

Colloidal Silica - Treatment and Removal



Colloidal silica is non-ionic, and is typically found in surface waters. It creates problems in water treatment because of its stability as an un-ionized compound, which makes it difficult to remove using ion exchange processes.

It can even cause some resin fouling where colloidal silica levels are exceedingly high. It is essential to remove colloidal silica from water to be used in high pressure boiler operations. Colloidal silica slips through the demineralisation (DM) plant to get converted into reactive silica at high temperature and pressure leading to severe problems in boilers.

When reverse osmosis (RO) plants are used in water treatment, colloidal silica and associated impurities can foul RO membranes leading to drop in productivity.

This article discusses the origin and measurement of colloidal silica, its effect on water treatment processes and methods for removal of colloidal silica.

What is colloidal silica?

Colloidal particles are small particles, intermediate in size between true solutions and suspended matter. They can be assumed to be any particle larger than 10 \AA units and < 1 micron in diameter.

Its Origin

Silica in water is present mostly as reactive or dissolved silica. In surface waters, a small quantity of non-reactive silica (in colloidal dimensions) may also be present during some parts of the year, especially during the monsoon.

As water passes through and over various soils into our lakes and rivers, the formation of carbon dioxide and organic acids resulting from microbial activity results in acid degradation of the silicate minerals (particularly clay particles). This acid attack on minerals will dissolve the iron, aluminum etc. and interaction of these components with silica results in the formation of colloidal silica that is stabilised with a coating of organic matter.

Measurement

Estimation of non-reactive silica in water is often difficult as it is present in very small quantities (generally $< 1.0 \text{ mg/l}$).

Non-reactive silica is usually measured indirectly by the difference between total silica (reactive silica + colloidal silica) and reactive silica.

Total silica may be measured by solubilising non-reactive silica by reacting it with hydrofluoric acid (HF) and then employing usual calorimetric procedures.

How does colloidal silica affect ion exchange processes/RO membranes?

Colloidal silica as such does not affect the ion exchange process but as it is a complex with organic matter, it can sometimes foul the anionic resin and some part of it then passes through the resin and reaches downstream equipment.

Colloidal silica can cause serious problems of organic fouling of RO membranes because the particles are small enough to pass through most pretreatment systems and because of its association with organic matter.

What are limiting parameters?

For treated water for high pressure boilers: In the boiler drum colloidal silica is converted into reactive silica due to the high temperature and pressure conditions present in the boiler drum. So limiting criteria are designed for total silica, as follows -

| Boiler Pressure (psig) | SiO ₂ Tolerance in Feed Water (ppm) |
|------------------------|--|
| 1000 | 0.02 |
| 1500 | 0.01 |

Typical surface water having about 0.5 ppm of colloidal silica with 0.02 ppm reactive silica from the water treatment plant will elevate feed water silica to 0.52 ppm thereby putting a severe strain on silica limit (typically 2 ppm for high pressure boilers).

What are the effects of colloidal silica on boiler & other critical equipment or processes?

Presence of silica in boiler feed water is harmful as silica tends to volatilize along with steam and gets deposited as glassy and hard scales on the turbine blades. This can be costly because of resultant shutdowns for the maintenance of turbines.

Keeping boiler drum silica values under control will then mean higher blowdown and loss of efficiency.

In a developing country like India, where the plant load factor is an important consideration, the additional investment in ultra filtration (to reduce colloidal silica) is quite justified since it reduces the number of shutdowns caused by turbine failure due to silica deposits.

What are different methods of removing/reducing colloidal silica?

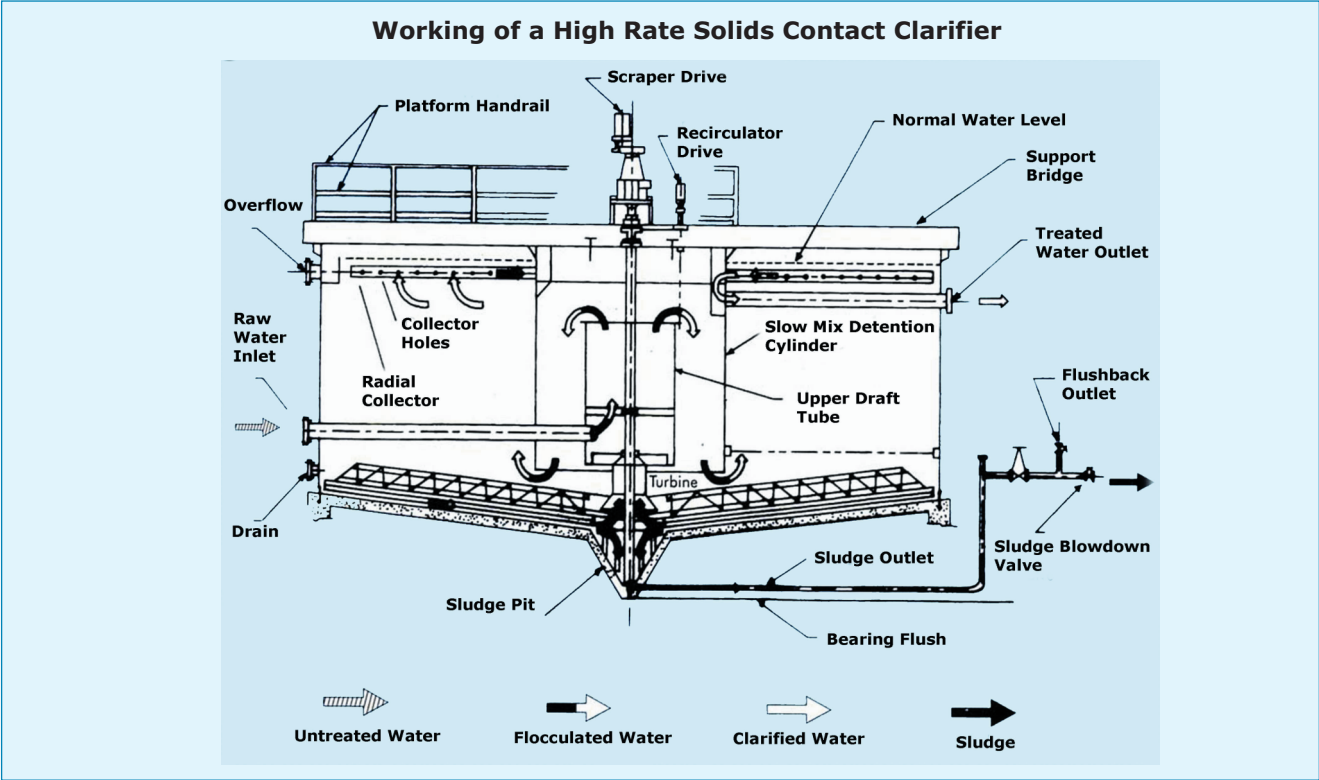
Colloidal silica may be reduced/removed by the following two methods -

Coagulation/Flocculation: Difficulties in removing non-reactive silica arise from the fact that it is not present as a simple colloidal particle and is not amenable to coagulation under normal conditions. It is mostly present as hydrated silica associated with organic matter naturally present in soil and hydrated oxides of iron & aluminum. A multi-pronged attack is therefore called for when one wants to remove non-reactive silica in a pretreatment plant.

Experience has shown that optimum removal of non-reactive silica can be achieved if all of the following conditions are met:

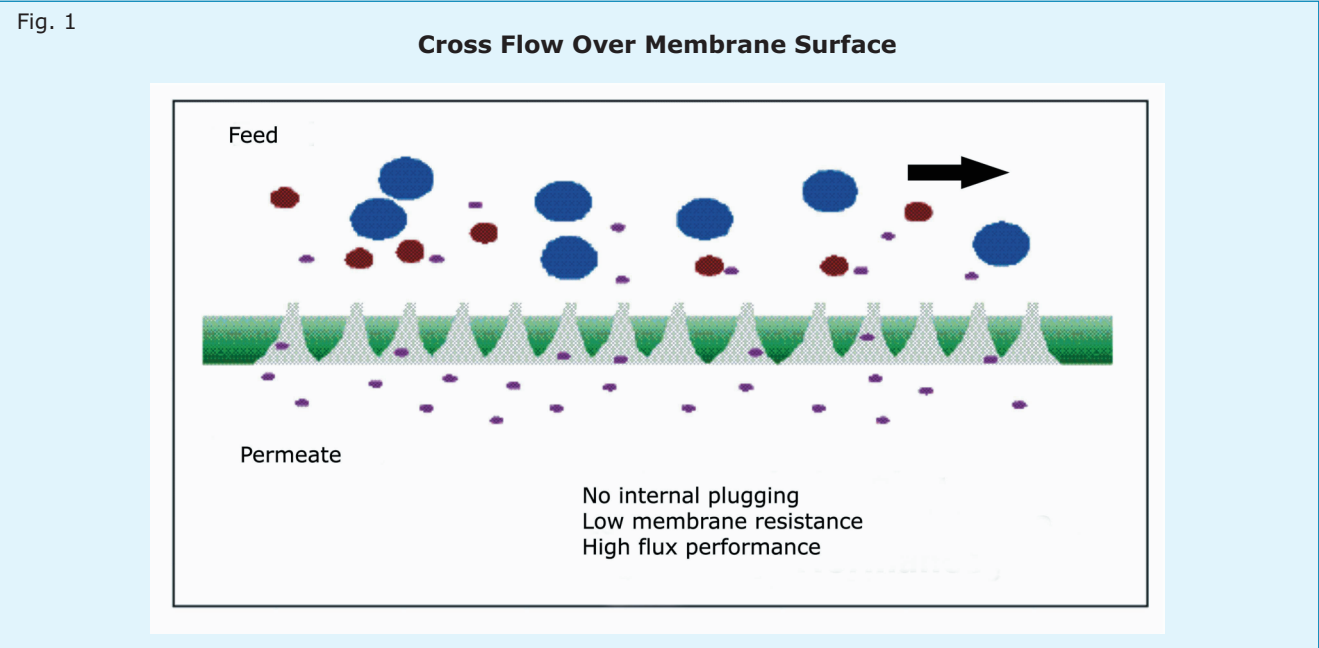
- Effective pre-chlorination of water to oxidise organic matter associated with colloidal particles.
- Maintaining optimal pH conditions and dosing of a primary coagulant like alum and a polyelectrolyte for flocculation, in dosages determined by jar tests.
- A solids contact type clarifier, with solids recirculation, provides ideal conditions for coagulation of non-reactive silica. As it is present in small quantities, recirculation of solids ensures adequate contact between the colloidal particles and the coagulant.

Coagulation, at best, is a physical process and, under ideal conditions, one can therefore expect to remove up to 80 to 90% of non-reactive silica present in water.



Ultra Filtration: The best way of ensuring maximum removal of non-reactive silica is to remove the bulk of it in the pretreatment plant and polish it with an ultra filtration (UF) system installed at the outlet of the mixed bed (MB) unit.

UF is a pressure activated process employing a semi-permeable membrane with asymmetric structure (Fig. 1) and can be effectively used for removal of non-reactive silica.



Membranes with a molecular weight cut-off (MWCO) of 100,000 remove upto 99% of non-reactive silica present in feed while

a tighter membrane with an MWCO of 10,000 removes upto 99.8% (Table 1).

Table 1

| Component | 10,000 MWCO | 100,000 MWCO |
|--------------------|-------------|--------------|
| Colloidal Silica | 99.8% | 99.0% |
| Turbidity | < 0.1 NTU | |
| Silt Density Index | < 2.0 SDI | |

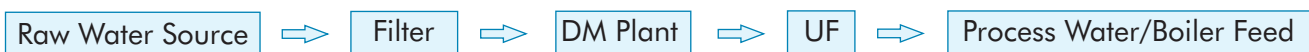
Being physical separation, the UF membrane is best suited to remove colloidal silica as compared to other pretreatment processes described earlier which involve complex monitoring, chemical addition and manpower intervention & experience to ensure successful removal.

For existing power plants using conventional ion exchange DM, the solution is to retrofit the plant with hollow fibre UF membranes downstream of the MB unit to physically retain and remove any colloidal silica that may have escaped the pretreatment and the ion exchange beds.

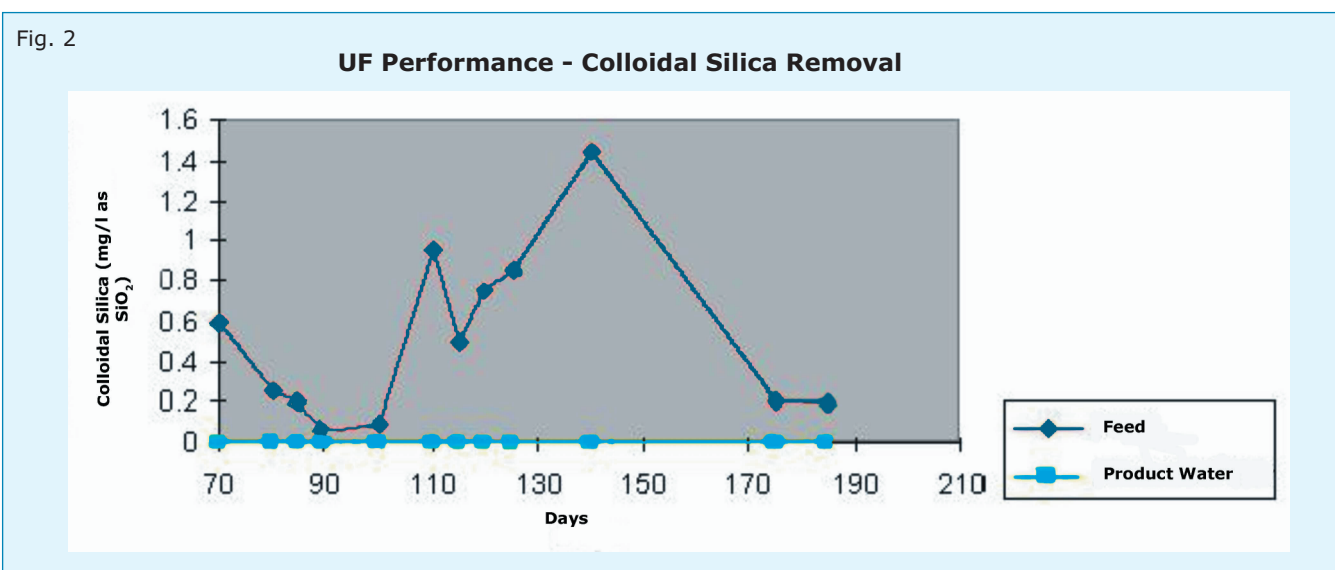
For new power plants, the solution is as follows -



Or



A chart showing UF performance at an installation for removal of colloidal silica is shown in Fig. 2.



The effectiveness of the system can be seen from the above results.

A number of similar installations supplied by us are in operation for various power stations in India.