



# Water Purification Using Carbon nanotube (CNT) Filters

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- Water purification using CNT filters
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# Introduction

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- **Water – The elixir of life**
- **Water crisis is one of the grand challenges of 21<sup>st</sup> century**
- **By 2025, 1800 million people will be living in regions with absolute scarcity (UN WWAP 2013)**

# Fresh water availability- Facts and Figures

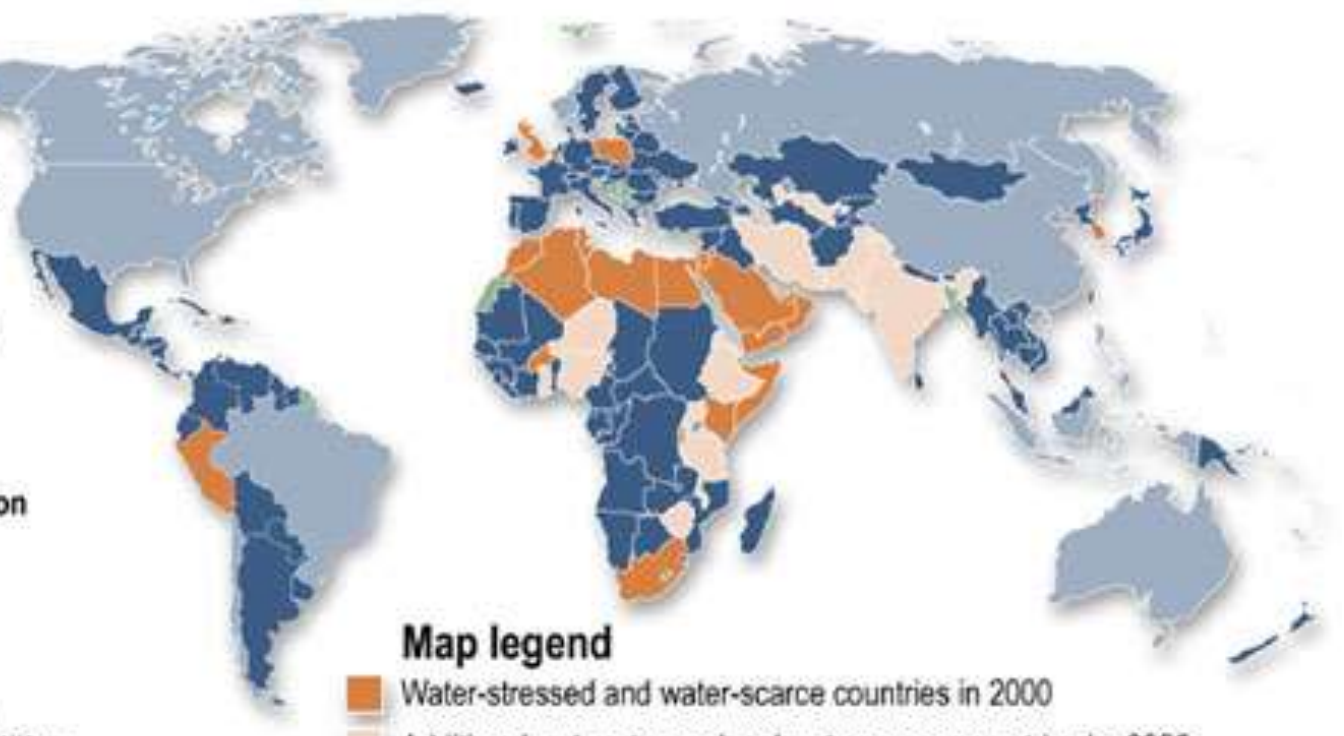
## World population by freshwater availability

- Relative sufficiency
- Stress
- Scarcity

2000  
Total population: 6 billion



2025 (medium projection)  
Total population: 7.82 billion



## Map legend

- Water-stressed and water-scarce countries in 2000
- Additional water-stressed and water-scarce countries by 2025
- No stress
- Low stress (0-10%)
- No data available

➤ 783 million people do not have access to clean and safe water

➤ 1 in 9 people world wide do not have access to safe and clean drinking water

➤ 443 million school days are lost each year due to water-related diseases

85% of the world population lives in the driest half of the planet

6 to 8 million people die annually from the consequences of disasters and water-related diseases

Yet future global agricultural water consumption alone is estimated to increase by ~19% by 2050



WORLDWIDE, 1 OUT OF  
EVERY 5 DEATHS OF  
CHILDREN UNDER 5  
IS DUE TO A  
WATER-RELATED DISEASE.



**Here comes, the importance of water purification.....**

# Water purification

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➤ **Process of removing :**

- ✓ **undesirable chemicals**
- ✓ **biological contaminants**
- ✓ **suspended solids**
- ✓ **gases**

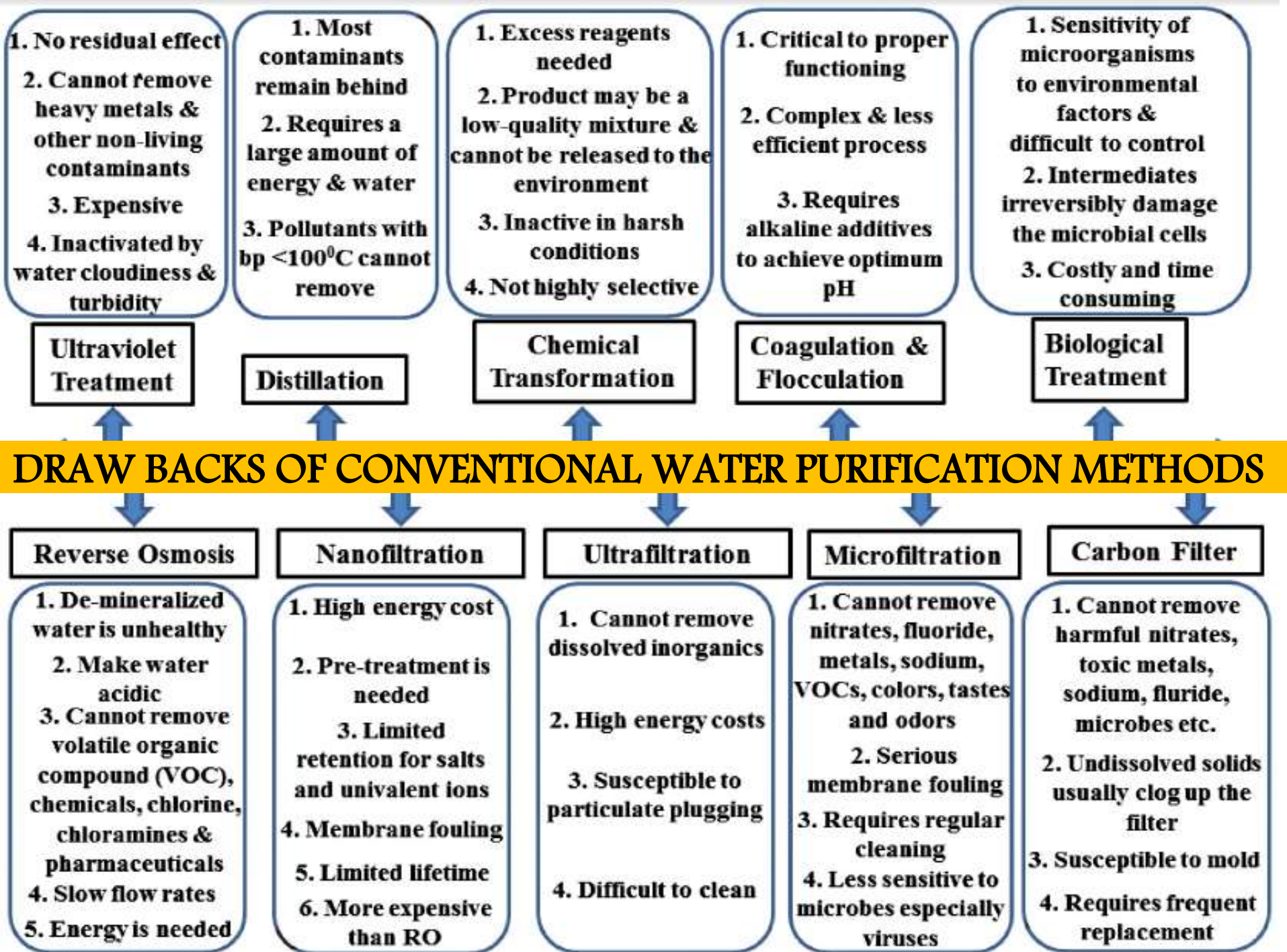
**from contaminated water**



# Conventional Water Purification methods

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- **Coagulation and flocculation**
- **Sedimentation**
- **Filtration**
- **Disinfection**
- **Chlorination**
- **Reverse Osmosis**
- **Distillation**



# So, the point is...

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➤ **Conventional methods are:**

- High energy requirement
- Less effective
- May produce undesirable odours
- Requires a large area of land

# What to do..?

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- **Advanced membrane technologies with controlled and novel pore architectures is important for the achievement of more efficient and cost effective purification**
- **Advances in activated carbon in conjunction with nanotechnology could be welcome relief to the problem of water treatment**

# Contd..



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- **Nanotechnology does appear to be the technology of the future that holds the key to the world's water problems.**
- **Carbon nanotube filters for water purification is an impressive nanotech solution for the water related issues of current century**

# Nanotechnology..???

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# Nanotechnology- Engineering concept

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- **Art and science of manipulating matter at the nanoscale**
- **Involves the study and building of matter and compounds at the scale of 0.1 to 100 nanometers**

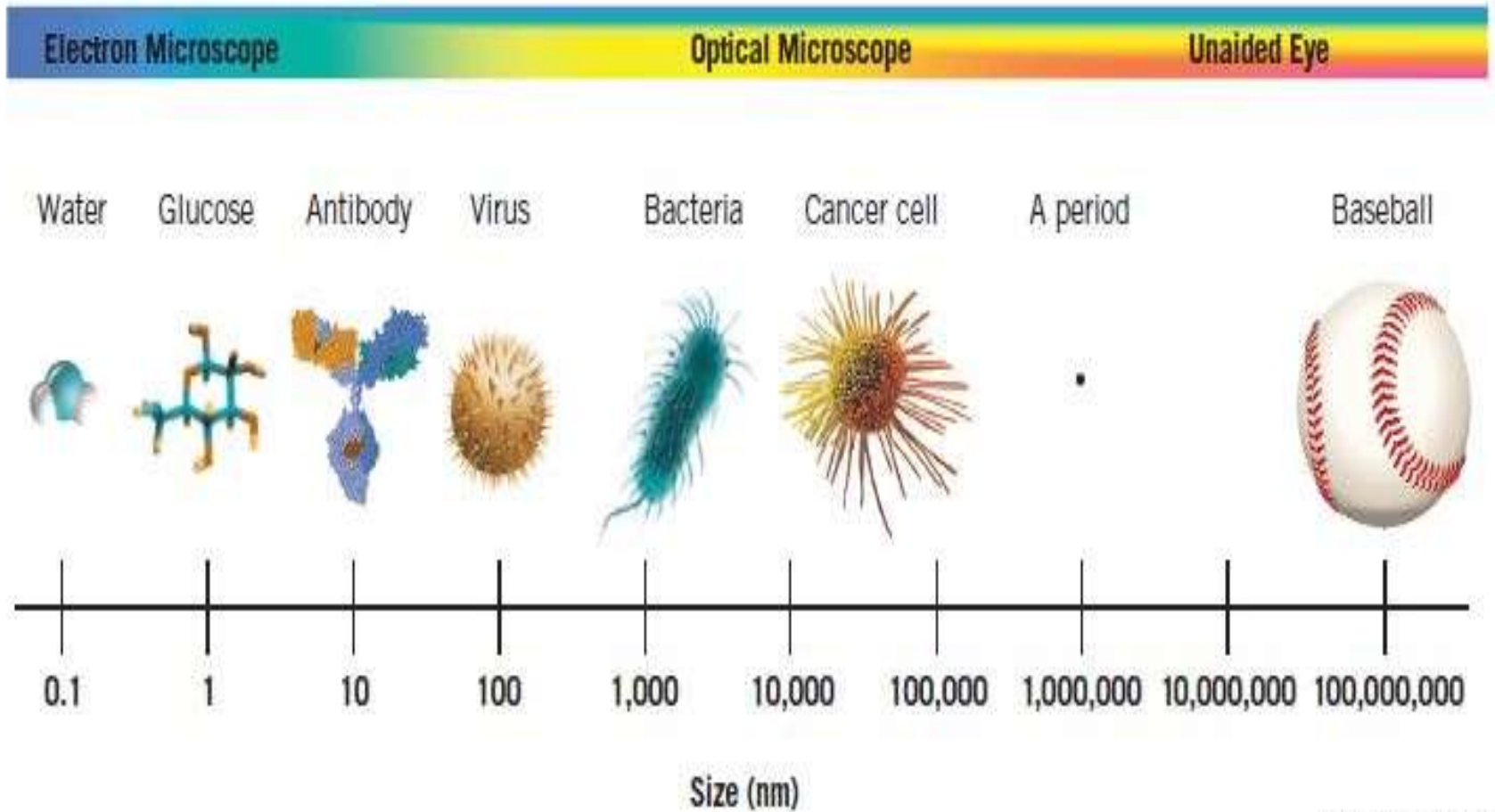
# Contd...



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- 1 nanometer = one billionth of a meter
- **Nanoparticle** – Collection of ten to thousands of atoms measuring about 1–100 nm in diameter
- Size of the nanoparticle is controlled by experimental conditions

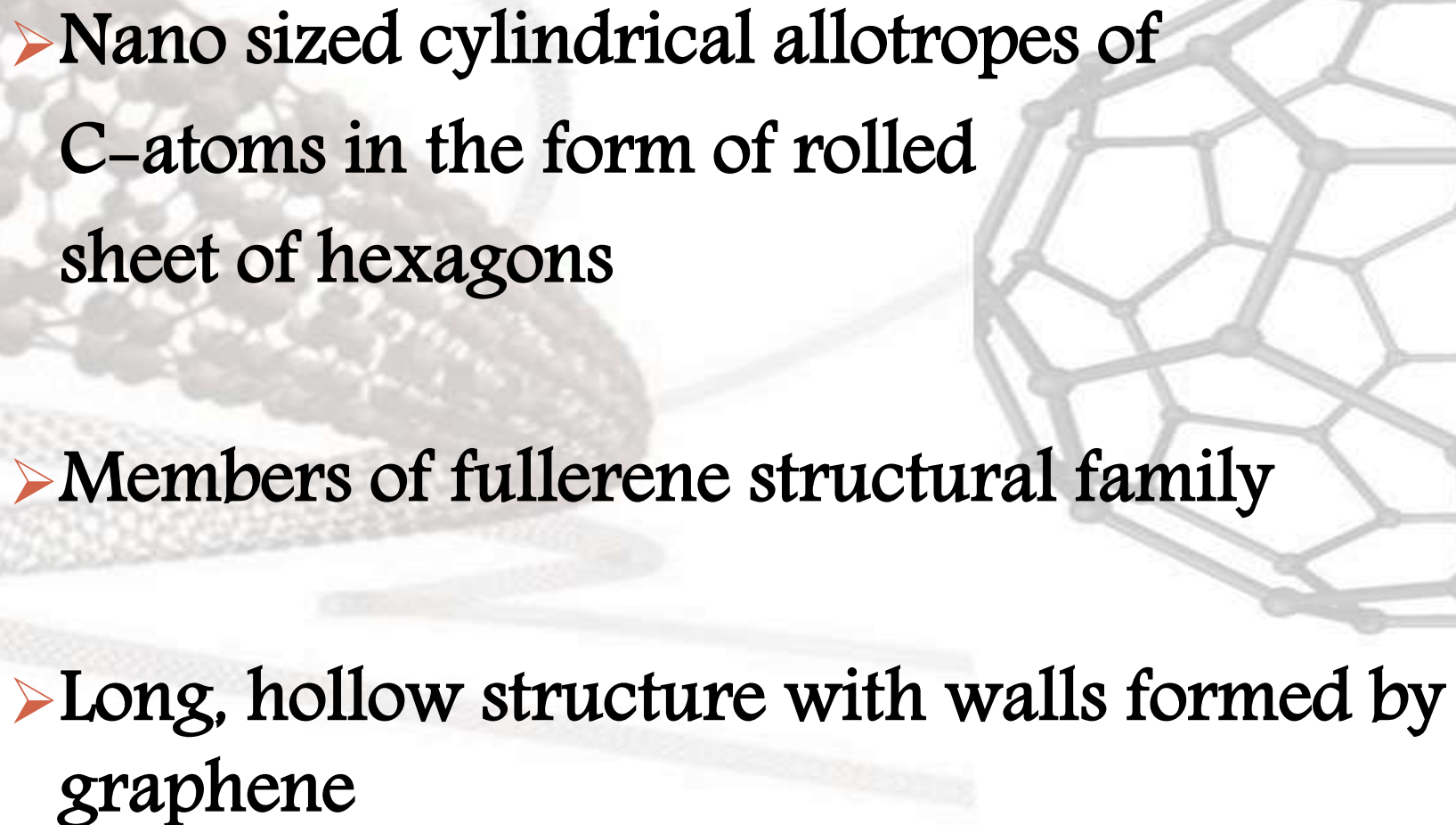
# SIZE COMPARISON

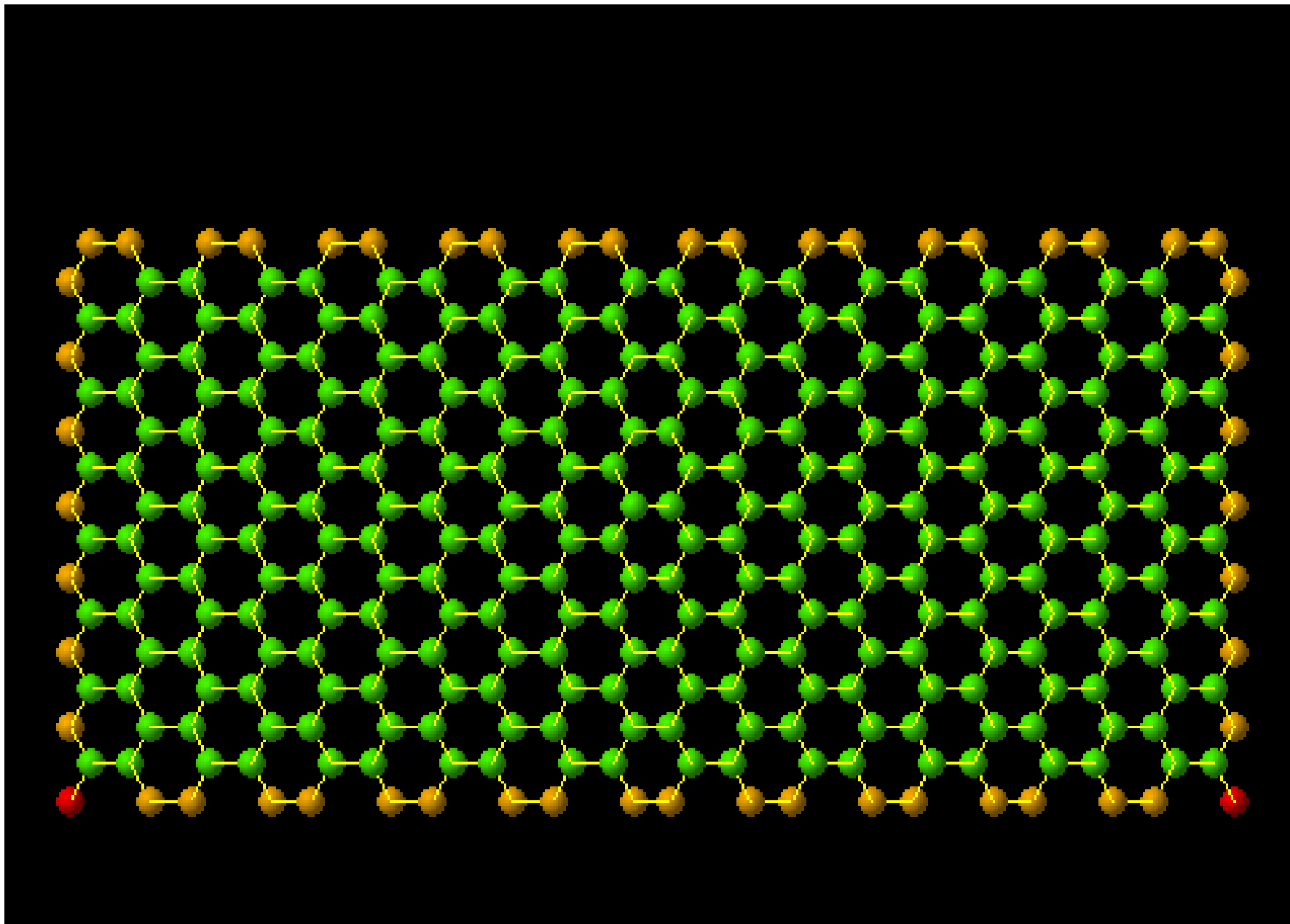


Particle Sciences

# Carbon nanotubes (CNTs)

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- Nano sized cylindrical allotropes of C-atoms in the form of rolled sheet of hexagons
  - Members of fullerene structural family
  - Long, hollow structure with walls formed by graphene
- 



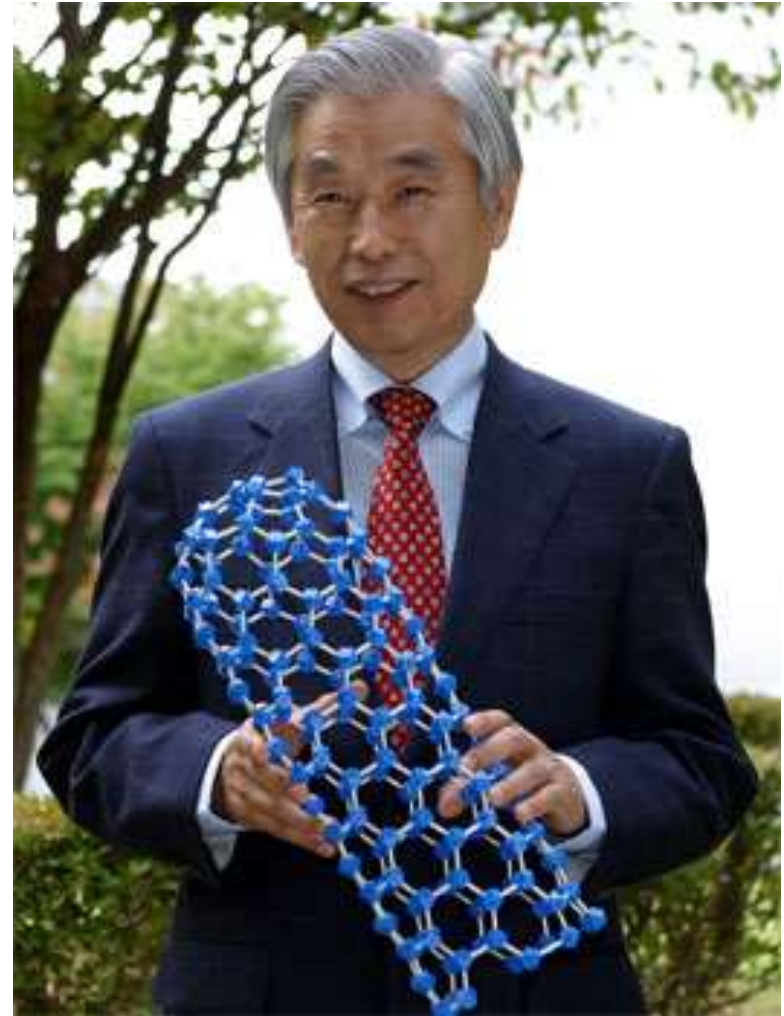
# Contd...

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## ➤ Discovered

- In 1991
- By Sumio Iijima
- By arc evaporation



# Contd...



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- **Property varies based on the method of rolling and arrangement of Carbon atoms**
- **Hundreds of times stronger than steel, but six times lighter**
- **Individual nanotubes align themselves into “ropes” held together by Vander Waals forces**

# Contd...



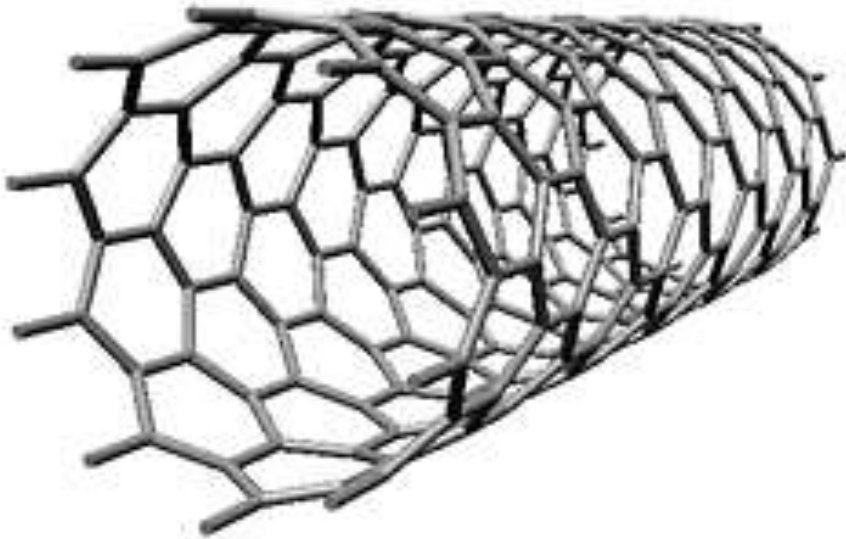
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- Act as effective semiconductors ,with right arrangement of atoms
- Tunable physical, chemical, electrical and structural properties
- Inspires innovative technologies to address water pollution problems

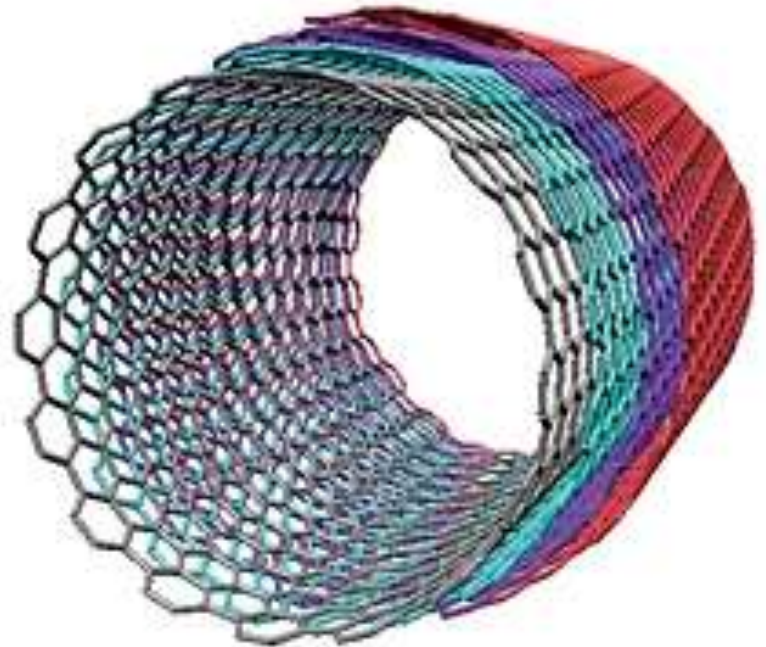
# Classification of CNTs

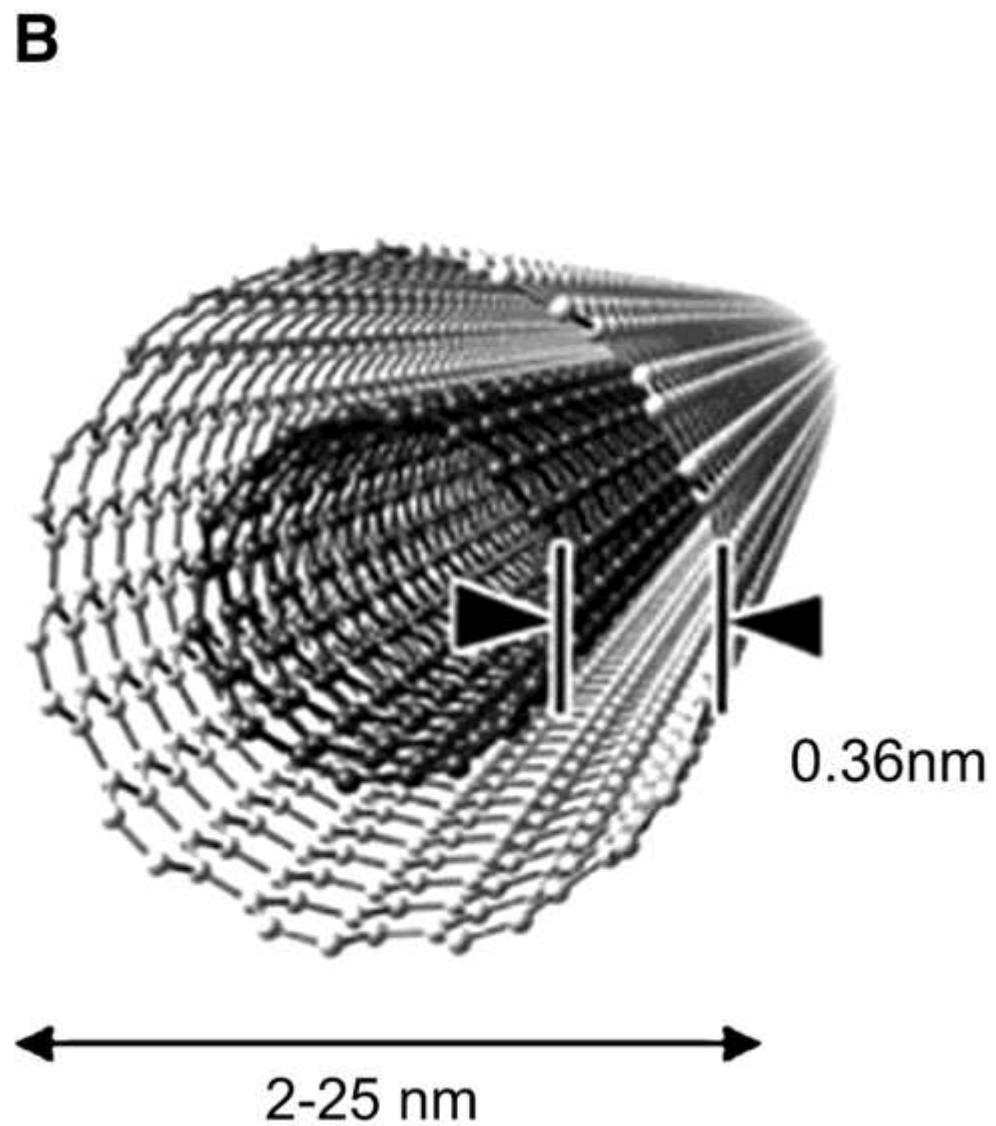
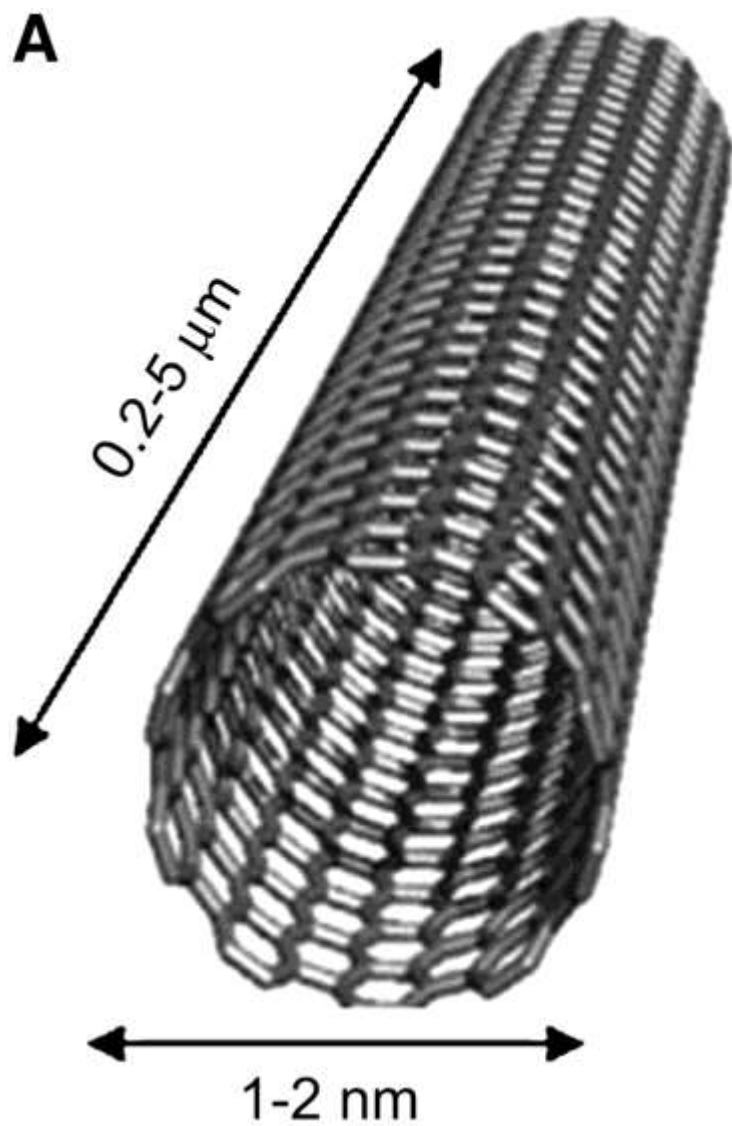
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Single-walled CNT



Multi-walled CNT





# CNT Synthesis

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➤ Arc discharge

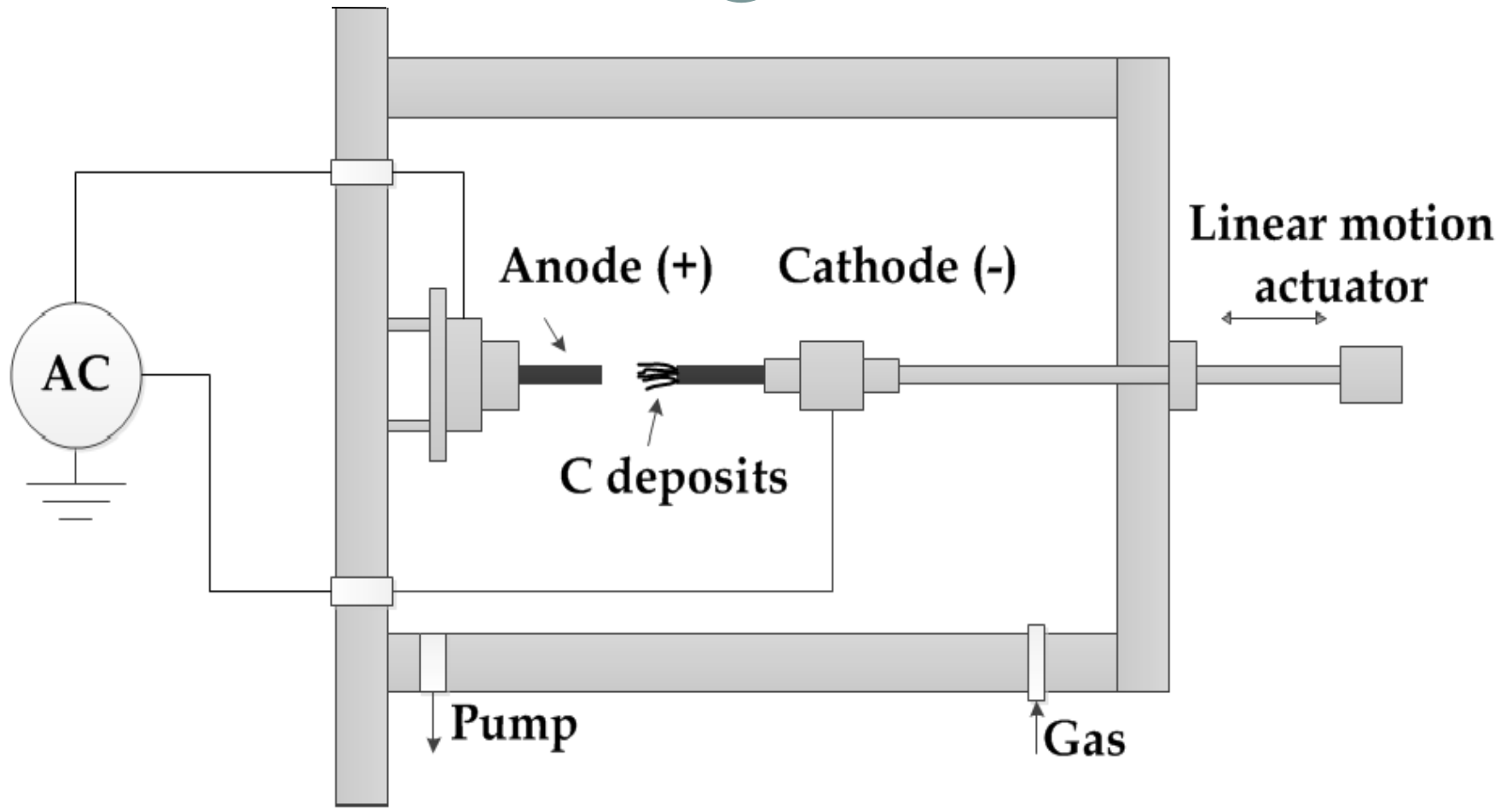
➤ Plasma torch

➤ Laser ablation

➤ Chemical vapor  
deposition

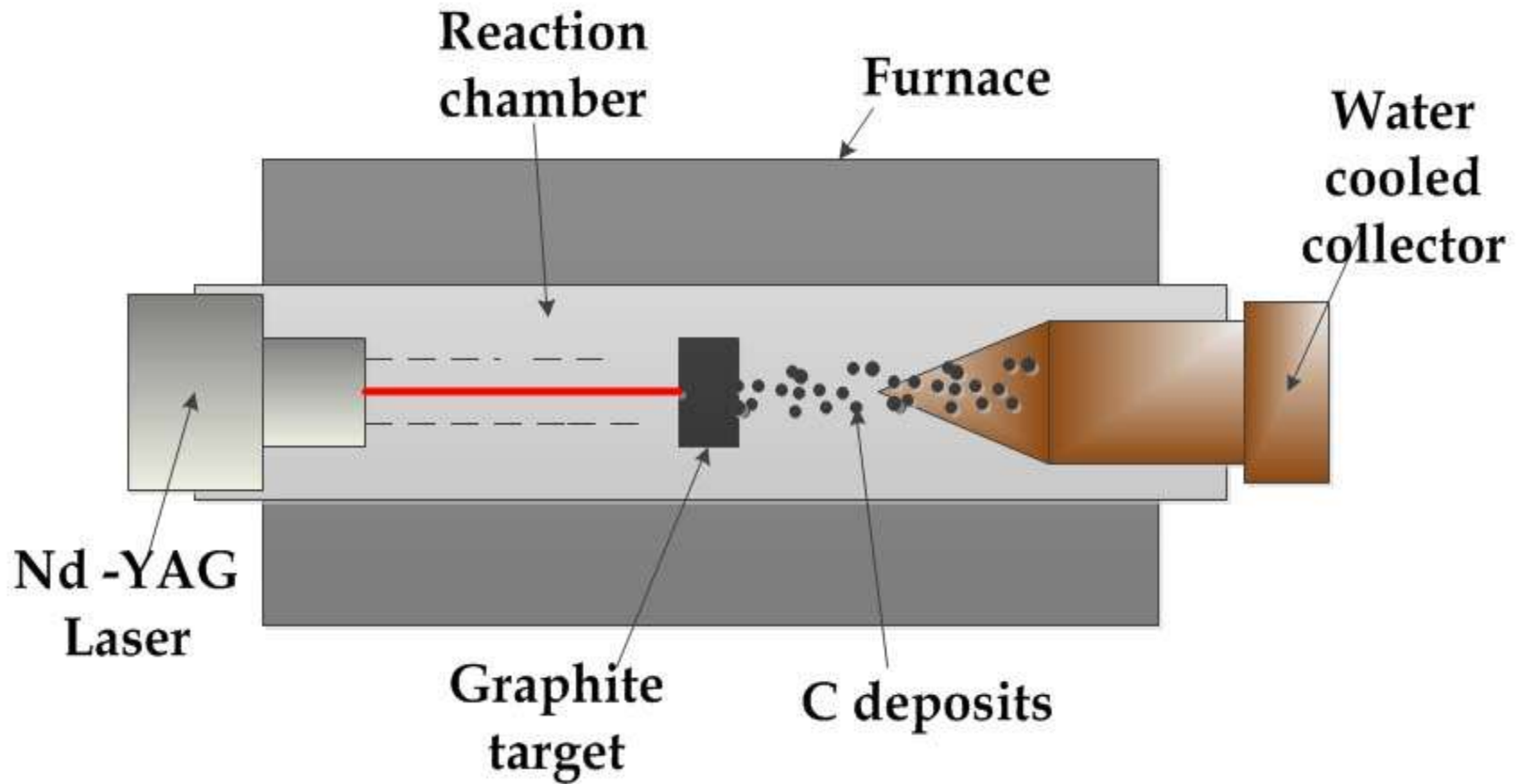
# Arc discharge method

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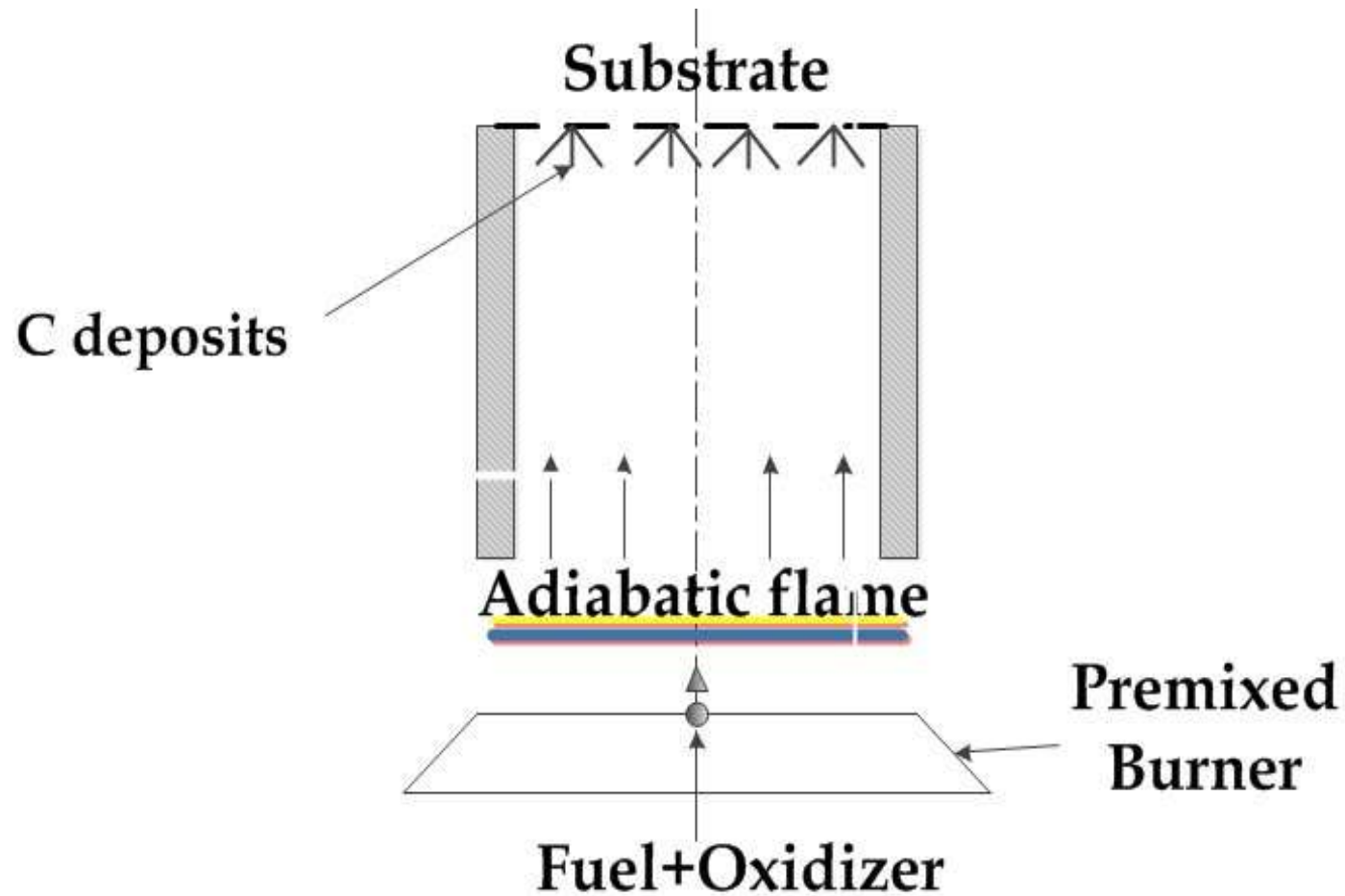
# Laser Ablation method

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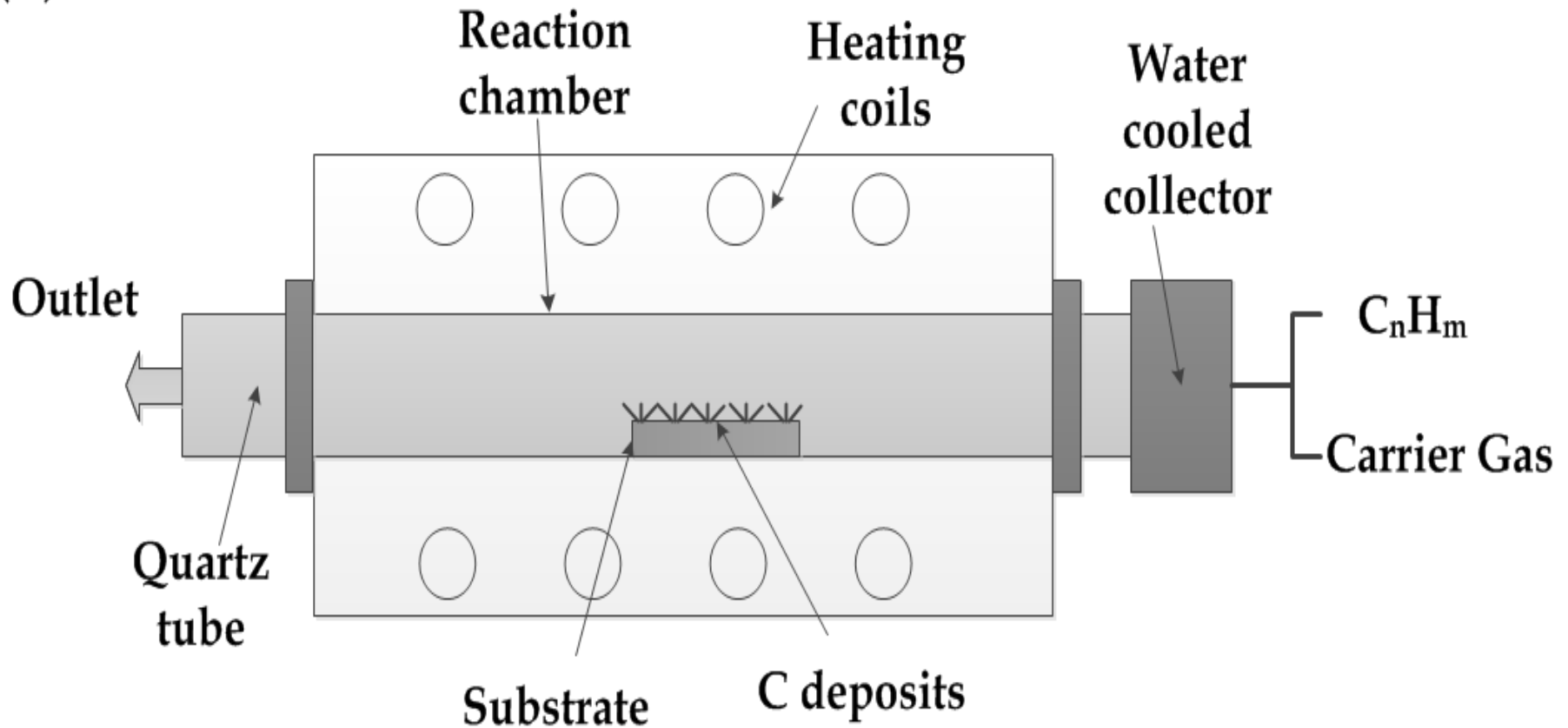
# Plasma torch method

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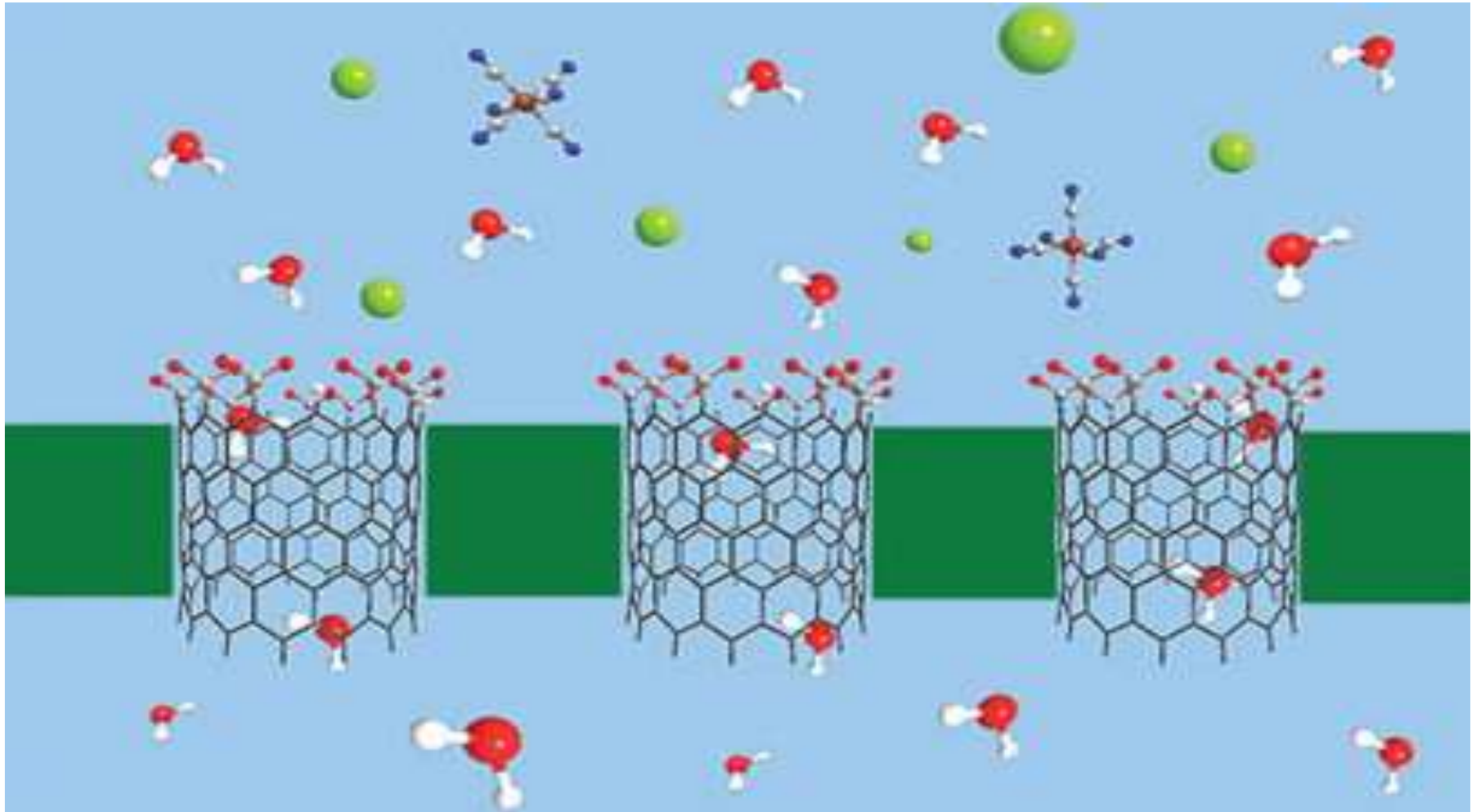
# Chemical Vapour Deposition method

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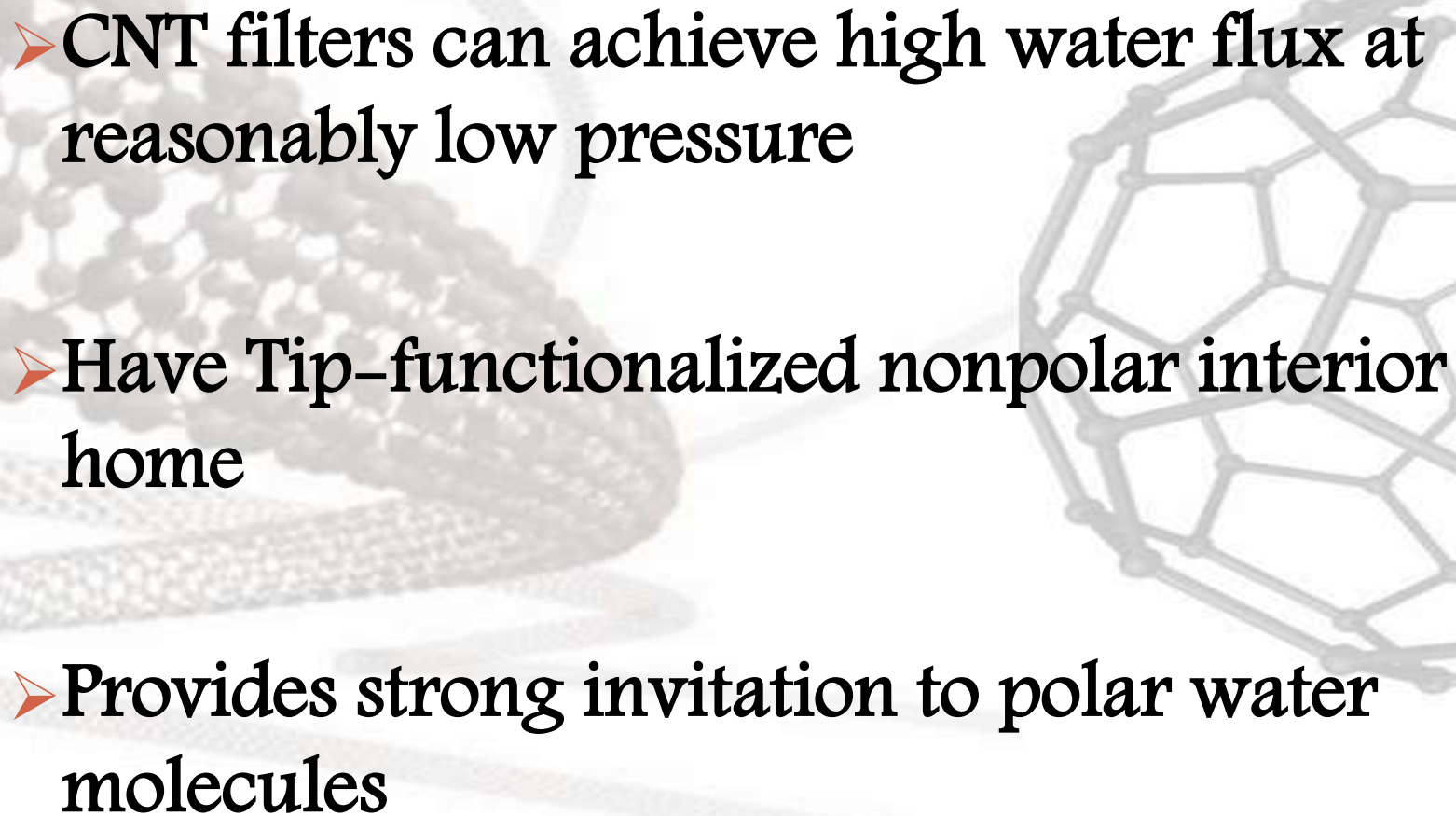
# CNT filters for Water Purification

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# Contd...

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- CNT filters can achieve high water flux at reasonably low pressure
  - Have Tip-functionalized nonpolar interior
  - Provides strong invitation to polar water molecules
- 

# Contd...

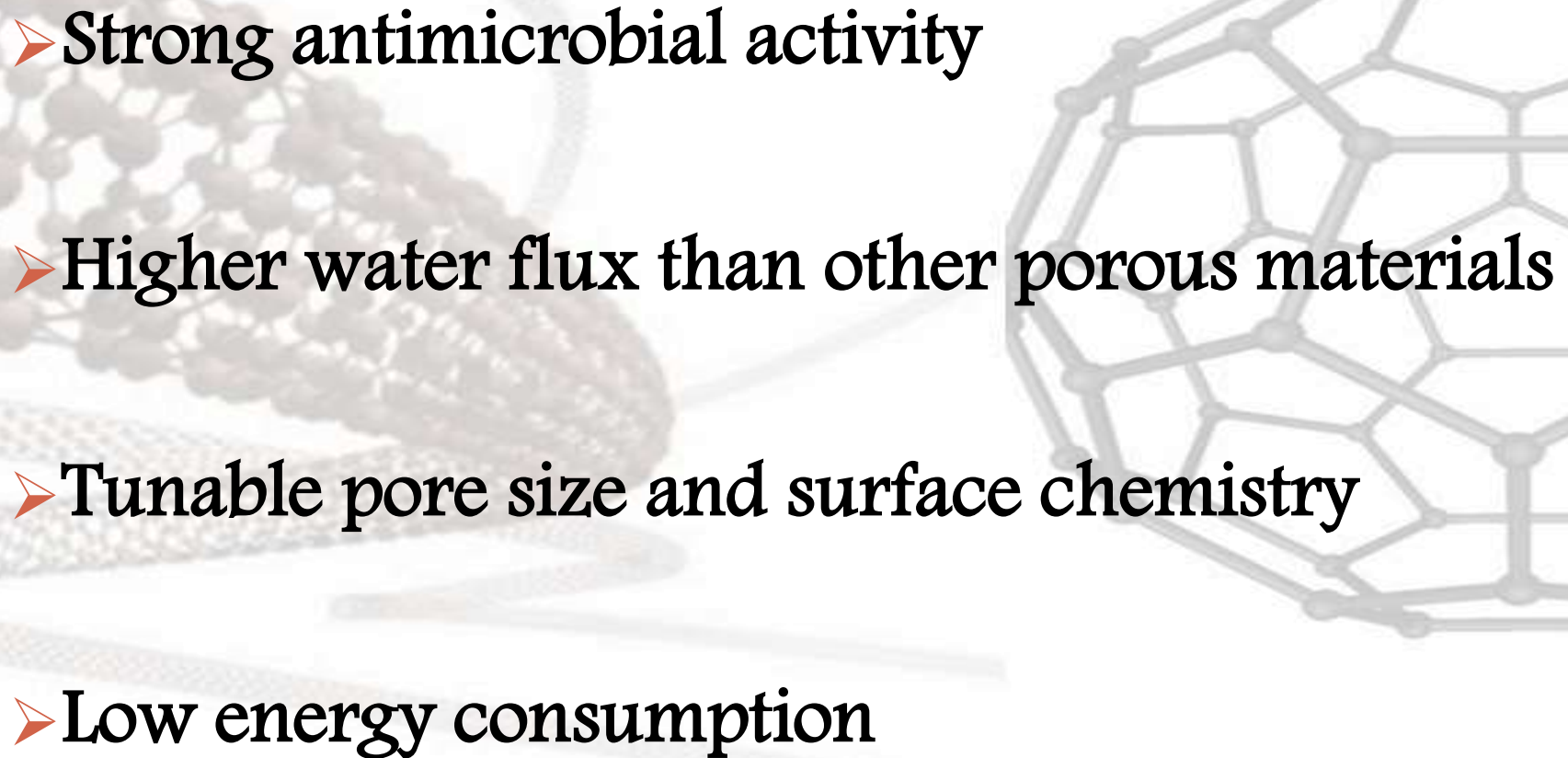
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- **Rejects salts and pollutants**
- **SWCNT filter shows high bacterial retention**
- **MWCNT filter exhibited high viral removal at low pressure**

# Properties of CNTs as water filters

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- Strong antimicrobial activity
  - Higher water flux than other porous materials
  - Tunable pore size and surface chemistry
  - Low energy consumption
- 

# Contd...



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- Antifouling and self-cleaning functions
- Remarkable electrical and thermal conductivity
- Very high tensile strength
- Very elastic  $\sim 18\%$  elongation to failure

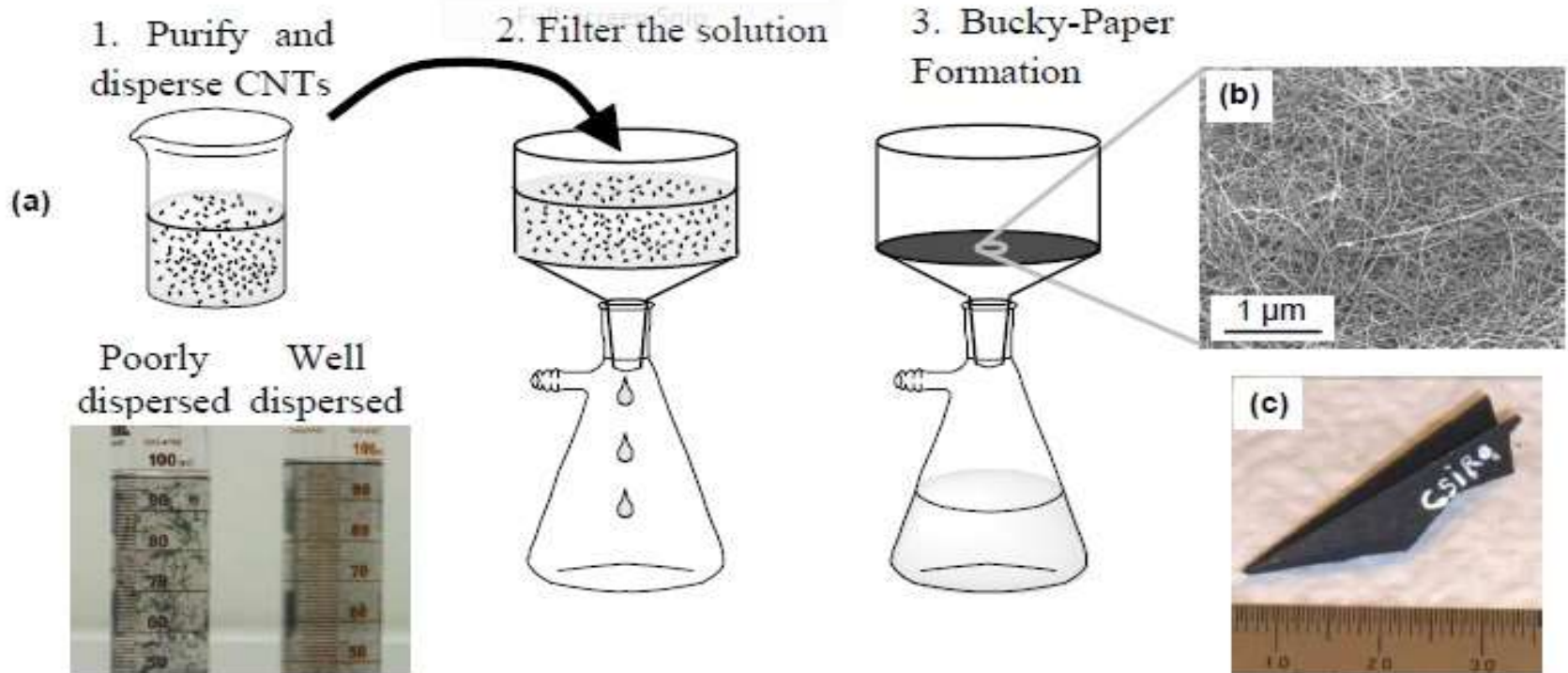
# Specific properties of CNTs selected for Water Purification

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- Outside diameter :  $\sim 1-100$  nm
- Inside diameter :  $\sim 1/3$  outside diameter
- Tube wall spacing :  $\sim 0.3$  nm
- Stiffness :  $\sim 5x$  steel
- Strength :  $\sim 30x$  steel
- Electrical &  
Thermal conductivity :  $\sim 10x5$  nm graphite

# Bucky-Paper CNT Membranes

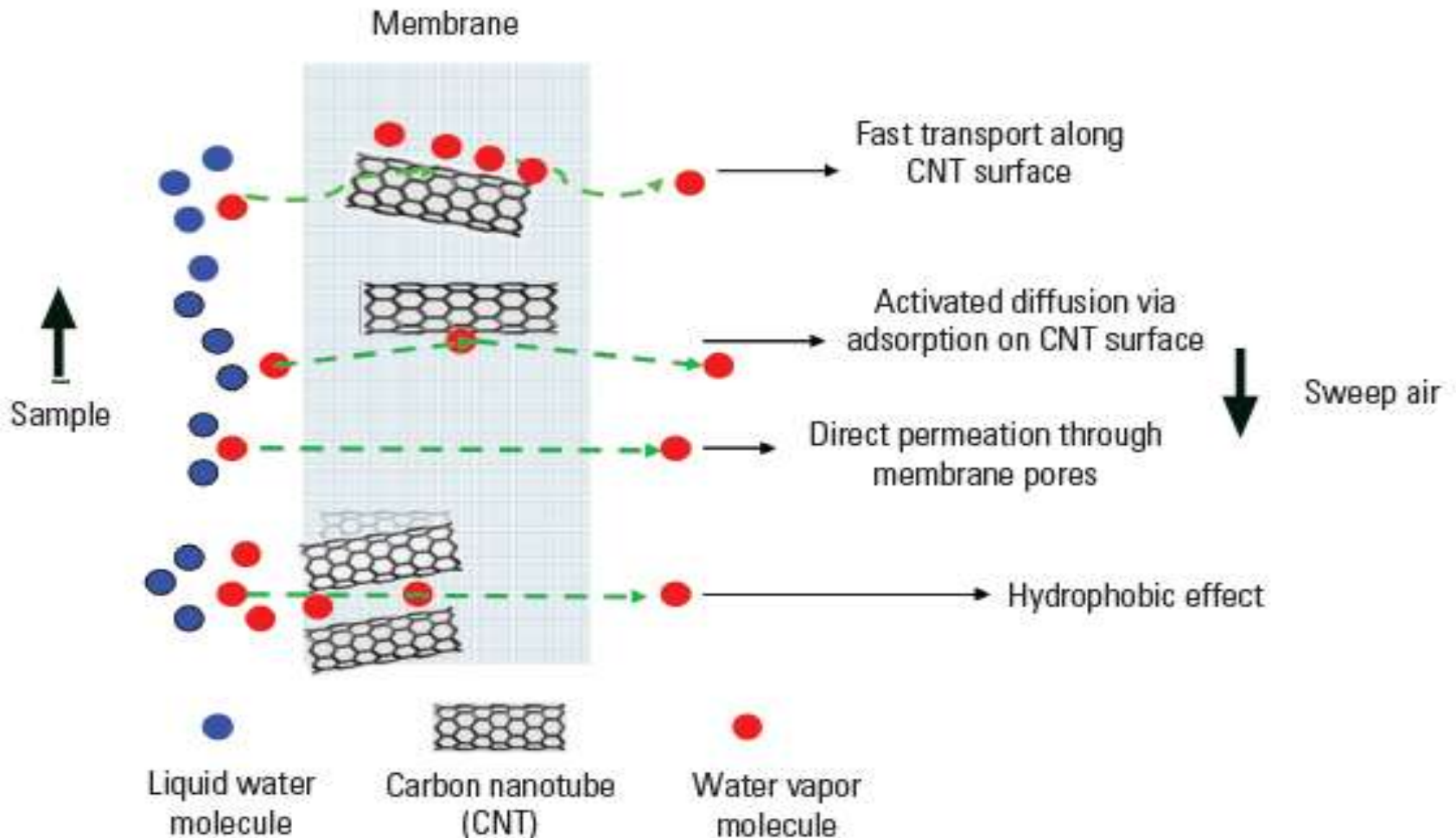
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(a) Process for manufacturing Bucky-papers (b) SEM image showing the Bucky-paper surface and (c) Bucky-paper demonstrating their flexibility & mechanical robustness.

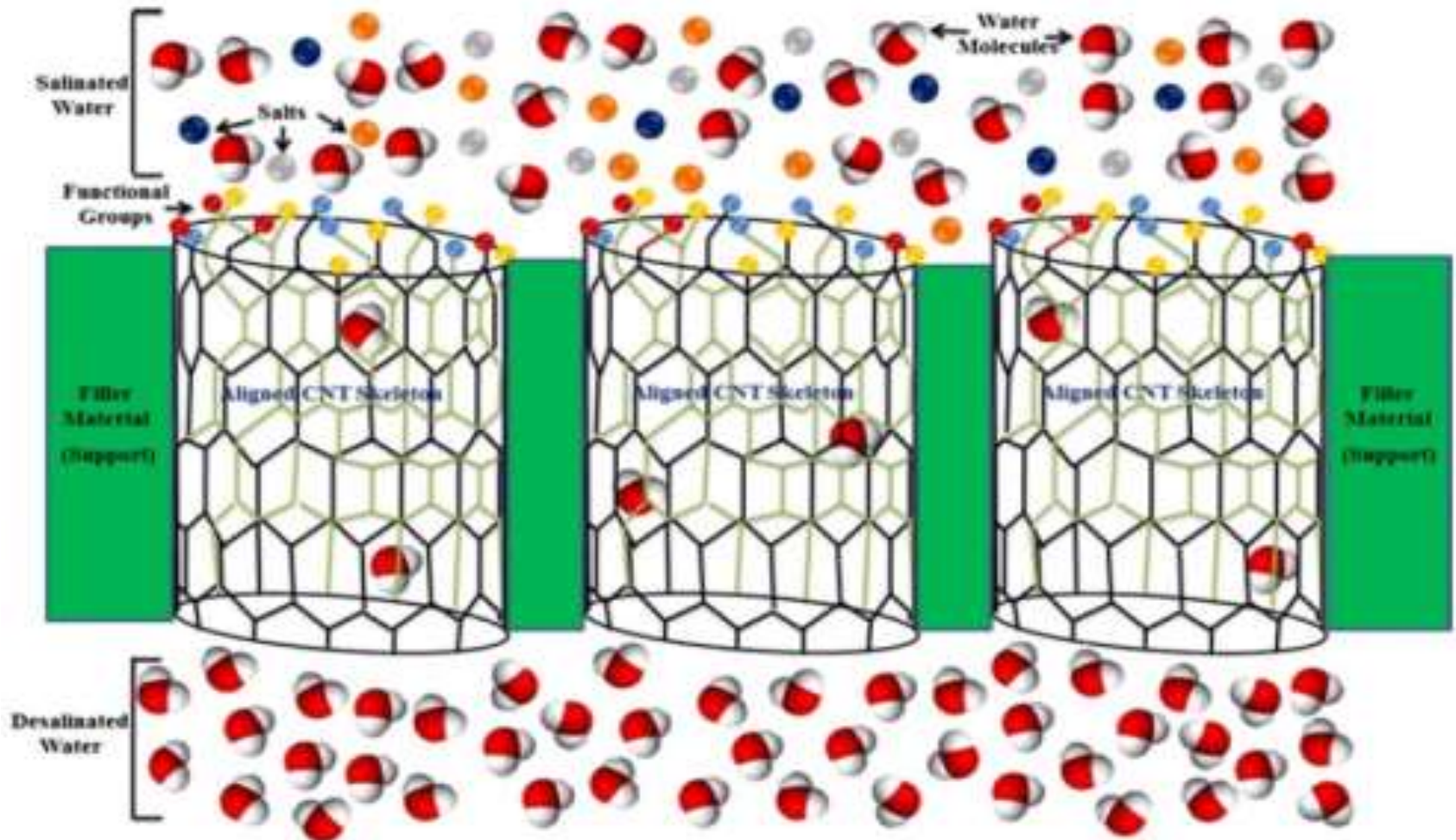
# Water purification technology using CNT filters

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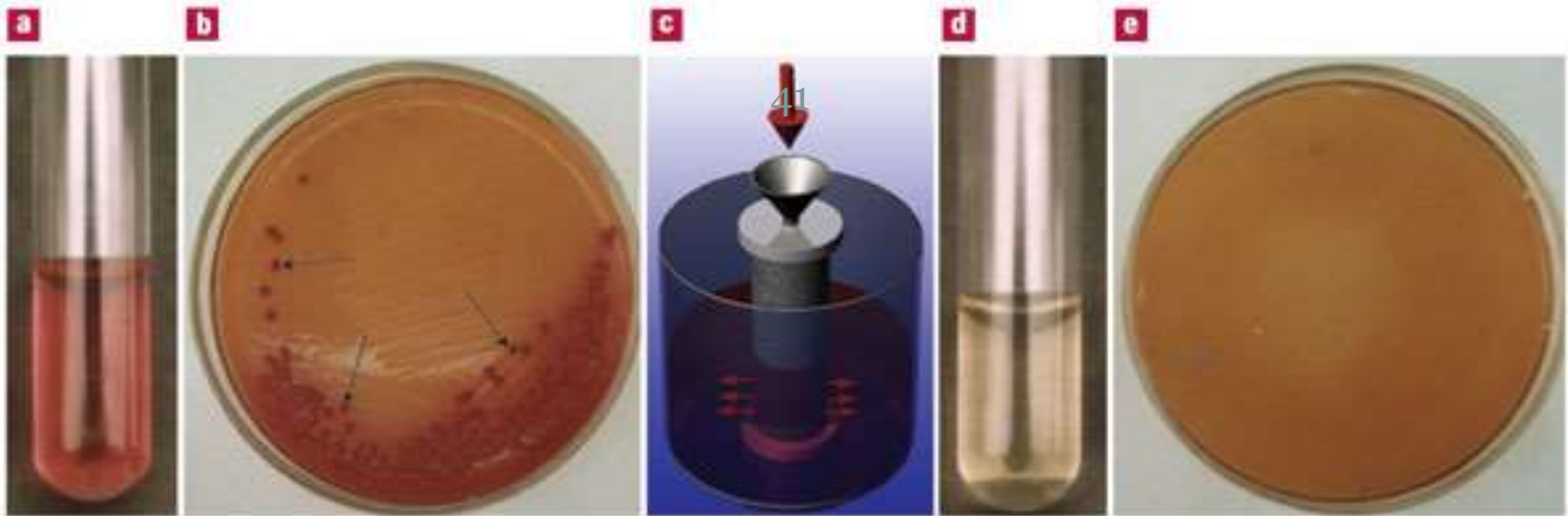


# Desalination using CNT filters

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# Removal of bacteria using CNT filters



a) The unfiltered water containing *E. coli* bacteria

b) The *E. coli* bacteria (marked by arrows) grown by the culture of the polluted water

c) The filtration experiment

d) The water filtered through nanotube filter

e) The filtrate after culture showing the absence of the bacterial

- [Polymer - CNT Membranes for Desalination & Water Filtration \(Scientific Animation\).mp4](#)

# Advantages of CNTs over conventional filters

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- Less pressure is required to pass water across
- More efficient, recyclable
- Have incredibly large surface areas
- Can be more easily cleaned by back-flushing



# Disadvantages of CNTs

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➤ CNT-based filters are expensive



➤ Clogging occurs due to crystalline deposition

# Applications of CNT in Water filtration

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- **Municipal water facilities**
- **Medical facilities and Industrial facilities**
- **Laboratories and Distilleries**
- **Desalination plants**
- **Wastewater treatment facilities**
- **Consumer markets**

# Case study

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**Filtration of sodium chloride (NaCl)  
from seawater  
using carbon hollow tube  
composed of Carbon nanotubes**

➤ **Done By:**

**Chaudhary Ravi Prakash  
Patel Prashant Tripathi, O.N. Srivastava  
and T.P. Yadav**

➤ **Done at:**

**Marina Beach, Chennai, India  
in 2013**

# Objective

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- **Filteration of seawater (Marina Beach, Chennai, India) by removing NaCl**
  - At lower cost
  - Lower input energy
  - Minimum use of chemicals and
  - Minimum impact on the environment

# Materials and methods

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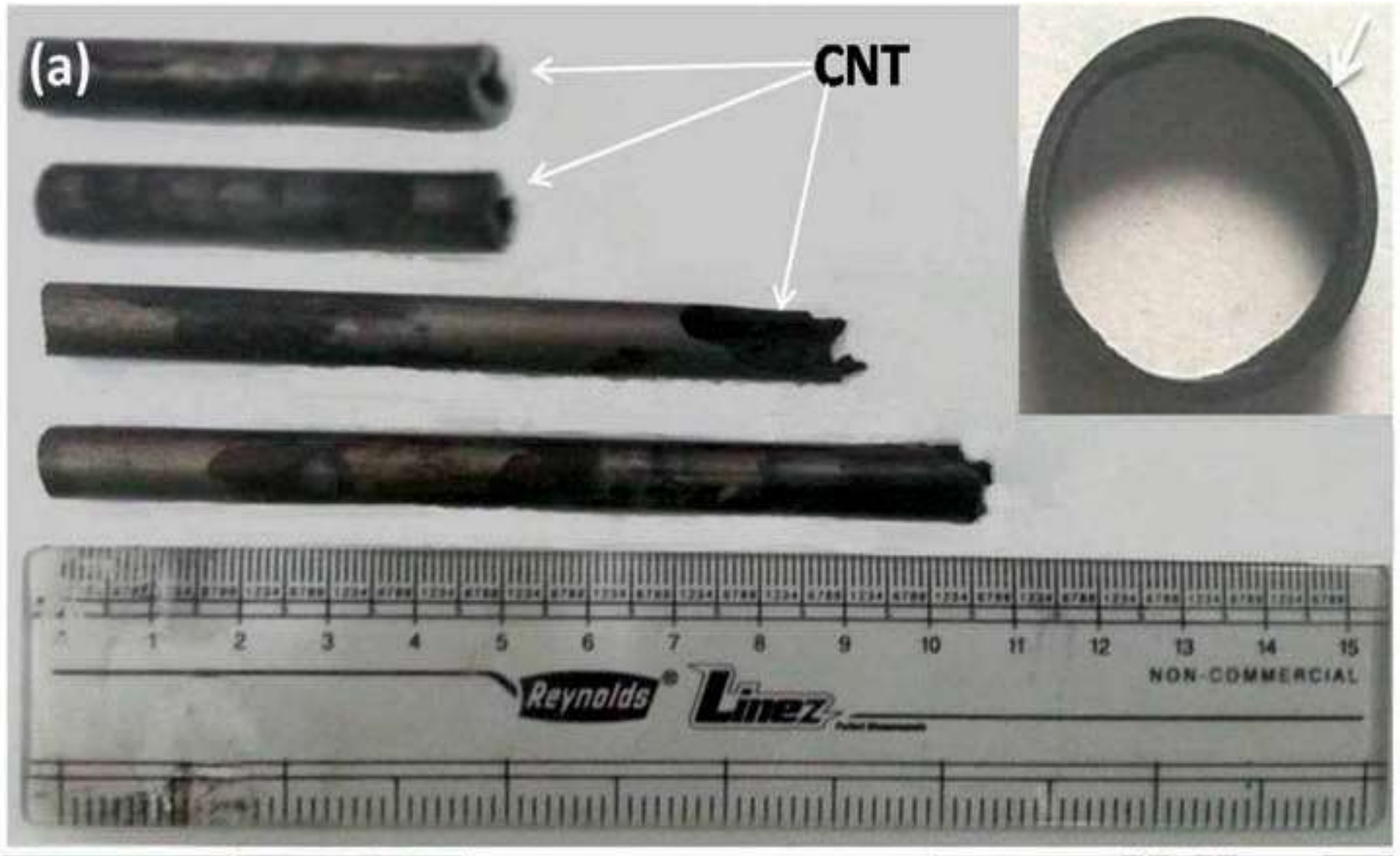
## ➤ **Materials required :-**

➤ Hollow carbon cylinder of diameter 1 cm , length ~ 10 cm having radial CNTs with diameter ~ 10–12 nm

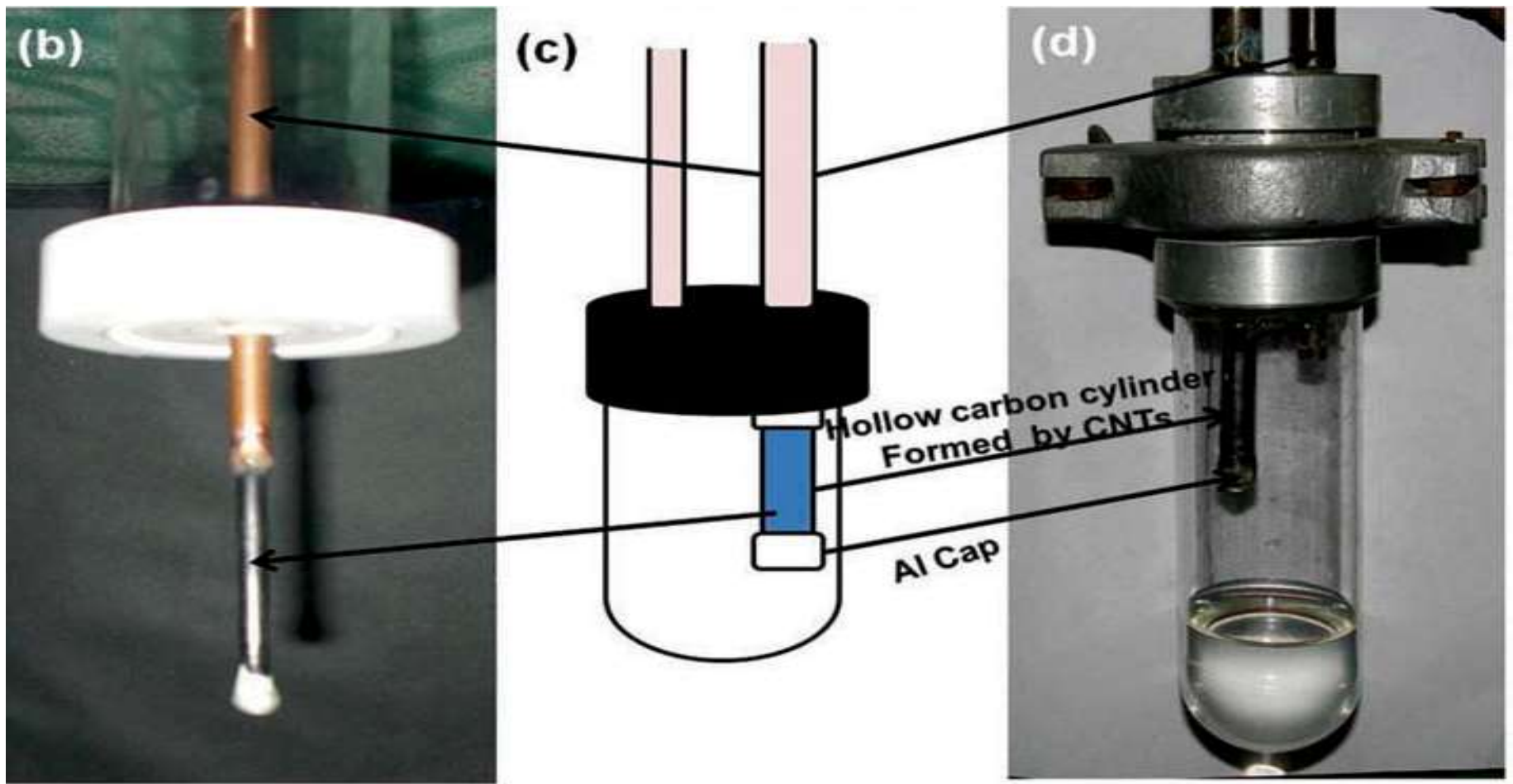
➤ Filtration setup

➤ **Methods adopted:-**

1. **Synthesis of carbon hollow cylinder consisting of radially aligned CNTs**
2. **Fabrication of filtration setup**



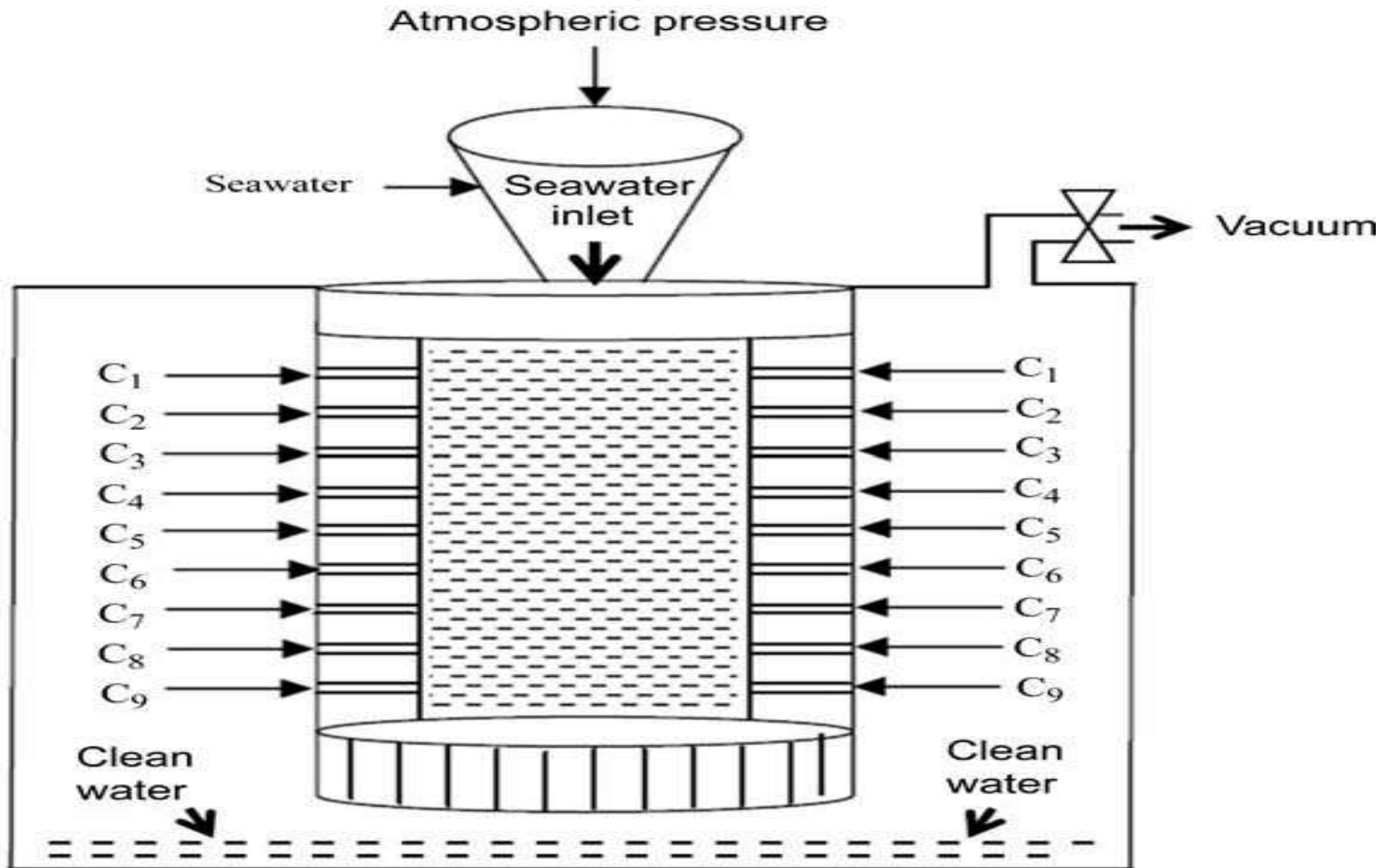
**(a) Hollow cylinder of CNTs**



- (b) Filtration setup of hollow cylinder of CNTs
- (c) The schematic diagram of the filtration setup
- (d) Optical photograph of the filtration setup.

# Experimental apparatus

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# Results and Discussions

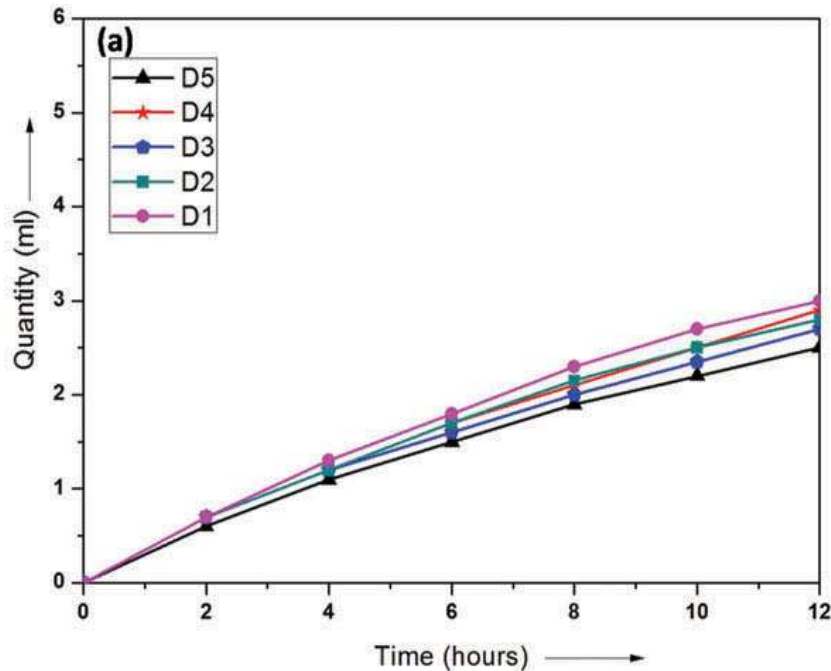
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- With the increase in the liquid column pressure, the filtration rate also increases
- Using vacuum, pressure difference of  $\sim 742$  torr gets applied at seawater entering points
- Amount of filtrated water was found to be nearly two times higher

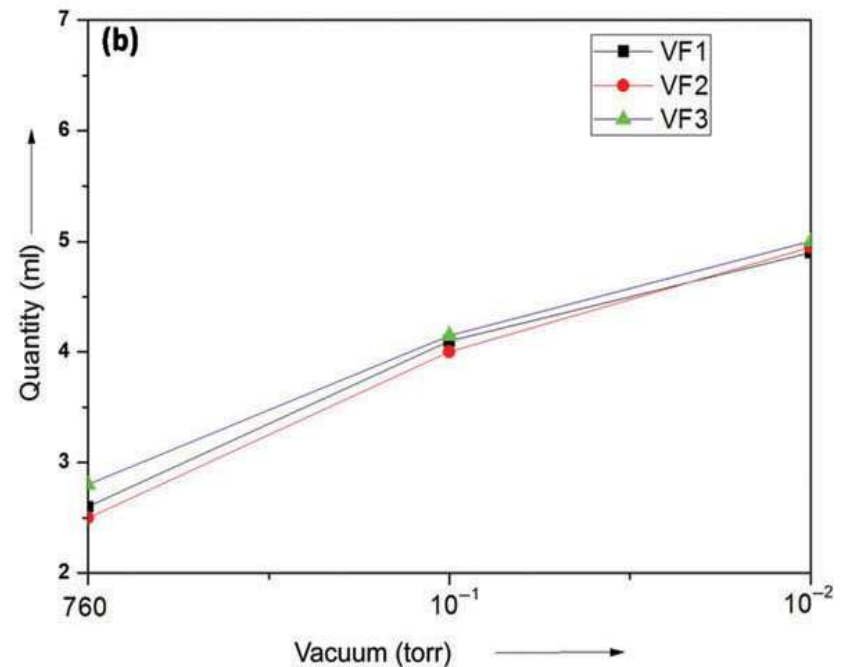
# Seawater filtration through CNT-based filter

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## Efficiency of seawater filtration:–



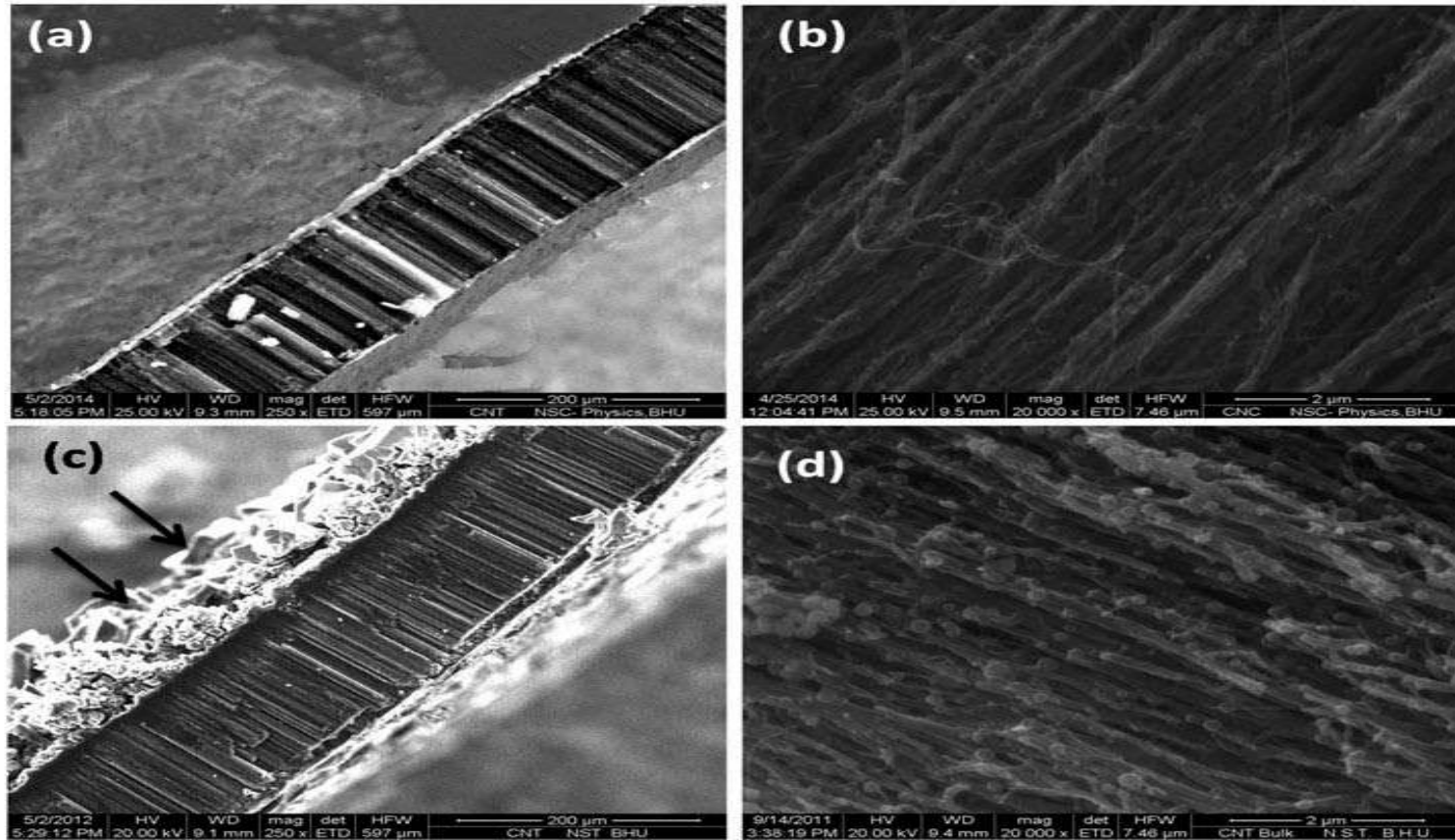
(a) With 100-cm water column of (pressure 10 Pa)



(b) With water collected as a function of vacuum in 12 h

# □ Characters of CNT filter before & after filtration

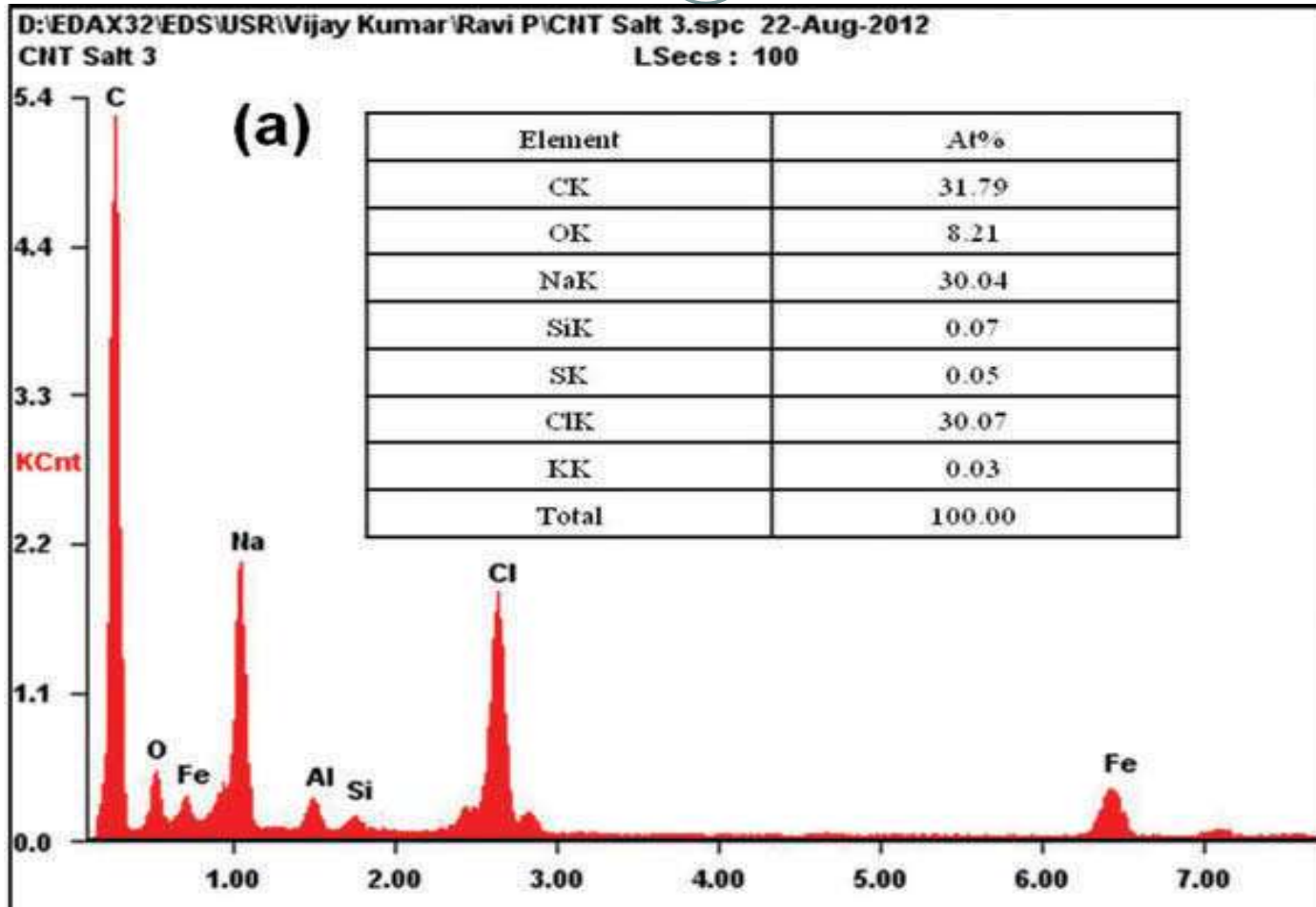
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SEM of the bulk hollow cylinder of CNTs before (a–b) and after (c–d) filtration of seawater

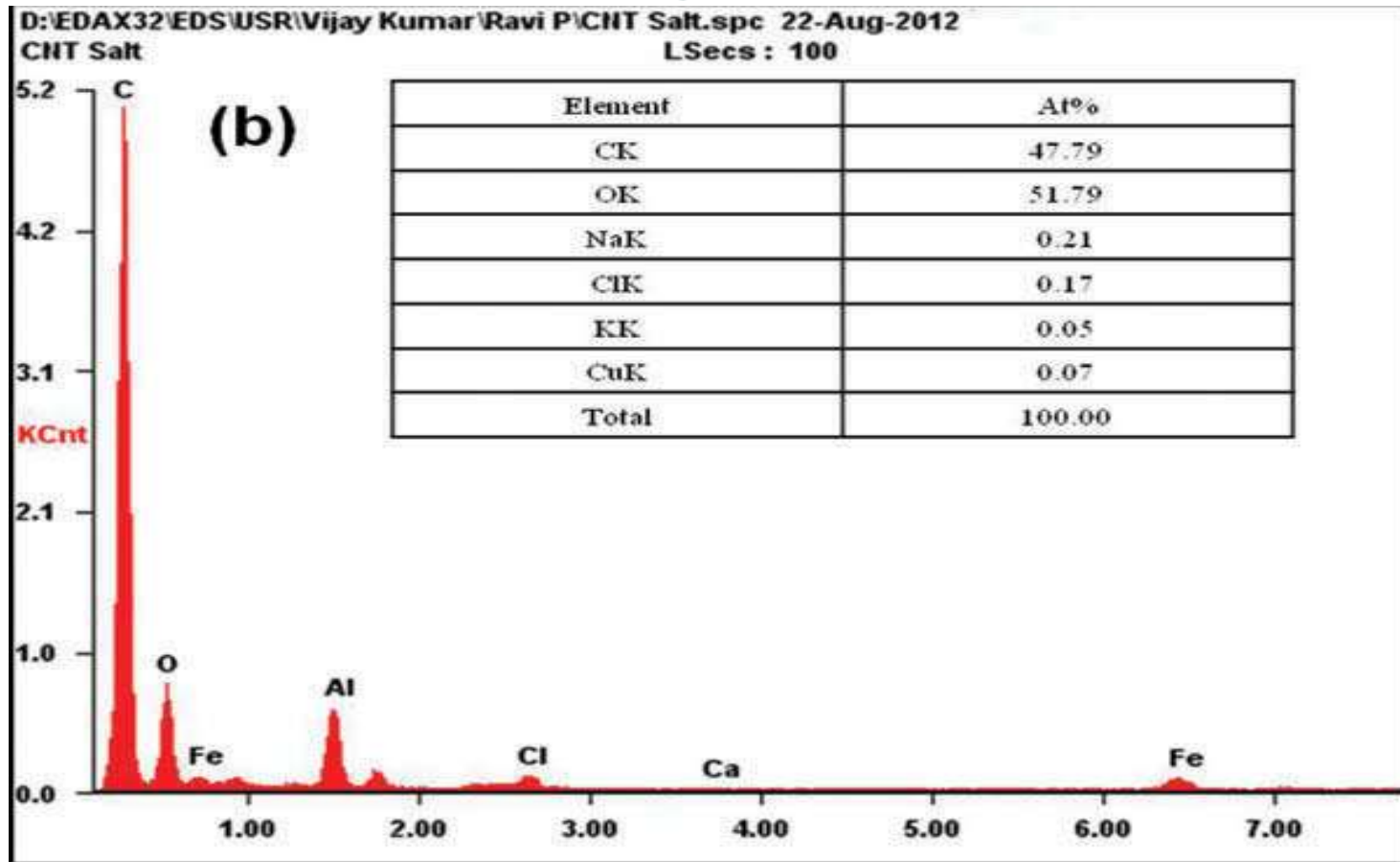
# EDX data of salt of seawater before filtration

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# EDX data of salt of seawater after filtration

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# Case study can be concluded as...

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- Rate of filtration through CNT filters holds promise for improvement
- Creating vacuum in the filtrate side improves the rate of filtration
- Amount of Na decreases from 30.06 – 0.4wt% and Cl from 11.44 – 0.17wt%

# Conclusion

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- **CNT membranes could potentially lead to more effective means of filtration.**
  - **Remove more impurities**
  - **Faster**
  - **More economical**
  - **More selective**
  
- **Aligned CNT membranes provides opportunities for future seawater desalination**

# References

- Harris, P. F. 1999. *Carbon Nanotubes and Related Structures*. Cambridge University Press, Cambridge, 123p.
- Chaudhary Ravi Prakash Patel., Prashant Tripathi, O.N., Srivastava, O. N., and Yadav, T. P. 2013. Filtration of sodium chloride from seawater using carbon hollow tube composed of carbon nanotubes. *Int. J. Smart and Nano Materials*. 5(3): 194–206. Available: <http://www.tandfonline.com/loi/tsnm20> .pdf. [25 Nov.2014]

And finally....



**"If We Could Produce  
Fresh Water From Salt  
Water at a Low Cost, That  
Would Indeed Be A Great  
Service to Humanity and  
Would Dwarf Any Other  
Scientific  
Accomplishment"**

**John F. Kennedy, 1962**



