A LOOK AT TECHNOLOGIES RANGING FROM THE MOST COMMON TO THE MOST RECENT AND INNOVATIVE AVAILABLE TO PURIFY DRINKING WATER

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Abstract

The most common and important liquid on earth, water is essential to all living forms. Purification of drinking water is becoming more difficult due to the expansion of industrialization, urbanization, and other human activities that have left drinking water susceptible. The purification techniques covered in this article range from the traditional ones that use activated carbon, activated alumina, silica, diatomaceous earth, etc. to the most recent ones that use nanomaterials, carbon nanotubes, and nanocomposites. Thin films, quantum dots, and aerogels are recognized as ground-breaking methods for the filtration of drinking water. Combining approaches is seen to be more advantageous than utilizing just one method since each has benefits and disadvantages in terms of efficiency, cost effectiveness, and pollutant removal.

Keywords: *Adsorbents, activated carbon, diatoms, nano materials, carbon nanotubes, nano composites, thin films, quantum dots.*

I.INTRODUCTION

All living things need water to survive. Water is abundant, but clean drinking water is scarce due to several factors.

Lack of clean water and sanitation is a global issue. Contaminated water, inadequate hygiene, and unclean environments kill 3.6 million people annually. Safe drinking water might save over 2 million lives in high-risk homes. Industrialization and urbanization will worsen water issues in the next decades. Even water-rich places are experiencing water constraint. To solve these issues, extensive research must be done to find innovative, low-cost, energy-efficient water purification systems that utilize fewer chemicals and have less environmental effect. The US Environmental Protection Agency (EPA) is assessing several centralized water treatment technologies as "small system compliance technology" to reduce supply system water pollution (USEPA, 1998). These include package treatment plants, point-of-entry (POE), and point-of-use (POU) treatment units that process small amounts of water entering a building, office, household, or specific tap/faucet [1]. Water purification removes parasites, bacteria, algae, viruses, fungus, minerals (including dangerous metals like Lead, Copper, Arsenic), and man-made chemical contaminants. Water quality regulations eliminate certain impurities to enhance smell, taste, and appearance. This study reviews drinking water quality-improving technology.

OVERVIEW OF METHODS OF PURIFICATION

Conventional water treatment may include chemical addition, coagulation, flocculation, sedimentation, filtration and disinfection, usually with chlorine [2].The drinking water treatment technologies used in the majority of systems include one or more of the processes using wide range of adsorbents, filtration techniques, electrical and disinfection methods, and latest technologies involving nanomaterials, carbon nanotubes, nano composites etc. as given in table-1.

Table-1. Various drinking water purification techniques:

nt s	Filtration Techniques	Electrical Techniques	Disinfection Techniques	Polymer and Nano technology
ce h	Membrane filtration	Electro Coagulation	Chemical treatment	Ion Exchange
s	a. Micro filtration	Electro Dialysis	Ozonation	Nano mat rials
d	b.Ultra filtration	Electro Floatation	Ultraviolet radiation	Carbon Nano tubes
d a	c. Nano filtration	Electrochemical method	Solar energy	Nano composites
de	d. Reverse Osmosis	-	Sonication	Thin films
s	Membrane distillation	-	Photo catalysis	Quantum dots
	Aerogels ,Chalcogels	-	-	

These procedures can purify drinking water. Each approach may separate one or more components, hence one method cannot treat drinking water completely. Recent study uses bio material like banana, apple, and tomato peels to purify water. Below are drinking water filtration technologies, their pros, cons, and uses in modern technology.

Adsorbents:

Most drinking water purification procedures use natural adsorbents. 1.1 Diatomaceous earth, or diatomite, is a soft, siliceous sedimentary rock created by diatoms, hard-shelled unicellular algae. 10–200 micrometer particles. Diatomite filters water, especially drinking water. It works effectively on ground water with high iron and manganese concentrations and surface waters with low influent turbidity, color, and microorganisms. Diatomaceous earth covered with cationic polyelectrolyte effectively removes viruses [3].

Zeta Plus filters, made of diatomaceous earth-cellulose-"charge-modified" resin mixtures with a net positive charge, efficiently adsorbed poliovirus from tap water at ambient pH levels 7.0 to 7.5[4]. Diatomite is a good adsorbent, but workers in the crsistobalite DE industry who are exposed to high levels of airborne crystalline silica over decades are at risk of silicosis.

Zeolites—microporous, aluminosilicate minerals known as "molecular sieves"—are another natural water purifier. Their affordability and quantity are advantages. Zeolites from throughout the globe have different ion-exchange capacities for cations like ammonium and heavy metals, anions, and organics from aqueous solutio-ns. Acid treatment, ion exchange, and surfactant functionalization increase organic and anion adsorption in natural zeolites [5].

Water filtration uses synthetic zeolites extensively. These zeolites are utilized as ion-exchange beds in home and commercial water filtration, softening, and other applications where molecules of specified sizes and shapes may pass through retaining pollutants.

Most water filtration adsorbents are activated carbon. Traditional centralized water treatment uses coal, wood, or coconut shell activated carbon. Coconut shell is most costly and effective. By imparting a positive charge, carbon "activates" to adsorb and reduce pollutants with a negative charge. Water filtration systems employ granulated activated carbon (GAC), activated carbon block, and catalytic carbon. Adsorption and catalytic reduction remove pollutants from water using activated carbon. VOCs, herbicides, pesticides, chlorine, radon, lead, and most man-made pollutants are eliminated. Activated carbon cannot remove heavy metals, nitrites, nitrates, dissolved inorganic pollutants, or silt.

In carbon water filters, particle and pore size, surface area, surface chemistry, density, and hardness affect adsorption [6]. This treatment may improve the quality of public or private water.

Bacteria may develop on activated carbon cartridges, posing a health risk. Silver-infused carbon surfaces limit bacterial development. Radon, a lung cancer-causing radioactive decay product of natural uranium, penetrates buildings via foundation fractures or soil and rock into groundwater. Granular activated carbon removes radon. Catalytic carbon, a new advanced activated carbon product, adsorbs chloramines, an alternative to chlorine that prevents carcinogenic trihalomethanes (THMs) from forming when chlorine interacts with organic plant materials [7]. Activated carbon is the most common and successful water filtration technology.

Activated alumina is a porous aluminum oxide with a surface area above 200 square meters/g. It filters drinking water fluoride, arsenic, and selenium. Fluoride in drinking water over 1.5 mg/l is hazardous. Activated alumina filters may readily decrease fluoride levels from.5 ppm to less than.1 ppm [8]. Water and alumina filter medium contact time determines fluoride leaching. Alumina in the filter reduces fluoride in the filtered water. Low-temperature and acidic water filter better. pH 5.5 permits 95% elimination. Tripathi, Jean, and Gopal found that alum-impregnated activated alumina (AIAA) can remove 99% of fluoride from water at pH 6.5, contact time of 3 h, dose of 8 g/l, and 20 mg/l of fluoride in 50 ml of water. Energy-dispersive X-ray study showed that only surface precipitation absorbs fluoride at the AIAA/water contact [9].

GFH removes arsenic [10]. Arsenic pollution of surface and subterranean waterways occurs everywhere. Arsenic penetrates aquifers, wells, and the water cycle naturally and anthropogenically. Arsenic is removed from drinking water via iron oxide adsorption. Inorganic arsenic causes skin, lung, and urinary bladder cancer and non-cancer consequences.

Granular ferric hydroxide can be readily treated and typical water treatment facilities can remove excess iron, making it a viable chromium adsorbent even in the presence of other interfering chemicals. Thus, this method is a safe and convenient solution to the problem of chromium-polluted water resources, as suggested by Asgari [11]. Tap water seeded with different microorganisms or untreated waste water passed through columns containing sand modified with a combination of ferric and aluminum hydroxide removes greater than 99% of Escherichia coli, Vibrio cholera, poliovirus 1, and coli phage MS-2 from dechlorinated tap water [12].

Ceramics-Ceramics filter dirt, debris, and pathogens from water utilizing their microscopic pores. Bacteria, protozoa, and microbial cysts are eliminated by filters, while viruses get through to the "clean" side. Recent investigations reveal that metal oxide-enhanced ceramic surfaces may catch and inactivate viral indicators in many waterways. Ceramic filtering does not remove chemicals. The ceramic filter cartridge's high-performance activated carbon core eliminates organic and metallic pollutants. Active carbon absorbs chlorine. Sterasyl, ceramic with silver-impregnated carbon, filters microbiologically hazardous water but does not eliminate fluoride. Ceramics are fragile and may shatter while handling.

Filtration methods:

Filtration uses a media that only fluids may traverse to separate solids from liquids or gases. Membrane filtration is becoming more popular across several media. Membrane-filtered public water systems in California provide drinking water.

Membrane filtering. Membrane filters filter water and sewage. Membrane filters eliminate Giardia and Cryptosporidium from drinking water. Filtration cannot remove dissolved compounds including phosphorus, nitrates, and heavy metal ions. Membrane filtration is classified by particle size as nano, ultra, micro, or reverse osmosis. In pressure-driven membrane processes, Bruggen & others argue that pressure on one side of the membrane drives solution separation into a permeate and retentate. Retentate is a concentrated solution that must be disposed of or treated, whereas permeate is normally pure water. Filtration methods utilize dense (no pores) to porous polymeric, organo-mineral, ceramic, or metallic membranes. Ultra filtration (UF) may remove suspended solids and colloids by retaining salts, tiny organic molecules, macromolecules, or particles. Nanofiltration (NF) removes divalent cations (water softening), NOM (natural colour, trihalomethane precursors), and TDS [14]. RO removes TDS and organic contaminants the best. Membrane distillation (MD) produces pure water. Water treatment, saltwater desalination, and aqueous solution concentration are key MD process applications [15].

Ceramics and metals may also make membranes. Ceramic membranes are microporous, thermally stable, chemically robust, and utilized for microfiltration [16]. High cost and mechanical fragility have limited its utilization. Stainless steel membranes are finely porous. Gas separation is their major purpose, although they may also filter water at high temperatures or support membranes. Most new WTP and expansion projects actively examine MF/UF. Membrane fouling and chemical stability remain key issues. Membranes are a popular water filtration option due to their affordability, versatility, and environmental friendliness.

Microfiltration: A microporous membrane with micrometer-sized filters removes impurities from liquids and gases. These porous filters pass water, monovalent species, dissolved organic materials, tiny colloids, and viruses but not particles, silt, algae, or big bacteria. Microfiltration membrane pores are typically 0.1 to 10 μm. It eliminates Giardialamblia cysts, cryptosporidium ocysts, and big microorganisms from drinking water. This application requires a 0.2 μm filter. Microfiltration membranes were initially used to treat easy-to-treat municipal waters in 1987. These devices remove suspended particles down to 0.1 micrometers in feed solutions up to 2-3%. Reverse osmosis and nanofiltration employ pressure to push water from low to high pressure, unlike microfiltration. Pressurized systems are not necessary for microfiltration [17].

Ultrafiltration (UF) is the drinking water treatment technique of choice due to its dependability and nanoparticle removal.

Most water-filtering UF membranes are hollow fibres with an inner diameter of 0.7 to 0.9 mm. Ultrafiltration membranes filter dissolved compounds without coagulants using polymer membranes with chemically produced tiny holes. Unlike reverse osmosis (RO), UF does not modify the mineral composition of water and may work at 4 to 14 psi. RO works best at 100 psi. Ultrafiltration prevents germs, viruses, and parasites. It eliminates flavor, odor, pesticides, and antibiotic residues using activated carbon prefiltration. It uses minimum filtration pressure and energy and is completely green. Michael and Dan advise running UF directly on solar power [18].

C.Nanofiltration is cheaper than traditional treatment methods. It is a relatively new membrane filtration process used most often with low total dissolved solids water like surface water and fresh groundwater to soften (polyvalent cation removal) and remove disinfection by-product precursors like natural and synthetic organic matter [19][20]. Nanoporous membranes for mechanical filtering have holes smaller than 10 nm. Ultrafiltration is membrane filtration at 10–100 nm. RO and UF membranes operate similarly. Dendritic polymers, soft nanoparticles with diameters between 1 and 20 nm, have numerous desirable properties for water purification [21].

D. Reverse osmosis is a popular and successful water treatment technique. Pressure-driven membrane water treatment. RO membranes, composed of thick polyamide film with microscopic holes through which water may flow, remove ionized salts, colloids, and organic compounds down to 100 kDa. Application-dependent pore diameters range from 0.1 to 5,000 nm. Water molecules may travel through these holes, but minerals and salt cannot. These remove germs and bacteria from water. Reverse osmosis removes TDS, turbidity, asbestos, lead, heavy metals, radium, and numerous dissolved organics from water. 31 of 35 American communities contain hazardous chromium 6 in their drinking water. Reverse osmosis removes Chromium-6 [22]. It also removes arsenic, barium, copper, lead, and fluoride. This technology wastes 3 to 9 gallons of water each gallon of cleaned water, its biggest drawback. Second, domestic reverse osmosis units take 3–4 hours to purify one gallon of water. Reverse osmosis membranes remove 99% of solutes, however vital minerals like calcium and magnesium ions are lowered to quantities below the World Health Organization guideline for drinking water.

Disinfection methods

Drinking water must be disinfected. Disinfectants in water systems kill disease-causing germs. Chlorination, chloramines, ozone, and UV light disinfect. Nanofiltration, sun radiation, sonication, chlorine dioxide, and potassium permanganate disinfect. Conventional disinfection procedures produce disinfection byproducts (DBPs), hence novel methods that improve disinfection reliability and robustness without DBPs were developed.

Chlorine gas, a primary and secondary disinfectant, kills practically all microbiological infections. At 0.1 percent air by volume, it is fatal from a liquid chlorine cylinder. Other chlorination processes use caustic sodium and calcium hypo chlorites. Although weak, chloramine kills bacteria and creates less disinfection byproducts. Chemical disinfection produces carcinogenic

halogenated byproducts. EPA recommends removing byproducts after they are generated, utilizing alternative disinfectants, and lowering organics in water before oxidation or chlorination[32].
Ozonation: Ozonation may purify water. It kills all microorganisms. Ozone disinfects by oxidizing organic and inorganic compounds, removing taste, odor, and color. Ozone kills 99% of waterborne bacteria, germs, viruses, and most pesticides by rupturing microorganism cells or oxidizing smells and chemicals.
Ozone disinfects air and water, but excessive quantities damage biological tissues. Since municipal chlorination sterilizes most drinking water systems, ozone is advised for microbiologically hazardous water as an alternative to UV-C sterilization.
Ultraviolet radiation: Recent studies have shown that biologically resistant water contaminants may be dissolved by UV light, solar energy with catalysts like Tio2, and ionizing radiation like high-energy electrons or Y-rays [33].UV disinfection kills cyst-forming protozoa including Giardia and Cryptosporidium, making it popular for drinking water purification. Adenoviruses are particularly resistant to UV disinfection and need large doses [34].UV with photocatalytic nanomaterials like TiO2 and Fullerol inactivates more.TiO2-coated UV reactors disinfect faster [35]. UV light kills germs and viruses, however water with significant suspended solids, turbidity, color, or soluble organic matter is inappropriate.
Solar water disinfection removes infectious biological organisms including bacteria, viruses, protozoa, and worms from polluted water. Due to harmful compounds or heavy metals, disinfection may not make all water safe to consume. Thus, disinfection may not be enough to make water safe to consume. Solar water disinfection uses energy, heat, and UV light. Solar thermal water disinfection briefly heats water to 700C–1000C. SODIS disinfects water using sunlight and PET bottles. SODIS is a free, simple, environmentally sustainable, low-cost method for decentralized water treatment and safe storage for people drinking microbiologically contaminated raw water [36]. Plastic bottles are constructed of PET (Poly Ethylene Terephtalate) or PVC (PolyVinylChloride) and include UV-stabilizers to prevent oxidation and UV radiation [37].SODIS cannot be utilized for turbid water, requiring further filtration.
Sonication-sound waves disinfect. Ultrasound (sound waves over 20 kHz) may impair cyanobacterial cell structure and function [38], and its application to reduce blooms has been considered in recent decades. High frequencies inhibit cyanobacteria better than low frequencies [38][39].Bacterial blooms in water bodies cause smells, tastes, and poisons. Chemical and physical approaches have been tried to reduce blooms, however contamination and large-scale application are issues. Sonication has recently been used to suppress cyanobacteria (blue-green algae) [40]. Sonication also reduced suspended solids (SS), chemical oxygen demand (COD), transparency, and total phosphate content. Sonication is greener than algaecide treatment.

Polymer and Nano technology

Ion-exchange process—exchanging ions between two electrolytes or solutions—is utilized in water treatment.Polymers are often employed in water purification as membranes or resins. Nitrates in water stimulate aquatic plant growth and modify the stream's vegetation and fauna. This impacts dissolved oxygen, temperature, and other indicators. Ion-exchange removes nitrate ions. Nitrate is removed by chloride ion-exchange, and the strong-base anion resin is totally regenerated in a closed circuit using a single-flow fixed-bed reactor packed with a Pd–Cu/Al2O3 catalyst [41].Organic and inorganic ion exchangers remove toxic transition metals including As, Mn, and Cr from water. Calcium, magnesium, ammonium, nitrates, bromides, and sulphates may be readily removed.Using activated carbon adsorbents boosts efficiency.

Nanotechnology's environmental applications have garnered attention. Due to their high specific surface area and reactivity, nanomaterials make great adsorbents, catalysts, and sensors. Silver nanoparticles, photo catalytic TiO2, fullerol, and carbon nanotubes are among the latest nanomaterials that have remarkable antibacterial capabilities.

Nanoparticles may chemically neutralize water contaminants. This approach has been found to reach contaminates in subterranean ponds at a cheaper cost than pumping water out of the earth for treatment.Water salt or metal removal is another issue. Deionization utilizing nanofiber electrodes may reduce the cost and energy needed to transform salt water into potable water. Virus cells cannot be filtered. Thus, a few-nanometer-diameter filter is being designed to remove virus cells from water. Nanoscavengers like silver nanoparticles kill germs in water and are removed by a magnetic field. Nanostructured palladium and gold pellets break degrade chlorinated chemicals in ground water. These pellets react practically every atom with chlorinated chemicals, lowering treatment costs.

Mercury, which harms the nervous system, and other dangerous metals in fluids may be measured inexpensively and easily using a strip of glass coated with hairy nanoparticles (nano-hair) [42].

Nanocomposites- Thalappil Pradeep, a materials scientist at the Indian Institute of Technology Madras, and his colleagues developed a novel family of nanocrystalline metal oxyhydroxide-chitosan granular composite materials. This cage-like matrix firmly binds nanoparticles. Nanoparticles release only ions at a regulated pace. Ions destroy water microorganisms without nanoparticles. "Nanostructured materials can purify water from a variety of contaminants". Purifiers cost modest households US$2.50 per year [43].

Carbon nanotubes (CNT)—In recent years, CNT has garnered interest for its water treatment abilities and effectiveness against chemical and biological pollutants. CNTs as an adsorbent media can remove heavy metals like Cr3+, Pb2+, and Zn2+, metalloids like arsenic compounds, organics like polycyclic aromatic organic compounds (PAH) and atrazine, and biological contaminants like bacteria, viruses, and cyanobacterial toxins. CNTs' physical, cytotoxic, and surface functionalizing capabilities make them effective biological contaminant adsorbents [44].Carbon nanotube (CNT) adsorption technique may enhance point-of-use (POU) water treatment for bacterial infections, natural organic matter (NOM), and cyanobacterial toxins. CNTs' fibrous form, high aspect ratio, huge accessible external surface area, and well-developed mesopores make them multifold efficient compared to other microporous adsorbents.

CONCLUSION

The effects of urbanization and industrialisation on drinking water quality have been dangerously worsening recently. The availability of clean, uncontaminated water is becoming an uncommon occurrence. Every type of treatment has its limits, and to efficiently treat water, a mix of treatments is sometimes needed. A multitude of innovative, effective, and affordable techniques for the purification of drinking water have emerged with the development of technology. To provide higher safety of drinking water, purification at the point of entrance and usage is seen to be more favorable than a centralized system.

REFERENCES

1. *Nora Savage and Mamadou S. Diallo, "Nanomaterials and water purification: Opportunities and challenges", Journal of Nanoparticle Research (2005) 7: pp. 331–342 Springer 2005*
2. *Water purification-Science Daily*
3. *Malay Chaudhuri, Parviz Amirhor, Richard S. Engelbrecht," Virus Removal by Diatomaceous Earth Filtration," Journal of the Environmental Engineering Division, Vol. 100, No. 4, pp. 937-953, July/August 1974.*
4. *M D Sobsey and B L Jones "Concentration of poliovirus from tap water using positively charged micro porous filters". Appl. Environ. Microbial. vol. 37, March 1979.*
5. *Shaobin Wang Yuelian Peng, "Natural Zeolites as effective adsorbents in water and wastewater treatment", Chemical Engineering Journal volume 156, issue 1, Jan 2010*
6. *Snoeyinck, V. L. "Principles of Adsorption by Activated Carbon". Paper presented at the Fourth Domestic Water Quality Symposium, Chicago, and Dec.pp. 16-17, 1985.*
7. *Hasbrouck, S. "Removing Radon from Water Using Granular Activated Carbon Adsorption", Information Digest University of Maine at Orono. June 1986.*
8. *Subhashini Ghorai, K.K. Pant " Equilibrium, kinetics and breakthrough studies for adsorption of fluoride on activated alumina", Separation and Purification Technology Volume 42, Issue 3, pp. 265–271, April 2005*

9. *Sushree Swarupa Tripathy, Jean-Luc Bersillon, Krishna Gopal Removal of fluoride from drinking water by adsorption onto alum- impregnated activated alumina Separation and Purification Technology Volume 50, Issue 3, pp.310–317,15 July 2006.*

[10].OS.Thirunavukkarasu,T.Viraraghavan and KS.Subramaniam,Arsenic removal from drinking water using granular ferric hydroxide, Water SA,Vol 29,No 2,2003.

10. *Asgari, F. Vaezi, S. Nasseri, O. Dördelmann, A. H. Mahvi, E. Dehghani Fad. Removal of hexavalent chromium from drinking water by granularferric hydroxide Iranian Journal of Environmental Health Science & Engineering. 5(4), pp. 277-282, 2008*
11. *Removal of microorganisms from water by columns containing sand coated with ferric and aluminium hydroxides.JerzyLukasic,Yueh-Fung Cheng,Fuhua Lu,Mark tamlin,Samuel RFarah,Water ResearchVol 33,Issue 3,pp. 769-777, Feb 1999.*
12. *Bart Van Der Bruggen, Carlo Vandecasteele, Tim Van Gestel, Wim Doyen, Roger Leysen, A review of pressure-driven membrane processes in wastewater treatment and drinking water production, Environmental Progress and sustainable Energy, Volume 22, Issue 1, 46– 56, April 2003*
13. *[14]A.B.F. Grose. A.J. Smith, A. Donn, J.O"Donnell andWelch, Supplying high quality drinking water to remote communities in Scotland, Desalinati on, 117(1998), pp.107-117.*
14. *K.W. Lawson and D.R. Lloyd, Membrane distillation, J. Membr. Sci., 124 (1997) pp. l-25*
15. *Baker, R. W. Membrane Technology and Applications, 2nd ed.; John Wiley & Sons, Ltd.: Chichester, 2004.*
16. *Crittenden, John; Trussell, Rhodes; Hand, David; Howe, Kerry and Tchobanoglous, George. Water Treatment Principles and Design, Edition*
17. *2. John Wiley and Sons. New Jersey. 2005.*
18. *Michael Hank and Dan Wyckoff "Ultrafiltration in Decentralised water treatment applications" Article from water conditioning and purificationMagazine, April2010*
19. *Raymond D. Letterman (ed.) (1999). "Water Quality and Treatment." 5th Ed. (New York: American Water Works Association and McGraw- Hill.)*
20. *Dow Chemical Co. "Nanofiltration Membranes and Applications"*

21. Nora Savage1 and Mamadou S. Diallo, "Nanomaterials and water purification: Opportunities and challenges" Journal of Nanoparticle Research (2005) 7: pp.331–342 Springer 2005
22. S. A. Mousavi Rad, S. A. Mirbagheri, and T. Mohammadi C "Using Reverse Osmosis Membrane for Chromium Removal from Aqueous Solution" World Academy of Science, Engineering and Technology 33, 2009
23. Bhausaheb L.Pangarkar, Mukund G.Sane, and Mahendra Guddad "Reverse Osmosis and Membrane Distillation for Desalination of Groundwater: A Review", ISRN Materials Science Volume 2011, 9 pages, 2011.
24. Thor Thorsen, Haral Flogstad, "Nano filtration in drinking water, Treatment", Techneau, 11th Dec 2006
25. Carmichael, Mary. " Newsweek International, pp. 08-13, 2007
26. [26] Zhuyin Sui, Qinghan Meng, Xuetong Zhang, Rui Ma and Bing Cao , "Green synthesis of carbon nanotube–graphene hybrid aerogels and their use as versatile agents for water purification", Mater. Chem., 22, pp. 8767-8771, 2012.
27. Satish.I. Chaturvedi, "Electro coagulation: A Novel Waste Water Treatment Method", International Journal of Modern Engineering Research (IJMER) Vol.3, Issue.1, 93-100 ISSN: pp.2249-6645 ,Jan-Feb. 2013.
28. Jyotsna Cherukuri, "The Study of an Eco-Friendly Electrochemical Technique for wastewater Treatment", The International Journal of Environmental, Cultural, Economic and Social Sustainability, Volume 5, Issue 2,pp. 7-16,2009.
29. Feng Qiyan "Electrocoagulation-Microfiltration for Drinking water treatment:A case study with the typical Micro polluted source waters",
30. Bioinformatics and Biomedical engineering,ICBBE 2009,3rd International Conference 11-13 June 2009
31. Ceren Ucar, Meltem Bilici Baskan, Aysegul Pala , "Arsenic removal from drinking water by electrocoagulation using iron electrodes"
32. Korean Journal of Chemical Engineering Vol 30, Issue 10, 1889-1895, 2013