Purification of Drinking Water with the Application of Modern Technology

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Abstract: ***Since the amount of water that is available to meet human requirements is decreasing quickly, it is critical to treat and purify waterworks' water resources so that the resulting clean water can meet demand. The primary focus of this article is the present state of research on advanced treatment technologies and tap water treatment technology to establish a foundation for the use of scientific researchers and social entrepreneurs. Water treatment systems come in a variety of forms. Make sure you buy the equipment that can properly treat your specific water quality issue because there isn't a single treatment method that works for every problem with water quality. You can find the best answer for your issue by using the information discussed below.***

Keywords: Water treatment, water scarcity, water quality, advanced treatment technologies, social entrepreneurs

1. Introduction

Water is necessary for living and for staying hydrated. It is also necessary for many applications, sanitation, and hygiene, as well as for the preparation and cooking of food. The safe drinking water needs to be devoid of any contaminants or dangerous substances [1 - 6]. Rain, springs, rivers, lakes/ponds, and subterranean resources are some of the ways that nature has given living things access to enough drinking water resources. However, people began choosing commercial products to treat their water supply at the home and community level due to the lack of access to safe drinking water everywhere and the limited supply of drinking water. They did this without knowing much about the technologies used in these commercial products and assumed that the treated water from these products was a sign of high purity potable water. Certain substances, including pesticides and product disinfection, are of interest, whilst other ingredients are not [7, 8]. Certain components are vital to human bodily functions and have a significant impact on human health. Magnesium and calcium are two important examples of these kinds of elements.

The need for efficient water purifiers is rising dramatically as more and more people become aware of the dangers of consuming tainted water from human sources. Most intestinal illnesses and diseases are brought on by microorganisms that are carried by water. As a result, more and more people are searching for trustworthy purifying solutions throughout India, not just in major cities but also in smaller towns and even in rural areas. There could be chemical and/or biological pollutants in the water supply [8 - 12]. Water that has been biologically contaminated can contain bacteria and viruses that can cause gastrointestinal problems and mild to serious diseases. Overuse of pesticides and fertilizers in the fields, as well as improper handling of municipal and industrial trash, are common sources of chemical pollution. Regular usage of chemically tainted water can cause major, long - term health problems [8, 13, 14].

One of the earliest and most effective ways to cleanse water is to boil it in order to eradicate the majority of bacteria. Since ancient times, Jains have employed the filtration technique because their religious leaders recommend using cotton cloth filters to remove pathogens from water. India still has a large number of families that use candle water filters. With so many different brands and technology accessible in India these days, how does one make a decision? Which type of water filtration system is right for you? The degree of purification, upkeep costs, and product cost are the standard selection criteria. Various technologies offer varying levels of purity.

On May 28, 2019, the Union Ministry of Environment, Forests, and Climate Change (MoEF & CC) received a notification from the National Green Tribunal (NGT) forbidding the use of drinking water treated by reverse osmosis (RO) systems in locations where the total dissolved solids (TDS) was less than 500 mg/L. This paper's goal is to raise public awareness of various water purification technologies so that they can select the best one for their needs in terms of safe drinking water.

Reason for water treatment:

Water treatment is done primarily for two reasons:

a) To get rid of pollutants that are bad for your health
b) To get rid of impurities that give the water an unpleasant flavor, smell, or appearance.

Early attempts at treating water concentrated on increasing the water's consumer appeal or aesthetic attributes because many dangerous pollutants are invisible, odorous, or tasteless. However, as science has improved, so too have our abilities to identify microbes and extremely low concentrations of hazardous substances. This has resulted in the development of sophisticated treatment methods to eliminate potentially harmful contaminants in minute quantities.

Aesthetic contaminants:

The water's flavor, odor, and appearance are all impacted by aesthetic pollutants. While the majority do not directly endanger human health, their existence may cause issues that could later raise health concerns. Cloudiness or turbidity, iron and manganese, color, hardness, and the smell of rotten eggs from hydrogen sulfide gas are a few examples of aesthetic pollutants [15, 16].

Health related contaminants:
Human health may be impacted by naturally occurring, artificially created, or process - related contaminants. Contaminants linked to health can be further classified as acute contaminants (which can cause illness or disease at very low levels or low exposures) or chronic contaminants (which can only cause illness or disease after prolonged exposure to the contaminants in drinking water). Contaminants that are harmful to health include pathogenic bacteria, inorganic substances including lead, arsenic, nitrate, and nitrite, and residues from chlorination that can be left behind after disinfection [17 - 20].

Some of the more common contaminants encountered in water treatment:

Contaminant	*Affects*	*Source*	*Common Treatment Options*
Giardia	Health	Organism	Filtration/Disinfection
Cryptosporidium	Health	Organism	Filtration
Viruses	Health	Organism	Filtration/Disinfection
Total Trihalomethanes	Health	Disinfection Byproduct	Filtration/Adsorption/Disinfectant Selection
Five Haloacetic Acids	Health	Disinfection Byproduct	Filtration/Adsorption/Disinfectant Selection
Arsenic	Health	Mineral	Co - precipitation/Adsorption
Lead	Health	Mineral/Corrosion	Corrosion Control
Copper	Health	Mineral/Corrosion	Corrosion Control
Nitrate	Health	Nitrogen	Ion Exchange/Reverse Osmosis
Manganese	Health/Aesthetic	Mineral	Oxidation/Filtration/Adsorption
Iron	Health/Aesthetic	Mineral	Oxidation/Filtration
Turbidity	Health/Aesthetic	Particle Matter	Filtration
Color	Aesthetic	Minerals or Organics	Oxidation/Filtration/Adsorption
Odor	Aesthetic	Hydrogen Sulfide	Oxidation/Aeration
Hardness	Aesthetic	Minerals	Ion Exchange/Reverse Osmosis

Drinking Water Qualifications:
The standard criteria for drinking water have been established by the Bureau of Indian Standards (BIS) (BIS, 2012). The maximum allowable level has been set in order to provide users with the freedom to make decisions about water quality standards, particularly in situations where there are no other available sources. Table 1 lists the essential water quality parameters for drinking purposes as specified by the BIS Standard.

Table 1: Drinking Water Specifications (BIS IS: 10500, 2012)

Sl. No.	*Characteristics*	*Acceptable limit*	*Permissible limit*
1.	Colour, Hazen units, Max	5	15
2.	Odour	Agreeable	Agreeable
3.	Taste	Agreeable	Agreeable
4.	Turbidity, NTU, Max	1	5
5.	pH value	6.5 to 8.5	-
6.	Total hardness ($CaCO_3$), mg/L, Max	200	600
7.	Iron (as Fe), mg/L, Max	0.3	-
8.	Chlorides, mg/L, Max	250	1000
9.	Free residual chlorine, mg/L, Min	0.2	-
10.	Dissolved solids mg/L, Max	500	2000
11.	Calcium, mg/L, Max	75	200
12.	Magnesium, mg/L, Max	30	100
13.	Copper, mg/L, Max	0.05	1.5
14.	Manganese, mg/L, Max	0.1	0.3
15.	Sulphate, mg/L, Max	200	400
16.	Nitrate (as NO_3), mg/L, Max	45	-
17.	Fluoride, mg/L, Max	1.0	1.5
18.	Phenolic compounds, mg/L, Max	0.001	0.002
19.	Mercury, mg/L, Max	0.001	-
20.	Cadmium, mg/L, Max	0.003	-
21.	Selenium, mg/L, Max	0.01	-
22.	Total arsenic (as As), mg/L, Max	0.01	0.05
23.	Cyanide, mg/L, Max	0.05	-
24.	Lead, mg/L, Max	0.01	-
25.	Nickel, mg/L, Max	0.02	-
26.	Anionic detergents	0.2	1.0
27.	Total chromium (as Cr), mg/L, Max	0.05	-
28.	PAH, mg/L, Max	0.0005	-
29.	Mineral oil, mg/L, Max	0.5	-
30.	Total alkalinity, mg/L, Max	200	600

31.	Aluminium, mg/L, Max	0.03	0.2
32.	Boron, mg/L, Max	0.5	1.0

Pesticide Residue Limit (µg/L)		
33.	Alachlor	20
34.	Atrazine	2
35.	Aldrin/Dieldrin	0.03
36.	Alpha HCH	0.01
37.	Beta HCH	0.04
38.	Butachlor	125
39.	Chlorpyriphos	30
40.	Delta HCH	0.04
41.	2, 4 - Dichlorophenoxyacetic acid	30
42.	DDT (o, p and p, p –Isomers of DDT, DDE and DDD)	1
43.	Endosulfan (alpha, beta and sulphate)	0.4
44.	Ethion	3
45.	Gamma– HCH (Lindane)	2
46.	Isoproturon	9
47.	Malathion	190
48.	Methyl parathion	0.3
49.	Monocrotophos	1
50.	Phorate	2

Removal of Arsenic:

Different proportions of pentavalent Arsenate As (V) and trivalent Arsenite As (III) can be found in groundwater. The majority of arsenic treatment systems have a very high removal efficiency for arsenate, but a very low removal efficiency for arsenite. As a result, oxidation is frequently used in treatment technologies as a pre - treatment step to change As (III) into As (V). For the oxidation process of arsenic, atmospheric oxygen, hypochlorite, and permanganate are most frequently utilized.

$H_3AsO_3 + ½ O_2 = H_2AsO_4^- + H^+$

$H_3AsO_3 + HClO = HAsO_4^- + Cl^- + 3H^+$

$3H_3AsO_3 + 2KMnO_4 = 3HAsO_4^- + 2MnO_2^+ + 2K^+ + 4H^+ + H_2O$

Other substances that are employed are ozone, gaseous chlorine, and other oxidizing agents. Arsenic oxidizes slowly in the air over several weeks, however the aforementioned compounds can oxidize arsenic quickly [19 - 22].

Water Purifiers:

There are several kinds of home water purifiers on the market, each using a different method. Simple water filters to highly sophisticated purifiers that use membrane technology for water filtering and UV lamp filters for disinfection are available in the water purification market. We'll talk about the typical water filtration techniques used to purify household water here.

Candle Filter:

The working process of a candle - style water purifier is straightforward. The candle typically contains pores that are less than 3 µm. Any particle that is too big for the pores gets trapped and can't move to the clean side. The suspended solids can be eliminated using the candle filter. It is capable of functioning without the need for electricity. Water must still be boiled before drinking because these filters cannot remove soluble pollutants like fluoride, arsenic, and the like in addition to bacteria. For the candle to function effectively, it must also be cleaned often. Furthermore, it takes time to filter drinking water using these candle filters, which is why automated water purification systems are becoming more and more common and are frequently seen as more dependable [7, 8].

Activated carbon filter:

Activated carbon filters are used in this water filter's purifying procedure. To a large extent, contaminants, pesticides, and chlorine can be eliminated by the carbon filters. The water's flavor and odor are altered by the filtering. It is capable of functioning without the need for electricity. However, it is also not particularly good at getting rid of microorganisms from water. Furthermore, the majority of commercial filter producers now use nano - silver coated carbon since conventional carbon filters serve as a haven for bacteria [20 - 22].

UV purification or e - boiling:

Ultraviolet light is used in UV (Ultra Violet) water treatment to render all bacteria, viruses, microorganisms, cysts, and other microorganisms inactive. A straightforward yet efficient method of purifying water, ultraviolet light kills 99.99% of the pathogens present in the liquid. The purifier contains a tiny mercury lamp that emits short wave UV radiation. These radiations penetrate the cells of bacteria and viruses and irradiate the water, killing the latter's capacity to proliferate. When the organisms and bacteria are unable to proliferate, they finally perish. The bodies of the inactivated germs remain in the water despite this purification procedure simply rendering the germs inactive. In order to physically eradicate the bacteria, separate filters are necessary. UV water purification is typically used in conjunction with activated carbon filters or reverse osmosis systems for additional filtration [21, 22].

RO purification:

Reverse osmosis, or RO, is the most used technique for purifying water. RO purges water of dissolved salts, pollutants, and bacteria using membrane technology. Water is separated from microorganisms and dissolved compounds via a semipermeable membrane (SPM). Reverse osmosis involves applying an externally applied excess pressure to trap bigger particles or pollutants on the pressured side of the membrane while allowing pure water to flow through. With a hole size range of 0.0001 - 0.001 μm, the RO membrane only permits water to flow through it, leaving behind all potentially dangerous substances, dissolved salts, and microorganisms suspended in water. As a result, the water is purified of the ions and particles bigger than the pore size of RO membranes [7, 8, 21].

UF purification:
Membranes used in the UF (Ultra - filtration) purification process resemble RO membranes but have larger holes (0.01–0.1μm). The majority of pathogenic microorganisms and turbidity are physically blocked by UF membranes, however dissolved solids and salts are not removed. When the water to be treated has less than 500 mg/L of TDS, ultra - filtration membrane - based water purifiers should be chosen over RO - based purifiers [15 - 18].

A Typical RO System:
The components of a typical RO system are as follows: i) a sediment pre - filter that removes sediment and dust particles using a micro - filter (typically 5 microns); ii) an activated carbon filter that traps organic compounds and other volatile substances to remove chlorine and odors; iii) a RO/UF membrane that removes dissolved particles, ions, and some minerals; occasionally, these membranes are equipped with extra cartridges (TDS Controller) that add back minerals to make the water potable. iv) A UV filter that destroys dangerous bacteria and viruses in the water; v) A post - carbon filter that improves the water's flavor and gets rid of any residual odors; and vi) A storage tank to hold the water after it has been treated [15 - 17].

Comparison of different purifiers:

Sl No.	*Name of the purifier*	*Function*
1.	Candle Filter	Can remove particles size larger than 3 μm.
2.	Activated carbon Filter	Can remove chlorine, pesticides and impurities
3.	UV purification or e - boiling	Can inactivate all germs, bacteria, microbes, cysts, etc. in water.
4.	RO purification	Can remove dissolved salts, impurities and germs from water.
5.	UF purification	Can remove pathogenic organisms and turbidity but fail to remove the dissolved solids and salts.

The phrase "total dissolved solid" (TDS) refers to the inorganic salts and trace amounts of organic materials that are found in water. Particles larger than 0.45 microns are typically removed by a cartridge (micron) filter. After filtering, dissolved molecules and ions make up the remaining impurities. In addition to altering the flavor of water, moderate to high TDS in water presents other health risks. The TDS level is one of the crucial aspects to take into account while searching for a water purifier. The design of a water purifier and the necessity of a RO membrane should be determined based on the TDS level. However, other pollutants also play a crucial role and TDS is not necessarily the main reason. Typically, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, chloride, sulfate, silica, and nitrate are the main ingredients of TDS. According to BIS (2012), if there isn't a substitute source of drinking water, the maximum allowable limit for TDS is 2000 mg/L and the acceptable limit is 500 mg/L.

Drinking water provides vital elements including calcium and magnesium. According to BIS (2012), the maximum allowable value for drinking purposes is 200 mg/L and the acceptable limit is 30 mg/L and 75 mg/L for calcium and magnesium, respectively. Because teeth's enamel is made up of calcium, magnesium, and phosphate molecules, low concentrations of these elements leave teeth vulnerable to acid - producing bacteria - induced decay. A lack of magnesium has been connected to a number of health problems, including high blood pressure, irregular heartbeats, illnesses, blood vessel problems, pre - eclampsia in pregnant women, type I diabetes, and osteoporosis.

Advantage of RO Purifiers:
1) Where there is a high TDS and hard water quality, it is recommended to use a RO purifier.
2) Bacteria, viruses, fluoride, iron, arsenic, and other metals as well as pesticide residues can all be eliminated by a RO purifier.

Disadvantage of RO Purifiers:
1) RO's primary disadvantage is that it changes the flavor of water by lowering its TDS and vital minerals.
2) The quantities of calcium and magnesium are likewise decreased after going through a RO purifier, to an unacceptable degree. Studies on the impact of low calcium and magnesium consumption on human health and activities have been published and reported. They also discussed the impact of low levels of magnesium and calcium in water on those who consume extremely soft water. Some RO companies assert that the water's important minerals are retained.
3) Regular care and maintenance are necessary for the semipermeable membrane. Moreover, it raises operational costs because it needs electricity to function.
4) Only around 25% of the raw water used in the majority of RO - based home water purifiers is obtained as treated water, with the remaining 75% being discarded as reject.
5) TDS and other elements rose in the RO Purifier reject water as compared to the inlet water, according to the analysis results. Reject water with high TDS and higher than average amounts of other elements that is disposed of on surface soil infiltrates underlying soil and contaminates ground water as well.

When we should go for RO Purifiers:
A RO purifier is useful in places where the total dissolved solids (TDS) level is more than 500 mg/L or where specific concerns with water pollution, such as pesticide contamination and difficulties with fluoride, iron, and arsenic, have been identified. If the RO water has an automatic TDS

controller or Mineral Stabilizer system that supplements all necessary minerals, then it is safe to drink.

2. Conclusions

A physico - chemical examination of water from several RO purifiers shows that the water's TDS and important minerals, such as calcium and magnesium, are decreased after it passes through the RO purifier; this results in demineralized water. RO purifiers are mostly required for hard water, which comes from numerous groundwater sources as well as some surface sources. A large amount of waste water is produced by RO systems, which can be collected and utilized for gardening, plants, and non - soap cleaning tasks like washing cars and floors. A combination of a UV filter, activated carbon, and candle is sufficient for the majority of surface water sources.

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