Storage and self purification environmental sciences essay

Abstract

Water Treatment has become of increasing importance in a world of limited resources (1). The quality standards required for health in the case of drinking water, or for reliability in the case of industrial process water, necessitate improved technologies for the treatment of the water before use, as well as before discharge (1).

Introduction

The United Nations has estimated that 1. 1 billion people lack access to potable water (2, 3). With so many people living on the brink of illness, a great deal of attention has been drawn to designing and implementing new and innovative methods of water purification, particularly in developing countries. Gradually, the goal of bringing safe water to the world has developed into a series of goals from educating to finding a method of purification that will be culturally accepted and sustainable (3, 4). Different options for surface water treatment in emergencies have been reviewed by Dorea et al. (2006), each having their inherent contextual advantages and limitations. The purpose of this literature remains what it has always been – to describe and comment on the various ways in which water can be treated before it can be safely consumed by human beings or efficiently used in industry. The main body of this literature discusses the various methods of purifying water, including their advantages and disadvantages. This paper relies heavily on the work of others, as is evidenced by the numerous references throughout the text collected in the bibliographies.

Storage and Self-Purification

During storage or while running, water undergoes a process of natural purification which was advocated by Houston (5) for use in Metropolitan Supply. Self-purification takes place in three stages: Firstly, the oxidation of organic matter, pure carbon compounds being more slowly oxidized than those containing nitrogen also. Secondly, diffusion and evaporation, as ammonia loss takes place readily under the action of light and air, being more rapid with quick-flowing rivers and in bright warm weather. Thirdly, the part played by water plants, where higher plants assimilate the nitrogen they require from organic substances in the water, and in the absence of carbon dioxide, they assimilate also carbon from organic compounds by photosynthetic process. The advantages of storage may be summarized as follows:-Reduction in number of bacteria and devitalizing microbes of water-borne disease. Reduction in amount of suspended matter, color, ammonical nitrogen, and oxygen absorbed from permanganate. When sand-filtered, storage has a leveling effect on the quantity of water delivered to the filters, whose life is prolonged, in the absence of algae. Storage renders any accidental breakdown in the filtering arrangements much less serious than might otherwise be the case. The disadvantages of storage were mentioned in same report by Houston as :-Prolonged storage, especially if the water remains stagnant, may lead, seasonally or occasionally, to the abnormal and abundant development of vegetable growths, materials harmless in themselves, but resulting in deterioration of the water as judged by chemical and physical standards, and causative of practical difficulties with its filtration. Storage in reservoirs necessarily results in the accumulation of organic matter at the bottom; variations in temperature produce a vertical circulation resulting in the whole volume being fouled by the stagnant bottom layers. Evaporation in a covered reservoir has been compared with loss from a similar open surface; and it was conclude that, if the saving in evaporation were capitalized, it would not cover the cost of roofing. Sedimentation is also a factor in self-purification, as it causes the deposition of suspended matters, and, to a lesser extent, bacteria. Stokes' equation may be usefully applied here as the velocity of deposition (V) depends on the densities of water (μ), and of the sediment (ρ), assuming the viscosity of water is 0. 01 at 20oC. R is the radius of the particles deposited and is of the order 10-6, and hence R2 is 10-10, substituting in the equation we obtain:

Sterilization:

Heat: –Modern medical practice considers that sterilization can best be achieved by some form of heat treatment. Many adaptations of this principle have been suggested and patented but cost excludes the use of this process on a large scale, although in times of drought or possible contamination of the supply, householders are warned to boil all water prior to human consumption. Although bringing water to the boil is effective in killing or inactivating most bacteria, viruses and pathogens, some are resistant and can survive several minutes boiling especially at high altitude where the temperature at which water boils is reduced. (Wikipedia)To avoid insipidity, water has been sterilized by heating it in a closed chamber to 120oC and subsequently cooling it (6). The advantages of Boiling Water include: In an emergency, boiling is the best way to purify water that is unsafe because of the presence of protozoan parasites or bacteria. For cloudy water, it is first filtered, or let to settle and drawn off before boiling. Boiling will also drive out some of the Volatile Organic Compounds (VOCs) that might also be in the water. Pathogens that might be lurking in the water will be killed if the water is boiled long enough. The disadvantages of Boiling Water include: Users of heated water do not like it as well as the polluted water, as the heated water may be flat to the taste and unsightly on account of deposited or suspended matter. Boiling may concentrate any harmful contaminants that do not vaporize as the relatively pure water vapor boils off. Boiling requires a reliable source of energy and is limited in terms of the volume able to be treated. Sound and Ultra-Violet Light:-Ultrasonic vibrations have been investigated and have a lethal effect on bacteria, the rate of destruction increasing with rise of temperature from 45oF to 98oF, but use of these vibrations on a large scale may be uneconomic (7). Sunlight has some power of killing bacteria in water, but its bactericidal effect depends on climatic and atmospheric conditions, with greater effect in equatorial countries. Ultraviolet light is electromagnetic radiation in the spectrum with a wave length between 100 and 400 nanometers (nm). The ultraviolet spectrum can be divided into three bands (several different divisions of this band exist); UV-A 320 to 400 nm, UV-B 280 to 320 nm, UV-C 100 to 280 nm. The UV-C band contains the wavelengths (250-270nm) which have been found to be very effective in destroying many microorganisms (optimum wavelength is 265nm). Ultraviolet purification uses a UV light source (lamp) which is enclosed in a protective transparent sleeve (usually quartz). The lamp is mounted such that water passing through a flow chamber is exposed to the UV-C light rays. (29)When harmful microbes are exposed to the UV rays, their nucleic acid absorbs the UV energy, which penetrates the cell wall of the microorganism and causes a reaction in the microorganism's DNA (deoxyribonucleic acid). This in turn, breaks the C= C carbon bond in the molecules of the microorganism. This causes cellular death, rendering the microorganism sterile and incapable of growing and multiplying. The cell is now considered dead and is no longer a threat. The sterilizing effect of ultra-violet light cannot be attributed to the destruction of intracellular enzymes, since these are still present in the sterilized water (8). The addition of a very dilute solution of a photo-dynamically active substance (e. g., eosin) to water containing humic substances enables the water to be really sterilized by ultra-violet light (9). The only source of ultra-violet light suitable for industrial use is the quartz mercury vapor lamp, which sterilizes with only a few seconds' exposure to the light. With this lamp toxins are destroyed as well as bacteria (10). Advantages: UV is very safe. There are no dangerous chemicals to handle or monitor. Disinfection results are immediate. UV has a low initial system cost and a very low cost of operation (requires about the same amount of energy as a 60 watt light bulb)UV is environmentally friendly. There are no byproducts from the UV process, and nothing is discharged into the environment. UV causes no change to the taste or odor of the water disinfected. It is impossible to over-treat water with UV. UV does not remove any of the minerals, which are a health benefit and provide water with its good taste. UV systems are very easy to install and maintain. The disadvantages of using UV include: UV radiation is not suitable for water with high levels of suspended solids, turbidity, color, or soluble organic matter. These materials can react with UV radiation, and reduce disinfection performance. Turbidity makes it difficult for radiation to penetrate water and pathogens can be 'shadowed', protecting them from the light. UV light is not effective against any non-living contaminant, lead, asbestos, many organic chemicals, chlorine, etc. Tough cryptosporidia cysts are fairly resistant to UV light. UV is typically used as a final purification stage on some filtration systems. If concerned about removing contaminants in addition to bacteria and viruses, one would still need to use a quality carbon filter or reverse osmosis system in addition to the UV system.

Chemical Methods of Sterilization

Hydrogen Peroxide and Ozone:-Hydrogen Peroxide will sterilize water by the liberation of nascent oxygen, but the method becomes too costly for general use. The sterilization can be effected by adding peroxide to water, and removing excess by passing through a filter of finely divided manganese dioxide and sand, which has been previously washed with a dilute solution of potassium permanganate (11). Another method is to treat water at ordinary temperature or at 40oC with a small quantity of hydrogen peroxide acidified with hydrochloric acid (12). Ozone (O3) is a naturally occurring component of fresh air. It can be produced by the ultraviolet rays of the sun reacting with the Earth's upper atmosphere (which creates a protective ozone layer), by lightning, or it can be created artificially with an ozone generator.

Ozonization is achieved by allowing the filtered water to trickle down one or more towers up which a current of ozonized air is forced. The advantages of using Ozone include: With the use of ozone, color and suspended matter are removed or reduced, The water becomes more sparkling and palatable. No residual chemical remains in the waterOzone is primarily a disinfectant that effectively kills biological contaminants. Ozone also oxidizes and precipitates iron, sulfur, and manganese so they can be filtered out of solution. Ozone will oxidize and break down many organic chemicals including many that cause odor and taste problems. At low temperatures, ozonization is superior to chlorination and the destruction of Esh. Coli has been estimated to be seven times as rapid with ozone as with hypochlorite (13). Ozone is the most powerful and rapid acting oxidizer man can produce, and will oxidize all bacteria, mold and yeast spores, organic material and viruses given sufficient exposure. Concentration of 0. 1 to 5mg per liter is recommended for sterilizing water (14). In the home, ozone is often combined with activated carbon filtration to achieve a more complete water treatment. The disadvantages of using Ozone include: Ozone treatment can create undesirable byproducts that can be harmful to health if they are not controlled (e. g., formaldehyde and bromate). Ozone is not effective at removing dissolved minerals and salts. Since ozone is made of oxygen and reverts to pure oxygen, it vanishes without trace once it has been used. In the home, this does not matter much, but when water companies use ozone to disinfect the water there is no residual disinfectant, so chlorine or another disinfectant must be added to minimize microbial growth during storage and distribution. The effectiveness of the process is dependent, on good mixing of ozone with the water, and ozone does not dissolve particularly well, so a well designed system that exposes all the water to the ozone is important. The process of creating ozone in the home requires electricity. The cost of applying ozonisation to a water supply is usually much greater than for chlorination, in part; this is accounted for by high maintenance costs in view of the more elaborate equipment necessary with this method. Chlorination: Chlorination has become the most common type of wastewater and water disinfection, as its sterilizing properties have been known for a long time. It should be noted that it is designed to kill harmful organisms, and generally does not result in sterile water (free of all microorganisms). Two types of processes are generally used: hypochlorination, employing a chemical feed pump to inject a calcium or sodium hypochlorite solution, and gas chlorination, using compressed chlorine gas (15). Water temperature, sediment level, and contact time are all factors that affect the effectiveness of chlorine treatment. Chlorine should not be used at temperatures below 20oC, otherwise there is a tendency for chlorine hydrate to separate out and clog the apparatus. Organic matter increases the chlorine demand of the water. Advantages:-Chlorine has a rapid initial bactericidal action which is dependent on the concentration of chlorine. Chlorination before and after filtration provides a ready means of reducing and equalizing the bacterial load on filters treating heavily polluted water. Chlorination is less costly than other disinfection systems and is generally easier to implement. Hypochlorite compounds are non-flammable, and the systems are extremely reliable. Disadvantages:-The use of chlorine in gaseous form or in solution can cause safety hazards; In small installations, when chlorine gas is liberated from a chlorine cylinder or moistened crystals or pellets, the fumes are extremely dangerous and may even be lethal. Chlorine is chemically active and can react with foreign ingredients (e. g., as found in industrial waste-waters) to form toxic compounds, a matter of increasing concern to the Federal Government and to many states and municipalities. Chlorine itself is a highly corrosive and toxic chemical. Chlorine is reactive and interacts with certain chemicals present in the product water, depending on pH and water temperature; This results in the depletion of the chlorine concentration, leaving only residual amounts of chlorine for disinfection (over-chlorination may result in the formation of chlorinated hydrocarbons, such as trihalomethanes, which are known to be carcinogenic). It may combine with phenol to form " clorophenols", another dangerously toxic compound. Chlorine is an additive material which may impart an undesirable taste to the water and a decrease in pH. It may combine with ammonia to form " chloramine" which is acutely toxic to fish even at low concentration. Chlorine will also oxidize ammonia, hydrogen sulfide, and metals present in the product water to their reduced states. Chlorine gas is heavier than air, and is extremely toxic and corrosive in moist atmospheres. Dry chlorine can be safely handled in steel containers and piping, but where moisture is present (as it is in most treatment plants), corrosion-resistant materials such as silver, glass, Teflon, and certain other plastics must be used - though not, as was said above, for pressurized gas. Hypochlorite may cause damage to eyes and skin upon contact, and, because it is a powerful oxidant, may cause fires if it comes into contact with organic or other easily oxidizable substances. (16)Iodine Treatment: The simplest method of disinfecting water with iodine is by dissolving iodine in water to form a saturated solution and then injecting the iodine solution into a water syste. Since Iodine is light sensitive, it must always be stored in a dark bottle. Iodine treatment is most effective at water temperature greater than 68° F (21° C). Advantage:-Iodine has been shown to be more effect than chlorine-based treatments in inactivating Giardia cysts. Disadvantage:-Some people are allergic to iodine, therefore cannot use it as a form of water purification.

Water Softening

The composition and total concentration of salts in brackish ground waters very greatly with the location. The major components are the same as in sea water but their relative abundances are often quite different. Surface waters have generally relatively low salinity, composed mostly of salts of calcium and magnesium. These salts cause the hardness of the surface waters. Sea water contains an even higher concentration of these salts and is therefore very hard. In addition, it contains such large amounts of sodium chloride that the weight of sodium exceeds that of calcium and magnesium sixfold. Hence softening alone is used to upgrade the quality of many surface waters, while sea-water purification calls for the more radical treatment of almost complete salt removal. (17)Major Constituents of Sea Water (17)(in parts per million)Concentration of salts in different salt watersDead Sea (100 m below surface)Great Salt Lake, UtahCaspian SeaSodium (Na+)1056132000673003200Magnesium (Mg+)127235, 7005600773Calcium (Ca++)40012, 700300297Potassium (K+)3806400340070Chloride (Cl-)189801786001129005500Sulfate (SO4--)2649400136002970Bicarbonate (HCO3-)142Trace20048Bromide (Br-)655200TraceOther solids34Total dissolved solids34, 483Specific gravity (20 deg. C)1. 0243Water (balance)965, 517Ion ExchangeThe ion exchange process percolates water through bead-like spherical resin materials (ion-exchange resins). Ions in the water are exchanged for other ions fixed to the beads. The two most common ion-exchange methods are softening and deionization. Softening is used primarily as a pretreatment method to reduce water hardness prior to reverse osmosis (RO) processing. The softeners contain beads that exchange two sodium ions for every calcium or magnesium ion removed from the " softened" water. (18)_deionDeionization (DI) beads exchange either hydrogen ions for cations or hydroxyl ions for anions. The cation exchange resins, made of styrene and divinylbenzene containing sulfonic acid groups, will exchange a hydrogen ion for any cations they encounter (e. g., Na+, Ca++, Al+++). Similarly, the anion exchange resins, made of styrene and containing quaternary ammonium groups, will exchange a hydroxyl ion for any anions (e. g., Cl-). The hydrogen ion from the cation exchanger unites with the hydroxyl ion of the anion exchanger to form pure water. These resins may be packaged in separate bed exchangers with separate units for the cation and anion exchange beds. Or, they may be packed in mixed bed exchangers containing a mixture of both types of resins. In either case, the resin must be " regenerated" once it has exchanged all its hydrogen and/or hydroxyl ions for charged contaminants in the water. This regeneration reverses the purification process, replacing the contaminants bound to the DI resins with hydrogen and hydroxyl ions. (18)Advantage:-Deionization can be an important component of a total water purification system when used in combination with other methods discussed in this primer such as RO, filtration and carbon adsorption. Some other other cations like barium, radium and iron may be reduced depending on the manufacturer's specifications. The nuisance factor of hard water is reduced. Disadvantage:-DI systems effectively remove ions, but they do not effectively remove most organics or microorganisms. Microorganisms can attach to the resins, providing a culture media for rapid bacterial growth and subsequent pyrogen generation. Removes dissolved inorganics effectively. Regenerable (service deionization). Relatively inexpensive initial capital investment. High operating costs over long-term. Typically, approximately 50 gallons of rinse water per cubic foot of resin is required to totally remove hardness and excess salt from the resin after each regeneration. The process of regenerating the ion exchange bed dumps salt water into the environment. The elevated sodium concentration of most softened water can affect the taste and may not be good for people on low sodium diets, or for watering plants.

Desalination

Desalination refers to the process of removing excess salts from salt water (i. e., brackish, seawater, brine, produced water) to produce potable water (30). The membrane treatment techniques use pressure-driven or electrical power. Pressure-driven membrane technologies include microfiltration, ultrafiltration, nanofiltration, and hyperfiltration, also known as RO. The electrical-driven techniques are electrodialysis (ED) and electrodialysis reversal (EDR). The most common types of membranes used for RO are polymeric, but over the last few years the use of ceramic membranes has increased greatly. Combined with the use of cross-flow filtration, this has increased the life of the membrane and in turn reduced operating costs. In general, membrane pretreatment requires all or some of the following treatment steps: Clarification; Hardness reduction; Iron removal; Polymer removal; Reduction of alkalinity by pH adjustment; Addition of scale inhibitor; and Filtration. In desalination processes globally, cost is a major factor, and it is usually site- specific. The normal factors affecting desalination cost are the quality of the feedstock. The higher the total dissolved solids (TDS), the more energy is required for treatment. Pretreatment costs to remove or reduce the levels of contaminants also can be significant.

Membrane Unit Operation

Membrane Distillation (MD)Membrane is a thin barrier through which fluids and solutes are selectively transported when a driving force is applied across the barrier (19). The process works by using a specialized membrane which will pass water vapor but not liquid water. This membrane is placed over a moving stream of warm water, and as the water vapor passes through the membrane it is condensed on a second surface which is at a lower temperature than that of the feed water. Although there are different configurations of MD, the key difference is the technique used to draw away and condense the vapor (decrease the vapor pressure). The four commonly used configurations of MD [2] described as follows: Direct Contact Membrane Distillation (DCMD), in which the vapor is condensed by liquid in direct contact with the permeate side of the membrane and colder than the feed. Air Gap Membrane Distillation (AGMD), in which the permeated vapor migrates across an air gap before condensing on a cold surface nearby. Condensed permeate falls under gravity as product water. Vacuum Membrane Distillation (VMD), in which the vapor is drawn by simple vacuum and is subsequently condensed, if needed, in a separate device. Sweep Gas Membrane Distillation (SGMD), in which a gas stream is used as a carrier for the permeate vapour. Figure 1 Configurations of various MD systemAdvantages of membrane distillation over reverse osmosis or other thermal methods of desalination include:• It produces very high-quality distillate. In most circumstances salt rejections of 99-100% are achievable.• Water can be distilled at relatively low temperatures (i. e. 5 to 80°C). As the driving force forMD is temperature difference; very low feed temperatures can produce reasonably high rates of product water and may be more practical considering the nature of some water impurities (e. g. scaling issues at high temperature).• Low-grade heat such as industrial waste heat, solar or desalination waste heat may be used.• The feed water does not require extensive pre-treatment that is typically required for pressure-based membrane processes. Disadvantages of membrane distillation: The formation of deposit is a major reason of a decline of the permeate flux during treatment of tap water in MD process. Rinsing the module with a diluted HCl solution can dissolve the $CaCO_3$ deposit (20). The application of MD for the production of demineralized water from tap water requires the pre-treatment of feed water, in particular, the removal of bicarbonate ions (20). Reverse Osmosis (RO)Reverse Osmosis is a separation process using semi-permeable membranes in order to achieve a separation between a solvent (e. g. water), which is allowed to pass through the membranes and the low molecular weight solutes (e. g. salts), which are rejected, by the application of an elevated working pressure in excess of the osmotic pressure of the solution which has to be separated (21). The pore structure of RO membranes is much tighter than UF membranes. The semi-permeable membrane rejects salts (ions) by a charge phenomena action: the greater the charge, the greater the rejection. Therefore, the membrane rejects nearly all (> 99%) strongly ionized polyvalent ions but only 95% of the weakly ionized monovalent ions like sodium (18). _revosNatural osmosis occurs when solutions with two different concentrations are separated by a semi-permeable membrane. Osmotic pressure drives water through the membrane; the water dilutes the more concentrated solution; and the end result is equilibrium. In water purification systems, hydraulic pressure is applied to the concentrated solution to counteract the osmotic pressure. Pure water is driven from the concentrated solution and collected downstream of the membrane. The principal applications of reverse osmosis include: the production of potable and industrial water, the treatment of industrial and municipal waste water and separations in the industry. Although desalination is the main application for reverse osmosis, the treatment of waste waters represents an important market. Tubular and plate-and-frame modules are mostly utilized for this kind of applications, because they are less susceptible to fouling and their cleaning can be performed easily (21). Membrane Separation Properties and Performance (22)Type of MembraneSeparation MechanismPore Size (microns)Molecular Weight (amu or Da)Operating Pressures (psi)Reverse OsmosisScreening and diffusion <0. 001100-200600-1500NanofiltrationScreening and diffusion0. 001-0. 01300-100050-250UltrafiltrationScreening0. 01-0. 11000-1000003-80MicrofiltrationScreening0. 1-20Over 1000001-30 (or vacuum)NanoFiltrationNanofiltration involves a process that rejects multivalent ions and organic compounds greater than 200molecular weight. Also called loose Reverse osmosis operates at lower pressure than RO but at higher flux, its rejection of monovalent ions is <70% (21). UltrafiltrationIn ultrafiltration, high molecular weight solutes (e. g. polymers and proteins) and colloidal substances (e. g. clays, latex articles) are separated from their solvents. The osmotic pressure of these solutions is lower, and the working pressures are much lower than those necessary for reverse osmosis. A microporous membrane filter removes particles according to pore size. Ultrafiltration membrane modules include: Tubular module, Plate and frame module, spiral wound, capillary, Rod membrane, and other newer applications. The most widely used polymers for ultrafiltration membrane are cellulose acetate (CA), aromatic polyamides, polysulfones, polyacrylonitirite - poly (vinyl chloride) co-polymers (22). MicrofiltrationIn microfiltration (MF), solutes and particulates with molecular dimensions > 100 to 10, 000 nm are rejected by the membrane. The separation mechanism is controlled by size exclusion (23). There are three types of microporous filtration: depth, screen and surface. Depth filters are matted fibers or materials compressed to form a matrix that retains particles by random adsorption or entrapment. Screen filters are inherently uniform structures which, like a sieve, retain all particles larger than the precisely controlled pore size on their surface. Surface filters are made from multiple layers of media. When fluid passes through the filter, particles larger than the spaces within the filter matrix are retained, accumulating primarily on the surface of the filter. _depthThe distinction between filters is important because the three serve very different functions. Depth filters are usually used as prefilters because they are an economical way to remove 98% of suspended solids and protect elements downstream from fouling or clogging. _surfaceSurface filters remove 99. 99% of suspended solids and may be used as either prefilters or clarifying filters. Microporous membrane (screen) filters are placed at the last possible point in a system to remove the last remaining traces of resin fragments, carbon fines, colloidal particles and microorganisms. Gas SeparationIn gas diffusion (GD) and gas permeation (GP), gases are separated on the basis of their relative transport rates through a membrane. The driving force in GD is a concentration gradient and in GP it is a pressure gradient across the membrane (23). PervaporationIn pervaporation (PV), the feedstream is a liquid mixture exposed to a pressure difference across the membrane. The permeate-side of the membrane may be maintained at vacuum pressures and may be flushed with an inert gas stream (e. g., nitrogen). The ddesired liquid component selectively permeates across the membrane and vaporizes on the low-pressure side. The vapor is condensed and recovered (23). Advantages:-RO membranes are capable of rejecting practically all particles, bacteria and organics > 300 daltons molecular weight (including pyrogens) and in removing several impurities from water such as total dissolved solids (TDS), turbidity, asbestos, lead and other toxic heavy metals, radium, and many dissolved organics. The process will also remove chlorinated pesticides and most heavier-weight VOCs. Reverse osmosis (RO) is the most economical method of removing 90% to 99% of all contaminants and requires minimal maintenance. Reverse osmosis and activated carbon filtration are complementary processes. Combining results in the most effective treatment against the broadest range of water impurities and contaminants. In addition, Reverse osmosis treatment is an insurance policy against nuclear radiation such as radioactive plutonium or strontium in the drinking water. If one lives near a nuclear power plant, this is a key way to ensure the household is drinking the best water for their health. Disadvantages:-Will not remove dissolved inorganics. Flow rates are usually limited to a certain gallons/day rating. Because RO membranes are very restrictive, they yield slow flow rates. Storage tanks are required to produce an adequate volume in a reasonable amount of time. Potentially high expendable costDialysisIn Dialysis, a difference in concentration is responsible for the separation. Dialysis is used to remove microsolutes from a solvent or solution of solutes through ion-exchange membranes. It is a purification or fractionation operation. A concentration gradient across the dialysis membrane provides the driving force for mass transport. For the most part, application of dialysis has been limited to laboratory and specific medical applications (hemodialysis) (23). ElectrodialysisIn Electrodialysis (ED), ions are separated from solvents and from solutions of neutral solutes by ion-exchange membranes. Ion-exchange membranes reject ions on the basis of charge; for instance, an anion-exchange membrane has positively-charged molecules attached to its surface and therefore rejects cations, but does not reject anions. A cation-exchange membrane, which contains negatively charged molecules, rejects anions but does not reject cations. In an ED cell, anion and cation-exchange membranes are arranged alternatively. When an electric field is applied, cations are attracted to the negative pole and the anions are attracted to the positive pole. However, anions cannot pass through the cation-exchange membranes and the c ations cannot pass through the anion-exchange membranes. As a result, the ions are removed from the feed (product) stream and are concentrated in the brine stream. (23)Electrodialysis reversal EDR is a very similar process except that the cation and anion reverse to routinely alternate current flow. Both ED and EDR remove or reduce contaminants from feed water, and the process is not sensitive to pH. Advantage:-The major application of electrodialysis has historically been the desalination of brackish water or seawater as an alternative to RO for potable water production and seawater concentration for salt production (primarily in Japan) (24). In normal potable water production without the requirement of high recoveries, RO is generally believed to be more cost-effective when total dissolved solids (TDS) are 3, 000 parts per million (ppm) or greater, while electrodialysis is more cost-effective for TDS feed concentrations less than 3, 000 ppm or when high recoveries of the feed are required. Disadvantage:-Electrodialysis has inherent limitations, working best at removing low molecular weight ionic components from a feed stream. Non-charged, higher molecular weight, and less mobile ionic species will not typically be significantly removed. Also, in contrast to RO, electrodialysis becomes less economical when extremely low salt concentrations in the product are required and with sparingly conductive feeds: current density becomes limited and current utilization efficiency typically decreases as the feed salt concentration becomes lower, and with fewer ions in solution to carry current, both ion transport and energy efficiently greatly declines (25). DistillationIn many ways, distillation is the reverse of boiling. To remove impurities from water by distillation, the water is usually boiled in a chamber causing water to vaporize, and the pure (or mostly pure) steam leaves the non volatile contaminants behind. The steam moves to a different part of the unit and is cooled until it condenses back into liquid water. The resulting distillate drips into a storage container. Salts, sediment, metals, anything that won't boil or evaporate, remain in the distiller and must be removed. Volatile organic compounds (VOCs) are a good example of a contaminant that will evaporate and condense with the water vapor. A vapor trap, carbon filter, or other device must be used along with a distiller to ensure the more complete removal of contaminants. Distillation units routinely use designs that conserve as much thermal energy as possible by interchanging the heat of condensation and heat of vaporization within the units. The major energy requirement in the distillation process thus becomes providing the heat for vaporization to the feed water. Thermal technologies also have been improving; the use of improved design in heat exchangers has greatly increased the effective operating efficiencies and related operating costs. All thermal processes produce a high-purity distillate product with a salinity of less than 10 ppm. The capacity of the thermal desalination processes varies over a wide range from 3, 145 b/d (500 cu m/d) to 345, 939 b/d (55, 000 cu m/day). Thermal technologies have rarely been used for brackish water desalination because of the high costs involved. For TDS concentration greater than 35, 000 ppm, thermal techniques are more economical and practical than membrane-based technologies (26). Thermal techniques can be sub-divided into three groups: Multistage Flash (MSF)Sea water is heated and made to flow through a series of flash chambers maintained at successively decreasing pressures. In this process, most of the water is vaporized. The vapor flows away on the surface of the pipes conveying the incoming sea-water feed, and is then led away for distribution. Multiple Effect (MED)In multiple-effect units steam is condensed on one side of a tube wall while saline water is evaporated on the other side (in a manner similar to the VC process). The energy used for evaporation is the heat of condensation of the steam. Usually there is a series of condensation-evaporation processes taking place (each being an " effect"). The saline water is usually applied to the tubes in the form of a thin film so that it will evaporate easily. Vapor Compression (VC)The vapor-compression process uses mechanical energy rather than direct heat as a source of thermal energy. Water vapor is drawn from the evaporation chamber by a compressor and except in the first stage is condensed on the outsides of tubes in the same chambers. The heat of condensation is used to evaporate a film of saline water applied to the insides of the tubes within the evaporation chambers. These units are usually built with capacities of less than 100m3/day and are often used at resorts and industrial sites. The advantages of Distillation include: A good distillation unit produces very pure water. This is one of the few practical ways to remove nitrates, chloride, and other salts that carbon filtration cannot remove. Distillation also removes pathogens in the water, mostly by killing and leaving them behind when the water vapor evaporates. If the water is boiled, or heated just short of boiling, pathogens would also be killed. As long as the distiller is kept clean and is working properly the high quality of treated water will be very consistent regardless of the incoming water - no drop in quality over time. No filter cartridges to replace, unless a carbon filter is used to remove volatile organic compounds. The disadvantages of Distillation include: Distillation takes time to purify the water, It can take two to five hours to make a gallon of distilled water (27). Distillers uses electricity all the time the unit is operating. Most home distillation units require electricity, and will not function in an emergency situation when electrical power is not available. Distillers requires periodic cleaning of the boiler, condensation compartment, and storage tank. Countertop Distillation is one of the more expensive home water treatment methods, using $0. 25 to $0. 35 of electrical energy per gallon of distilled water produced - depending on local electricity costs. The cost of ownership is high because one not only have the initial cost of the distillation unit to consider, but also must pay for the electrical energy for each gallon of water producedFiltrationThe topic of water filters is complicated because there are so many models available (over 2, 500 different models manufactured by more than 500 companies), and because there are so many types of filtration strategies and combinations of strategies used. The basic concept behind nearly all filters, however, is fairly simple. The contaminants are physically prevented from moving through the filter either by screening them out with very small pores and/or, in the case of carbon filters, by trapping them within the filter matrix by attracting them to the surface of carbon particles (the process of adsorption). A micron is a unit of measure - one micron is about 1/100 the diameter of a human hair. A filter that removes particles down to 5 microns will produce fairly clean-looking water, but most of the water parasites, bacteria, cryptosporidia, giardia, etc. will pass through the pores. A filter must trap particles one micron or smaller to be effective at removing cryptosporidia or giardia cysts. Viruses can not be effectively removed by any filtration method. In theory, reverse osmosis will remove viruses, but a small flaw in the membranes would allow viruses to pass undetected into the 'filtered' water. (27)There are two main types of filters (sediment and activated carbon), and sometimes they are combined into a single unit. A third type, which will be considered as a separate topic, is reverse osmosis. Sediment Filters - Solid Particles are strained out of the Water: Fiber Filters: These filters contain cellulose, rayon or some other material spun into a mesh with small pores. Fiber filters are often used as pre-filters to reduce the suspended contaminants that could clog carbon or RO filters. The finer the filter, the more particles are trapped and the more often the filter must be changed. Ceramic Filters: Ceramic filters are much like fiber filters and use a process where water is forced through the pores of a ceramic filtration media. This type of filter can reduce asbestos fibers, cysts (if the pores are one micron or smaller), some bacteria (with pore sizes in the 0. 2 - 0. 8 micron range**) and other particulate matter. Advantage: A benefit of all home filtration systems is that they are passive. That is, they require no electricity to filter the water, and normal home water pressure is used to force the water though the filter. Disadvantage: Both Fiber and Ceramic filters will not remove contaminants that are dissolved in the water, like chlorine, lead, mercury, trihalomethanes or other organic compounds. These filters may be used as a back-end to an activated carbon filter to provide a more thorough removal of contaminants.

Activated Carbon Filters: Activated carbon (AC) is particles of carbon that have been treated to increase their surface area and increase their ability to adsorb a wide range of contaminants - activated carbon is particularly good at adsorbing organic compounds and is made of tiny clusters of carbon atoms stacked upon one another. The carbon source is a variety of materials, such as peanut shells, coconut husks, or coal. The raw carbon source is slowly heated in the absence of air to produce a high carbon material. The carbon is activated by passing oxidizing gases through the material at extremely high temperatures. The activation process produces the pores that result in such high adsorptive properties (27). Contaminant reduction in activated carbon filters takes place by two processes, physical removal of contaminant particles, blocking any that are too large to pass through the pores (obviously, filters with smaller pores are more effective), and a process called adsorption by which a variety of dissolved contaminants are attracted to and held (adsorbed) on the surface of the carbon particles. The two basic kinds of carbon filters include Granular Activated Carbon (GAC) and Solid Block Activated Carbon (SBAC). GAC filters contain loose granules of activated carbon while in SBAC filters, the activated carbon is in the form of very small particles bound into a solid, matrix with very small pores. Advantages:-GAC filters can reduce chlorine and particulate matter as well as improve the taste and odor of the water, and both GAC and SBAC filters do not waste water. Loose granules of carbon do not restrict the water flow to the extent of Solid Block Activated Carbon (SBAC) filters. This enables them to be used in situations, like whole house filters, where maintaining good water flow rate and pressure is important. Disadvantages:-The filters might become breeding grounds for the bacteria they trap. Unless the filter plugs up or you notice an odor in the " filtered water", it may be difficult to know when the filter has become saturated with contaminants and ineffective. Because of the filter characteristics discussed above, the most effective Point of Use activated carbon filters are large SBAC filtration systems, and the least effective are the small, pour-through pitcher filters. Under a scanning electron microscope the activated carbon looks like a porous bath sponge. This high concentration of pores within a relatively small volume produces a material with a phenomenal surface area: one tea spoon of activated carbon would exhibit a surface area equivalent to that of a football field. KDF " Filters": KDF filters employ a matrix (generally small granules) of a zinc/copper alloy, which allegedly eliminates contaminants from water by utilizing electrochemical oxidation reduction. Zinc and copper are the preferred metals used in the KDF alloy since both are relatively good reducing agents with respect to common inorganic contaminants (such as chlorine), and both can be tolerated in solution in moderate concentrations without adverse side effects. The advantages of KDF filters include: KDF removes contaminants from running hot water (unlike carbon filters where hot water can release trapped contaminants into the water stream). This makes them ideal for use in the shower. Chemical properties of KDF include its alleged ability to: Remove chlorine (actually changes free chlorine to a less active form), Kill algae and fungi, Control bacterial growth in the filter, Remove hydrogen sulfide, iron, lead, cadmium, aluminum, mercury, arsenic and other inorganic compounds and partially reduce hardnessThe filters change the free chlorine some people are allergic to into a form (zinc chloride) that is much more easily tolerated. The disadvantages of KDF filters include: KDF filters do not, by themselves, remove organic chemicals (pesticides, disinfection byproducts, MTBE, etc.), or parasitic cysts (giardia and cryptosporidium). KDF filters need to be backwashed periodically with hot water to remove the insoluble contaminants. This method wastes many gallons of hot water and there is no way to prevent dislodged pollutants from coming out later with the supposedly filtered water.

ENERGY REQUIREMENT

All purification processes require power. There exists a theoretical minimum of power for the production of fresh water from ocean water. This minimum power requirement is about 1kw for each hourly production rate of 1 metric ton. The theoretical minimum power for producing 1000tons of water in a 24-hr day is about 42kW. In practice, much more power is used. Even if power were available free of charge, a relatively large investment would be necessary to build desalination plants. The theoretical minimum of work for desalting sea water (salinity 34. 3% at 25deg. C) is 0. 0007kW. hr/l. This minimum work consumption increases with increasing temperature. By similar calculations it is found that, at 70degC, 0. 00081kW. hr and, at 0degC, only 0. 00065kWhr are theoretically required to desalinate 1000liter of water. (28)The reverse osmosis process requires energy for the pump which drives the feed solution under the high operating pressure through the module. This pressure has to be considerably higher than the osmotic pressure of the feed solution. The energy consumption for sea water desalination is greater than for brackish water desalination, because the osmotic pressure depends on the salt concentration. The required energy is however well below that needed for other separation processes such as distillation, because there is no phase change involved in reverse osmosis.

Energy consumption to desalinate 1 wt. % feedwater (21):

Water Purification Method

Energy consumption

Electric Heat (boiling)0. 625kW. hr/lFlash distillation0. 037 kW. hr/lVapor compression distillation0. 024 kW. hr/lElectrodialysis0. 0105 kW. hr/lReverse Osmosis0. 002-0. 005 kW. hr/lSolar evaporationNone

COST

While the protection of the source of a supply is undoubtedly better than chemical treatment, yet the possibility of conveying pure water from a distance should be compared with the cost of treating impure water close at hand, the ‘ critical’ distance depending on the cost of treatment, quantity of water delivered, and the distance of transport (5). In present-day circumstance, it will often be found more economical to treat the nearby source as often some form of remedy is necessary for " pure" water on account of acidity which produces risk of corrosion or deposit (5).

Desalination of sea and brackish water is the most important application for reverse osmosis. For brackish water, reverse osmosis has to compete with electrodialysis; for sea water, distillation is a competitor. Both capital cost and operation costs have to be considered to weigh reverse osmosis against other separation processes. Compared with distillation, the capital costs are lower for reverse osmosis; concerning the operation costs we must distinguish between energy costs, pretreatment costs and maintenance costs (e. g. membrane replacement) (21). Ozone is the most expensive but also the most powerful oxidant which can be used in all situations. The investment costs for production and treatment plants are highest. The main purpose of this table is to present an approximate idea of the investment and operating requirements of desalting plants. It would be quite wrong to select a process on the strength of one particular economically favorable feature alone. For instance, the investment for the multistage flash still of capacity 4 liter/day is listed somewhat higher than for the compression still of the same capacity. This does not mean that the cost of the water produced by the latter method is necessarily lower (17). ENERGY REQUIREMENTS AND INVESTMENT COSTS OF SELECTED DESALTING PLANTS (17)

Method

Capacity liter per day

kW. hr per liter

Efficiency %

Investment, $ per daily liter

Multistage flash40. 17kg steam per liter3. 8410Electrodialysis (sea water)0. 01-0. 030. 0362. 71100Electrodialysis of brackish water110. 003152. 473Solar EvaporationNoneLess than 17500Compression Still40. 0214. 6340

Some contaminants and the WQA recommended treatment methods including costs per liter

Contaminant

Water Quality Association (WQA) recommended Treatment Methods

Cost ($/liter)

Arsenic (+3)Chemical OxidationReverse OsmosisDistillationIron Based MediaAnion ExchangeActivated Alumina0. 026 – 0. 0530. 066 – 0. 0920. 00260. 0053 – 0. 011Arsenic (+5)Coagulation/FiltrationSubmicron FiltrationAnion ExchangeActivated AluminaReverse OsmosisDistillationElectrodialysisIron Based Media0. 0026 – 0. 0260. 0026 – 0. 0660. 00260. 0053 – 0. 0110. 026 – 0. 0530. 066 – 0. 092Arsenic (organic complexes)Activated Carbon0. 0026 – 0. 066ChlorineActivated CarbonReverse Osmosis0. 0026 – 0. 0660. 026 – 0. 053

Summary

Water is composed of two parts hydrogen and one part oxygen. It is not the materials of the water but the contaminants in it that make it important. If we look at a chemical reaction, we would be happy with a yield of 99. 95% purity. However, for water this level of impurity is unacceptable. We are dealing with a substance where the levels of contaminants that we often consider insignificant can spoil the quality or use of this product. Although nearly all newly derived water purification methods have improved the water quality in developing countries, few have been accepted and maintained for long-term use. Field studies indicate that the most beneficial methods use indigenous resources, as they are both accessible and accepted by

communities they help (31). http://www. usbr.

gov/pmts/water/media/pdfs/report081. pdfhttp://pdfserve. informaworld.

com/262438_751309558_747937299. pdf