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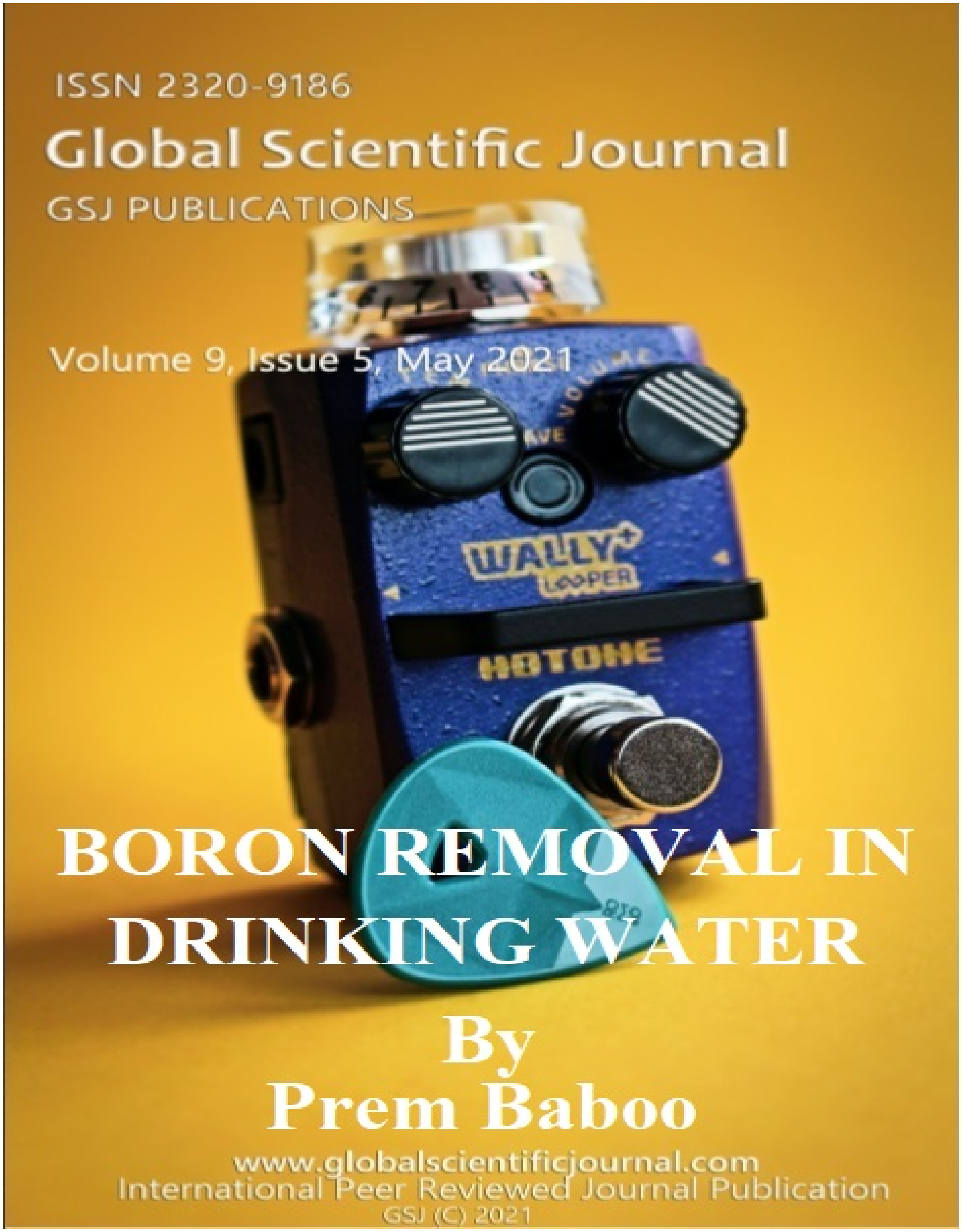

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By
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By

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DGM (Production & Process)

Abstract

Purpose of Boron Removal and Remineralization is to produce drinking water by removing boron from a permeate water stream. . It cannot be removed by conventional water treatments and its separation still remains an issue. Boron is a naturally occurring element most often found as boric acid or boric acid salts Boron is an essential micronutrient that has raised much interest, given the narrow balance between its necessity and toxicity. As boron is not a dietary requirement for humans, added sources of boron to the amount that is already consumed from foods is toxic for the human body. Boron is often present in water streams to be treated to match final user specifications or environmental restrictions The plant is designed to treat 1.57 m^3/h of inlet water to produce 1.1 m^3/h of treated water with a Boron content of 2.4 mg/l through a dedicated Reverse Osmosis Technology. Downstream RO a Remineralization Section is requested to cope the TDS required limits in drinking water. The World Health Organization (WHO) has consequently set a boron concentration limit for drinking water to be below 0.5 mg/L in addition to the standard of 1 mg/L for all other water applications. . Different water sources carry varying degrees of contaminants (compounded with boron) that are influenced by other varying factors like pH level and temperature which require different treatment processes in order to effectively purify water for the intended applications. Reverse Osmosis and other conventional techniques. This unique method is most effective when treating a relatively large amount of water, irrigation as well as drinking waste water applications.

Keywords-Boron, Remineralization, Drinking water, RO, membrane.

Introduction

Boron is an indispensable component for human and animal taking its major roles in human are for brain function and perception temporary memory. Also boron has protective characteristics against prostate cancer. In the desalination process for seawater, boron is not easily removed because pH of about 6.5 should be maintained by adding acid such as sulfuric acid in order to remove scales such as calcium and silica. Therefore, the normal practice is to convert seawater into fresh water by using the RO (Reverse Osmosis) membrane of two stages, but such practice shows to be inefficient due to high costs of maintenance.

The human body contains approximately 0.7 ppm of boron, an element that is not considered as a dietary requirement. Still, we absorb this element from food, because it is a dietary requirement for plants. Daily intake is approximately 2 mg. Amounts over 20 g are life threatening. A possible correlation exists between the amount of boron in soils and drinking water, and the occurrence of arthritis among people. The amount of boron present in fruits and vegetables is below the toxicity boundary. At a daily intake of over 5 g of boric acid the human body is clearly negatively influenced, causing nausea, vomiting, diarrhea and blood clotting.

Dangote Fertilizer Project consists in the realization of an Ammonia and Urea complex with associated facilities. The Project is set up at LEKKI Free Zone in Ibeiju-Lekki Local Government Area of Lagos State, Nigeria.

Ammonia and Urea complex process plants include:

1. 2X2, 200 MTPD Ammonia Trains based on HTAS technology (and BASF Technology for CO_2 capture in Ammonia Plants).
2. 2X3,850 MTPD Melt Urea Trains based on Saipem TM technology
3. 2X3,850 MTPD Urea Granulation Trains based on Uhde Fertilizer technology

4. Demineralized water

The unit includes the following functional sections:

1. Demineralized Water Production and Storage;
2. Condensate Polishing System.

Associated Utility Units (Common to both Ammonia-Urea-Granulation Trains)

WATER TREATMENT SYSTEM

The filtered water available at Fertilizer complex battery limit and coming from Raw Water Treatment Plant (RWTP) is used for following water production:

1. Service water
2. Firefighting water a.
3. Drinking water

The filtered water is arrived at plant battery limit from RWTP with a minimum pressure of 4.5 kg/cm^2 (g). A maximum flow rate of 150 m^3 /h is sent to the Filtered Water Storage Tank (12-T-01), having a capacity of about 5840 m^3 . This tank feeds demi water production, firefighting, service water distribution and drinking water production. The autonomy of this tank is about 24 hours based on daily filtered water consumption as service water, drinking water and demi water make-up, while the section of tank dedicated to firefighting is considered for four (4) hours of water demand. The tank is cone roof atmospheric type. Filtered Water Storage Tank (12-T-01) provides distribution of the filtered water to Service Water Distribution and Potable Water Storage

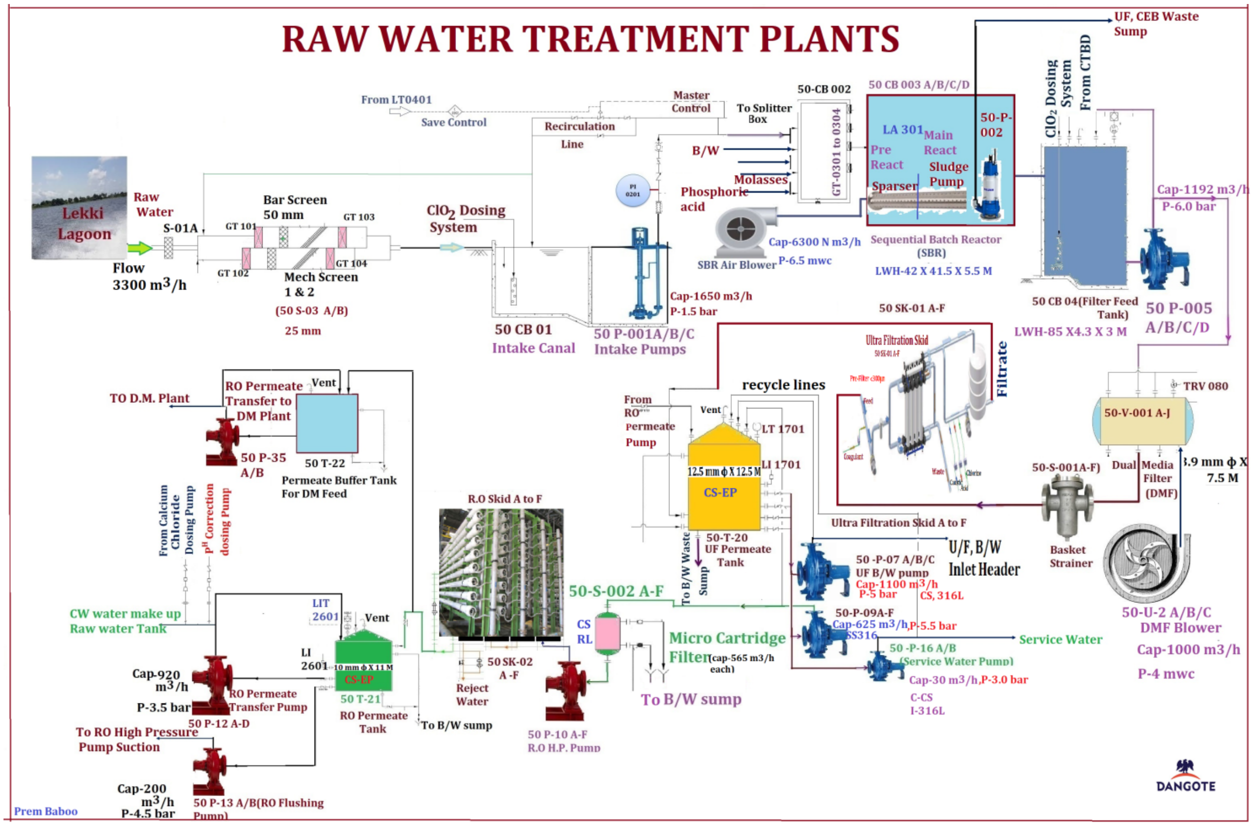

Fig-1

Tank (18-T-01) by means of Filtered Water Transfer Pumps (12-P-02 A/B), while provides feed to Desalination Package by means of Desalination Feeding Pumps (12-P-06 A/B). Filtered water is treated first by dedicated Self Cleaning Filters (included in 12-PK-04) and then passed through Mixed Bed Ion Exchangers (12-PK-10) via Desalination package (12-PK-04). Desalination package (12-PK-04) is able to handle a normal net flow-rate of about 120 m3 /h and a design net flow-rate of 220 m³/h. The desalination system is composed of the following treatment units and electromechanical components:

1. Cationic Exchangers
2. Anionic exchangers
3. Regenerations and Neutralization Chemicals Facilities

The above described system is provided in common with Demineralization Package (12-PK-10).The desalinated water after the cationic/anionic exchangers is mixed with process condensates at the inlet of mixed beds (MB) to be further treated in order to reduce salts/silica contents to levels suitable to produce steam. Consequently it is necessary to add a further polishing treatment by means of ionic exchange resins contained into mixed bed units, a technology that allows to have a treated water with: conductivity < 0.2 µS/cm, silica < 0.02 mg/l SiO2, pH 7 ± 0.5. The demineralized water is stored into Demi Water Tank (12-T-02), with a capacity of about 10000 m3 . Demi Water Tank provides distribution of demineralized water to Deaerator (13-V-01) and to other users by means of Demineralized Water Transfer Pumps (12-P-03 A/B). The demineralized water produced is further deaerated to produce Boiler Feed Water (BFW) suitable for KS steam generation in the Waste Heat Boilers (Ammonia Unit) and HS Steam Generation in Auxiliary Boilers (Utility Unit). Generated steam is suitable for use in steam turbines. The demineralized water quality is as follows:

Conductivity at 25°C µS/cm ….< 0.2
pH ………………………..…...7 ± 0.5
Sodium as Na+ µg/l ……………..≤ 20
Silica as SiO2 µg/l ……………....≤ 20
Total Iron µg/l ……………….….≤ 20

Process description

The package inlet water is at first added with Caustic Soda for pH adjustment and then go through Activated Carbon Filter 18-S-60 where the residual chlorine is removed. Caustic Soda dosing system consists in one Soda Hydroxide Tank 18-T-60 and two (one operating and one spare) Soda Hydroxide Dosing Pumps 18-P-60A/B. In order to protect RO membranes by scaling and eventual presence of suspended solids, addition of anti-scalant and a RO Safety Cartridge Filter 18-S-61, with a filtration degree of 5 µm, are foreseen on RO feed water. Anti-scalant dosing system consists in one Anti-scalant Dosing Tank 18-T-60 and two (one operating and one spare) Anti-scalant Dosing Pumps 18-P-61A/B. Water is then pumped by RO HP Pumps 18-P-63 A/B (one operating and one spare) through RO Vessel 18-L-60 filled in with two 8” membranes. The foreseen temperature operating range of inlet water is 22-34°C; the reverse osmosis calculation sheets at the two above temperature is reported in attachment. Performance of RO is monitored by a conductivity analyser 18-AT-8023 located downstream RO vessel. Downstream osmosis plant, a remineralising product is added to provide a product water with a total hardness of 100 mg CaCO3/lt min. This dosing system consists in one Salt dosing Tank 18-T-62, equipped with a mixer 18-L-62, and two (one operating and one spare) Salt dosing Pump 18-P-62A/B. Drinking water quality is monitored by a conductivity analyser 18-AT-8025. Drinking Water is stored in a Final Product Tank 18-T-64 that has a capacity of 2 m^3 and then is pumped by Product Water Booster Pumps 18-P-64 A/B (one operating and one spare) to the Potable Water Storage Tank 18-T-01 (outside package battery limits). Requested pressure at package Battery Limit is 6.1 kg/cm2g. Brine from RO system is routed to sewer. Boron Removal and Remineralization Package (18-PK-05) consists mainly of a reverse osmosis technology. For Boron Removal process a dedicated Reverse Osmosis (RO) technology with single pass is used. For Re-mineralization process, suitable re-mineralization salt is used. The package is designed for a continuous treated water production of 1.1 m^3 /h. The drinking water system is sized to cover the expected drinking water demand up to a peak of 17 m^3 /h. The drinking water demand for the plant has been provided based on the following assumptions:

Total users = 120 people/day
Individual consumption = 200 L/person/day

The operating and design conditions of drinking water distribution at Dangote site are the following:

1. Operating Supply Temperature -------- Ambient
2. Operating Return Temperature--------- Ambient
3. Operating Pressure ------------------------ 5 kg/cm2 (g)
4. Normal Flow rate (one safety shower)--- 6 t/h
5. Design Flow rate ------------------------ 30 t/h
6. Design Pressure ------------------------- 10 kg/cm2 (g)
7. Design Temperature -------------------- 70 °C

Osmosis is a natural process involving fluid flow across a membrane, which is said to be 'semi-permeable'. A semi-permeable membrane is selective in that certain components of a solution, usually the solvent can pass through, while others, usually the dissolved solids cannot pass through it. The direction of solvent flow is determined by its chemical potential, which is a function of pressure, temperature and concentration of dissolved solids. In case pure water is available on both sides of a semi-permeable membrane at equal pressure and temperature, no resultant flow can occur across the membrane, as the chemical potential is equal on both the sides. However, if any soluble salt is added on one side of the membrane, the chemical potential of the water on that side is reduced. The osmotic flow from the pure water on one side to the salt solution on the other side is occur across the membrane until equilibrium of solvent chemical potential is restored. The Thermodynamic requirement for osmotic equilibrium is that the chemical potential of the solvent be the same on both sides of the membrane. No such condition is imposed on the solute, since the membrane prevents its passage. The Equilibrium State occurs when the pressure differential on the two sides is equal to the osmotic pressure, a solution property that is independent of the membrane. The application of external pressure to the solution side, which equals the osmotic pressure, is also accomplish equilibrium. A further increase in pressure is increase the chemical potential of the water in the solution cause a reversal of the osmotic flow towards the pure waterside, which is at a lower solvent chemical potential relative to the solution. This phenomenon is termed as Reverse Osmosis and is the basis for a process to desalinate water without phase change. The Reverse Osmosis unit essentially works on molecular level. It separates the molecular impurities from the water thus making reject stream rich in salt molecules and other stream lean in salts thus reducing the TDS of the water.

Actually, with new RO membrane specific for boron removal at the typical sea water pH (8.2), boron removal efficiency is in the range 85-92%, higher boron removal efficiency (>98%) can be achieved at pH 10,4. According to the boron concentration in the feed water and according to the boron removal target to reach, it is designed a RO configuration with single pass. Remineralization process is based on suitable re-mineralization salt. The Potable Water Cartridge Filters (2x100%) are designed to have outlet water solid content with maximum 5 μm of particles size. System make-up is designed to provide an average continuous flow-rate of 1 m3 /h, based on 200 L/person/day of water demand for 120 persons. The calculated peak drinking water requirement is about 17 m3 /h corresponding to two safety showers operating simultaneously (about 6 m3 /h each one) plus domestic users peak demand (5 m^3 /h considering the average continuous demand adjusted with a peak factor of 5). The Potable Water Storage Tank (18-T-01) is sized to provide about 92 hours of autonomy in absence of make-up, considering the average continuous demand. Potable Water Storage Tank is a cone roof tank with no blanketing made in CS internally epoxy lined. The drinking water quality is suitable for drinking service, for eye wash fountains, safety showers and domestic users. The circulation is realized by the Potable Water Pumps (18-P-01A/B) provided in 2x100% configuration. A minimum recirculation is maintained when drinking water is not required by the users through orifice 18-FO-0501. A pressure controller (18-PIC-0002) regulates the closed loop pressure by acting on an automatic control valve, 18-PV-0002 installed on the return line to the storage tank. The water is then chlorinated by a dedicated Sodium Hypochlorite Dosing Package (18-PK-01) in order to keep its bio purity. Distribution to users is provided by means of a closed loop. Emergency power supply is provided for the electric motors of circulating pumps. The main domestic users are grouped as following, each of them is fed by a dedicated drinking water line:

After ensuring that the filtered water supply is available, start the Boron Removal and Remineralization Package to produce drinking water starting from a R.O. permeate water with a Boron concentration that is still higher than Drinking Water guidelines WHO 4th Edition. Refer to package 18-PK-05 vendor documents for details of Package start-up.

Drinking water is fed by Filtered Water Transfer Pumps (12-P-02A/B) to the Potable Water Tank (18-T-01) after being further produced through the Boron Removal and Remineralization Package (18-PK-05) and filtered through the Potable Water Cartridge Filters (18-S-01A/B). Boron Removal and Remineralization System consists mainly of a reverse osmosis technology. Boron chemistry is quite complex. Boron present in water is generally in some form of boric acid, a very weak acid similar to silicic acid with a pK value of 9.1. At a pH lower than 7, boric acid is not dissociated as H_3BO_3 or B(OH).

$B(OH)_3 + H_2O \leftrightarrow [B(OH)_4] + H^+$

At pH higher than 11.5, boron occurs as dissociated borate [B(OH)4] - . In concentrated solution, polymeric ions are formed:

$2B(OH)_3 + [B(OH)_4] \leftrightarrow [B_3O_3(OH)_4] - + 3H_2O$

RO is much better at removing charged ions. Hence the removal of borate ion is much better than the removal of boric acid. Due to the new RO membrane generation, a good removal performances has been reached also towards Boric Acid.

Actually, with new RO membrane specific for boron removal at the typical sea water pH (8.2), boron removal efficiency is in the range 85-92%, higher boron removal efficiency (>98%) can be achieved at pH 10,4. According to the boron concentration in the feed water and according to the boron removal

Fig-2

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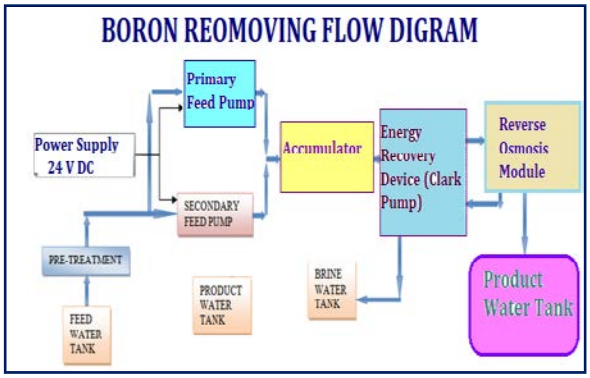

Fig-3

fountains, safety showers and domestic users. The circulation is realized by the Potable Water Pumps (18-P-01A/B) provided in 2X100% configuration. A minimum recirculation is maintained when drinking water is not required by the users through orifice 18-FO-0501. A pressure controller (18-PIC-0002) regulates the closed loop pressure by acting on an automatic control valve, 18-PV-0002 installed on the return line to the storage tank. The water is then chlorinated by a dedicated Sodium Hypochlorite Dosing Package (18-PK-01) in order to keep its bio purity. Distribution to users is provided by means of a closed loop. Emergency power supply is provided for the electric motors of circulating pumps. The main domestic users are grouped as following, each of them is fed by a dedicated drinking water line:

1. Workshop
2. Sub-station SS-5
3. Sub-station SS-4
4. Canteen
5. Gate House 1 / Gate House 2
6. Administration/Fire house/Laboratory/Medical Facilities

Emergency power supply is also foreseen for hypochlorite metering. Safety showers /eye wash station Safety shower and eyewash stations are provided in process areas where operators may be exposed to large quantities of materials which are either highly corrosive or highly toxic by skin absorption.

Eyewash Facilities are provided in all battery rooms due to acid presence and in process areas where Safety Showers are present; The Eyewash Facilities and Safety Showers are also located in the critical loading / unloading areas and handling areas, and in the vicinity of critical sample points. Drinking water is used for Eyewash and Shower Facilities and the drinking water lines are insulated for solar radiation to avoid increase of water temperature. The Eyewash Facilities and Safety Showers have stay-open valves so than an individual can use both hands to hold the eyes open or to remove clothing. It's chemical composition ranges from acid form (boric acid) to ion form. While it is most concentrated in water sources like seawater and well water due to other compounds that contain boron, it also occurs naturally in plants as a productive sugar mobilizer. Boron is a key component in the mitosis process of micro organismal growth making it present in plants and other products like fruits and vegetables. In addition, multiple salts and rocks are made up of compounds consisting of boron, which add up to the amounts of boron creating toxic effects on plants, animals, and humans alike. Toxicity affects the growth and product yield of plants and fish species suffer from high intakes of boron as well. Consuming only around 3 grams more than the required daily amount can result in nausea, vomiting, blood clotting, and any higher amounts can even be life threatening. Increased levels of boron in drinking water and soil have been correlated with individuals having arthritis. The level of boron is associated to the level of salinity in seawater and total dissolved solids (TDS) in brackish/well water. Due to the lack of chemical charge that boron possesses, the means by which removal of boron is necessary can be quite complicated.

The behavior and chemical composition of boron varies in an aqueous environment. Boron is a metalloid and behaves as a Lewis acid and exists primarily as un-dissociated boric acid or borate ions. The borate ions dominate at higher pH, while boric acid dominates at lower pH (Fig. 4). This nonionic form of boron yields a very stable molecule difficult to selectively remove.

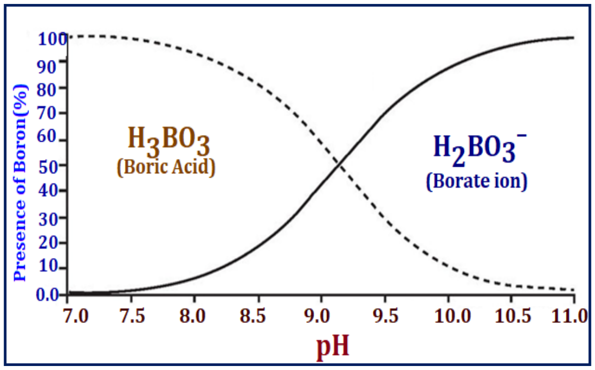

Fig-4

The behavior and chemical composition of boron varies in an aqueous environment. Borate ions dominate at higher pH, and boric acid dominates at lower pH. Reverse osmosis (RO) reclaims fresh water from brines at higher flow rates than those associated with distillation. The use of RO for oilfield waters is limited by the salinity to approximately 100,000 ppm. A higher salinity would yield a system requiring multiple passes to fully clean the influent. Additionally, RO at a neutral pH provides poor boron rejection. The boric acid at neutral pH is suspected to diffuse through the membrane in a manner similar to water itself. Therefore, to achieve greater boron rejection, the pH must be elevated. Although an RO system may be suitable in brackish waters, special seawater membranes along with various pretreatment The experiment carried out to obtain the optimum value of pH condition during the boron removal process. Boron is completely dissociated with $B(OH)^{4-}$ at pH higher than 11 and is formed as H_3BO_3 at pH lower than 7 . The samples of the raw water containing boron concentration of 4.5 mg/L adjusted to pH of 7, 8, 9, and 10 with 1: 100 of Mineral cluster. Boron removal efficiency showed that it

steps would be necessary in the concentrate brines observed in the Bakken play. In this case, the resulting effluent remains brine water, but is less concentrated. Ideally, the boron would be rejected at 99%. If the water is completely reclaimed, it may be reused in any way deemed suitable. An additional limitation with RO systems is the efficiency of the process. Typically, two-thirds of the water is reclaimed and one-third is concentrated waste. The concentrate stream must be disposed of, or it may be again treated. Adding RO to the equipment currently employed would be ineffective and uneconomical. Rather, RO should be treated as a separate system with quite high initial capital costs. These systems that yield fresh water presents the opportunity to reuse wastewater in new ways, but the flow rate limitations and initial capital cost are to be considered. Along with clean-water applications, there are various systems to treat the water selectively and include boron in the process.

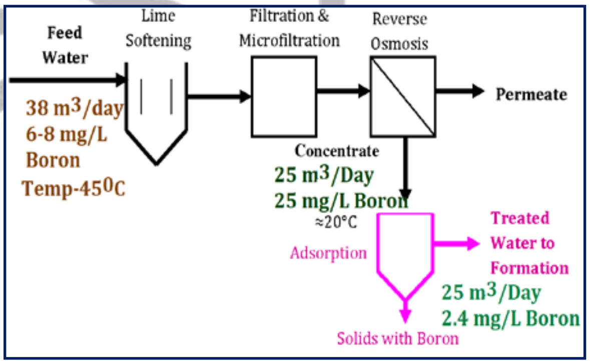

Fig-5

Boron Removal Rate according to pH

increased with pH value between 8 and 9. The highest efficiency of boron removal is 40.0% and 2.7 mg/L at pH 9 and boron removal is 31.3% and 3.1 mg/L at pH 8 in Fig -6. 28.9% (3.2 mg/L) and 15.6% (3.8 mg/L) of boron is removed at pH 10 and 7 respectively. Boric acid is a very weak acid, with an acid dissociation constant (pKa) of 9.15. Therefore, boric acid and the sodium borates exist predominantly as undissociated boric acid [B(OH)3] in dilute aqueous solution below pH 7; above pH 10, the metaborate anion [B(OH)4 −] becomes the main species in solution. From about pH 6 to pH 11 and at high concentrations (>0.025 mol/l), highly water soluble polyborate ions such as B3O3(OH)4 − , B4O5(OH)4 − and B5O6(OH)4 − are formed. The chemical and toxicological properties of borax pentahydrate (Na2B4O7·5H2O), borax (Na2B4O7·10H2O), boric acid and other borates are expected to be similar on a molar boron equivalent basis when dissolved in water or biological fluids at the same pH and low concentration.

Boron removal mechanism can be explained with the coagulation and adsorption mechanism of Alum and Iron. Alum coagulant is successfully removed at the pH range of 5.5 and 8 and Iron does best at pH range of 5.0 and 11.0 . Mineral cluster solution contains a variety of minerals especially Alum (530 mg/L) and Iron (373 mg/L) in high extent amount, which took major roles in the coagulation process. Therefore the optimum efficiency can be deduced to around pH 9 in Mineral cluster.

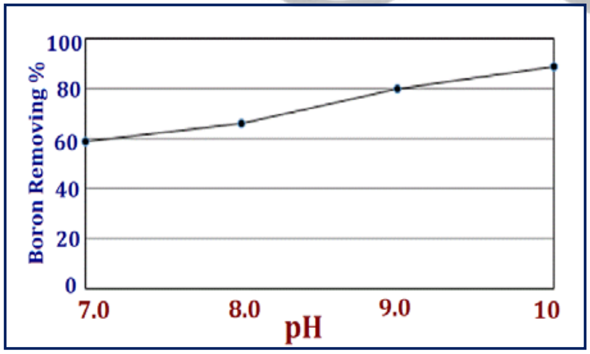

Fig-6

Reproductive and developmental toxicity

Short-term and long-term oral exposures to boric acid or borax in laboratory animals have demonstrated that the male reproductive tract is a consistent target of toxicity. Testicular lesions have been observed in rats, mice and dogs administered boric acid or borax in food or drinking-water . After sub-chronic exposure, the histopathological effects range from inhibited spermiation (sperm release) to degeneration of the seminiferous tubules with variable loss of germ cells to complete absence of germ cells, resulting in atrophy and transient or irreversible loss of fertility, but not of mating behavior. In time–response and dose–response reproductive studies, adult male Sprague-Dawley rats are administered two boron doses in 1 day, with a total boron dose of 0 or 350 mg/kg body weight in the time–response experiment (animals are sacrificed at 2, 14, 28 or 57 days post-treatment) and a total boron dose of 0, 44, 87, 175 or 350 mg/kg body weight in the dose–response experiment (animals are sacrificed after 14 days). Adverse effects on spermiation, epididymal sperm morphology and caput sperm reserves are observed during histopathological examinations of the testes and epididymis. The no-observed adverse-effect level (NOAEL) for boron for male reproductive effects in the dose–response study is 87 mg/kg body weight per day. In a multi-generation study, boron (as borax or boric acid) at concentrations of 0, 117, 350 or 1170 mg/kg feed administered to male and female rats. At the highest dose, rats are found to be sterile, males showed atrophied testes in which spermatozoa are absent, and females showed decreased ovulation. The NOAEL for boron in this study is 350 mg/kg feed, equivalent to 17.5 mg/kg body weight per day, compared with the top boron dose of 58.45 mg/kg body weight per day. To investigate the development of testicular lesions, boric acid fed at 61 mg/kg body weight per day as boron to male F344 rats; sacrifice of six treated and four control rats is conducted at intervals from 4 to 28 days.

At 28 days, there is significant loss of spermatocytes and spermatids from all tubules in exposed rats, and basal serum testosterone levels are significantly decreased from 4 days on . In another study, the activities of enzymes found primarily in spermatogenic cells are decreased, and enzyme activities associated with premeiotic spermatogenic cells are significantly increased in rats exposed to boron at doses of 60 or 125 mg/kg body weight per day for 60 days. Mean plasma follicle-stimulating hormone levels are significantly elevated in a dose-dependent manner in all boron treatment groups (30, 60 or 125 mg/kg body weight per day) in this study after 60-day exposures. Reversibility of testicular lesions evaluated in an experiment in which F344 rats are dosed with boric acid at 0, 3000, 4500, 6000 or 9000 mg/kg feed (equivalent to 0, 26, 39, 52 or 78 mg/kg body weight per day as boron) for 9 weeks and assessed for recovery up to 32 weeks post-treatment. Inhibited spermiation exhibited at a boric acid concentration of 3000/4500 mg/kg feed (5.6 µg of boron per milligram tissue), whereas inhibited spermiation progressed to atrophy at a boric acid concentration of 6000/9000 mg/kg feed (11.9 µg of boron per milligram testes); there is no boron accumulation in the testes to levels greater than those found in the blood during the 9-week period. After treatment, serum and testis boron levels in all dose groups fell to background levels. Inhibited spermiation at a boric acid concentration of 4500 mg/kg feed is reversed by 16 weeks post-treatment, but focal atrophy, which did not recover up to 32 weeks post-treatment, detected . Showed that male rats treated with boric acid doses of 150 mg/kg body weight per day for 3 weeks tended to have a lower fertility index, whereas those treated with 500 mg/kg body weight per day are sterile. Developmental toxicity has been demonstrated experimentally in rats, mice and rabbits . Rats are fed a diet There is a decreased incidence of rudimentary extra rib on lumbar 1 (a variation) in the high-dose group that deemed biologically, but not statistically, significant. The NOAEL for boron in this study is 9.6 mg/kg body weight per day, based on a decrease in fetal body weight at the next higher dose. Developmental toxicity and teratogenicity of boric acid are investigated in mice exposed to boron during gestation days 0–containing boric acid at boron doses of 0, 14, 29 or 58 mg/kg body weight per day on gestation days 0–20 . An additional group of rats received boric acid at 94 mg/kg body weight per day as boron on gestation days 6–15 only. Average fetal body weight per litter is significantly reduced in a dose-related manner in all treated groups compared with controls. The percentage of malformed fetuses per litter and the percentage of litters with at least one malformed fetus are significantly increased at boron doses of ≥29 mg/kg body weight per day. Malformations consisted primarily of anomalies of the eyes, the central nervous system, the cardiovascular system and the axial skeleton. The most common malformations are enlargement of lateral ventricles in the brain and agenesis or shortening of rib XIII. The lowest observed-adverse-effect level (LOAEL) for boron of 14 mg/kg body weight per day (the lowest dose tested) for rats occurred in the absence of maternal toxicity; a NOAEL is not found in this study. Boric acid administered in the diet to Sprague-Dawley rats on gestation days 0–20. Dams are terminated and uterine contents examined on gestation day 20. The intake of boric acid is 0, 3.3, 6.3, 9.6, 13 or 25 mg/kg body weight per day as boron. Fetal body weights are 99%, 98%, 97%, 94% and 88% of controls for the low- to high-dose groups, respectively. Incidences of short rib XIII (a malformation) or wavy rib (a variation) are increased in the 13 and 25 mg/kg body weight per day boron dose groups relative to control litters.

17 at 0, 43, 79 or 175 mg/kg body weight per day in the diet (Heindel et al., 1992). There is a significant dose-related decrease in average fetal body weight per litter at boron doses of 79 and 175 mg/kg body weight per day. In offspring of mice exposed to boron at 79 or 175 mg/kg body weight per day during gestation days 0–20, there is an increased incidence of skeletal (rib) malformations. These changes occurred at doses

for which there are also signs of maternal toxicity (increased kidney weight and pathology); the LOAEL for boron for developmental effects (decreased fetal body weight per litter) is 79 mg/kg body weight per day, and the NOAEL for boron is 43 mg/kg body weight per day. Developmental toxicity and teratogenicity of boric acid in rabbits are investigated by Price et al. (1996b) at boron doses of 0, 11, 22 or 44 mg/kg body weight per day. given by gavage on days 6–19 of gestation. Frank developmental effects in rabbits exposed to boron at 44 mg/kg body weight per day included a high rate of prenatal mortality, an increased number of pregnant females with no live fetuses and fewer live fetuses per live litter on day 30. At the high dose, malformed live fetuses per litter increased significantly, primarily because of the incidence of fetuses with cardiovascular defects, the most prevalent of which is interventricular septal defect. Skeletal variations observed are extra rib on lumbar 1 and misaligned sternebrae. The NOAEL for maternal (reduced body weight gain, reduced gravid uterine weight and number of corpora lutea) and developmental effects is 22 mg/kg body weight per day as boron.

Design calculation at 22^{0}

Sr. No.	Parameters	Value
1	H.P. pump Flow	2.57m^3/hr
2	Feed Pressure	13.43 bar
3	Feed temperature	22^{0}C
4	Concentrate recirculation	1 m^3/hr
5	Feed water pH	8.8
6	Chemical dose mg/Lit, 100%	3.3 NaOH
7	Specific Energy	1.13 KWH/m^3
8	Pass NDP	12.9 bar
9	Average Flux rate	14.8 lmh
10	Permeate Flow	1.1 m^3/hr
11	Raw water Flow	1.57 m^3/hr
12	Permeate recovery	42.83%
13	Total system Recovery	70%
14	Element age	3.0 yrs
15	Flux decline %, per year	3.0 %
16	Fouling Factor	0.91
17	SP increase per year	5.0 %

Table-1

Feed Type RO Permeate

Pass stage	Permeate Flow m^3/hr	Feed Flow Vessel, m^3/h		Flux.lmh	DP	Flux Max, lmh	Beta	Permeate TDS	Element Type
		Feed,	Conc.						
1-1	1.1	2.6	1.5	14.8	0	14.9	1.12	2.8	SWC4-BLD

Table-2

Boron and element Concentration in different stream in waste water.

Sr.No	Ion mg/Lit	Raw Water	Feed water	Permeate Water	Concentrate-1
1	Harness as $CaCO_3$	8.79	12.96	0.015	22.6
2	Ca	0.42	0.80	0.001	1.4
3	Mg	1.4	2.67	0.001	1.4
4	Na	28.9	58.59	0.321	102.2
5	K	3.09	5.88	0.040	10.2
6	NH_4	14.32	27.23	0.186	47.5
7	Ba	0.000	0.000	0.000	0.000
8	Sr	0.000	0.000	0.000	0.000
9	CO_3	0.02	4.13	0.000	9.3
10	HCO_3	22.24	46.73	0.148	78.0
11	SO_4	0.11	0.21	0.000	0.4
12	Cl	39.54	75.41	0.133	131.7
13	F	0.03	0.06	0.000	0.1
14	NO_3	48.68	91.67	1.205	159.4
15	PO_4	0.000	0.000	0.000	0.000
16	SiO_2	0.000	0.000	0.000	0.000
17	**B**	**4.9**	**8.68**	**0.795**	**14.6**
18	CO_2	2.82	0.06	0.06	0.06
19	TDS	163.65	322.20	2.83	559.7
20	pH	7.10	9.06	6.59	9.27

Table-3

Conclusion

Drinking water and even mineral water may contain boron until a few ppm and WHO has recommended a limit of 0.3 mg boron/lit .Some studies have shown that very high concentrations of Boron in drinking water can cause reproductive malfunctions in human and developmental abnormalities. However, these occurred at much higher levels of Boron than are commonly found in drinking water. Despite the important role of boron as a micronutrient in the ecosystem for plants and animals, the emission of boron from various industrial sources to the environment endangers the ecosystem. The orientation of hydroxyl groups in the chelates plays a crucial role in stabilizing the borate ester complex formed during the separation.

The risk to human health is through ingestion only – drinking, cooking, teeth brushing. Well water with Boron levels greater than 0.5 mg/L may safely be used for bathing, hand-washing, and dishwashing. The RO or electro coagulation can be used for boron removal. Testing conducted on boron removal proved that it can be selectively removed from flow back and produced waters. The testing also showed that the processes required are complex and typically can be expensive if no thorough investigation has been done to mitigate costs. Boron removal via chemical additives is possible, but large chemical demand is involved. Further studies are necessary to develop an efficient polymer or highly selective media to remove boron. Precipitation using softening may be a viable option, but temperature control is necessary. With appropriate testing and sizing, alternative processes such as. There has been work conducted on water reuse for hydraulic fracturing, and the obstacles encountered are being resolved. Also, cross linking polymers are being developed by pressure pumping companies to control the rheology of a gel in the presence of boron. Given these new developments, water reuse is sure to remain a priority within the oil and gas industry for years to come.

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