Volume 2 : Edition 1 – Case Study : Treatment of water with high Reactive Silica (SiO2) Jan 31, 2022

Dear Water Warriors,

Theory needs to be put into practice. In this case study special, we discuss the application of process know & technology to support our customers. For achieving a goal of treatment efficiency designer shall explore multiple options available in theory and evaluate them on 1 key parameter often ignored: "Operator Friendliness & Simplicity"

SiO_2 found in abundance in our planet is usually under 25 mg/l. But what if it's 175 mg/l, it will scale on RO.

The issue of 'Waughter', enjoy know how to address SiO_2.

Nidhi Jain – Civil Engineer

Why SiO2 is a Problem ?

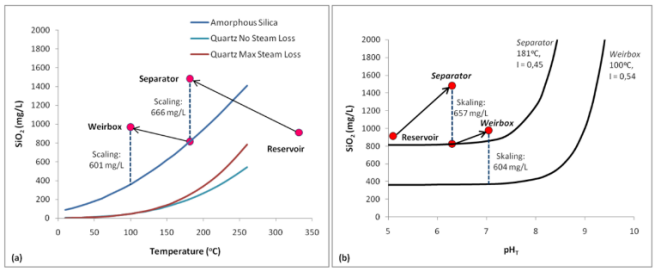
At 25^0 C, SiO_2 is soluble in water up-to 120 mg/l and therefore normally not available in water beyond this limit. Most water contain SiO_2 < 24 mg/l, but in India we have extreme cases of SiO_2 in bore water up-to 77 mg/l in certain regions in Karnataka.

As we know as an engineer if we apply Reverse Osmosis for purification, the salts are rejected (but concentrated). So, if we have Recovery in Fraction say 0.75 the Cycle of Concentration will be = 1 /(1-R) = 4 and your SiO_2 must concentrate to 77*4 = 308 mg/l i.e much beyond the solubility limit of < 120 mg/l under normal conditions.

The RO operators know this and limit the SiO_2 in brine < 120 mg/l to ensure no Scaling or up-to 180 mg/l with moderate scaling which can be removed using NaOH during membrane cleaning.

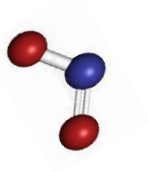
Silicon Dioxide – SiO2

The Solubility of SiO_2 is pH and Temperature dependent and while both Hardness and SiO2 cause scaling, Hardness exhibits "Inverse Solubility" i.e. Solubility decreases with elevation of temperature, whereas SiO2 solubility increase with rise in temperature.



"The Solubility of SiO_2 is highly depended on pH and this knowledge that at elevated pH, you can keep SiO_2 up-to 900 mg/l in soluble state is basis of this design." The next question need answer how to avoid Ca & Mg issues at elevated pH.

Post invention of Antiscalant agents which are polymeric products, RO designers depending upon the type of Antiscalant used started the design of RO Recovery to keep



SiO_2 in Brine : 250 – 300 mg/l

And avoid RO scaling due to SiO2.

The presence of Ca & Mg is also important as Mg tends to form complex with SiO_2 and even other wise presence of Alkalinity offers two challenges to RO designers:

1. $CaCO_3$ Precipitation – Scaling
2. Silica Precipitation – Scaling
3. Mg-Silicate Complex formation

And all the three concerns were a non starter for a project that we are discussing here. Further, In RO application, we can not think of elevated temperatures because of "High Salt Passage" i.e. treated water quality deteriorates rapidly beyond 25^0 C.

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Waughter

AKTION CONSULTANCY

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Reverse Osmosis performance and high Recovery for extremely high feed water Silica SiO_2

Wazir in Kenya has a unique situation with respect to water. It has very low rainfall, ground water table quite deep and most of the underground water not suitable to any application due to high Hardness and SiO_2. The Sample water report is given below to have an idea on severity of the issue.

Parameter	Unit	Sample 1	Sample 2	Design
pH	-	7.4	7.22	7.0 – 7.5
Conductivity	µS/Cm	NA	2120	< 2200
TDS	mg/l	1200	1069	1600
Hardness	mg/l as $CaCO_3$	700	534	600
Total Suspended Solids	mg/l	2	1	10
Turbidity	NTU	1.5	0.6	5
Ca Hardness*	mg/l as $CaCO_3$	600	175	600
Mg Hardness*	mg/l as $CaCO_3$	100	195	300
Chloride	mg/l as $CaCO_3$	50	526	600
Sulphate	mg/l as $CaCO_3$	15	99	100
Nitrate	mg/l as $CaCO_3$	5	37	45
M-Alkalinity	mg/l as $CaCO_3$	700	544	700
P-Alkalinity	mg/l as $CaCO_3$	0	0	0
Silica, Reactive	mg/l as SiO_2	120	109	120
Fe Dissolved	mg/l as Fe^{++}	NA	0.02	0.3
Cu Dissolved	mg/l as Cu	NA	2.05	3

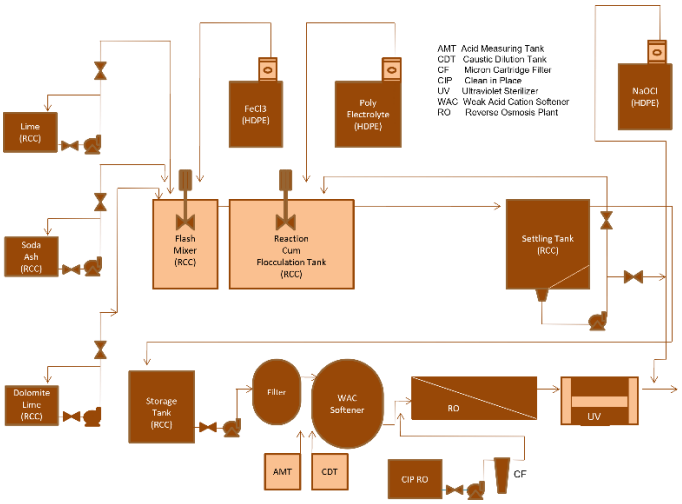
The data marked, Red above were a cause of concerns and in such situation, Hydrolab – Kenya, the producer of Glacier brand of packaged water in Country were looking for designers to develop a Reverse Osmosis Plant, that can give > 75% recovery.

The customer was about to finalize the project as suggested by an Expert from Kenya, but through some reference decided to consult Aktion. The scheme as given by the WTC (Scheme 1) is most common scheme for such situations. Aktion Consultancy explained the situation to customer that:

1. Finding chemicals and managing sludge could be challenge.

2. A greater control on pH would be needed and failure to do so could lead to a bigger issue of RO non- performance.

3. The process requires attention of M,P-alkalinity and Hardness data on every shift basis and training to operators & lab chemist to ensure they adjust the dosing of lime, Soda ash and Dolomite (Check Mg).



On top of it we explained to them the *Chemistry of Dolomite Process*, the Point 3 above in more details.

1. CO_2 will react with $Ca(OH)_2$ to make $CaHCO_3$.

2. Ca will precipitate as $CaCO_3$ (Ideal pH– 8.3)

3. Mg will precipitate as $Mg(OH)_2$ ideal pH is around 10.4

4. Once Mg is precipitated $Mg(OH)_2.xSiO_2$ complex will form and that will require final causticity in water ~ 25 mg/l (Free OH- ~ 25 mg/l)

5. At elevated pH, $CaCO_3$ precipitate again re-solubilize as it's least solubility is at pH ~ 8.3 as 30 mg/l

Even if you solve above 5 issues, every shift you still will end up ~ 80 mg/l treated water hardness and a pH of 10.4 that would need to be reduced to ~ 7.0 using HCl to control Ca scaling on membranes. MgCl2 would not scale.

And finally, let's not forget the cumber associated with sludge management, slurry flow pumping, right % chemical preparation etc. No way customer was going to accept all above and suggested Aktion to simplify above, even at higher Capex & Opex.

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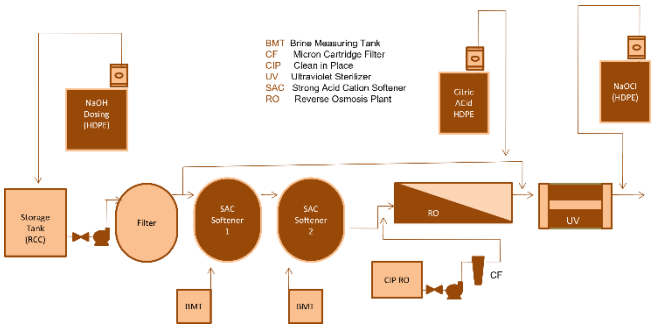
Our Proposed Solution

The idea of this Aktion scheme was to deal the issues of Hardness & SiO_2 separately and focus on solution that aim at "Conventional" skills and not complicated chemistry, normally associated with Dolomite lime treatment:



2 prong strategy was used:

1. Manage Hardness with Series Softening ensuring no possibility of Scale on membrane and no need of use and control of Antiscalant.

2. Precipitate Silica through EOR Process (Electro-oxidation & Reduction)

   Or

   Increase SiO_2 solubility in water by pH Control.

After detailed discussion and evaluations and feasibility of transporting equipment from India, it was concluded to drop EOR Process and rely on high pH Solubility of SiO2.

The first aim was achieved by Simply introducing a SAC exchanger using SAC-Na resin, designed for counter current regeneration to optimize salt. The next exchanger again was a SAC-Na in series, that brings down Ca < 1 mg/l.

We repeat if not understood it's $CaCO_3$ is a problem in RO never $CaCl_2$ or $MgCl_2$, the next problematic structure is $CaSO_4$ but that was not enough in water.

The pH is still important as we need to reach ~ 9.8 to ensure SiO_2 in brine of ~ 480 ppm is in soluble from at the reject point of RO system, else a big issue as Mg is still present and willing to make a complex with SiO_2.

To achieve higher pH NaOH need to be injected, but where to inject is next question. Since the scheme is designed with SAC-A & SAC-B both in Na form, NaOH injection right at SAC inlet was not a problem. but it may lead to little bit precipitation of MgOH2 on SAC-A. Thus preferred to dose NaOH after SAC-A and before SAC-B.

The final solution included:

1. SiO_2 rejection of RO 1 , that is being operated for over 5 years now on Brine/Reject SiO_2 of ~ 900 mg/l. Increased recoveries have further deteriorated feed water SiO_2.

2. 2 stage Softening brings the Ca < 1 ppm at RO feed. No RO cleaning reported ever for SiO_2 and Citric acid cleaning of RO 1.

3. Injection of Citric acid in permeate of RO 1 and passing the same to filter that adds bi-valent Ca and then again pass-through RO.

The water thus produced is sweet, ozonated before finally packing in the No1 brand in Kenya: Glacier

In past 5 years of operation, the RO 1 membranes were changed 1 time after 3 years, that too using the discarded membranes from RO 2. In 2nd pass RO new membranes were provided. The membranes in RO1 are specialized product developed for high pH operation ~ 10.3 on continuous basis.

Customer benefited with:

1. Biofouling as both RO1 & RO2 always worked in sterile environment.
2. No scaling, as RO never received Ca, the chief responsible for Scaling.
3. No SiO_2 fouling as SiO_2 was always soluble
4. No Corrosion as no HCl or aggressive chemicals were procured by Operation team.

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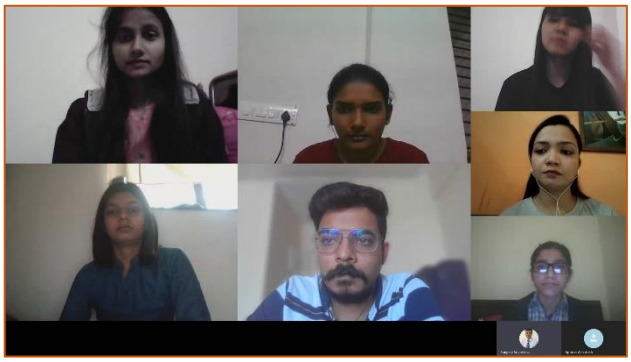
Future .. Waughter Worriers

Post Covid India and may be whole world fought against many challenges that surfaced due to this unprecedented situation. One challenge of all and was and is is the "Young Graduates from Engineering, Management & Commerce" though fighting against odds : No Vaccine, No College, Online Study, Online Exams no Hi-Fi gadget like Laptop or Wi-fi etc. yet completing their graduation, not finding a job or internship. ☹

Practice what you preach: Aktion Consultancy, not only requests all Water Warriors to do their bit to nurture the young talent, have recruited 4 graduates as Full time engineers and inducted few 4th year students as paid intern in company to learn and up-skill themselves to be a future Waughter Warrior.



You guessed it wrong!!

If you see the Movie "The Intern", you would know the guy in "Greys" here is an intern in a start-up company.

While we all apricate such entertainment, shy away from responsivity. Let's be responsible and offer work to fresher graduates.

जल जीवन जननी !!


Nidhi Jain
Civil Engineer
1mo • Edited •

Dear Water Warriors,

I am very happy today that I am launching the Waughter magazine on "Operation and maintenance of ETP, STP and Recycle plant" for the first time not Sanjeev Srivastava. I have learnt a lot and I am sure You are also learned a lot through our magazine. #operation #maintenance #magazine

Next Month We want to go to "Case Study Special". So, I would need a project assistance to take the magazine at next level. so, Fresh Angels are welcome. #project #maintenance #experience #freshers #hiring

The magazine is the plant of experience of Sanjeev Srivastava and realization of Larity Nongsiej Surabhi Kumari. Proud of you both the engineers!

#watermanagement #waterindustry #experience #realization #siteengineer #projectmanagement #projectmanager

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Our world is Waughter

The technical knowledge share attempt of Aktion Consultancy and the contents in the magazine shall be qualified by Sanjeev Srivastava our Technology Lead.

Our next edition focuses on: "Sewage Treatment Plant for a Large Office Complex"

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