Nanofiltration and Reverse Osmosis in Water Treatment Systems

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(Received on: February 2, 2018)

ABSTRACT

Nanofiltration and reverse osmosis are two of the most-used methods in the water treatment systems for water purification. Both RO and NF water purification method involves the process of forcing the water through a membrane. RO system filters out anything that is 0.0001 µm or larger than water molecules. The most mineral particles that are required by our body such as sodium, magnesium and iron are larger in size than water molecules also get removed along with contaminants from water by semipermeable membrane of the RO system thus render water unhealthy for consumption. Nanofiltration however is slightly coarser filtration than RO, with its ability to remove particles as small as 0.002 to 0.005 µm in diameter including pesticides and organic macromolecules, while retaining minerals that RO would otherwise remove. The World Health Organisation has conducted a study which exposes some of the health risks associated with demineralised drinking water. Reverse Osmosis, the health risks associated with drinking reverse osmosis water and benefits of nanofiltration are discussed here.

Keywords: Desalination of waste water, reverse osmosis, nanofiltration.

INTRODUCTION

A community drinking water supply comes from ground and surface water sources. Drinking water regulations require municipalities to treat and disinfect drinking water before distributing it to public due to the possibility of the presence of micro-organisms, toxic minerals, metals, pesticides, organic chemicals etc. Many diseases are caused by drinking improperly treated water. The guidelines about drinking water standards are given by World Health Organisation and European Union. Membrane filtration is a process which involves the pressure driven passage of water through a membrane which acts as selective barrier to
restrict the passage of pollutants such as inorganic metal ions, organics, nutrients, turbidity, microorganisms, and other oxygen depleting pollutants, and allows relatively clear water to pass through. With advancement of technology and the increasing demand of water quality criteria, membrane processes are becoming a more preferred solution to the challenge of quality water and water reuse. Depending on their pore size, the membrane process has been classified into four broad categories as: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) membranes.

RO system filters out usually anything that is 0.0001 µm or larger than water molecules. The most mineral particles that are required by our body such as sodium, magnesium and iron are larger in size than water molecules and get removed from water by semipermeable membrane of the RO system thus render water totally demineralised, thus unhealthy for consumption. Actually all substances present in water are not harmful to our health, some of them are not harmful to our health. Some of them are health improving too. The water almost or completely free of dissolved minerals as a result of deionisation, distillation, reverse osmosis or other technologies is called demineralised water. There are many pros and cons on drinking demineralised water. The arguments favouring drinking demineralised water is that the minerals present in water interfere with our body functions. Many articles written by doctors or nutritionists claim that the presence of minerals in drinking water cause diseases like occurrence of cardiovascular diseases, diabetes, cancer, respiratory diseases etc. The argument against drinking demineralised water are that by distilling or reverse osmosis we have lost a primary source of necessary minerals in our diet and that the water has lost its own minerals will attract and absorb minerals in our body resulting in deficiency of minerals.

The awareness of the importance of minerals and other beneficial constituents in drinking water is even mentioned in Rig Veda in which properties of good drinking water are described as, “Sheetham (cold), Sushihi(clean), Sivam(should have nutritive value and required minerals), Istham(transparent), VimalamLahuShadgunam(its acid base balance should be within normal limits). Initially demineralised water, first distilled water, later deionised or reverse osmosis treated water had been used for laboratory, technical and industrial purposes. These technologies became more extensively used for obtaining drinking water in 1960s due to limited drinking water sources in coastal and inland areas, the increasing drinking water demands resulting from increasing populations, higher living standards, development of industries and mass tourism. Demineralisation of water was also required in the areas where the water sources are sea water or highly mineralised brackish water. Demineralised water was also used in ocean going ships and spaceships where this was the only source of drinking water. Initially these water treatments were not used at homes since they were costly, but with improvement of economic status, these days RO system has become an essential gadget at the homes of middle class in India.

Demineralised water is defined as water almost or completely free of dissolved minerals, obtained by distillation, deionisation, reverse osmosis or Nano filtration etc. The total dissolved solids (TDS) in this water is quite low approximately 1mg/l. From the
beginning it was clear that demineralised water without further enrichment with some minerals might not be fully suitable for consumption due to following reasons.

1. Demineralised water is highly aggressive and if not treated, it attacks the water distribution pipes and storage tanks thus leaches metals and other materials from pipes and other plumbing materials.
2. Demineralised water has poor taste.
3. Evidence was available that some substances present in water could have beneficial effects on human health. For example artificially fluorinated water resulted in decrease of tooth caries.

The potential for adverse health effects from long term consumption of demineralised water is of concern not only in countries which lack adequate fresh water, but also in countries where such types of home water treatment systems or bottled water are widely used. So the exposures and risks should be considered not only at community level but also at the individual or family level.

HEALTH RISKS OF DEMINERALISED WATER

Review of some experimental facts obtained from the experiments conducted on laboratory animals and human volunteers and observations obtained from populations supplied with demineralised water and infants given beverages prepared in distilled water, the possible adverse consequences of demineralised water consumptions are listed by WHO.

1. Little or no intake of magnesium and calcium from low mineral water.
2. Direct effects on the mucous membrane, metabolism and other body functions.
3. Low intake of essential elements and micronutrients.
4. Loss of magnesium, calcium and other essential elements in food prepared in RO water.
5. Possible increase in dietary intake of toxic metals.

Low or no intake of magnesium and calcium from low mineral water: Calcium and magnesium are essential elements for our body. Calcium is part of bones and teeth. It is important in conducting myocardial system, heart and muscle contractibility, blood clotting etc. The most common disease caused by calcium deficiency is osteoporosis. Its deficiency is also proved to cause hypertension.²

Magnesium has been found to play an important role in glycolysis, ATP metabolism, transport of elements such as potassium, sodium and calcium through membranes, synthesis of proteins and nucleic acids, muscle contraction etc. Its deficiency increases the risks to humans of developing various pathological conditions such as hypertension, cardiovascular diseases, vasoconstrictions, diabetes and osteoporosis etc.³

It is found that drinking water low in magnesium can cause increased morbidity and mortality from cardiovascular diseases, pregnancy disorder, risks of motor neuronal disease. Water low in calcium taken for long duration of time causes high risk of fracture of bones in children, certain neurodegenerative diseases, preterm and low weight birth etc. Deficiency of both magnesium and calcium can also cause some types of cancers.⁴
Direct effects of low mineral or RO water on the intestinal mucous membrane: It was reported by WHO and other studies that drinking of demineralised water can cause electrolyte imbalance in body as all the minerals from such water are filtered off or removed by distillation in case of distilled water. So this mineral free water in our body leaches electrolytes from our tissues, so that our body can function normally and can eliminate waste. If water redistribution process in our body is not functioning properly, one may feel fatigue, muscle cramps, weakness, headache and abnormal heart rate. In the past acute health problems were reported in mountain climbers who used to drink water obtained from melted snow that was not supplemented with necessary ions. A more severe problems caused due to such condition are brain oedema, convulsions, metabolic acidosis etc.  

Low intake of essential elements and micronutrients: Some essential elements are usually present in natural water as free ions and they are readily absorbed from water as compared to food. The epidemiological studies suggests that drinking lower mineral or RO water for long term may cause hypertension, coronary heart disease, pregnancy complications, gastric ulcers, goitre, jaundice, anaemia, bone fractures, growth disorders etc. A study was conducted by Lutai in 1927, on two populations living in areas with different levels of dissolved minerals which have shown that the population of area provided with water low in minerals had higher incident rates of these diseases. Children in this area exhibited slower physical development, growth abnormalities and the pregnant women suffered more from oedema and anaemia than those living in areas with water moderate in minerals. 

Loss of calcium, magnesium and other essential elements in food prepared in low mineral water: When demineralised water is used for cooking, it results in a great loss of essential elements from food i.e. about 60% magnesium and calcium, 70% manganese, 86% cobalt, 66% copper etc. But when the cooking is done in natural water these losses in metals are not reported. Since some nutrients are only ingested with food, low mineral water used for cooking may take away these nutrients from food and cause a marked deficiency in these elements. So any factor that causes the loss of essential elements and nutrients during cooking and processing of food should be avoided as the diet these days taken by us already do not provide necessary elements in sufficient quantities. 

Possible increase in dietary intake of toxic metals: Demineralised water is highly aggressive to materials it comes into contact. So it readily dissolves metals and organic substances from the pipes, storage tanks, containers and other plumbing materials and thus itself becomes contaminated. Calcium and magnesium in water and food are found to have antitoxic activity and hence they can prevent the absorption of some toxic elements from the intestine into blood. 

Bacteria contamination of low mineral water: The regrowth of bacteria is encouraged by lack of a residual disinfectant and great availability of leached nutrients in aggressive water particularly when it has high temperature.
High acidic nature of demineralised water: As demineralised water contains no minerals, it absorbs other elements very easily. So when it comes in contact air it absorbs carbon dioxide which increases its acidity. Acidic water can lead to imbalance of pH in blood, which should be alkaline. In the natural health and medical communities, acidosis in the body is considered an underlying cause for most of the degenerative diseases. In the natural health and medical communities, acidosis in the body is considered an underlying cause for most of the degenerative diseases. Low mineral water increased diuresis i.e. the production of urine by the kidneys by 20% on average and significantly increased the elimination of sodium, potassium, calcium, magnesium and chloride ions from the body as reported by WHO in a study.

Some critical contaminants are not removed: Reverse osmosis is effective for removing most of the contaminants from water but it alone does not remove volatile organic compounds (VOC), chlorine, chloramines, pharmaceuticals and other chemicals found in municipality water. But these days R.O. systems have multistage filtration media, such as activated carbon, in addition to R.O. membrane which removes chlorine and certain pesticides.

Dental health: Reverse Osmosis also removes fluoride that natural water contains. Lack of fluoride in drinking water causes tooth decay and cavities in children. Some dentists relate lack of fluoride in drinking water as a cause of an increased number of cavities in young children who consume distilled or demineralised water.

NANO FITRATION

Both charge and size of particles play important role in NF rejection mechanism as NF membrane exhibits properties between those of ultrafiltration (UF) and reverse osmosis (RO). NF has been described as a charged UF system by Simpson et al. (1987) and as low pressure RO system by Rohe et al. (1990). However, NF has advantages of operating at lower pressure compared to RO. Recently, nano-filtration membranes, with high water fluxes at low pressures, have been developed as new systems in wastewater treatment. These membranes are also found to reject organic compounds with molecular weights above 200 to 500. Due to these properties, some exciting new applications in wastewater treatment has become possible, such as selective separation and the recovery of pollutants that have charge differences, the separation of hazardous organic compounds from monovalent salt solutions, and membrane softening to reduce hardness and trihalomethane precursors from drinking-water. Nanofiltration membranes have engrossed a high attention for use in water softening and the removal of various contaminants from drinking-water. Nanofiltration (NF) processes can reduce TDS, hardness, colour, agricultural chemicals, and high molecular-weight materials that can form trihalomethanes when chlorinated.

Some characteristics of nanofiltration include:
1. Nanofiltration can block particles that are 0.002 to 0.005 μm in diameter, but it does not remove dissolved compounds.
2. Nanofiltration does not remove all minerals that may be present in the water so water is not totally demineralised, but it removes harmful microbes and divalent ions which cause water hardness.

3. As nanofiltration works on gravity and not electricity so it is an energy efficient alternative as compared to reverse osmosis.

4. Nanofiltration does not involve any wasting of the water that is fed to it, whereas reverse osmosis wastes up to 50% of the water fed to it.

Nanofiltration applications include wastewater recycling, treating well water, and any applications where the water quality allows for the presence of some minor dissolved elements such as salts and minerals. So it finds application to be used in purification of water for drinking purposes.

The WHO provided recommendations in 2004 for the drinking water mineral content standards:

1. For magnesium, a minimum of 10 mg/l and an optimum of 20-30mg/l.
2. For calcium, a minimum of 20mg/l and an optimum of about 50mg/l.
3. For total dissolved salt concentration (TDS), the sum of calcium and magnesium should be 2 to 4 mmol/l.

At these concentrations no adverse health effects were observed. The recommended magnesium levels were based on cardiovascular system effects, while changes in calcium metabolism and ossification were used as a basis for the calcium levels.

CONCLUSION

RO systems are doing a great work of removing impurities/contaminants from the water but the problem with RO systems is that they do not discriminate between the good and bad minerals as they remove everything. So the need is to remineralise the water once it has passed through the RO membrane. So adding back the calcium and magnesium in proper concentration solves the problem. RO industry has become aware of the reality that long term consumption of demineralised water is not good for health. They are also trying to find solutions to make their RO filtered water healthy. Initially some industries offered corosex and calcite solutions. Though corosex and calcite will remineralize water but they were not designed to work with the aggressive acidic water produced by RO system. Hence corosex and calcite minerals can dump more minerals into water than our kidneys can digest and end up in the formation of kidney stones. So corosex and calcite are not the right solution for remineralization of aggressive acidic water produced by RO machines. These days Nano filtration and ultrafiltration is gaining the rapport as these filters are cost effective, much smaller and allow faster flow of water.

The filter required depends upon the source of your water. For the water supplied by municipality does not require to be cleaned by RO system unless the municipality adds fluoride to it. While comparing nanofiltration and reverse osmosis water purification systems,
nanofiltration is preferred for energy efficient water purification where absolute removal of minerals isn’t the great concern, while reverse osmosis is the right choice for industrial applications that require all dissolved minerals to be removed.

There is a new water filter (made in America) which is consist of two types of filters, activated carbon and zeolite minerals bound with polymers to form a carbon block. It removes 85% of fluoride at the rate of water flow rate 2 litres per minute and 95% if flow rate of water is reduced to 1 litre per minute. So problem of mixing of fluoride by municipality in water supply can be solved.

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1. Basics of Reverse Osmosis and Nanofiltration
1.1 Historical Background
1.2 Desalination Technologies and Filtration Processes
1.3 Principle of Reverse Osmosis and Nanofiltration
1.4 Membrane Description
1.5 Membrane Performance
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Table 25. Historically, nanofiltration and other membrane technology used for molecular separation was applied entirely on aqueous systems. The original uses for nanofiltration were water treatment and in particular water softening. Nanofilters can "soften" water by retaining scale-forming, hydrated divalent ions (e.g. Ca2+, Mg2+) while passing smaller hydrated monovalent ions.[5][6]. One of the main advantages of nanofiltration as a method of softening water is that during the process of retaining calcium and magnesium ions while passing smaller hydrated monovalent ions, filtration is performed without adding extra sodium ions, as used in ion exchangers.[7] Many separation processes do not operate at room temperature (e.g. distillation), which greatly increases the cost. Online course about reverse osmosis and nanofiltration, increasingly important technologies in the production of drinking water, industrial water treatment and desalination. Describe the rejection mechanism of ions and organic compounds in the membrane system. Explain the advantages and disadvantages of the application of RO. Explain different application of RO membranes (seawater, brackish water and freshwater).

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Explain different water flows and their routing in a membrane module. Explain the particulate and biological fouling in the membrane. Explain the concentration polarization mechanism and scaling problem. Calculate an RO unit and design a treatment plant including the RO unit as the heart (seawater, brackish or freshwater). Download brochure. Reverse osmosis vs nanofiltration is a hotly debated subject in the water treatment industry. Supporters of both membrane filtration technology have continued to highlight the advantages of each water purification system that makes them the better of the two. RO and NF systems share similarities in terms of appearance and features. However, nanofiltration systems utilize newer technology and incorporates added features which allow it to do certain things that RO systems can not perform as efficiently. For instance, reverse osmosis systems were found to filter out precious nutrients that are be