

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

Synthesis of Carbon Nanotubes and Its Application in Treatment of Contaminated Groundwater

Raksha. R¹ and D. Istalingamurthy²

P G Student, Department of Environmental Engineering, Sri Jayachamarajendra College of Engineering, JSS Technical
Institution Campus, Manasagangothri, Mysuru, Karnataka, India¹

Professor, Department of Environmental Engineering, Sri Jayachamarajendra College of Engineering, JSS Technical
Institution Campus, Manasagangothri, Mysuru, Karnataka, India²

ABSTRACT: Groundwater is the largest source of usable, fresh water in the world. Groundwater is often drawn for agricultural, municipal and industrial use by constructing and operating extraction wells. Groundwater is vulnerable to contamination due to many human and environmental activities. Nanotechnology has wide application in environment and has the potential to offer several benefits that are not offered by other conventional technologies. Where carbon nanotube is key component of nanotechnology, hence an attempt is being made in the present study to treat polluted groundwater using carbon nanotubes. In this work, carbon nanotubes were synthesized using open arc discharge method and groundwater containing objectionable parameters such as iron, nitrate, fluoride, phosphate and total dissolved solids was filtered using carbon nanotubes as filter media. The filtration was carried out by CNTs and natural sand with three different packing methods; deposited, layered and mixed. The work concluded that a maximum removal efficiency of 87.5% for iron, 88.93% for nitrate, 80% for fluoride, 84.14% for phosphate and 73.7% for total dissolved solids was obtained at a depth of 8cm in deposited CNTs packing method compared to other methods.

KEYWORDS: Groundwater, pollution, objectionable parameters, nanotechnology, carbon nanotubes, filtration.

I. INTRODUCTION

Groundwater is the largest source of fresh water and makes up about 20% of world's fresh water. Groundwater is often used for agricultural, drinking, municipal and industrial purposes. Groundwater contamination or pollution mainly occurs due to improper disposal of wastes directly on land and also due to naturally occurring contaminants such as fluoride, arsenic, etc. Using such contaminated or polluted groundwater causes health hazards through poisoning and spread of disease. Nanotechnology has wider applications in environmental remediation like water purification, wastewater treatment, air pollution, groundwater remediation, nanosensors for environmental monitoring, etc (Alinaet al., 2003). Carbon nanotubes (CNTs) are key component of nanotechnology and have great application in environment due to its unique properties. CNTs are nanomaterials that are rolled up into a tube and are of two types; single walled carbon nanotube (SWNT) and multiwalled carbon nanotube (MWNT). CNTs are produced using three major processes; Electric arc discharge method, Chemical Vapour deposition method(CVD) and Laser ablation method (Andrea et al., 2010). CNT poses unique and all essential properties to maintain water of high quality. Hence CNTs are used here to treat contaminated groundwater.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

II. MATERIALS AND METHODOLOGY

Materials

Graphite plate as cathode of high purity (99.5%) with 150mmx150mmx20mm and IC 6003 grade specification was selected. Graphite rods as anode of 99.5% purity with 150mm length, 6mm diameter and IC 6002 grade specification were selected. These were purchased from Carbon Products (India), Mumbai to produce CNT.

Sampling of groundwater

The sampling point for this study was in Geekhalli, Nanjangudutaluk, Mysore district, Karnataka, India. The reason for considering this sampling point was due to the proximity of village to Distillery industry nearby. The release of spent wash generated by distillery directly on ground behind the distillery causes the groundwater contamination. Groundwater has yellowish brown color and also various objectionable parameters.

Synthesis

Carbon nanotubes were synthesized by open air arc discharge method. The graphite rod as anode of 150mm length and 6mm diameter and graphite plate as cathode of size 150mmx150mmx20mm were used as electrodes. A manual arc welding machine was used for arching process at 150A and 40V with 3mm gap between electrodes. Graphite rod was manually passed on stationary graphite plate to produce arc and no automation was employed. Soot was formed on the graphite plate which was then scraped off and collected for further purification process. Purification of synthesized CNTs was carried out with three simple steps in order to remove amorphous carbon, fullerenes and impurities (Senthil et al., 2010).

Step 1: Soot was crushed into fine powder and heated in closed muffle furnace at 650⁰c for 1 hour.

Step 2: Then heat treated CNTs were washed in distilled water and treated with toluene for 5 hours. Later sample was dried in hot air oven at 100⁰c.

Step 3: Sample was then subjected to liquid phase oxidation with 20% hydrogen peroxide for 2 hours. Then it was washed in distilled water and dried in hot air oven at 100⁰c.

Hence obtained CNTs were subjected to SEM analysis to know morphology and structure of produced CNTs.

Fixed filter bed column experiment

A column of 40cm length and 2cm diameter was used for filter. Filter bed experiments were used to investigate removal of objectionable parameters in CNT-sand media via three different CNT packing methods. Layered, mixed and deposited CNTs were three ways of packing incorporated in the study. The sand is sieved to obtain grain size of 0.6mm. The sand was washed with de-ionized water and dried naturally (Yuan et al., 2012).

For deposited CNTs packing method the column was first filled with sand. The dried sand was mixed with water to obtain wet slurry which was then wet packed into the column at a fixed depth of 8cm. This was done in order to obtain better compaction and to prevent the formation of air voids. De-ionized water was then again passed through the sand bed to determine the absence of parameters such as nitrate, iron, fluoride, phosphates and TDS. This sand layer acts as a supporting media for the CNTs and also helps in the prevention of CNTs passing through. The synthesized and treated CNTs were then placed on the sand layer with different depths as shown in Figure 1. This layer of CNTs acts as the filter bed which at varying depths provides filtration of the ground water sample. The depths which were considered for this research study are 2cm, 4cm, 6cm and 8cm. The groundwater was passed through these varying depths of CNTs to remove the objectionable parameters like iron, nitrate, fluoride, phosphate and TDS. The samples were collected after passing through the filter beds and were analyzed for the above mentioned parameters. The sample before and after passing through CNTs is shown in Figure 6.

For the layered CNT packing method, firstly sand washed with de-ionized water and dried naturally was filled in the column at depth of 2cm. Then the synthesized and treated CNTs were packed at equal depth of 2cm as shown in figure 1. This type of packing sand and CNTs in layers alternately with equal depth was repeated for two more layers. The ground water was passed through these layers to remove the objectionable parameters like iron, nitrate, fluoride, phosphate and TDS. The sample was collected after passing through the layered filter bed and was analyzed for above mentioned parameters. The sample before and after passing through layered CNTs packed bed is shown in figure 6.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

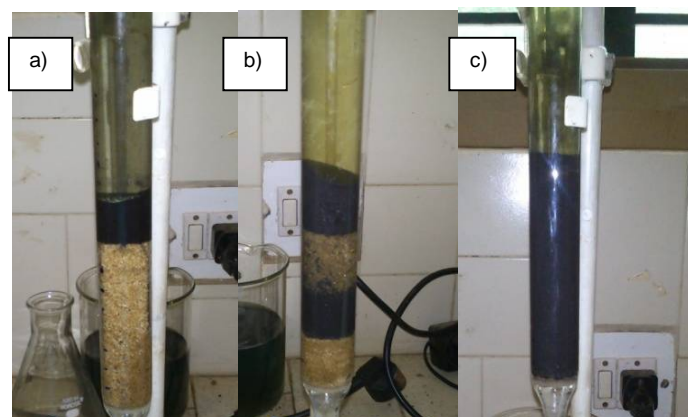


Figure 1: Different CNTs packing methods (a) Deposited packing method, (b) Layered packing method and (c) Mixed packing method.

For the mixed CNT packing method, sand washed with de-ionized water and dried naturally was weighed for 16gm. The synthesized and treated CNTs were weighed for 10gm. Then these weighed sand and CNTs were mixed thoroughly and packed in the column as shown in figure 1. The ground water was passed through this mixed layer to remove the objectionable parameters like iron, nitrate, fluoride, phosphate and TDS. The sample was collected after passing through the mixed filter bed and was analyzed for above mentioned parameters. The sample before and after passing through mixed CNTs packed bed is shown in figure 6.

III. RESULTS AND DISCUSSIONS

SEM analysis of CNTs

The SEM micrograph showed in figure 2 shows the presence of CNTs which are needle like structures. The picture was taken at a magnification of $1\mu\text{m}$. The SEM picture shows densely stacked graphite layers which are formed due to the sudden quenching of plasma and high current densities used during arcing process.

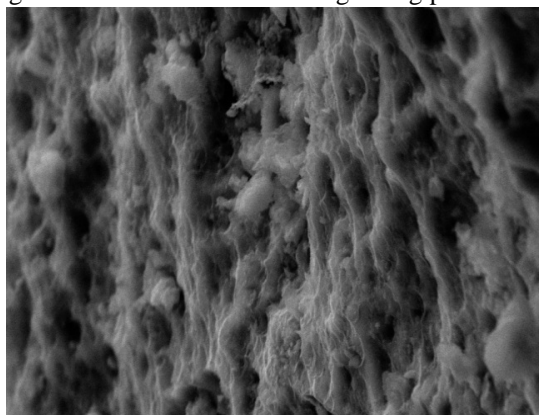


Figure 2: SEM micrograph of CNTs

Results of filtered groundwater

In deposited CNTs packing method groundwater filtered through different media depth has increasing filtering efficiency with increase in depth of CNTs and also yellowish brown color of groundwater was removed and colorless was obtained. At 2cm depth of CNTs filter bed groundwater was treated with minimal efficiency. pH was increased to 7.6 making acidic groundwater alkaline. Removal rate of phosphate, nitrate, iron, fluoride and TDS was 57.4%, 56.8%,

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

51.2%, 50% and 32.7% respectively is as shown in graph. At 4cm depth of CNTs filter bed groundwater was treated with good efficiency. pH was maintained to 7.4 making groundwater neutral. Removal rate of phosphate, nitrate, iron, fluoride and TDS was 66.3%, 69.5%, 62.9%, 60% and 48.2% respectively is as shown in graph. At 6cm depth of CNTs filter bed groundwater was treated with high efficiency and pH was maintained to 7.2. Removal rate of phosphate, nitrate, iron, fluoride and TDS was 72.2%, 82.8%, 79.1%, 70% and 62.5% respectively is as shown in graph. At 8cm depth of CNTs filter bed groundwater was treated with higher efficiency and pH was maintained to 7.2. Removal rate of phosphate, nitrate, iron, fluoride and TDS was 84.1%, 88.9%, 87.5%, 80% and 73.7% respectively is as shown in graph figure 3.

Table 1: Characteristics of groundwater before and after treatment by CNTs with different packing methods

Parameters	Initial characteristics	Final characteristics					
		Deposited packing method				Layered packing method	Mixed packing method
		2cm	4cm	6cm	8cm		
pH	6.2	7.6	7.4	7.2	7.2	7.8	7.9
Turbidity, NTU	2	2	1	0	0	4	3
Phosphate, mg/L	3.135	1.335	1.056	0.8698	0.4970	1.739	1.708
Nitrate, mg/L	15.672	6.766	4.771	2.6891	1.734	7.807	3.094
Iron, mg/L	0.24	0.117	0.089	0.05	0.03	0.091	0.073
Fluoride, mg/L	2.5	1.25	1.0	0.75	0.5	1.5	1.0
TDS, mg/L	2320	1560	1200	870	610	1080	910

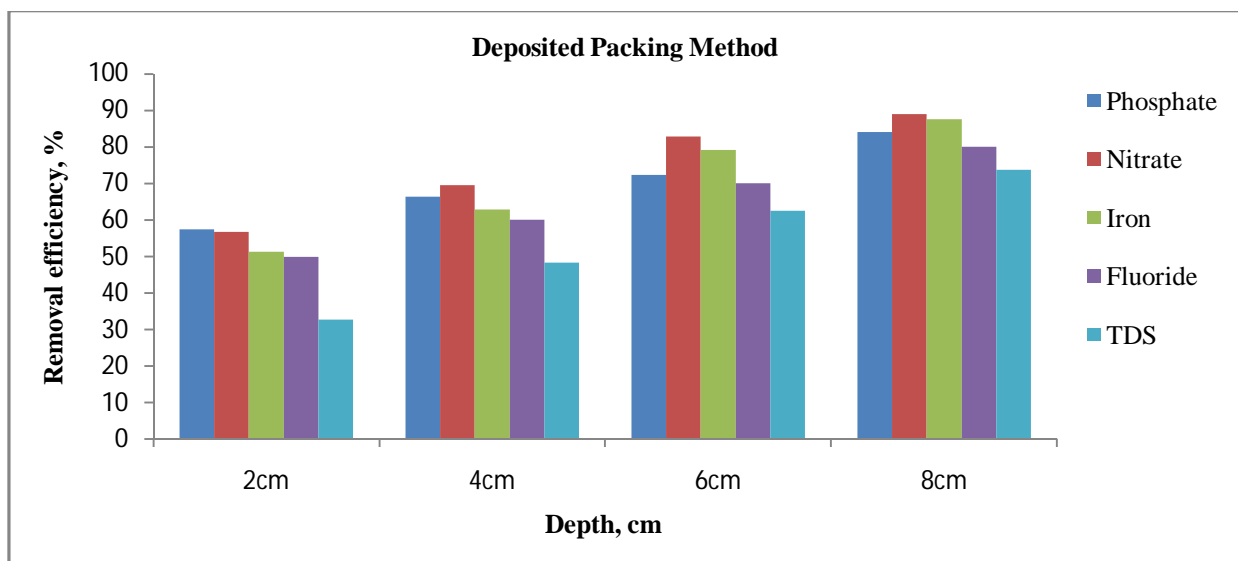


Figure 3: Graph depicting removal efficiencies at different depth in Deposited CNTs Packing Method

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

In mixed CNTs packing method groundwater filtered through mixed bed had average filtering efficiency compared to deposited packing method and color was also reduced to colorless efficiently. pH increased to 7.9 making groundwater alkaline. Removal rate of phosphate, nitrate, iron, fluoride and TDS was 45.5%, 80.2%, 69.5%, 60% and 60.7% respectively is as shown in graph figure 5.

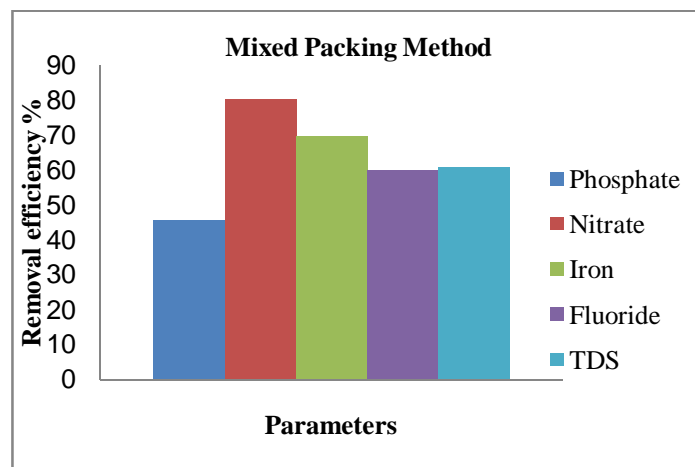


Figure 5: Graph depicting removal efficiency in Mixed CNTs Packing Method

In layered CNTs packing method groundwater filtered through layered bed had lower filtering efficiency compared to deposited and mixed packing method and color was reduced to colorless efficiently. pH increased to 7.8 making groundwater alkaline. Removal rate of phosphate, nitrate, iron, fluoride and TDS was 44.5%, 50.1%, 62%, 40% and 53.7% respectively is as shown in graph figure 4.

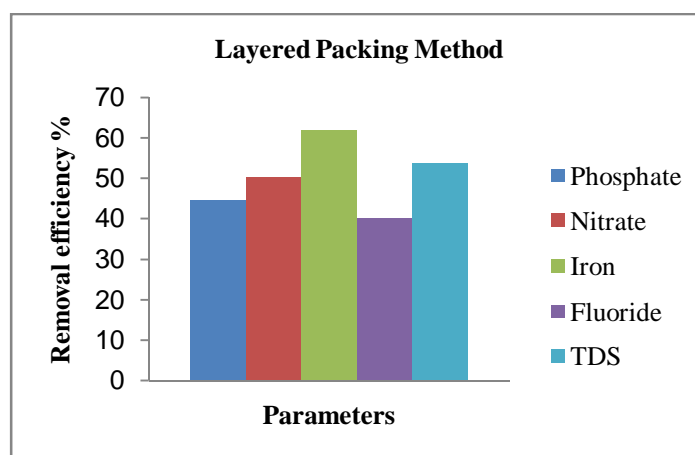


Figure 4: Graph depicting removal efficiency in Layered CNTs Packing Method.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

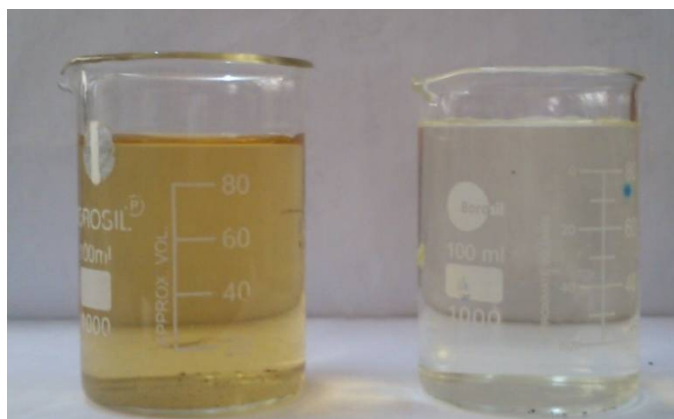


Figure 6: Sample before and after treatment with CNTs

IV. CONCLUSION

Open air arc discharge method was incorporated to synthesize CNTs in this study as it was easier and economic method of synthesis. For filtration natural sand and CNTs were packed in three different packing methods namely deposited, layered and mixed method. All the three CNT-sand packing methods were effective and safe ways of using CNTs as filter media to remove contaminants from contaminated groundwater. As a result, the CNT-sand column packed with CNT deposited method showed the best results and efficiency compared to other packing methods. Hence CNTs are most efficient in treating contaminated groundwater than conventional methods. CNTs have major advantage over conventional filters as it can be repeatedly cleaned by simple methods. From this research work it can be informed that with development of innovative and high efficiency CNT based filters for various environmental applications, especially for contaminated water and wastewater treatment.

V. ACKNOWLEDGEMENT

Thanks to the efforts of parents, teachers and all my friends who helped in the preparation of this research study. The authors are grateful to the University of Mysuru for providing SEM results. The authors are also thankful to The HOD of Environmental Department, Sri Jayachamarajendra College of Engineering (Autonomous), Mysuru, Karnataka, India for encouragement and providing facilities for the study.

REFERENCES

- Alina Catrinel Ion, Ion Ion, Alina Culetu (2003) "**Carbon based nanotubes environmental applications**".
- Andrea Szabo , Caterina Perri, Anita Csato , Girolamo Giordano , Danilo Vuono and Janos B. Nagy (2010) "**Synthesis Methods of Carbon Nanotubes and Related Materials**", International journal of Materials, vol 3, pp 3092-3140.
- Anna S. Brady- Estevez, Seoktae Kang, and Menachem Elimelech (2008) "**A Single-Walled-Carbon-Nanotubes Filter for Removal of viral and bacterial pathogens**", Vol 4, pp.481-484.
- Dharmendra K. Tiwari, Behari. J. Prasenjit Sen (2008) "**Application of Nanoparticles in Waste water Treatment**", Journal of World Applied Sciences, Vol 3(3), pp.417-433.
- Mostafavi. S. T, Mehrnia. M. R, Rashidi. A. M (2009) "**Preparation of nanofilter from carbon nanotubes for application in virus removal from water**", International Journal of Chemical Engineering, Vol 238, pp.271-280.
- Mubarak. N. M, Daniel. S, Khalid. M, Tan. J (2012) "**Comparative study of functionalize and non-functionalized carbon nanotube for Removal of Copper from polluted water**", International Journal of Chemical and Environmental Engineering, Vol 3, pp.314-317.
- Rajan. C. S (2011) "**Nanotechnology in Groundwater Remediation**", International Journal of Environmental Science and Development, Vol. 2.
- Sandeep Agnihotri, Massoud Rostam- Abadi, Mark J. Rood, Ramsay Chang (2002) "**Energy and Environmental Applications of Carbon Nanotubes**", Vol 47(2), pp.474-476.
- Senthil Saravanan. M. S, Kumares Babu. S. P, Sivaprasad. K, Jagannatham. M (2010) "**Techno-economics of carbon nanotubes produced by open air arc discharge method**", International Journal of Engineering, Science and Technology, Vol 2, pp.100-108.
- Srivastava. A, Srivastava. O. N, Talapatra. S, Vajtai. R, Ajayan. P. M (2004) "**Carbon nanotube filters**", Vol 3, pp.610-614.
- Yuan Tian, Bin Gao, Veronica L. Morales, Lei Wu, Yu Wang, Rafael Murioz-Carpena, Can Cao, Qingguo Huang, Liuyan Yang (2012) "**Methods of using carbon nanotubes as filter media to remove aqueous heavy metals**", Journal of Chemical Engineering, Vol 352, pp.392-1864.