGO-R2

Size range:
8-15 nm

High Resolution Transmission Electron Microscopy Image



Fe-rGO-R1

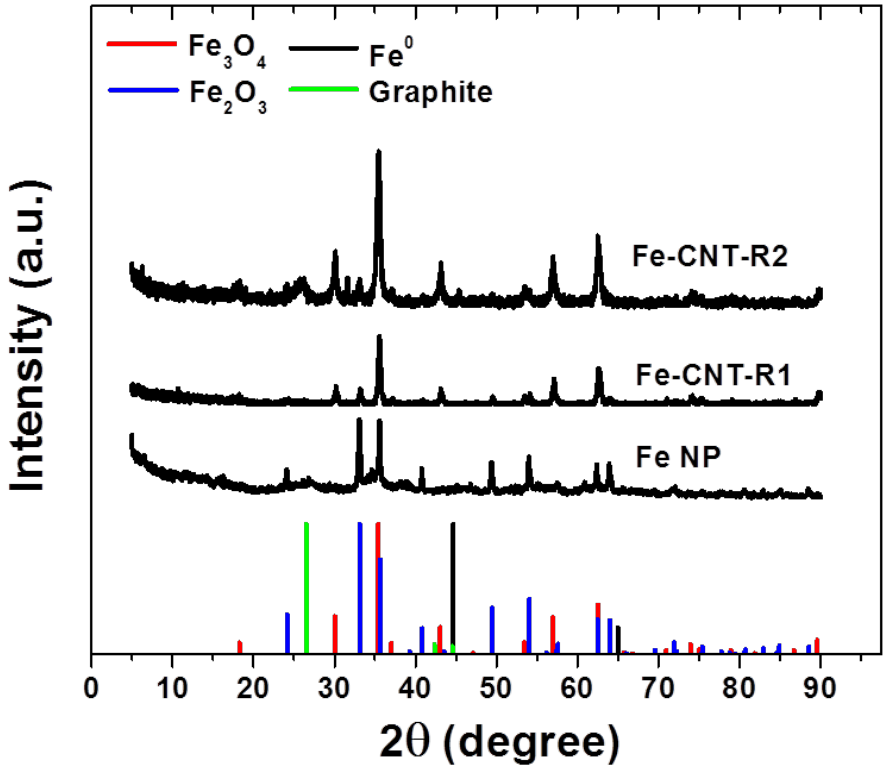
Size range: 20-50 nm

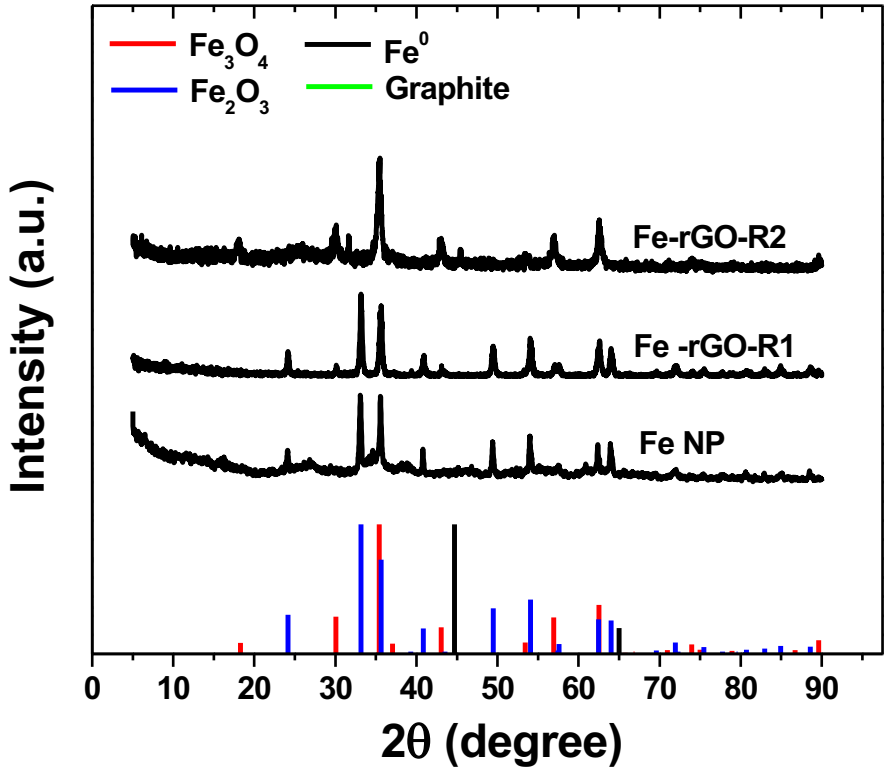
rGO thermally exfoliates and crumples

Fe-rGO-R2

Size range: 8-15 nm

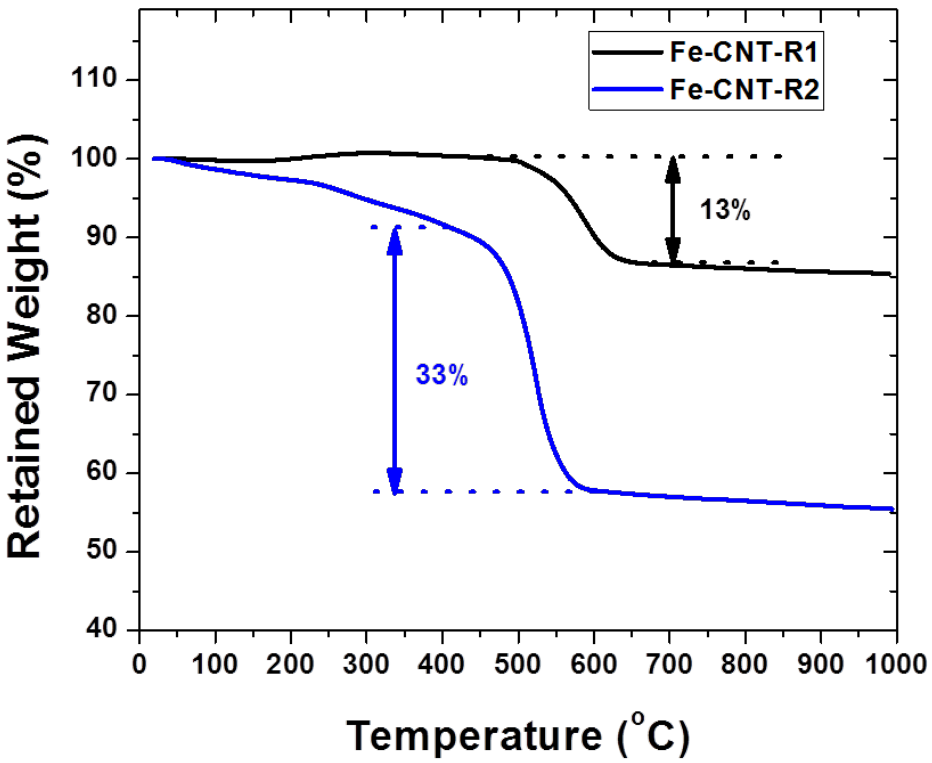
X-ray Diffraction Spectroscopy (XRD)

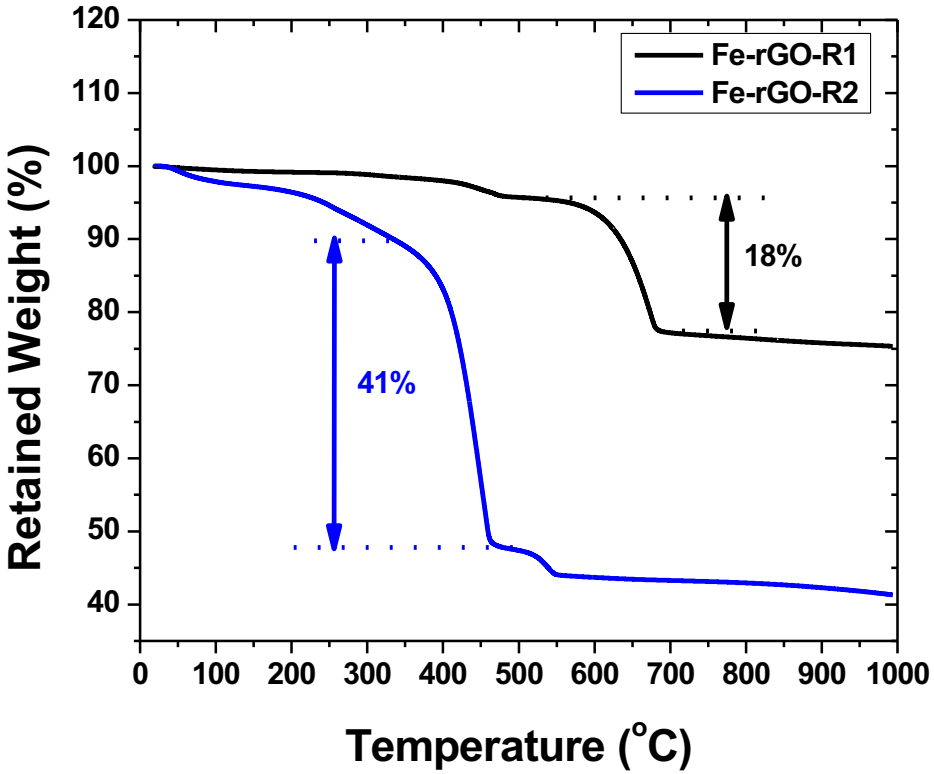




More reduced form of Fe NPs with increase of Carbon content

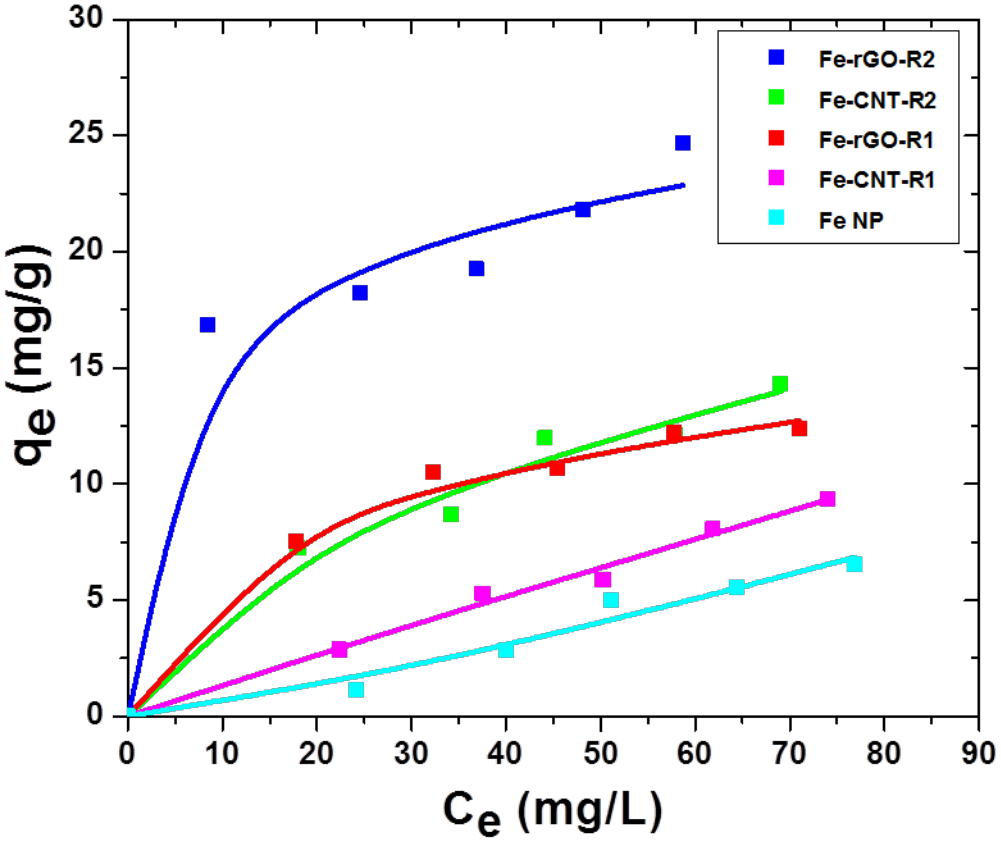
Thermogravimetric Analyses





Estimated CNT in Fe-CNT-R1 *13%*	Estimated rGO in Fe-rGO-R1 *18%*
Estimated CNT in Fe-CNT-R2 *33%*	Estimated rGO in Fe-rGO-R2 *41%*

Heavy Metal Removal: Cr (VI) Adsorption Isotherm

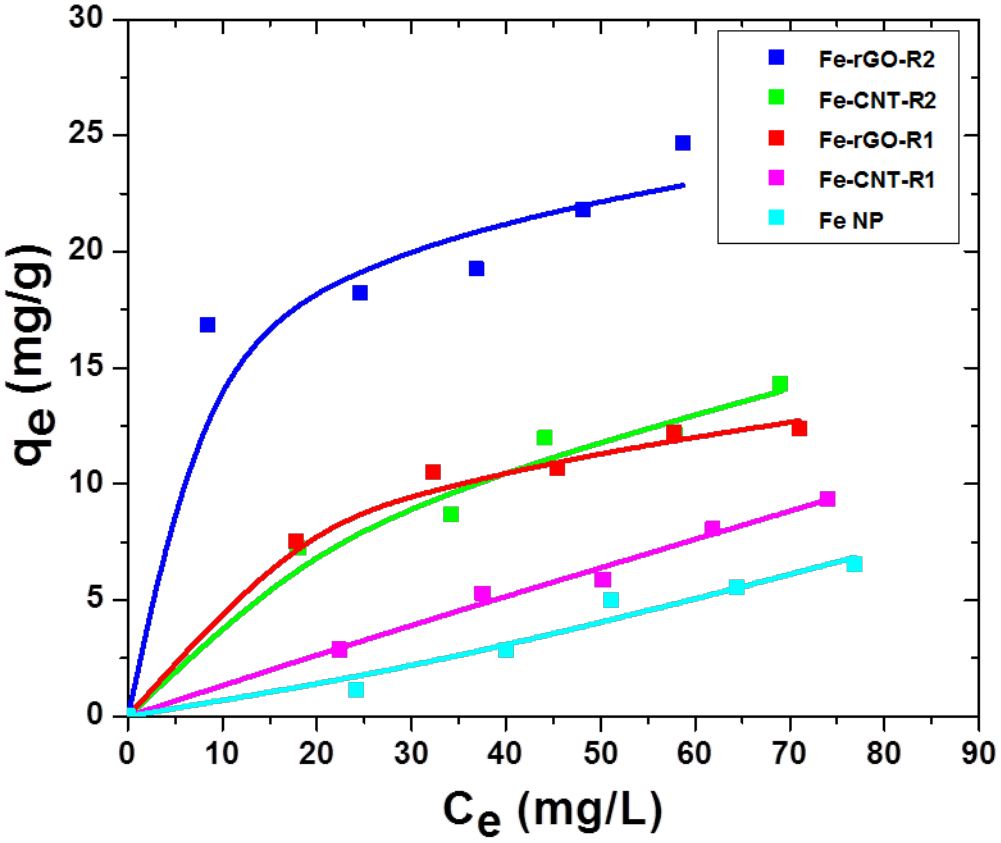


USP Product	Adsorption Capacity (mg/g)	BET Surface area (m^2/g)
Fe-rGO-R1	12	27
Fe-rGO-R2	***25***	26
Fe-CNT-R1	9	36
Fe-CNT-R2	14	23
Fe NPs	6	8

Increased surface area in nanohybrids aid their higher adsorption

Fe-rGO-R2: Highest adsorption due to uniformly dispersed and smallest Fe NPs

Heavy Metal Removal: Cr (VI) Adsorption Isotherm



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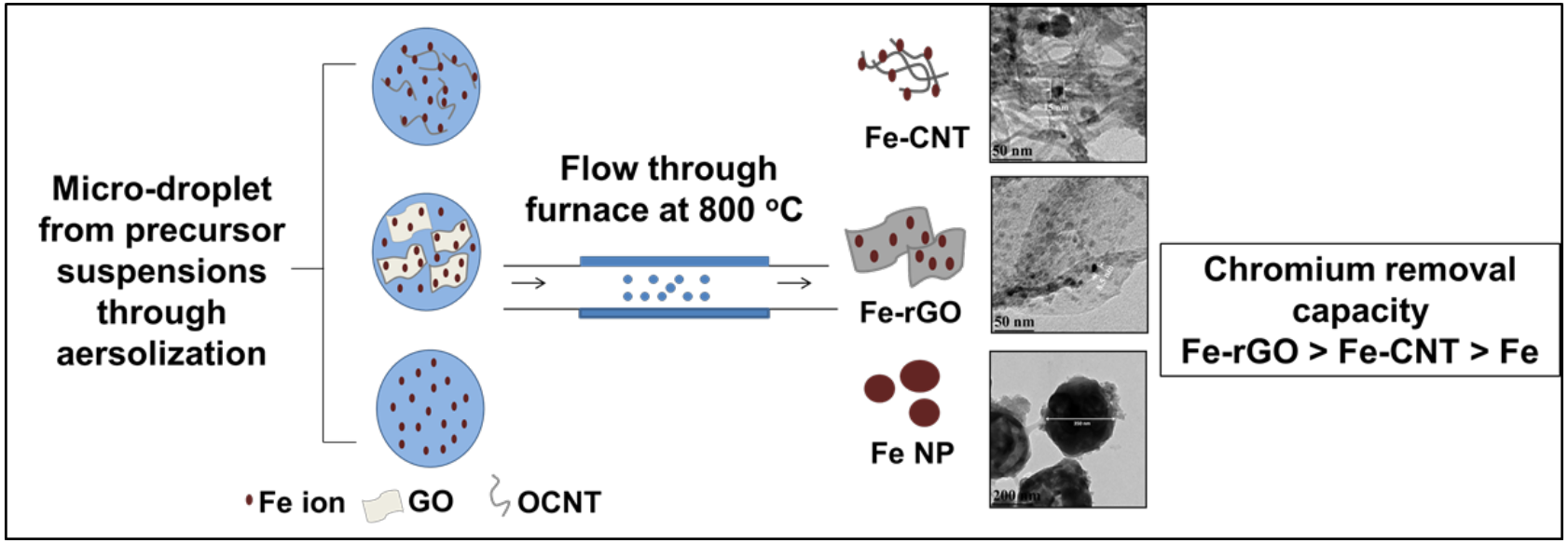
Fe-CNT << Fe-rGO
Bundled vs Exfoliated

Increased surface area in nanohybrids aid their higher adsorption

Fe-rGO-R2: Highest adsorption due to uniformly dispersed and smallest Fe NPs

Summary and Future Perspective



- USP-derived Fe-rGO performs better than Fe-CNT for Cr(VI) removal **(shape-effect)**
- Tuning of Fe content is critical
- Influence of environmental parameters (pH, ionic strength) needs to be studied
- More investigation is needed to clarify the mechanisms of contaminant removal

Masud, Atkinson, Aich, J Nanopart Res, Submitted

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Physicochemical Property Characterization and Application

Nanomaterial Safety for Environment and humans

Safer-by-Design Multifunctional Nanomaterials for Environmental Application

Nanohybrid Toxicity

Fe-rGO Nanohybrid Toxicity to Bronchial Epithelial Cell (BEAS-2B)

Acknowledgements

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- Yanbin Cui

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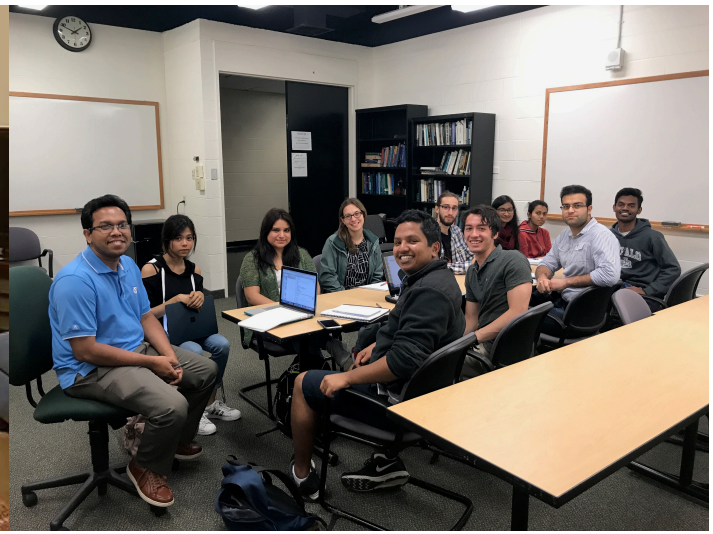
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY



Thank You