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REVIEW ARTICLE

A Review on various Point of Use - Drinking Water Purification Technologies

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ABSTRACT
Different domestic drinking water purification technologies have been studied in laboratory for their roles in purifications, advantages, disadvantages, efficacy and shelf life. Out of them, some were micron filter, ultra filtration, reverse osmosis and uv radiation. It was found that each and every technology has their advantages and disadvantages. Out of them reverse osmosis was single technology to removes dissolved inorganic salts up to 2000 ppm. Only industrial model could help beyond this limit. It was concluded that offline models are better solution when TDS and hardness are within the limits; as per IS: 10500. UV models could be better solution when there were higher suspended solids and turbidity but TDS should be within the limit. It is also suggested that a nano filtration membrane before reverse osmosis could be a solution in higher hardness areas and high brine membrane could be a solution up to 2500 ppm TDS.
KEY WORD: *Domestic drinking water, purification technologies*

INTRODUCTION

Improving the sustainability of water resources is a human challenge that needs solutions. Research and innovation on eco technologies and green technologies will contribute to tackle this challenge as well as the transition to a green economy [13]. Clean water is one of the most important needs of body. It is a sad fact that something as essential to life as clean drinking water can no longer be granted to us. Unsafe water is not just a third world problem. In fact, safe drinking water is even harder. According to research articles and news, most tap and well in India are not safe now for drinking due to heavy industrial and environmental pollution. We have reached to a point that, all sources of our drinking water, including municipal water systems, wells, lakes, rivers, and even glaciers, contain some level of contamination. Contaminants range from naturally-occurring minerals to man-made chemicals and by-products. We are not sure about the quality of supply water or drinking water. Due to rapid urbanization and industrialization water sources are under threat. Supply water frequently going contaminated during the course of its traveling to home. Ground water is also getting pollutant and contaminant due to leaching and regeneration by industries and homemade soak pits [19].

There are two major types of waste inorganic waste and organic waste. Organic wastewaters are potent sources of water pollution [15]. While many contaminants are found at levels not enough not to cause immediate discomforts or sicknesses, it is proven that even low-level exposure to many common contaminants will, over time, cause severe illness including liver damage, cancer, and other serious ailments. Even the chemicals commonly used to treat municipal water supplies such as chlorine are toxic and are known to have significant adverse effects on the human body. Consumption of this type of unsafe water continues to be one of the major causes of the 2.2 million diarrhea disease deaths occurring annually, mostly children [20].

Boiling or heating is effective in destroying the bacteria [1], but it is not solution for organic and inorganic impurities. A good water filter is the best and maybe the only solution nowadays. Anyone could install and maintain the filters themselves and can ensure and feel safe about the water which they and their family drink. Just make sure that the filter you choose removes the most spectrums of contaminants. Usually a professional filtration system worth invest-in is a 4 to 5 stage water purifier system. Each stage will remove certain types of contaminants, and all stages combined should protect you from just about every contaminant. A reverse osmosis water filter with pre-filters and activated carbon plus an ultraviolet light are believe to be the most thorough and cost effective way to purify drinking water. Such a system will pay for itself within half a year and can last 10-15 years with easy annual filter changes.

There are 35,000 pesticides containing 600 chemical compounds. Many of these chemicals are known to cause birth defects, nerve damage, sterility and cancer. More than 700 organic chemicals have been identified in drinking water, and some of them are suspected cancer causing agents. According to the WHO and UNICEF, dirty drinking water kills 2.2 million people per year, over 1.5 million of whom are children under the age of five [20]. Unfortunately, this means that contaminated drinking water is in a tight competition with diseases like AIDS and cancer to be the biggest killer of human beings on Earth. This is a tragedy because many of the world's water problems can be solved with education and technology. Gastrointestinal diseases like diarrhea cause 1.70 million deaths per year worldwide due to poor water quality, sanitation and hygiene [21]. Studies about comparison water quality between tap and POU water exist in different parts of world [2, 4, 5 and 15, 17 -19] but tap water was contaminated. Recent systematic reviews of water, sanitation, and hygiene interventions suggest that the beneficial effects of improving household drinking water quality at the point of use (POU) to reduce diarrhea disease risks had been previously underestimated. Contemporary reviews estimate 30-40% reductions in diarrhea disease by improving household drinking water quality at the POU, making such treatment more effective than improvements at the source [9 -10 ; 6 and 11]. The goal of POU household water treatment (HWT) and safe storage technologies is to empower people without access to safe water to improve water quality by treating it and storing it safely in the home. There are a number of different POU technologies which policy-makers, implementers, and users can select as appropriate for particular circumstances and populations [6 and 11]. Although a variety of POU technologies have been suggested, tested, and disseminated, not all have an evidence base of effectiveness and sustained use [6 and 11]. One of the challenges to making informed choices about widespread dissemination of these technologies is the lack of rigorous scientific evidence of sustained use, positive health impact, and water quality improvement over extended periods of use [6]. These challenges include a requirement for robust, cost-effective, low maintenance technologies that can achieve the required levels of treatment [3, 7]. Such research should be underpinned by accessible on-site test facilities where new technologies and processes can be tested, demonstrated and optimised in a real-world environment [3,8].

The most important membrane-based water technologies include reverse osmosis (RO), electrodialysis (ED), nanofi ltration (NF), ultrafi ltration (UF) and microfi ltration (MF) [16-18]. This review focuses on those technologies for which performance efficacy and sustained use have been documented by microbiological efficacy and diarrhea disease reduction studies. The POU technologies to be critically reviewed are the following: Table I

Table – I : POINT OF USE DRINKOING WATER TREATMENT TECHNOLOGIES

Technology	Example	Advantage	Disadvantage
Boiling	Boil	Removes Microorganisms	Unable to remove organic impurities
Ceramic candle Filters	Silver Coated and Non Silver coated candles	Removes suspended solids and bacteria up to some extents.	Fouled after some time
05-07 Stage candle Filter	07 stages	Remove Iron, Chlorine and improve pH up to some extents.	Unable to reduce micro organism by 99.9999%.
Silver impregnated Carbon Block Candle	Candle made by Activated granular carbon	Removes Suspended solids, Bacteria and organic impurities up to some extents.	No TDS reduction
Ion Exchange	Softener	Remove Hardness and prevent scaling	Require regeneration
Filtration	Micron Filters	Remove turbidity, suspended particles, clay, large particles, soil, large cyst etc.	Insufficient to remove Micro-organisms
Sand Filter	Gravel and pebbles	Removes large particles and suspended solids	Removes only large particles and macro molecules
Carbon Adsorption	Activated Granular Carbon made by Coconut husk	Removes organic impurities, chlorine, Bad taste, odor, pesticides and Trihalomethanes	some time generate carbon fines
Ultra Filtration	Micro porous membrane filter	Removes large colloidal particles, Bacteria, viruses, cyst, algae and fungi	Will not remove dissolved in-organics.
Nano Filtration	Spiral wounded membrane of 0.001 µm	Removes divalent cation	Unable to filter monovalent ions
Reverse Osmosis	Spiral wounded membrane of 0.0001 µm	Removes inorganic salts as well as microorganisms.	Flow rates are usually limited to a certain gallons/day rating.
Ultra Violet Radiation	UV lamp of 254 nm	Inactivate Microorganisms.	Potency of light decreases after certain time.
Chlorination	Trichlorocyanuric Acid, Sodium hypochlorite, Calcium chloro hypochlorite, Hypo chlorite	Kill microorganism	Producing carcinogenic byproducts

Iodinated Resin	Penta Iodide	Kill microorganisms	Not recommended for pregnant women.
Brominated Resin	Bromine charged beads	Kill microorganisms	Producing carcinogenic byproducts
Arsenic Removal	Resin charged with Lanthanum dioxide	Removes Arsenic	Life reduces after some time, require change
BIRM Resin		Remove Iron	Life is 8000 to 10000 liter
Green sand Filter		Remove Manganese, Iron and sulphide	Life is 8000 to 10000 liter

Micron Filters

String wound filter cartridges utilize polypropylene inner cores as a base. This base is nominally 10" long (actual length = 9 27/32") and the final filter cartridge length fits standard 10" filter housings sold by a variety of manufacturers. Special FDA compliant polypropylene filter yarn (typically called string,) is carefully wound onto the core in a specific pattern and density to meet the micron particle size requirements of that particular filter cartridge. String wound filter cartridges are referred to as "depth" filters since particulate is trapped within the full volume or "depth" of the cartridge. The lower the micron rating of the filter cartridge, the smaller the contaminating particle size it will remove from the liquid being filtered. Cartridges wound to very low micron ratings such as 1 or 5 micron utilize a phenomenon called "Van Der Walls" attraction forces to capture and hold the contaminant. Micron ratings of string wound filters are nominal. String wound polypropylene filter cartridges, as with any filter cartridge, will create a pressure drop in a flowing liquid system. A clean filter cartridge will create a minimal pressure drop depending on the liquid flow rate. The higher the flow rate, the higher the pressure drops. As the filter becomes clogged with contaminants, the pressure drop will gradually increase and flow will, correspondingly, decrease. Typically, a maximum pressure drop of 20 PSI is allowed for string wound filter cartridges as higher pressure drops may overcome the Van Der Walls holding forces allowing contaminating particles to release again from the surface of the polypropylene filter media. Given the strength of the polypropylene core, crushing of string wound filter cartridges due to a high clog condition is almost non-existent at low operating temperatures. At higher temperatures, collapsing may occur at about a 50 to 70 PSI pressure drop. Typical flow rates for string wound filter cartridges vary from 3 Gallons per minute (GPM) for cartridges rated at 1 micron to 6 GPM for cartridges rated at 50 micron. The larger the micron rating, the larger the filter pores is, which allow for higher flow rates. Safe operating temperatures for polypropylene filter cartridges are up to 150° F. Micron recommends operating temperatures be kept below 140°F to maintain a margin of safety. Micron polypropylene filter cartridges are compatible with a wide variety of liquids to be filtered, including, but not limited to: Acetic Acid, Caustic Soda, Potable Water, Compressed Air, Citric Acid, Milk Alcohol, Diesel Fuel, Mineral Oil, Cane and Beet Sugar Liquors, Fruit Juices, Salt Water, Carbonated Water, Glycerin, Vinegar and Bio Diesel Fuels Other variants of micron filters are spun pp filter, pp pleaded cartridge.

Ceramic candle Filters

Silica-like sediment resulting from kiesel algae (one celled algae) deposited on the bottom of geological lakes and lagoons millions of years ago. This is the same material used in making the finest bone china (like of royal doulton) and numerous other applications. The filter elements are produced using the latest ceramic techniques to provide a hollow porous ceramic which is fired at a temperature in excess of 1000°C. The chemically inert ceramic filter can be stored for eternity without losing its effectiveness. Doulton ceramic remove particles from the water but leaves oxygen and mineral contents unchanged. Pathogens of the most varied diseases which are reliably filtered from the water include; cholera, typhus, cryptosporidium, amoebic dysentery, ecoli, colibacillose or bilharzia, anthrax spores among others. But it requires cleaning of surfaces and boiling after each 15 days.

Granular Activated Carbon

Granular Activated carbon (GAC) is a natural material derived from bituminous coal, lignite, wood, coconut shell etc., activated by steam and other means, and each one have different adsorption properties. Some manufacturers use various blends of carbon to achieve specific water quality and contaminants reduction (e.g. coconut shell carbon for "sweet taste"). Activated carbon surface properties are both hydrophobic and oleophilic; that is, they "hate" water but "love" oil. When flow conditions are suitable, dissolved chemicals in water flowing over the carbon surface "stick" to the carbon in a thin film while the water passes on. This process is called *adsorption.* As a result of the adsorption process, activated carbon is an effective method in removing chlorine and it's by-products (TTHM's - Trihalomethane) and volatile organic compounds (carbon based VOC's).

Most popular forms of activated carbon used in the treatment of POU drinking water filters are granular activated carbon (GAC), extruded solid carbon block (CB) and powdered activated carbon (PAC). All activated carbon forms including granulated activated carbon (GAC) have a tremendous surface area resulting from its porous structure. GAC filters degree of effectiveness depends on the flow rate of the water and contact time with the water. If flow rate is excessive their efficiency could be as low as 0% and if the flow rate is slow their efficiency can match and or exceed those of different carbon forms. On a large scale such as municipal water treatment pools (gravity filters) for taste, odor and chemical reduction GAC is cheaper, very effective and can be re-used. No form of carbon filter removes bacteria. In fact under quite normal operating condition all carbon forms can and do become perfect breeding grounds for bacteria, including pathogenic bacteria. Silver based GAC are effective in controlling bacterial growth and multiplications (bacteriostatic) only for a short time because the silver is in form of a "spray" over a small percent of granules (usually 1.05% of the total GAC content). As the water passes the granules "rub off" each other leaching the silver prematurely are measured in mesh size similar to that of your window screen. Coarse carbon is used in different applications while in domestic POU finer mesh is used followed by a cloth like "filter" to prevent granule escaping. Backwashing is necessary after some and steaming could be the one option to prevent from contaminations.

Ion Exchange

Most typical ion-exchange resins are based on cross linked polystyrene. The required active groups can be introduced after polymerization, or substituted monomers can be used. For example, the cross linking is often achieved by adding 0.5-25% of divinylbenzene to styrene at the polymerization process. Non-cross linked polymers are used only rarely because they are less stable. Cross linking decreases ion- exchange capacity of the resin and prolongs the time needed to accomplish the ion exchange processes. Particle size also influences the resin parameters; smaller particles have larger outer surface, but cause larger head loss in the column processes. Besides being made as bead-shaped materials, ion exchange resins are produced as membranes. The membranes are made of highly cross-linked ion exchange resins that allow passage of ions, but not of water, are used for electro dialysis. There are four main types differing in their functional groups:

Strongly acidic (typically, sulfonic acid groups, e.g. sodium polystyrene sulfonate or polyAMPS), strongly basic, (quaternary amino groups, for example, trimethylammonium groups, e.g. polyAPTAC), weakly acidic (mostly, carboxylic acid groups), weakly basic (primary, secondary, and/or ternary amino groups, e.g. polyethylene amine). There are also specialized types:

Chelating resins (iminodiacetic acid, thiourea, and many others) ion-exchange resins are used to replace the magnesium and calcium ions found in hard water with sodium ions. When the resin is fresh, it contains sodium ions at its active sites. When in contact with a solution containing magnesium and calcium ions (but a low concentration of sodium ions), the magnesium and calcium ions preferentially migrate out of solution to the active sites on the resin, being replaced in solution by sodium ions. This process reaches equilibrium with a much lower concentration of magnesium and calcium ions in solution than was started with. The resin can be recharged by washing it with a solution containing a high concentration of sodium ions (e.g. it has large amounts of common salt (NaCl) dissolved in it). The calcium and magnesium ions migrate off the resin, being replaced by sodium ions from the solution until a new equilibrium is reached. This is the method of operation used in dish washers that require the use of 'dishwasher salt'. The salt is used to recharge an ion-exchange resin which itself is used to soften the water so that lime scale deposits are not left on the cooking and eating utensils being washed.

Production of high purity water

Water of highest purity is required for electronics, scientific experiments, production of superconductors, and nuclear industry, among others. Such water is produced using ion-exchange processes or combinations of membrane and ion-exchange methods. Cations are replaced with hydrogen ions using cation-exchange resins; anions are replaced with hydroxyls using anion-exchange resins. The hydrogen ions and hydroxyls recombine producing water molecules. Thus, no ions remain in the produced water. The purification process is usually performed in several steps with "mixed bed ion-exchange columns" at the end of the technological chain.

Sand Filter

Filtration is one of the oldest water treatment technologies known. If properly designed, constructed, operated and maintained, a sand filter produces a very high quality effluent. Sand filters are beds of granular material, or sand, drained from underneath so that pretreated wastewater can be treated, collected and distributed to the land application system. They are normally used Sand based water filters have been used for over 100 years to treat water. They are generally used on a larger scale to treat a water supply for a whole community, and will be custom made. Most units require a constant flow of water to work correctly, and so wouldn't be suitable for well water treatment.

Ultra Filtration

UF have asmaler range of pose sizes than MF Membrane (.01 to .1 Micron) [16] An ultrafiltration membrane is a membrane that effects separation on the principle of sieving. The membrane has pores that are in the nanometer size range, and will therefore prevent particles, colloids, microorganisms and dissolved solids that are larger in dimension than the pores in the membrane surface from passing. The membrane therefore acts as a physical, size-exclusion barrier, and it is for that reason that ultrafiltration membranes produce such a high quality product. Ultrafiltration membranes are produced in either flat-sheet or tubular-type geometries. A micro porous membrane filter removes particles according to pore size. The ultra filter is a tough, thin, selectively permeable membrane that retains most macromolecules above a certain size including colloids, microorganisms and pyrogens. Smaller molecules, such as solvents and ionized contaminants, are allowed to pass into the filtrate. Ultrafiltration is a separation process using membranes with pore sizes in the range of 0.1 to 0.001 micron. Typically, Ultrafiltration will remove large size molecules and substances, colloidal materials. Low molecular-weight organics and ions such as sodium, calcium, magnesium chloride, and sulfate are not removed.

Designates a membrane separation process, driven by a pressure gradient, in which the membrane fractionates components of a liquid as a function of their solvated size and structure. The membrane configuration is usually cross-flow. In UF, the membrane pore size is larger allowing some components to pass through the pores with the water. It is a separation/ fractionation process using a 10,000 MW cutoff, 40 psig, and temperatures of 50-60°C with polysulfone membranes.

Nanofiltration membrane

It rejects divalent ions in water such as the water calcium and magnesium ions, and, therefore, produces soft water. A nanofilter membrane allows most monovalent ions such as sodium and chloride to pass through, while it rejects divalent ions. monovalent ions create osmotic pressure and requires high pressure to pump water through a reverse osmosis membrane. Therefore, nanofilter membranes require much less pressure to pump water through the membrane because the hydraulic driving force does not have to overcome the effect of osmotic pressure from monovalent ions. Nanofiltration is based on the same principle as reverse osmosis. The separation line is slightly lower. Ions solved in water are kept back by Nano membrane filtration, however, this happens in a lower way than compared to reverse osmosis in the end this save operation costs.

Reverse Osmosis

Reverse osmosis use spiral wound membranes mounted in high pressure containers. The membrane stack is two; very long semi permeable membranes with a spacer mesh between them that is sealed along the two long sides. This is then wound up in a spiral tube with another spacer to separate the outside of the stack. The spiral winding provides a very high surface area for transfer. Between each membrane layer is a mesh separator that allows the permeate (pure) water to flow. Water is force in one end of the spiral cylinder and out the out other end. Backpressure forces the water through the membrane where it is collected in the space between the membranes. Permeate then flows around the spiral where it is collected in the center of the tube. Out of all reverse osmosis is the only one technology which could remove the total dissolved solids.

Contamination Removed By Ro System

Bactaeria 100% Crplosordiumi-100% Tds 95% Chlorides-90% Copper-97% Floride-90% Lead97% Potassium-92%Nickel 97%, Detergents 97% Chromate-92% Nitrate-80% Barium-97%.Silver 85% Silicate 96% Sulphate-97% Strontium 97%Bicarbonte 94% Radium 97% Calcium -97% Insecticides 97% Pesticides 97% Herbicides 97%

Ultra-Violet Radiation

Ultraviolet radiation has widely been used as a germicidal treatment for water. Mercury low pressure lamps generating 254 nm UV light are an effective means of sanitizing water. The adsorption of UV light by the DNA and proteins in the microbial cell results in the inactivation of the microorganism. Ultraviolet light alters the genetic (DNA and RNA) material. So that bacteria, viruses, molds, algae and other microorganisms can no longer reproduce. The microorganisms are considered dead, and the risk of disease from them is eliminated. Devices are most effective when the water has already been partially treated, and only the cleanest water passes through the UV flow chamber.

Chlorination

Municipality using chlorination to reduce micro-organism from water. They are using the same due to easy availability and lower cost. The maximum acceptable limit of chlorine in drinking water is 0.2 ppm [12]. Although chlorine can kill serious microorganisms such as those that cause cholera and typhoid fever, putting chlorine in drinking water involves health risks. The reaction results in by-products, the most common of which is Trihalomethanes. Trihalomethanes have been shown to increase the risk of cancer in laboratory animals. Tests on humans also show a possible link between the trihalomethanes produced by chlorine in drinking water and cancer. A report released by The U.S. Council of Environmental Quality states that "Cancer risk among people drinking chlorinated water is 93% higher than among those whose water does not contain chlorine.

Iodination

Another purifier technology on the market is iodinated resins. This is filtration media where iodine is bound to a positively charges structure [3]. Waterborne bacteria and viruses are negatively charged, so the positive charge attracts these contaminants, and then iodine is released to penetrate and kill the microorganism. This attraction reduces the contact time necessary to inactivate the microorganisms [3]. A large iodinated resin system, capable of treating 45 gallons per minute, it is found to reduce *E. coli* by greater than 6 log reduction (99.9999%), and MS-2 bacteriophage (a surrogate for viruses) by greater than 99.9% (EPA, 2001). Most of the iodine was removed by the carbon filters, but iodide ions were not removed by the post-treatment carbon filters. Carbonari (1999) recommends a 1-micron filter pretreatment with iodinated resin systems, because it is not practical to have the 3-minute contact time necessary to inactivate *Giardia* and *Cryptosporidium*.

Bromination

Bromine is very reactive. To maintain an adequate disinfection, the amount of bromine that is added must be high. Bromine aggressively reacts with metals and it is a corrosive material. The brominated disinfection byproducts i.e. bromoform, chlorodibromomethane and bromodichloromethane can be harmful to human health. The desirable limit of these individual byproducts is 0.1 mg/l as BIS standards [12] . These may be carcinogenic beyond this limit.

Iron Adsorbed (BIRM)

It is an efficient and economical media for the reduction of dissolved iron and manganese compounds from raw water supplies. It may be used in either gravity fed or pressurized water treatment systems. Birm acts as an insoluble catalyst to enhance the reaction between dissolved oxygen (D.O.) and the iron compounds. In ground waters the dissolved iron is usually in the ferrous bicarbonate state due to the excess of free carbon dioxide and is not filterable. Birm, acting as a catalyst between the oxygen and the soluble iron compounds, enhances the oxidation reaction of Fe^{++} to Fe^{+++} and produces ferric hydroxide which precipitates and may be easily filtered. The physical characteristics of Birm provide an excellent filter media which is easily cleaned by backwashing to remove the precipitant. Birm is not consumed in the iron removal operation and therefore offers a tremendous economic advantage over many other iron removal methods. Other advantages of Birm include; long material life with relatively low attrition loss, a wide temperature performance range and extremely high removal efficiency. Negligible labor costs are involved because Birm does not require chemicals for regeneration, only periodic backwashing is required.

Green Sand Filter

A green sand filter uses manganese green sand to filter iron, sulfur, hydrogen and manganese out of household and drinking water. Water polluted with these materials may stain, smell like rotten eggs, be discolored, taste bad and possibly be unsafe to drink. Reducing the impurities in water can help improve the safety, taste and smell of drinking water. A green sand filter contains manganese green sand, which forces impurities in the water, such as iron, to oxidize. The oxidized impurities are then trapped in the sand and held there. Typically, a water purification filter that includes a green sand filter will also include water-purification and disinfectants. When the green sand filter has become exhausted, it may be regenerated through the backwash process with potassium permagnate. When properly cared for and regularly backwashed, the green sand filter will last for many years.

Reverse Osmosis with Nano filter Membrane

There are nothing to tackle with TDS >2000 ppm for point of use in house purpose. Still there is no product having RO and NF in same line. The idea is in laboratory, but the concept is unique where there is higher hardness with higher TDS. A NF membrane prior to RO could remove the bivalent ions like hardness (Ca and Mg) from the water, and reduce the load to RO membrane which further gives reduction in TDS up to 2500 – 3000 ppm to 250-300. RO membrane as single will be chock easily. It is require in this model to use SHMP (sodium hexa meta phosphate) or polyphosphate crystals and carbon block to improve feed water quality.

Very Common Configuration of POU RO Based water Treatment System Membran system
Typical Membrane System consist of various steps which are described below Table- II

Table - II Common Configuration Of Reverse Osmosis Based Pou Water Purifiers For House Hold Purpose

Sr. No.	Stage	Technology
1.	First	Sediment Filter
2.	Second	Carbon Filter
3.	Third	Reverse Osmosis Membrane
4.	Fourth	Post Ultra Violet / Ultra filter treatment
5.	Fifth	Post Carbon

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