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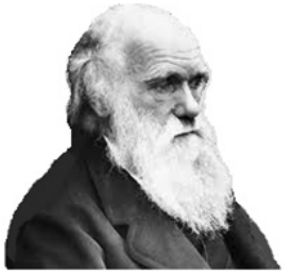

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RO Reject Water Management Techniques

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ABSTRACT

In the last five decades, the variation for increase in population and decrease in available clean water is noticeable. To meet with growing water requirements, along with the wastewater from municipal sewage treatment plants, it is critical to consider the reuse of industrial wastewater wherever possible. In the Indian context, this has already been started in some of the big industries, especially in metro cities and it must be implemented at all level possible industries. Ultrafiltration (UF), reverse-osmosis (RO) and membrane bioreactors (MBR) will be integral parts of this. Waste water reuse is not only a necessity, it also provides several eco-friendly benefits.

***Keywords*:** water treatment, reverse osmosis, phytoremediation, passive oxidation

1. INTRODUCTION

Reverse Osmosis is the technique to remove bulk particles, ions, molecules, etc. from the water to be used for drinking purpose by employing a semi permeable membrane for the purpose [1]. To overcome the colligative property of the molecules i.e. osmotic pressure, a pressure is applied to it. Bacteria and many other suspended particles can also be removed from the water by this method [2]. This leads to the retention of the solute on the side experiencing high pressure while the treated solvent flows to the other face. “Selective permeability” implies that the membrane does not allow bulk particles to pass though it and allows only the smaller particles to flow to the other end easily.

In the ordinary osmosis technique, the dissolvable actually moves from a region of low solute focus (high water potential), through a layer, to a region of high solute fixation (low water potential). The main impetus for the development of the solvent is the diminishment in the free energy of the framework when the distinction in solvent focus on either side of a film is lessened, producing osmotic pressure because of the solvent moving into the more thought arrangement. Applying an outer pressure to switch the characteristic stream of immaculate dissolvable, in this way, is termed as reverse osmosis. The procedure is like other layer innovation applications. Be that as it may, key contrasts are found between filtration and reverse osmosis. The dominating expulsion component in membrane filtration is stressing, or size prohibition, so the procedure can hypothetically accomplish consummate productivity paying little mind to parameters, for example, the arrangement's weight and fixation.

The present use or applications of this RO discharge include sea water desalination, food products and cosmetic products, laboratory water purification, industrial water purification. Also the water availability for potable water is far less in many parts of the country.

Technologists work closely on the issues of water reuse but are far from having solved all concerns related to the practice [3]. From Decision Support Systems to the simplest analytical tools, all knowledge is valuable. As public health concerns are normally among the main constraints for reuse any scenario will need to include detailed risk assessments. Although wastewater reclamation and reuse has gained approval as a necessary tool to be included in sustainable integrated water resources management [4], there are still several key points to be developed for safe use of the resource. Well water purification, pharmaceutical water purification, bottled drinking water purification, car washing, medical device manufacturing, etc.

2. METHODS

2. 1. Applications at domestic level

2. 1. 1. Phyto-remediation

Without the need of disposing the contaminants, the problems related to the environmental pollution can be coped up with the use of plants having the characteristic feature of mitigating the environmental problems. Lethal substantial metals and natural toxins are the real focuses for phytoremediation. An excess of TDS can lessen or prohibit crop production while too little can decrease water invasion which affects the crops. TDS or EC is the measure of salt concentration for irrigation water [5]. Common range in water system for TDS is 0-2000 mg/l. Thusly the TDS up to 2000 mg/l appears to be alright for a wide range of plants. Banana is one such plant that can blossom with the levels over this.

We have found that flowers grow equally well at this TDS. Water with the inlet TDS 1100 mg/l prompting the reject water with around 2000 TDS and is utilized in gardening with no issue at all. Issues in reject water for plants happen when they are unnecessary in specific minerals like calcium and nitrogen, at local level, straightforward strategy which can be applied for remediation of somewhat abundance TDS/salts in water is to utilize phytoremediation i.e use of plants, i.e in the upstream regions arrange and have conciliatory plants/foliage doing root-zone treatment utilizing reeds.

The following three plants are worth trying:

1. Rhizophora racemosa
2. Avicennia Africana
3. Nypa Fruticans- Palm

Advantages of phytoremediation include: The cost of the phytoremediation is lower than that of customary procedures both in situ and ex situ, the plants can be efficiently examined, the probability of the recuperation and re-utilization of significant metals increases. It is conceivably the slightest unsafe strategy since it utilizes normally happening life forms and jams the earth in a more characteristic state.

2. 1. 2. Aquariums (Recreational purposes)

While there are some exceptionally colorful freshwater species (bettas, neon tetras, discus, etc.) there are many more saltwater species that are truly breathtaking to view. The RO reject water can be directly put to use by filling fish aquariums and keeping special type of fishes in them which are adaptable to the high TDS.

2. 2. Treatment of water

2. 2. 1. Removal of Fluoride

According to WHO standards, the Fluoride in drinking water should be within a range that slightly varies above and below 1 mg/L. In temperate regions, where water intake is low, Fluoride level up to 1.5 mg/L is acceptable [6]. The Bureau of Indian Standards, BIS has prescribed a desirable limit and permissible limit of Fluoride in drinking water as 1.0 and 1.5 mg/L respectively.

2. 2. 1. 1 Tulsi Plant

The strategy found by analysts from Rajasthan University is safe, shoddy and promptly accessible, making it a perfect option for groups who can't bear to utilize the more propelled strategies of evacuating fluoride that are promptly accessible in the West. A test was led in the Yellareddyguda town of Narketpally Mandal [7].

The scientists drenched 75 mg of Tulsi leaves in 100 ml of water that contained 7.4 sections for every million of fluoride in the water. After just drenching the Tulsi leaves for eight hours, it was found that the level of fluoride in the water was lessened from 7.4 sections for each million, to just 1.1 parts for every million.

A declaration was made in 2012 that the Tulsi plant's stem and different parts can detoxify water with high fluoride levels making it ok for individuals to devour, and it was generally revealed by numerous normal wellbeing sources including the Fluoride Action Network. As indicated by that report, a group of Indian scientists from the division of ecological sciences, Sardar Patel Mahavidyalaya, Chandrapur, found that the stem and leaves specifically of the Tulsi plant can detoxify water by filling in as a characteristic magnet to draw in particles of fluoride from the water. The analysts said that 20 minutes was all it took for the plant to tie to the particles at an adequate rate.

2. 2. 1. 2 Pine Char

The pine chars successfully treated fluoride-contaminated groundwater at pH 2.0. The chars swelled in water due to their high oxygen content (8–11%), opening new internal pore volume. Fluoride could also diffuse into portions of the chars' subsurface solid volume promoting further adsorption. Ion exchange and metal fluoride precipitation are modes of adsorption. Remarkably, these chars (S_{BET}: 1–3 m^2g^{-1}) can remove similar amounts or more fluoride than activated carbon (S_{BET}: ~1000 m^2g^{-1}).

2. 2. 2. Removal of arsenic

2. 2. 2. 1 Ultrafiltration Process

Arsenic (As) is known to be an extremely poisonous component and a cancer-causing agent to human [8]. Indeed, even a trace amount of arsenic can be unsafe to human wellbeing. The World Health Organizations (WHOs) provisional guideline for arsenic in drinking water is 10 ppb. In India, states like Uttar Pradesh, Bihar, Jharkhand, West Bengal, Assam, Manipur, essentially in Ganga-Meghna-Brahmaputra (GMB) plain covering a zone of around 569749 sq km with a population of more than 500 million have announced genuine diseases because of presence of arsenic.

The arsenic expulsion from drinking water by physicochemical process gives process for purification of water as for arsenic. BARC created know how of ultrafiltration (UF) based membrane technology for water disinfecting regarding microbiological pollution at both domestic and community scale is accessible for transfer independently. The present technology is a novel Ultrafiltration (UF) film helped physicochemical process for expulsion of arsenic from ground/surface water to make the water drinkable.

Applications:

1. Removal of arsenic from ground/surface water to give safe drinking water free from primary contaminant like arsenic and also optional contaminants like iron and microorganisms.
2. This technology can be adopted at both communities as well as at household level.

The whole procedure of ultra-filtration process includes two stages:

1. Sorption of arsenic species on the in situ produced sorbent by straightforward expansion of two reagents.
2. Filtration of arsenic containing sludge utilizing UF layer device in view of the innovation created by BARC. The two reagents required for the initial step are to be readied utilizing the technique given in the innovation exchange archive.

2. 2. 2. 2. Oxidation

Most arsenic evacuation advancements are best in expelling the pentavalent type of arsenic (As (V), arsenate), since the trivalent frame (As (III), arsenite) is overwhelmingly non-charged beneath pH 9.2. Therefore arsenate is significantly less versatile than arsenite, as it keeps an eye on co-accelerate out with metallic cations or to adsorb onto strong surfaces. In this way, numerous treatment frameworks incorporate an oxidation venture to change over arsenite to arsenate. Arsenite can be oxidized by oxygen (O_2), hypochlorite (HClO), permanganate ($HMnO_4$) and hydrogen peroxide (H_2O_2). Climatic oxygen is the most

promptly accessible oxidizing operator and numerous treatment forms favor oxidation via air. Nonetheless, air oxidation of arsenic is a moderate procedure and can take weeks for oxidation. Air oxidation of arsenite can be catalyzed by microscopic organisms, solid acidic or antacid arrangements, copper, powdered initiated carbon and high temperature.

2. 2. 2. 3. Passive oxidation and sedimentation

Oxidation with the oxygen contained normally noticeable all around amid gathering and ensuing stockpiling in houses may bring about a diminishment in arsenic fixation in put away water, which is otherwise called uninvolved sedimentation [9]. For aloof sedimentation, the water should be put away for an adequately long time permitting the trading of oxygen from the air to the water. Arsenic lessening by plain sedimentation seems, by all accounts, to be reliant on water quality, especially the nearness of encouraging iron in water. High alkalinity and nearness of iron in the tube wells water increment arsenic expulsion by capacity.

In-situ Oxidation of Iron and Arsenic in the Aquifer

In-situ oxidation of iron and arsenic in the aquifer has been tried under the DANIDA (Ministry of Foreign Affairs of Denmark) Arsenic Mitigation Pilot extend in Bangladesh. The procedure innovation is to concentrate water from a tube well to give it a chance to oxygenate at the air with barometrical oxygen. Oxygenated water is then permitted to keep running once more into the iron and arsenic polluted aquifer through a similar tube well. This permits framing covering of iron hydroxide on sand grains around the strainer of the well. Water re-gathered from the well will be fundamentally decreased in arsenic and iron.

2. 2. 2. 4. Coagulation and filtration

Coagulation and filtration with metal salts and lime took after by filtration is the most intensely reported strategy for arsenic expulsion from water. During the time spent coagulation, arsenic is expelled from arrangement through three instruments.

Precipitation: Formation of insoluble compounds.

Co-precipitation: Incorporation of solvent arsenic species into a developing metal hydroxides stages (e.g. co-precipitation with Fe(III));

Adsorption: The electrostatic coagulation of dissolvable arsenic to outer surfaces of the insoluble metal hydroxide.

2. 3. Applications at Commercial level

2. 3. 1. Vertical Tube Falling Film Brine Concentrator

High TDS and immersion of low solvency scaling salts, for example, calcium sulfate ($CaSO_4$) and silica (SiO_2) restrain the rate of water which can be recuperated in a routine evaporator framework. The salt water concentrator utilizes a special procedure called seeded slurry evaporation to defeat the restriction forced on ordinary evaporators by the immersion furthest reaches of low dissolvability scaling mixes. The seeded slurry prepare includes setting up and keeping up a slurry of calcium sulfate seed crystals in the circulating brine in the evaporator. With careful thermal and mechanical design, the $CaSO_4$ and SiO_2 can precipitate preferentially on the recirculating seed crystal rather than on the tubes. A definitive

fixation achievable in the salt water concentrator is constrained by the boiling point elevation of the brine, the relative convergences of sulfate and chloride (e.g. the twofold salt, $CaSO4•Na_2SO_4$, [glauberite] does not shape), and the dissolvability of the sodium salts. The salt water released from the brine concentrator is further gathered in the crystallizer [10].

The condensate can be conveyed as distillate water, make-up water, or mixed with RO item water. The saline solution is concentrated to around 17 percent add up to solids in the salt water concentrator**.**

2. 3. 2. Evaporation Ponds

Evaporation Pond or Solar Pond is likewise a decent other option to restrain the reject water amount however is restricted to regions where the evaporation rate surpass the yearly precipitation. Desalination plants which are situated in bone-dry ranges, for example, the Southern United States can utilize such procedures. The design of evaporation pond should include liners, spillage checking, and precise estimating computations. The estimating figuring can be confounded as a few contending components must be assessed including inflow rate, yearly precipitation, and vanishing rates. Adequate abundance limit must be given. The cost of development will fluctuate a lot contingent upon the territory and site conditions. Once introduced, the genuine working expenses are moderate in any case, one cost regularly ignored is the closure of the pond at the end of the life.

Table 1: Standards for drinking water (considerable TDS)

Total organic carbon	5.0 mg/L	Fluoride	2.0 mg/L
Arsenic	0.010 mg/L	Lead	0.015 mg/L
Barium	2.0 mg/L	Mercury	0.001 mg/L
Cadmium	0.005 mg/L	Selenium	0.05 mg/L
Chromium	0.1 mg/L	Uranium	0.1 mg/L
Cyanide	0.2 mg/L	Vinylchloride	0.002 mg/L

2. 3. 3. Deep well injection process

The choice of Deep Well Injection is limited by the hidden topography. Any profound well release must be secured against blending with drinking water aquifer supplies. The allowing procedure can likewise be long and difficult. usually this process is a last resort as it is time consuming and difficult from other disposal methods. Costs for disposal wells will be related with allowing, boring, and logistics. It can be conceivable that the disposal well areas are not in an indistinguishable zone from well water supply for drinking water. This implies saline solution reject would need to be channeled and pumped many miles to a reasonable area with porous rock formations. One other factor is that Oil rich territories, oil wells are getting to be plainly exhausted. Such spent wells are contender for disposal wells. There are a

few costs required in changing over the well to a disposal well, but overall there are cost savings in cases where the existing wells can be used for this purpose.

3. RESULTS

METHODS:	RESULTS:
At Domestic Level PHYTO-REMEDIATION	Utilizing waste high TDS water for growing crops and Plant species which are suitable for growing in High TDS water. The probability of the recuperation and re-utilization of significant metals increases
(Recreational Purpose) AQUARIUMS	Utilizing RO reject water containing high TDS for recreational purposes like in acquariums at domestic level reduces the risks of mixing up of high TDS water with freshwater streams and also reduces water wastage from RO .
Treatment of water (Removal of Fluoride) Tulsi plant	Drenching of Tulsi leaves for eight hours can reduce the water fluoride level from 7.4 sections for each million, to just 1.1 parts for every million. and it is found that leaves and stem can detoxify water by filling in as a characteristic magnet to draw in particles of fluoride from the water.
Pine Char	Swells in water due to its high oxygen content causing diffusion of fluoride on its subsurface solid volume causing adsorption. It is more efficient than activated carbon.
(Removal of Arsenic) Ultrafiltration process	Gives safe drinking water free from primary contaminant like arsenic and also optional contaminants like iron and microorganisms.

Oxidation	Arsenic removed or neutralized by Oxidization of arsenic by process of air oxidation in few weeks which is further catalyzed by microscopic organisms, solid acidic or antacid arrangements, copper, powdered initiated carbon and high temperature.
Passive oxidation & Sedimentation	Arsenic lessening by plain sedimentation seems, by all accounts, to be reliant on water quality and this process also permits framing covering of iron hydroxide on sand grains around the strainer of the well and results in reduction of Arsenic and iron from the water re-gathered from the well.
Coagulation & Filtration	Coagulation and filtration with metal salts and lime took after by filtration is proved to be the most intensely reported strategy for arsenic expulsion from water. During the time spent coagulation, arsenic is expelled from arrangement through precipitation, co-precipitation and adsorption.
At Commercial Level Vertical Tube Falling Film Brine Concentrator	The saline solution is concentrated to around 17 percent add up to solids in the salt water concentrator**.**
Evaporation Ponds	Evaporation of fresh water takes place leaving behind the dissolved salts on the surface of the pond.
Deep Well Injection Process	This process implies saline solution reject would need to be channeled and pumped many miles to a reasonable area with porous rock formations. One other factor is that Oil rich territories, oil wells are getting to be plainly exhausted. Such spent wells are contender for disposal wells.

4. CONCLUSIONS

Although, RO system is very vital in eliminating the TDS (Total Dissolved Salts) from the supply water, a large amount of waste water is obtained. Due to the presence of comparatively less back pressure, domestic RO unit consumes large amount of water. As a consequence of this, only up to 15% of water is recovered out of the water which is given as the input to the system discharging the rest of the water as the waste part. As there are several contaminants in the rejected water, it makes unfeasible the recovery of water from the rejected bulk. The connection is made between the waste water discharge and the drains and so the septic tanks face a heavy load. Up to 90 gallons of water is discharged by the RO unit which delivers around 5 gallons of purified water in a day.

As the large scale units including municipal or other industrial units can produce higher pressure in comparison to the domestic one, they are capable of recovering up to 80% of the water fed to the system which sometimes may even hike up to 90%. On contrary, with the increase in the waste water recovery in the large scale units, the rate of removal of contaminants from it gets reduced which can be witnessed clearly by the TDS level in the resultant water out of such units. This research focusses on several small scale techniques which can be employed at domestic level for recovering or putting to use that reject water from RO. Although main emphasis is at domestic level like Phyto- remediation, removal of fluoride and arsenic from reject water, using it for recreational purposes, a bit of commercial scale techniques like deep well injection have also been proposed which can prove to be counter- productive.

References

[1] B. der Bruggen, C. Vandecasteele, T. Van Gestel, W. Doyen, and R. Leysen, A review of pressure-driven membrane processes in wastewater treatment and drinking water production, *Environ. Prog. Sustain. Energy*, vol. 22, no. 1, pp. 46–56, 2003.

[2] R. Saravanan, A. Arun, S. Venkatamohan, Jegadeesan, T. Kandavelu, and Veeramanikandan, Membraneless dairy wastewater-sediment interface for bioelectricity generation employing sediment microbial fuel cell (SMFC), *African J. Microbiol. Res.*, vol. 4, no. 24, pp. 2640–2646, 2010.

[3] D. Bose and A. Bose, Graphene-based Microbial Fuel Cell Studies with Starch in sub-Himalayan Soils, *Indones. J. Electr. Eng. Informatics*, vol. 5, no. 1, pp. 16–21, 2017.

[4] D. Bose and A. Bose, Electrical Power Generation with Himalayan Mud Soil Using Microbial Fuel Cell, *Nat. Environ. Pollut. Technol.*, vol. 16, no. 2, pp. 433–439, 2017.

[5] J.-P. Schwitzguébel, E. Comino, N. Plata, and M. Khalvati, Is phytoremediation a sustainable and reliable approach to clean-up contaminated water and soil in Alpine areas? *Environ. Sci. Pollut. Res.*, vol. 18, no. 6, pp. 842–856, 2011.

[6] A. P. P. Santos, B. H. Oliveira, and P. Nadanovsky, Effects of low and standard fluoride toothpastes on caries and fluorosis: systematic review and meta-analysis, *Caries Res.*, vol. 47, no. 5, pp. 382–390, 2013.

[7] P. Mondal and A. Nandan, Removal of fluoride from water by suitable low cost environmental friendly methods, 2014.

[8] S. P. S. Teotia, M. Teotia, and N. P. S. Teotia, Symposium on the non-skeletal phase of chronic fluorosis: The Joints, in *Symposium on the non-skeletal phase of chronic fluorosis: The Joints*, 1976, vol. 9, pp. 19–24.

[9] J. M. McArthur, P. Ravenscroft, S. Safiulla, and M. F. Thirlwall, Arsenic in groundwater: testing pollution mechanisms for sedimentary aquifers in Bangladesh, *Water Resour. Res.*, vol. 37, no. 1, pp. 109–117, 2001.

[10] W. F. Heins and others, Is a paradigm shift in produced water treatment technology occurring at SAGD facilities?, *J. Can. Pet. Technol.*, vol. 49, no. 1, pp. 10–15, 2010.

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