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NETRA

R & D APPROACHES
TO POWER PLANT WATER TREATMENT ISSUES
&
THEIR MITIGATION

WATER TREATMENT GROUP

NETRA, NTPC LTD

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NETRA

R&D Approaches to Power Plant Water Treatment Issues and their Mitigation

Water Treatment Technology Group, NETRA

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C V Anand
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FOREWORD

As we all know that water is a very scarce resource and in the recent past, the availability of water has been a key concern for power developers. Competing uses, limited supplies as well as shortages in various parts of the country have resulted in a shortage of water for power generation. Further, the norms on water consumption have been made more stringent by the Ministry of Environment, Forests and Climate Change vide their notification in December 2015. The revised norms demand the existing power plants to achieve a specific water consumption of 3.5 cubic meters per MWh by December 2017. Power plants deploying the once-through cooling mechanism need to install cooling towers. Meanwhile, all power plants being set up after January 2017 need to operate at a water consumption level of 3.0 cubic meters per MWh and achieve zero liquid discharge. Due to the locational diversity of the power plants across the country, different power plants face different issues with respect to quality and quantity of water and its impact on the boilers and CW systems. As a result, many of such plants had to suffer a lot on account of delayed commissioning, threat to loss of generation, increased blow downs, loss of efficiency and life of vital equipment. Many of such issues were referred to NETRA and by way of systematic root cause analysis(RCA), customized solutions had been provided.

Water Treatment Technology Group (WTG) of NETRA has compiled all such case studies in the form of an e- book for circulation within NTPC, with the aim of sharing knowledge so acquired. Although, it must be understood that such solutions, being case specific, may not be applicable in general for power plants facing similar problems. The case studies highlights that a systematic problem solving approach can provide sustainable solution. It also highlights that deeper understanding of emerging technology would eventually lead to a problem free water chemistry in NTPC and shall help NTPC professionals understand the issues from a different perspective and bring clarity to their decision making.

C V Anand

P D Hirani
General Manager I/C (NETRA)

PREFACE

Over the years, fresh water has become a very scarce resource, due to altered weather patterns including droughts or floods, increased pollution, increased human demand and overuse of water. We have now entered into a situation where the available potable, unpolluted water within a region is less than that region's demand. As a result, the reduction of water scarcity is a goal of many countries and governments including India. The power plants within the radius of 50 km have been mandated to use the treated sewerage water from the STP's. Besides the availability, there are lot of variations in the water quality parameters also which is adversely affecting the performance of industries including the power plants. In recent past due to the deviation from design water analysis many of our stations have experienced water related issues affecting the plant performance. NETRA has been actively associating in resolving these issues and have provided the customised solutions. I am happy that Water Technology Group has compiled such cases for the benefit of all concerned across NTPC.

(P D Hirani)

Contents

Preamble: Water related Issues

Despite the great deal of Engineering plan and design based on which water treatment plants are constructed at stations across NTPC, the change in quality of water due to various factors such as seasonal, industrial and domestic contaminants ingress in the water bodies lead to various kind of operational issues.

Traditionally a water treatment plant is designed based on general impurities like, TDS, turbidity. But owing to high pollution of surface water there is a plethora of other emerging contaminants that have necessitated more technological awareness. Advent of membrane based systems like UF, RO make it more urgent to consider in detail about the nature of contaminants, their seasonal variation, method of measurement, data authenticity and various technological options.

Recently, NTPC has faced quite a few cases where it suffered high financial loss and operational constraints due to such problems. Many of the problems carried new aspects on which no traditional knowledge existed. A good deal of research underwent to arrive at a generally acceptable and effective solution; in many cases, the whole process took several months before attempting a viable solution.

This book deals with the issues faced by WTP of NTPC stations, the approaches adopted for mitigation, root cause analysis and outcome of the remedial measures undertaken.

Types of Impurities:

A quick review of the types of impurities would help appreciate the intricacy of each impurity, the complexity of their measurement and impact of them on power plant cycle.

TSS (Total Suspended Solids): These are general impurities and colloidal in nature that mostly are removed by clarification, filtration, sedimentation. Presence of them would foul the downstream components. For membrane based system its impact is the most severe.

TDS (Total Dissolved Solids): These are all salts and carbonates that remain dissolved and need to be removed depending upon the application. For boiler system these have to be removed to the greatest extent possible. Normally ion-exchange resin and RO system are used for this. Chloride salts are problematic for boiler as they can initiate hydrogen embrittlement, if not taken care of adequately and also for SS-304 metallurgy, if go beyond a certain limit, they initiate pitting corrosion in condenser tubes. Any hardness, TOC and silica & colloidal silica can cause scaling in heat exchanger and fouling in RO membrane.

Silica: Silica exist in mainly two forms reactive and colloidal. These form scales in boiler, cooling tower, condenser tubes and RO membranes. Reactive silica can be measured and can be eliminated by Ion exchange resin or RO membranes. Colloidal silica cannot be easily measured and can go undetected to create problems in boiler, resin or RO membrane. NETRA has developed a reliable and accurate method of determination of colloidal silica and is being used at NTPC and across India.

TOC (Total organic carbon) has taken up recent interest among power plant professionals. EPRI has taken up quite a few research initiatives on this to fully understand its impact on power plant cycle. TOC could consist of many fragments that can be classified into suspended, and dissolved. Based upon their profile various technological options could be taken. Needless to say this requires careful testing and testing procedures of many of them are not available at NTPC. In general, presence of TOC creates problem in steam water cycle by increasing ACC, and initiating corrosion. It also induces resin fouling and RO membrane fouling.

Recent mandate of using treated STP water would also pose many issues for cooling water system.

NTPC Power stations have been facing various kinds of issues in the recent past. Systematic data collection and analysis have unearthed root causes after which remedial actions along with technological interventions, of which many are of novel ones, have been provided by NETRA, some of these issues are described here as Case Studies:

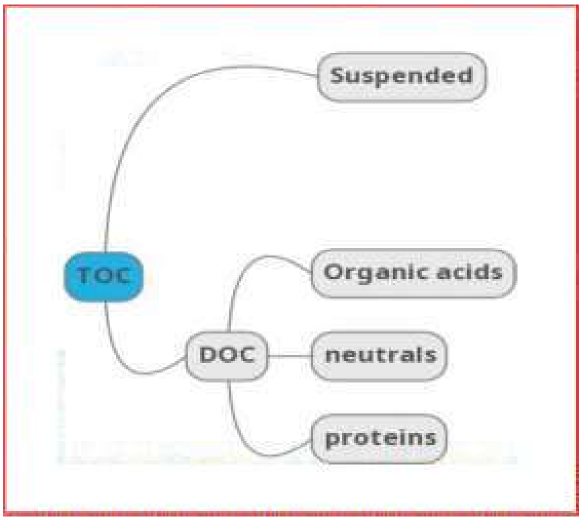
Brief Description of Case Studies:

1. Mouda :

Problem faced: Load restriction by 150 MW for a 500 MW unit.

Root cause found: "High Organics and Colloidal Silica Problem in water and steam cycle" resulting in frequent blow down and high ACC in feed water restricting operating load.

R&D Work: A reliable, accurate and validated Colloidal silica testing methodology was developed in-house, which was deployed for correction of the situation. An effective chemical formulation based on Ferric Alum, Poly Aluminum Chloride (PAC) along with Poly DADMAC (Di allyl dimethyl ammonium chloride) was developed which was implemented to reduce colloidal silica, and TOC carry over at the pre-treatment stage. It was found that 40 ppm Alum and 60 ppm PAC level along with Solid DADMAC at 5 ppm is the most effective combination for colloidal silica removal from Mouda water. Further, for TOC reduction use of a special SBA resin was found to be more effective than the existing one. Use of ClO2would also mitigate the ClO2 issue to a great extent.



Details are given at Case Study-1.

2. Dadri:

Problem faced: Stage-II units at Dadri used to lose huge HR (equivalent to condenser vacuum as high as 30 mm Hg) on account of dirty tubes loss.

Root cause found: Units used to suffer from frequent scaling, particularly during the time when Ganga canal was closed and underground water having high TDS was used as make up to the CW system. The CW system of Stage-II used to run at COC 2.5 losing huge quantity of water.

R&D work done:

A lesser known scale-inhibition technology based on galvanic system was implemented, which is the first of its kind for a 500 MW system in India and the world.
The device was fitted in the inlet to condenser at the CW inlets of the Dadri Stage–II units comprising of a galvanic metal couple grid where the pipe itself acts as the cathode and a trapezoid-shaped anode lies at the center. It is a simple device, with around 1.2-meter length. When water passes through this core OH^- ions are attracted towards the cathode, creating localized high pH condition in the bulk that helps CaCO3 to form as seed crystals and circulates in colloidal form, thus preventing scale deposit ion in the tubes. No scale formation in the condenser tubes was observed even at 8.5 COC and at a pH of 8.2-8.4, only some loose deposits found both in condenser and PHE (Plate type Heat Exchanger), which are easily washable. This technology helped conserve water in stage-II units by reducing blow down.

Details are at Case Study -2

3. Kudgi:

Problem faced: High silica in the units during steam-blowing phase. Under performance of RO plant. Deteriorated quality of RO water and reduction of production, frequent regeneration of mixed-bed, and total contamination across DM chains, DMW storage tanks, and boiler system. COD schedule was at threat.

Root cause found: Passage of colloidal silica, TOC, and higher reactive silica than designed in the source water.

R&D work done: It was observed that inlet raw water quality was different from the design value in respect of reactive silica and the issue of colloidal silica was not considered in the design. Many commissioning defects were corrected before addressing the main problem. As per OEM, pretreatment would require Ferric Chloride and Polyelectrolyte only, and it was not effective to remove both colloidal silica and TOC. After trying various formulations at lab scale it was found that 25 ppm Ferric chloride, 0.3 ppm anionic polymer, and 5 ppm lime is quite effective to reduce colloidal silica to more than 80% which is quite a good performance. The role of lime was found to be crucial to make the total formulation effective in respect of TOC and colloidal silica and iron carryover from higher FeCl3 addition. For this three factors three level statistical DOE was employed. It is observed that from 2.5 ppm of colloidal silica in raw water, it was reduced to 0.3-0.8 ppm after clarification. Further, specialized chemicals were employed to clean the RO membranes.

As a result of our study Colloidal silica parameter has been introduced as a new design parameter in engineering documents to avoid such issues in future installations of Water Treatment Plants.

Details are at Case Study-3

4. Solapur:

Problem faced: DM plant was facing problems related to bad quality water with respect to high inlet Silica, short operating cycle of ion-exchangers, high acid consumption due to frequent regeneration and water loss.

Root cause found: Silica design value found less than actual. High Na+ slippage through cation exchangers due to faults in internals causing internal hydraulic disturbance resulting in flow channeling. Significant reduction in exchange capacity of ion exchange resins observed.

R&D work done: 1 M3/hr pilot trial study at Faridabad for reduction of reactive silica from CT blowdown was done employing EC (Electro –Coagulation technology). The results obtained from pilot study were quite encouraging. Total silica reduction to great extent was observed (from 25 ppm to 5 ppm). Based on the experience gained a full-fledged Electrocoagulation (EC) system of capacity 150 M3/hr (150 M3/hr + standby 50 M3/hr) adjacent to clarifier and treated water technique as a supplement to pretreatment to reduce reactive silica has been recommended to Solapur with the following envisaged benefits:

a. Silica reduction in pretreatment increase the DM water quality
b. Reduction in SBA & MB regeneration cycle saves cost of chemicals.
c. Trouble free DM Plant operation ensures both quality and quantity water output

Details are at Case Study-4

5. Talcher-K

Problem faced: Tertiary treatment of existing STP to meet NGT norms.

Root cause found: Existing ASP (Activated Sludge Process) has limitation of BOD and COD in STP outlet to meet the existing limits of BOD< 10 ppm while COD <50 ppm.

Retrofit of Activated Filter Media based tertiary treatment with the existing system enables to get outlet parameters to meet the current NGT norms.

Developmental work done: An on-site pilot trial with Activated Filter media was conducted with activated amorphous alumino-silicates and having high surface area mesoporous media of capacity of 5 M3/hr at Talcher-K for three months. This has yielded encouraging results. A novel and simple filtration methodology which can be easily retrofitted with the existing STP's without any alterations can improve the outlet water quality to meet the NGT norms. Based on the pilot study data, a full-fledged system has been recommended for Talcher-K.

Details are at Case Study-5

6. Simhadri & Talcher-K

Problem faced: High acidity and foaming problem of Fire Resistant Fluid (FRF) causes severe hunting problem (frequent tripping problem) at Simhadri.

Root cause found: Side stream filtration contains fullers earth started leaching calcium and magnesium ions into FRF causing soap formation at high acidity conditions. The acidity in FRF once started accelerates the deterioration process demanding replacement of entire oil at a huge cost.

Developmental work done: A dry Ion Exchange Resin based filtration media was studied initially at Lab and Pilot scale revealed that both acidity and foaming issue of FRF could be controlled. Later on the success achieved in the pilot scale on-site trials were carried out at Talcher-K unit 1 & 2 later similar exercise carried out at Simhadri, unit-2.

Details are at Case Study-6

7. Faridabad:

Problem faced: Pitting corrosion of SS-304 condenser tubes in high chloride environment.

Root cause found: The presence of high chloride in makeup water that is 500 ppm was responsible for pitting corrosion in SS-304 metallurgy of condenser tubes. This also does not allow to operate CW COC at high as the safe chloride limit for SS-304 is 200 ppm.

Developmental work done: A Molybdate based chemical treatment in cooling water system has been suggested based on the data developed out of Lab and pilot scale study. This treatment has proved that even at 2000 ppm of chloride level (operating at 5 COC) no pitting corrosion by high chloride concentration has been observed in last 6 years.

Details are at Case Study-7

8. Ramagundam:

Problem faced: Reduction in output between Regeneration (OBR) of CPU at Ramagundam, increases number of regeneration, sodium and chloride premature slippages and increased water & chemical consumption.

Root cause found: The Regeneration system consist of three numbers of vessel used for resin separation and regeneration. After back wash separation anion resin separated from cation vessel is subjected to 16 % caustic and by floating method anion is isolated from cation. However, it was observed that the impurities removed is still exposed to anion resin and may get equilibrated which results part of anionic impurities may still have carried by anion resin that may reduce the performance during service cycle. Complete removal of these impurities is necessary before resin separation. Therefore, NETRA suggested to go for use of 6% caustic prior to use of 16 % caustic so that anion resin is regenerated prior to resin separation. If complete regeneration in resin separation vessel is not ensured for some reason, there is scope for carry out the same in MB vessel for which caustic injection line is to be provided to MB vessel.

Developmental work done: Based on study results, an innovative additional step was introduced in the regeneration process. During regeneration, 6 % NaOH (2 BV) (0.6 MT NaOH @ 48%) to be injected at the flow rate of 100 lit/min ± 10% for 50±5 min. The temperature of 6% NaOH was maintained at 50±5 °C. The regeneration was carried out in co-flow (down flow) regeneration technique. After regeneration 1 BV of DM water (2500 lits) was passed with the same flow and in same direction as that of regenerant used. As a result of this exercise, increase of OBR and reduction of chemical and water consumption are achieved.

Details are at Case Study -8

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Case Study: 1

High Organics and Colloidal Silica Problem at Mouda Super Thermal Power Station

Introduction: Raw water supply to the plant is from Nag River and its quality fluctuates in different seasons across the year. The increased industrial activities and urban growth along the Nag River has resulted in high pollution load in the water, particularly the colloidal silica and TOC/BOD contents are abnormally higher. Site experienced severe problem in running the units at full load due to high level of contamination in the makeup water requiring continuous high blow down. This situation continued for more than a year. This problem was referred to NETRA through CC-Engineering for a sustainable solution.

NETRA carried out detailed investigation in which it was found that organics and high silica were the major issue.

Lab Study:

Part-I: Chemical optimization study:

It was observed after detailed investigation across the water supply chain that the major two contaminating factors are colloidal silica and organics. The study was divided into following three approaches.

Part-IA: It was found in study that Colloidal silica can be reduced by chemical method or by membrane filtration method. More than twenty-five formulations with different chemicals like Solid DADMAC, Liquid DADMAC, Poly-1, Poly-2 and Poly-3 along with Alum and PAC were tried at NETRA. Out of which a formulation of 40 ppm alum and 60 ppm PAC along with 5 ppm (as required basis) Poly Dadmac was found to be most effective. The findings are Tabulated below.

S N	Alum dosage	PAC Dosage	Total Silica	Reactive Silica	Colloidal Silica
1	Raw Water As Such		19.5 ppm	11.6 ppm	7.9ppm
2	40 ppm	60 ppm	12.8 ppm	11.3 ppm	1.5 ppm

S N	Poly Electrolyte with 40 ppm alum and 60 ppm PAC	Total Silica (ppm)	Reactive Silica (ppm)	Colloidal Silica (ppm)	TOC (ppm)
1	Mouda Raw Water-2 lot as such	26.9	18.5	8.4	2.3
2	Mouda Raw Water-3 lot as such	24.9	17.6	7.3	--
3	Mouda Clarified Water as such	26.5	16.8	9.7	2.3
4	Solid DADMAC (5 ppm)	13.3	12.5	0.8	3.2
5	Liq DADMAC (5 ppm)	13.2	12.2	1.0	2.3
6	Poly-1	13.4	12.2	1.2	--
7	Poly-2	14.2	12.8	1.4	--
8	Poly-3	13.4	12.6	0.8	2.3

Note.: Dosing chemicals are as received basis.

The data shows that at 40 ppm Alum and 60 ppm PAC level along with Solid DADMAC at 5ppm and Poly-3 at 5ppm are most effective combination for colloidal silica removal from Mouda water.

Further, along with optimized dose of alum, PAC, samples were also subjected to ClO2 treatment for TOC reduction.

Part-IB: Total Organic Carbon Control & Testing carried out in NETRA:

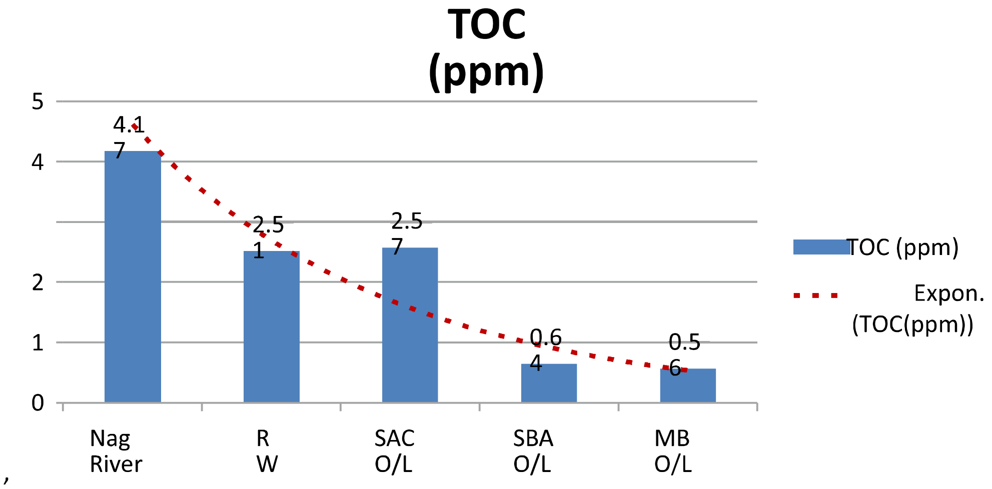
Combination of different disinfectant such as Cl2, Sodium Hypochlorite, bleaching powder, Hydrogen peroxide for TOC control were used in different concentrations

Activated carbon bed & resin stream and TOC was also monitored. The above test results indicate that reduction of TOC up to 2 ppm level can be achieved. However, further reduction is not possible even with higher dosage of disinfectants. With Chlorine dioxide relatively higher reduction was observed in comparison to other disinfectants. The data for ClO2 is given in following table:

S No	Sample details (Aug'15)	TOC in ppm
1	Nag River	4.2
2	Raw Water at Reservoir Mouda	2.5
3	Clarifier water	1.8
4	ACF Outlet	1.9
5	Degasser Inlet	2.5
6	Degasser Outlet	2.7
7	SBA Outlet	0.64
8	MB Outlet	0.56
9	DM Storage Tank	0.47

S No	Sample details	TOC in ppm
1	Raw Water at Reservoir Mouda	4.3
2	Raw Water + 0.5 ppm ClO2	3.8
3	Raw Water + 1.0 ppm ClO2	3.5
4	Raw Water + 5 ppm ClO2	3.6
5	Clarified water	3.7
7	Clarified water + 0.5 ppm ClO2	2.7
8	Clarified water + 5 ppm ClO2	2.6

After cleaning of clarifier, another set of samples were tested for Total organic carbon (TOC). Moderately higher TOC was found in reservoir, however some reduction in TOC was found in Clarified water sample. There was increase in TOC content in degassed water sample.



ultimately resulting in significant organics in DMW Storage Tank. It carries to feed water from makeup water causing increase loading on anion resin bed and higher TOC in ACC. The data is given in following table and trend is also shown graphically.

Part-IC.1: Study with special SBA resin for assessing efficacy for Colloidal silica & TOC removal:

S N	Sample details	Reactive silica (ppm)	Total Silica (ppm)	Colloidal Silica (ppm)	TOC (ppm)
1	SBA outlet water from Mouda	0.43	1.83	1.40	---
2	Clarified water in 40:60 Alum :PAC passed through cation and then Mouda brine treated normal SBA resin	0.42	0.47	0.05	0.455 (From 2.5)
3	Clarified water in 40:60 Alum :PAC passed through cation and then special SBA resin	0.42	0.42	Nil	0.358 (From 2.5)

Efficacy of the SBA resin for organic & colloidal silica removal was tested. The TOC value was found to decrease from 2.5 ppm to 0.35 ppm where as in normal SBA resin it reduced upto 0.45 ppm. Regarding Colloidal silica removal both normal SBA resin (after Brine treatment) and special SBA showed good results. However, in respect of colloidal silica, the special SBA resin is most effective.

Part-IC.2: Study with UF (0.2 µ)/RO portable system

S N	Sample description	TOC (ppm)
1	Clarified Water	2.4
2	Clarified water passed through UF	1.8
3	UF outlet passed through RO	0.35

It was also found the above combination also reduces TOC level to the same extent as obtained in SBA resin.

Recommendation:

1. Clarification may be carried out with 40 ppm Alum + 60 ppm PAC+ 5-7 ppm Solid DADMAC/ Poly-3 to get the acceptable performance.
2. Disinfection treatment of chlorine with chlorine dioxide with residual chlorine of 0.2 ppm is to be done.
3. Periodical brine treatment of SBA, MB and WBA once in six months in hot condition at 50 deg C with 10% NaCl and 2%NaOH.
4. To control TOC in DM water Storage Tank, intermittent cleaning of degassed tank and DMST should be done.

Outcome: After implementation of the recommendations, the issue was resolved and the units started operating at full load after a long time.

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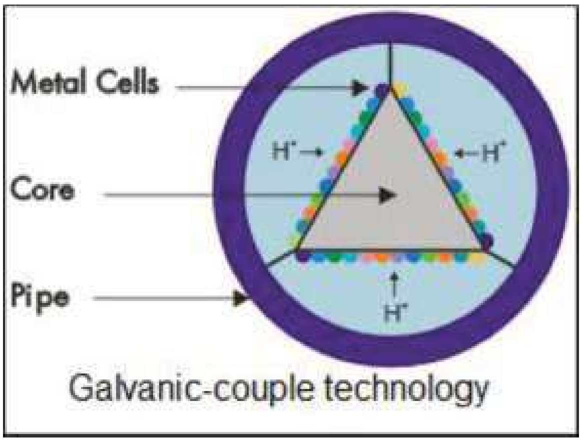
Case Study:2

Trial experiment of Non-chemical scale inhibition system at NTPC- Dadri

Introduction: During cooling tower operation, the evaporation causes concentration of salts in the circulating water and subsequent scaling in the condenser tubes. Across NTPC NETRA-based chemical formulation is used in the cooling water treatment. But in Dadri due to some special reasons condensers were suffering from heavy scale leading to huge heat rate loss for years. The situation used to become more severe during Ganga canal closure when the station are compelled to use underground water which has higher scaling propensity. The stage-II units are most affected as it cannot use softened water unlike stage-I units and units could not run on higher COC and station had to incur higher water wastage. The case was referred to NETRA to find out some permanent solution to the problem.

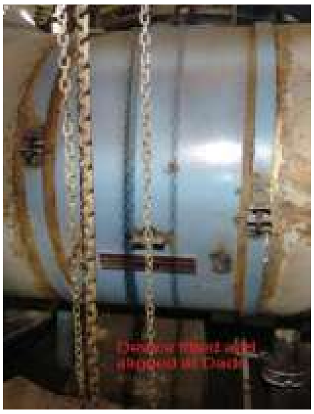
There are some non-chemical methods that claim to inhibit scales even at higher hardness water and at higher COC. One of such technology which is based on galvanic couple technology (GCT) has some referral in the literature. Extensive literature search revealed that even in India one group has developed some system like this which was not evaluated ever. Looking into the very high relevance of such technology for NTPC, a management approval was taken to give such a technology a chance by directly applying to a running condenser system. Such approach is fraught with high danger as the unit may suffer adversely if such installation failed to perform.

After a number of lab trial on the concepts, and close examination of the technology, management gave approval to such trial at Dadri stage-II units.



The technology was installed in Unit-5 In April 2014, and in Unit-6 in March 2015. The installation covered condensers and all the associated heat exchangers.

Trial condition was setup by a cross-functional team consisting of NETRA, OS, Engg, Site and CenPeep. . The data to be monitored was finalised. Trial started in June 2015 and scale inhibitor chemical was withdrawn on and from May' 2015. However other required chemicals were continued as per requirement. After some initial problems of inconsistent unit running and external debris accumulation in condenser with associated rise of vacuum loss, scale inhibitor restored. However, after some cleaning of the condenser the trial was restarted in Unit-5 only from 29th Nov to 30th Dec 2015 with the pre-defined technical criteria since Unit-6 was under shut-down. COC of the system was kept initially 5. From 2nd May 15, COC was gradually increased in step of 0.5 COC. For complete one month in unit 5, COC was kept at 7.5 to 8.4. Since May 2015 scale inhibitor dozing was totally stopped. To achieve higher COC blow down was stopped completely in the month of Dec 2015. Sulfuric acid consumption got reduced by 2 Ton per day due to operation of the system at high PH at about 8.4 – 8.5 to confirm if the technology was capable to work at this high pH and could save acid consumption



Evaluation:

Vacuum loss in unit 5 due to air ingress /dirty tube was 14.52 initially on 25.11.2015 and on 29.12.2015 it was 12.09 after operating at approx 8 COC in last one month.

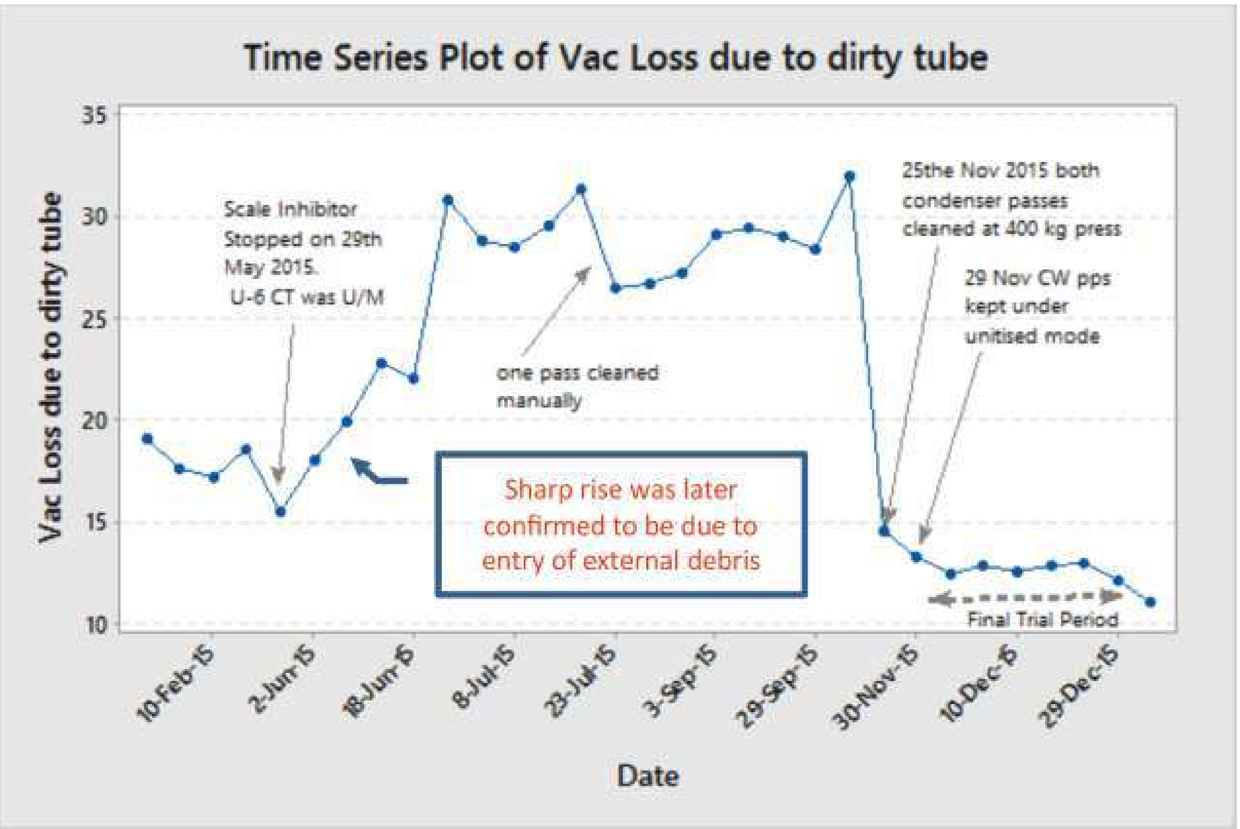
Hardness of water was in range of 640 to 680 ppm and Rynzer index was 4.7 to 5.3 which indicated strongly scaling condition.

One PHE (5B) was opened on 30.12.2015 for physical observation. It was opened after continuous operation of 10 months and no hard scale was observed but only loose sludge which was removed by normal water washing. The trial revealed that the technology is effective to prevent scaling. The loose black deposit sample later analysed at NETRA revealed as mainly of silica and organic matter and not CaCO3. The loose deposits was also

causing some heat rate loss. This could be eliminated or reduced by using appropriate biocide and good quality dispersants like ter-polymer, but this was out of the scope of the experiment.

There was some increase in dP across condenser which was attributed to the loose deposits. 0.7 deg C increase in temperature rise across condenser was observed. CW pump power consumption was lower indicating that flow was reduced due to loose deposits. However, apparently there was no loss in condenser vacuum due to dirty tubes. COC reached up to around 8.0 and pH 8.2-8.5. A comparison was done by analysing parameters before and after GCT implementation and with normal chemical dosing and with GCT without scale inhibitor & dispersant. The trial showed more reliable operation and maintenance of condenser vacuum and the system was operated at high COC. Better reliability ensured sustained good vacuum that made it more rewarding.

The technology needs little monitoring with a life expectancy of 20 years



Pros and Cons of the Technology:

Pros

- Little monitoring and no maintenance required.
- High reliability
- No operating cost
- Unattended operation. Fit it and forget it.
- High COC operation possible.
- Limitation of pH is there
- For installation unit shut down required.

Cons

- All the heat exchangers within same cooling system require this device independently.
- Other chemicals like, biocide, corrosion inhibitors still are required, so not completely chemical free system.

Outcome:

- This is the first such trial in 500 MW set at NTPC with a little known non-chemical scale inhibition technology and no reported case available in international journals.
- Decades of scaling problem that Dadri faced, came to a complete end in these units.

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Case Study:3

Research and mitigation of RO plant design issue and performance restoration at Kudgi

Introduction:

Unit-1 of Kudgi station was undergoing steam blowing operation where site chemistry observed heavy contamination of silica. At the same time station chemistry was hard put to supply adequate quantity of DM water as DM plant was facing quality and output problem. The whole circumstances seemed out of control and threatened commission schedule and there was an apprehension of COD getting delayed. Top management wanted a quick solution to this.

The problem was referred to NETRA and the thorough analysis of the problem was decided in a joint meeting of NETA, CC-Engg, OS, and vendor.

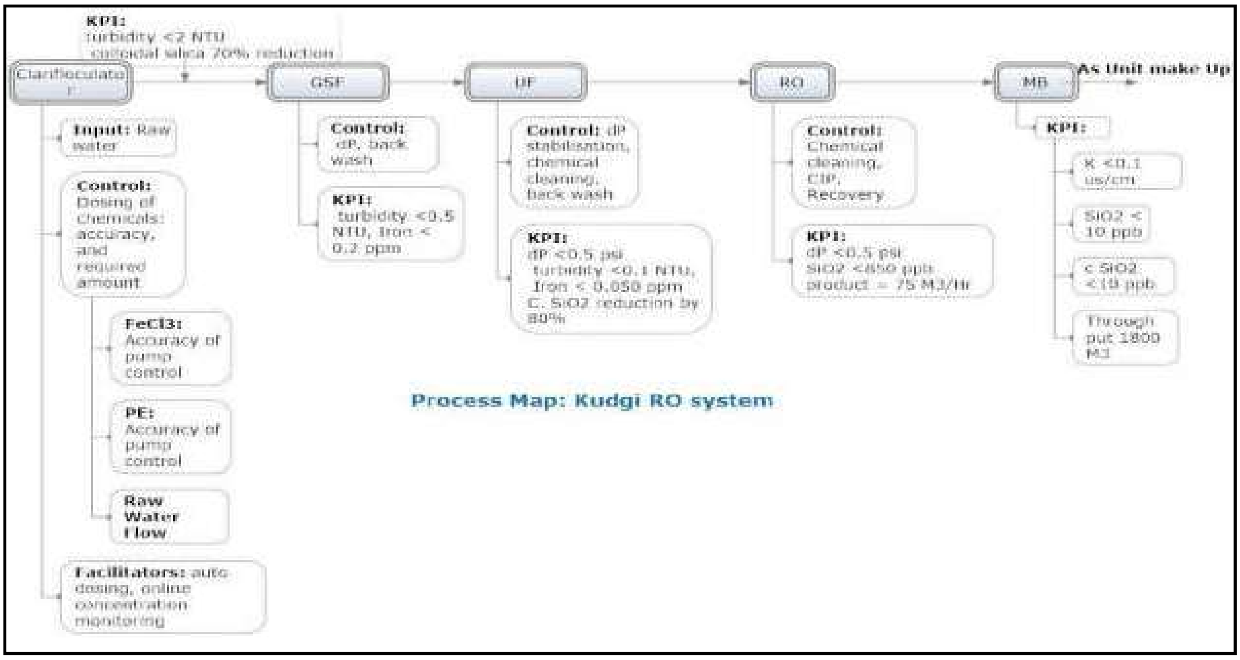
A preliminary observation revealed that the DM water produced was of low quality and a lot of silica was getting passed through the DM plant chain, contaminating DM storage tanks, steam water cycle and affecting main plant operation. Mixed-bed was getting quickly exhausted, causing frequent regeneration resulting in higher chemical consumption, operator's extended engagement, and lower availability. It was found that against the design through put of 1800 M3, Mixed Bed was giving below 1000 M3 output.

During steam blowing operation unusually high silica was persisting due to which the commissioning activity has to be stopped temporarily. Objectives of the investigation was to find all the root causes of the problem, finding out the source to the contamination problem and restore the capacity of the RO plant in respect of both designed output and final water quality so that commissioning activities could be restored.

Investigation:

At first the process was understood deeply, chemical measurement system was reviewed and base line study done. Based on literature survey the expected efficiency improvement of sub-processes are anticipated. The inter-Laboratory comparison between site lab and NETRA was done to validate Chemical Measurement process (CMP) of both.

Process Map: RO System and various Quality Control Factors (QCF)



Process Map: Kudgi RO system

Chemical Measurement process (CMP): method, accuracy, range of analysis study of analytical system

	UOM	Range	Accuracy	Calibration	Method	Equipment	Lab
Reactive silica	ppm	0-5	0.1	External standard	ASTM	spectrophotometer	Site & NETRA
	ppb	0-100	5				
Colloidal silica	ppm	0-20	0.1	External standard	NETRA Developed	Micro wave digestion and spectrophotometer	NETRA
	ppb	0-100	10				
TOC	ppm	1-4	RSD 5%	External standard	EN	TOC Analyser	NETRA
Iron	ppb	0-500		External standard	ASTM	spectrophotometer	Site & NETRA

Since site does not have facility for TOC measurement, in its place KMnO4 no determination has been established at site.

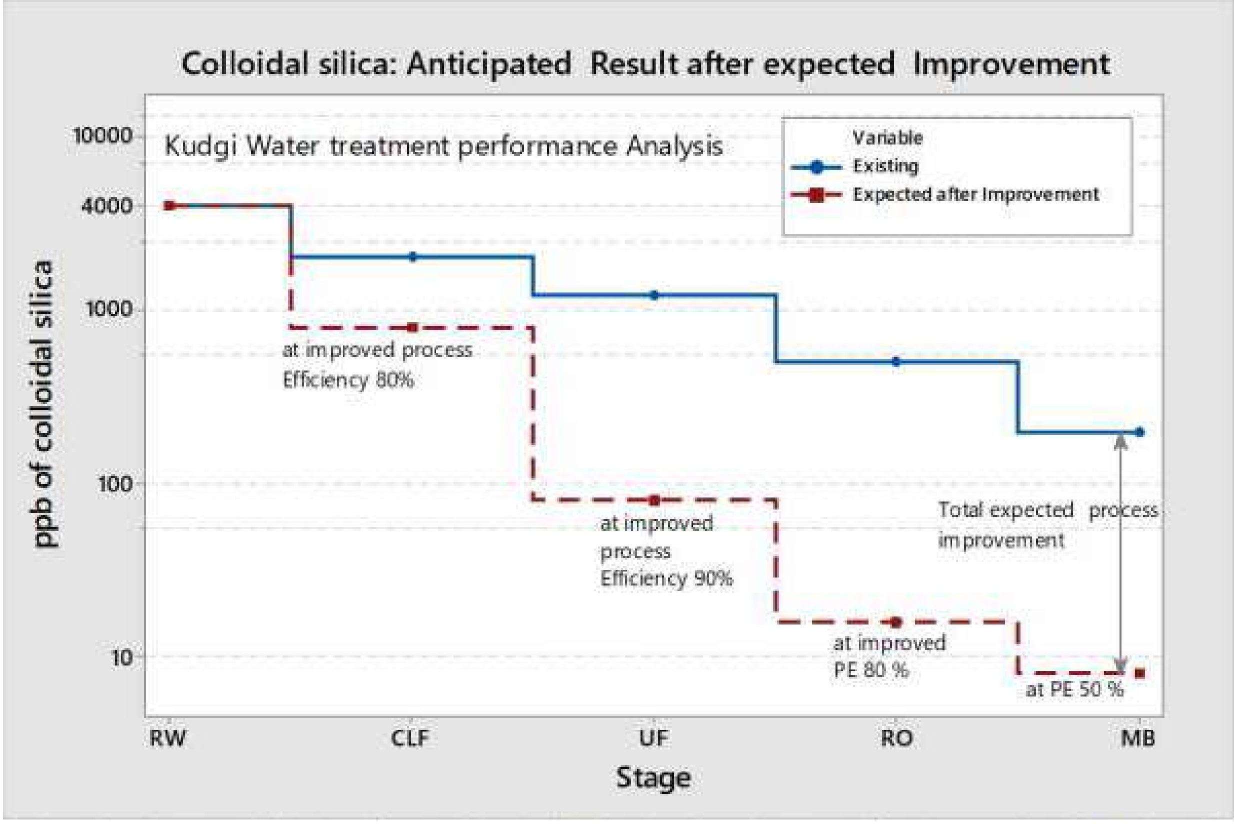
NB: Other than this, some more investigative techniques were also needed: like autopsy for RO, and integrity test for UF. These were to be done at outside agency.

Sampling Plan: samples were collected from site and tested at NETRA before starting of optimization at site. After that samples collected and tested at site for which analytical facilities are available.

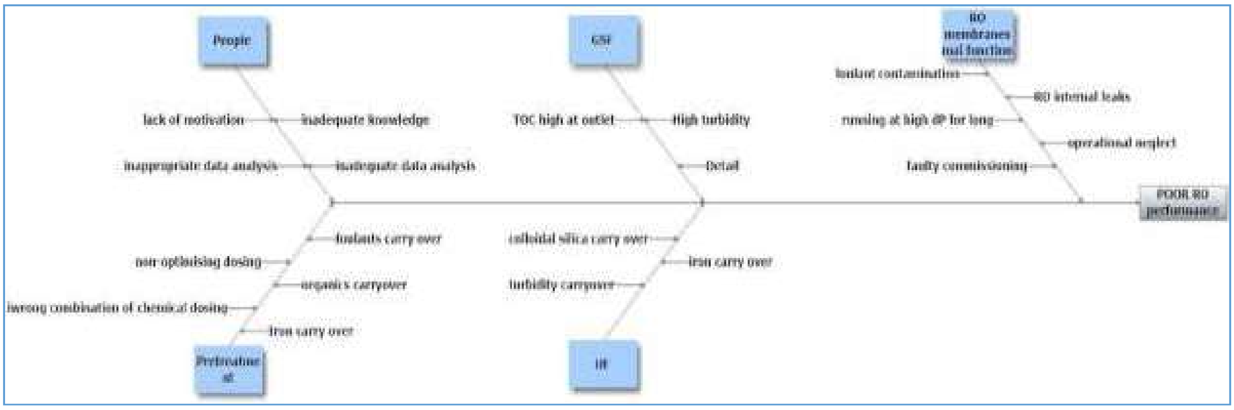
Current performance of sub-processes

	KPI	UOM	Value
Clarifier	Turbidity	NTU	3.7
	Iron	ppb as Fe	0.7
	TOC	ppm	0.7
	Colloidal silica	Ppm as SiO2	---
GSF	Turbidity	NTU	1.8
	Iron	ppb as Fe	0.8
	TOC	ppm	1.7
UF	Turbidity	NTU	0.9
	dP	Kg/cm2	0.8
	Iron	ppb as Fe	50
	TOC	ppm	1.4
	Colloidal silica	ppb	---
RO	Product	M3/hr	50
	Silica	ppm	1.8
	Colloidal silica	ppb as SiO2	---
	dP	Kg/cm2	7.6
	TOC	ppb	---
	K	Us/cm2	42
MB	Colloidal silica	ppb	---
	Reac SiO2	ppb	<10
	K	µS/cm	<0.1
	Throughput	M3	1800

The anticipated scope of improvement:



Cause-Effect diagram



Investigation and Root cause analysis:

1. **Pretreatment:** Walk through audit of the PT plant was done by NETRA team and site persons. A number of anomalies were noticed. The dosing points to clarifier was at the flocculator. In this arrangement there was not enough agitation for mixing. It was shifted to near aerator to have enough opportunity for mixing and reaction time.

2. **UF:** It was noticed that UF was having periodical dP high for which backwash was needed to be done once in a day. The rise of dP from about 0.5 psi to 0.9 psi was unusual. The main cause for this was supposed to be Iron and Turbidity fouling.

a. Sample collection and analysis was carried throughout the entire value chain. It was found that UF is not at all preventing the passage of colloidal silica which it was expected to do.

b. Clari-floculator was not functioning well and a lot of sludge was being carried over.

3. **Autopsy Analysis of RO:** some membranes were extracted earlier for autopsy analysis. This analysis reveals the type of foulants that have clogged the membranes, thus facilitating root cause analysis and prevention in the future. As per report the main foulants were silica, colloidal silica, phosphate and iron. The sample elements were taken from front and rear end of RO stage-1. The visual observation showed the fouling, the front one was more fouled indicating iron and colloidal fouling was predominant factors. This also validated the initial assumption.

a. Dosing tanks and pumps were inspected: The idea was to have accuracy in chemical preparation, and pumping, a chemical calculation matrix was developed so that dosing can be improved.

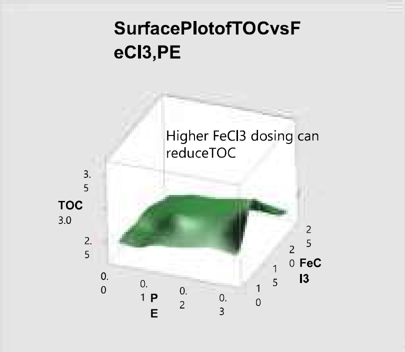
b. It was observed that clari-flocculator scrapper's rotation was counter- clock wise. It was reversed so that efficient removal of sludge can take place.

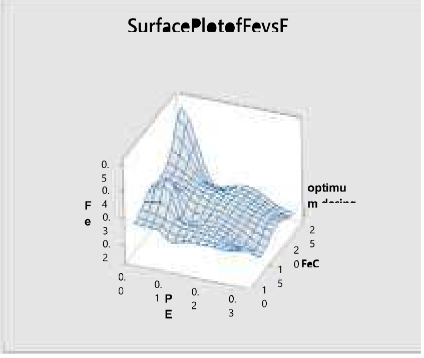
4. **Lab Simulation:**

Three-Factor – Three-Level Experiment design			
Factors/Level	0 (low)	1 (Med)	2 (High)
FeCl3 ppm (as 40%)	10	15	25
PE (poly electrolyte) ppm	0.1	0.2	0.3
Lime ppm	0	3	5

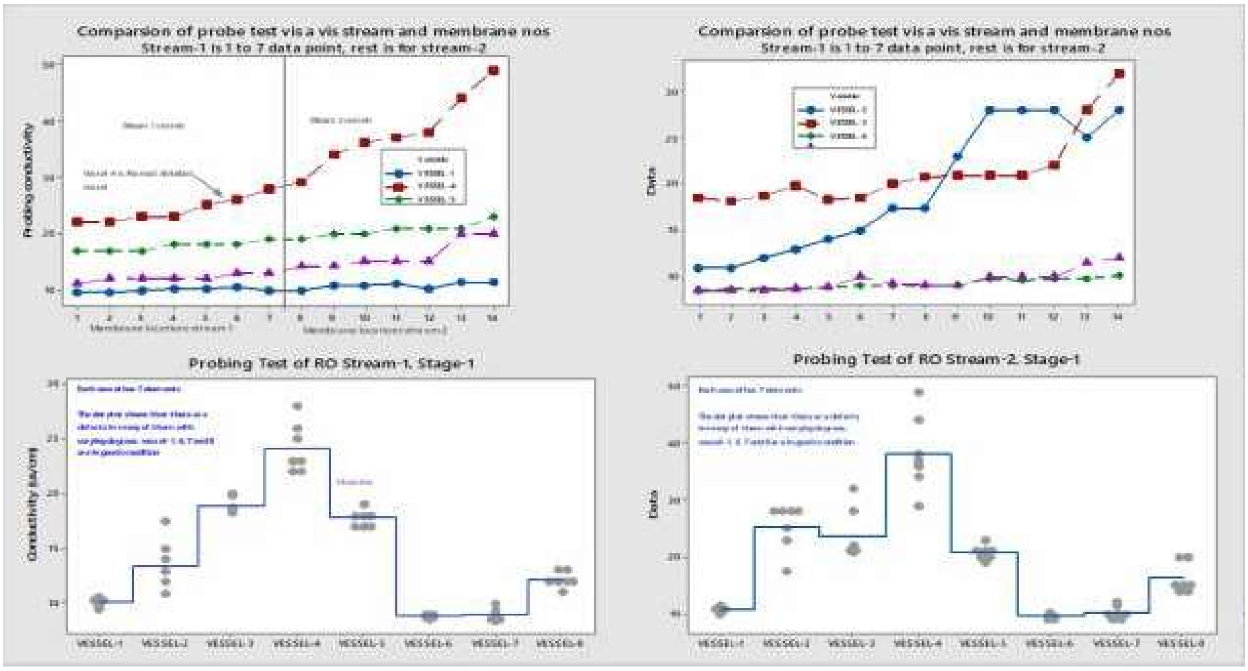
Efforts were initiated at NETRA lab to find out main factors, establishment of synergy among factors, if any, and to discover any other controlling factors that might exist to make pre-treatment at site more effective and efficient. The Design of Experiment (DOE) initially constituted with two factors with

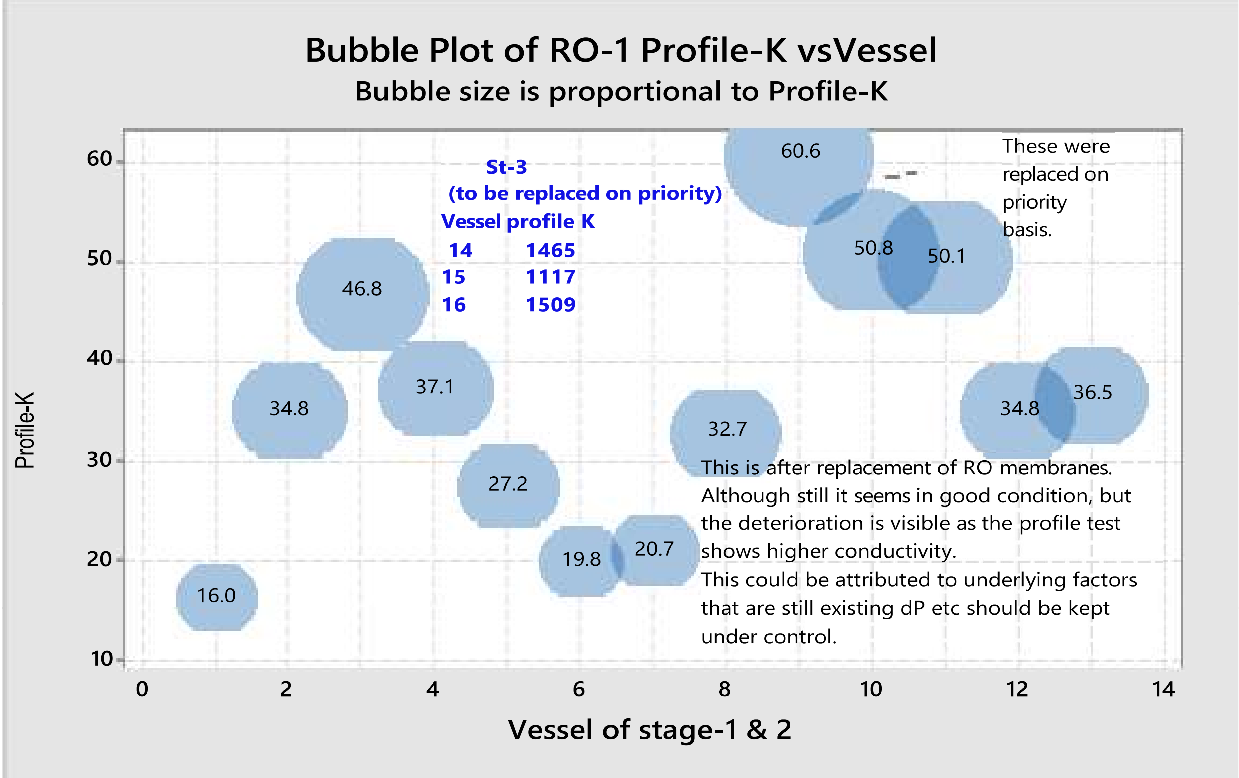
5. FeCl3 and PAC as originally designed by specification. When this did not yield the desired result, another chemical was found out and a three-factor with three-level experiment was planned. In total twenty experiments were carried out at lab. Finally, an optimum formulation of chemicals was found out that produced acceptable result as per the objectives set out in the planning stage. The most noteworthy was the finding that with an additional factor of lime at 5 ppm could reduce both iron, TOC and colloidal silica through a three-factor synergy. The lime addition was not envisaged in the original design and the site process was modified through CC-Engg to accommodate the requirement. The above multi-factor response surface map (RSM) demonstrated the optimum points.


SurfacePlotofTOCvsFeCl3,PE


SurfacePlotofFevsF

RO Probing: Probe test and its analysis revealed many of the membranes were badly damaged. Also, there was problem of flow balancing, among membranes. The flowing set of graphs and the bubble plot shows the affected membranes and the severity of the problem.





St-3
(to be replaced on priority)

Vessel	**profile K**
14	**1465**
15	**1117**
16	**1509**

These were replaced on priority basis.

This is after replacement of RO membranes. Although still it seems in good condition, but the deterioration is visible as the profile test shows higher conductivity.
This could be attributed to underlying factors that are still existing dP etc should be kept under control.

Improvement Stage:

At this stage it was endeavored to apply all these findings to improve the situation at site. During the investigation stage certain lacunae like, infrastructural gap, testing competency, and dearth of proper standard chemicals etc. came to the notice that were worked upon. The following were changed:

a. Lime dosing introduced, which was previously not envisaged at the time of design.

b. The site staff were trained on analysis. Fresh standard graphs were generated. Jar test was replicated with both NETRA and Vendor's recommendation. Both were found acceptable, however, in the latter the dosage was high. After trying the latter for some time, site resorted to do as per NETRA's plan.

c. Proper chemical dosing system was established. Operators were trained and effective supervision by senior staffs were established. Proper recording was also begun.

d. GSF was soak-cleaned with hypo-chlorite to remove any accumulated bacteria and organic matter as TOC was found higher after GSF.

e. Most severely fouled RO membranes were replaced

Improvement observed: The chemical regime was implemented in Aug 2017 and following improvement observed.

S No	Sample details	02/08/2017 ppm as Fe	03/08/2017 ppm as Fe	04/08/2017 ppm as Fe	06/08/2017 ppm as Fe
1	CLF Outlet	1.3	2.0	1.6	0.8
2	GSF Outlet	0.6	0.7	0.2	0.2
3	UF Outlet	0.1	<0.005	<0.005	<0.005

(i) PT plant iron carry over reduced that in turn reduced UF cleaning frequency.

(ii) Turbidity of CCF decreased, GSF turbidity has also decreased. The combined effect was positive for UF.

(iii) After cleaning RO output increased by 50%.

(iv) Remaining problem: after cleaning RO salt passage also increased. This indicated damages of some RO membranes that required replacement phase wise

Monitoring and Control:

(a) The dosing consistency to be maintained.

(b) Frequent monitoring need to be continued to sustain the gain.

(c) Normalized monitoring of UF, RO parameters, particularly, dP, product recovery, and salt passage, to be initiated. Data to be collected through DAS for trending, portability.

(d) Some unanticipated observation was that Raw Water quality was drastically changed (See the table below) with respect to some parameters. Sulphate was found abnormally high, conductivity was also high. RO has to take this extra load

Changes in Raw Water Quality

SN	Parameters	Unit	Prev data	Current Data
1	pH		7.6	8.9
2	Conductivity	µS/cm	313	533
3	TDS	in mg/l	149	320
4	Turbidity	In NTU	4.7	4.9
5	Total hardness	Ppm as $CaCO_3$	110	160
6	Calcium	Ppm as $CaCO_3$	72	88
7	Magnesium	as $CaCO_3$ in mg/l	38	72
8	P-Alkalinity	as $CaCO_3$ in mg/l	Nil	10
9	M-Alkalinity	as $CaCO_3$ in mg/l	70	140
10	Chloride	as Cl in mg/l	33	74
11	Sulphate	as SO_4 in ppm	25.0	105

Other recommendations for improvements:

(a) At high pH, hypo-chlorite dosing is not effective. In its place ClO2 dosing to be initiated. This will effectively take care of organic carry over.

(b) Vessel 9, 10,11,14,15 &16 need to be replaced on priority basis. Decision on the rest shall be taken after thorogh testing and analysis. However, vessels for replacement may be further probed because may be only few membranes within the affected pressure vessels are damaged, in such a case all these membranes need not be replaced.

(c) UF integrity needs to be done. This would reveal the reason of colloidal silica passing through. Sometimes it happened if there is damage of fiber inside.

(d) It was found that third stage RO does not have enough pressure for proper flow as per design. A design intervention may be considered to place one booster pump at stage-2 of RO.

Outcome:

- The station overcame the severe chemistry issues. COD declared at normal schedule.
- The most of the problem were addressed, the remaining problem could be countered by following the recommendation given.
- Knowledge upgradation of site people and design rectification for future.

Table:1 Optimization of jar test

SN	Sample Clarified in Jar test	Total silica (ppm)	Reactive silica (ppm)	Colloidal silica (ppm)	TOC (ppm)	Turbidity	Iron as Fe (ppm)
1	Raw Water as such	22.4	19.8	2.6	2.0	2.39	0.14
2	RW+25 FE + 0.1 PE + 5 Lime	19.2	18.4	0.8	2.4	1.01	0.21
3	RW+25 FE + 0.3 PE + 5 Lime	19.8	19.5	0.3	2.4	0.95	0.17
4	RW+15 FE + 0.1 PE + 5 Lime	20.3	19.5	0.8	2.6	1.60	0.16

Table-2: Jar test Results:

SN	Sample description	pH	K	TDS	Turbidity	TOC	Iron	Observations
1	Raw Water	8.06	432	259	2.39	2.50	0.14	
2	RW+15 FE+0.1 PE	7.70	430	258	1.61	2.90	0.20	Smaller flocs, highly dispersed
3	RW+15 FE+0.3 PE	7.60	432	259	1.50	2.64	0.16	Smaller flocs, highly dispersed
4	RW+15 FE+0.1 PE+3 Lime	7.90	440	264	1.71	2.65	0.29	Smaller flocs but settled
5	RW+15 FE+0.3 PE+3 Lime	7.93	440	264	1.60	2.64	0.16	Smaller flocs but settled
6	RW+10 FE+0.1 PE	7.50	438	263	1.28	2.54	0.31	Larger flocs, discrete, less settled
7	RW+10 FE+0.3 PE	7.50	438	263	1.51	2.65	0.21	Larger flocs, aggregated, less settled
8	RW+10 FE+0.1 PE+3 Lime	7.90	440	264	1.23	2.55	0.15	Larger flocs, discrete, more settled
9	RW+10 FE+0.3 PE+3 Lime	7.90	440	264	1.23	2.54	0.29	Larger flocs, aggregated, more settled
10	RW+25 FE only	7.30	437	262	1.52	2.31	0.50	does not give bigger flocs
11	RW+25 FE+5 ppm Lime	7.65	446	268	1.05	2.27	0.46	dispersed flocs no significant change
12	RW+25 FE+0.1 PE+5 Lime	7.30	438	263	1.01	2.37	0.21	bigger flocs but suspended in upper layer
13	RW+25 FE+0.3 PE+5 Lime	7.60	447	268	0.95	2.38	0.17	bigger flocs but settled
14	RW+10 FE +0.05 PE	7.60	435	263	1.42	2.39	0.29	Smaller flocs
15	RW+15 FE +0.05 PE	7.60	438	263	1.51	2.28	0.36	Smaller flocs, settled
16	RW+10 FE +0.05 PE+3 ppm Lime	7.80	440	264	1.50	2.49	0.25	Smaller flocs
17	RW+15 FE +0.05 PE+3 ppm Lime	7.80	440	264	1.40	2.44	0.40	Smaller flocs, settled

Table-3 A: Water Analysis Data

S.NO.	Parameters	Unit	Almatti Dam	DM Clarifier Inlet	DM Clarifier Outlet	UF Inlet	UF Outlet H-1	UF Outlet H-2
1	pH		7.6	7.9	7.2	7.3	7.2	7.2
2	Conductivity	µmhos/cm	313	421	456	484	484	486
3	TDS	In mg/l	149	201	218	237	231	231
4	Turbidity	In NTU	4.7	5.8	3.5	1.6	0.3	0.3
5	Total	As $CaCO_3$	110	122	122	122	118	118
6	Calcium	As $CaCO_3$	72	80	80	76	76	76
7	Magnesium	As $CaCO_3$	38	42	42	46	42	42
8	P-Alkalinity	As $CaCO_3$	Nil	Nil	Nil	Nil	Nil	Nil
9	M-Alkalinity	As $CaCO_3$	70	100	105	100	90	90
10	Chloride	As Cl in	33	48	55	52	52	52
15	Silica	As SiO_2 in	18.0	21.5	20.5	20.0	18.4	17.5

Table-3 B: Water Analysis

S.No.	Sample Description	Unit	Total Silica (ppm)	Reactive Silica (ppm)	Colloidal Silica (ppm)
1	Almatti Dam	ppm	20.3	18.0	2.1-2.5(2.3)
2	DM Clarifier Inlet	ppm	25.5	21.5	3.6-4.4(4.0)
3	DM Clarifier Outlet	ppm	22.5	20.5	1.8-2.2(2.0)
4	Gravity Sand Filter	ppm	22.5	20.5	1.8-2.2(2.0)
5	Ultra filter(UF)Inlet	ppm	21.8	20.0	1.6-2.0(1.8)
6	UF Hdr-1 Outlet	ppm	19.6	18.4	1.0-1.4(1.2)
7	UF Hdr-2 outlet	ppm	18.6	17.5	0.9-1.3(1.1)
8	UF Tank Outlet	ppm	18.0	17.5	0.4-0.6(0.5)
9	Reverse Osmosis	ppm	18.5	18.0	0.4-0.6(0.5)
10	RO Hdr-1 Outlet	ppm	2.0	1.5	0.4-0.6(0.5)
11	RO Hdr-2 Outlet	ppm	1.9	1.5	0.3-0.5(0.4)
12	RO Tank Outlet	ppm	1.8	1.5	0.2-0.4(0.3)

13	Mixed Bed-A	ppb	217	17	200
14	Mixed Bed-C	ppb	154	14	140
15	DM Tank-2	ppb	234	23	211

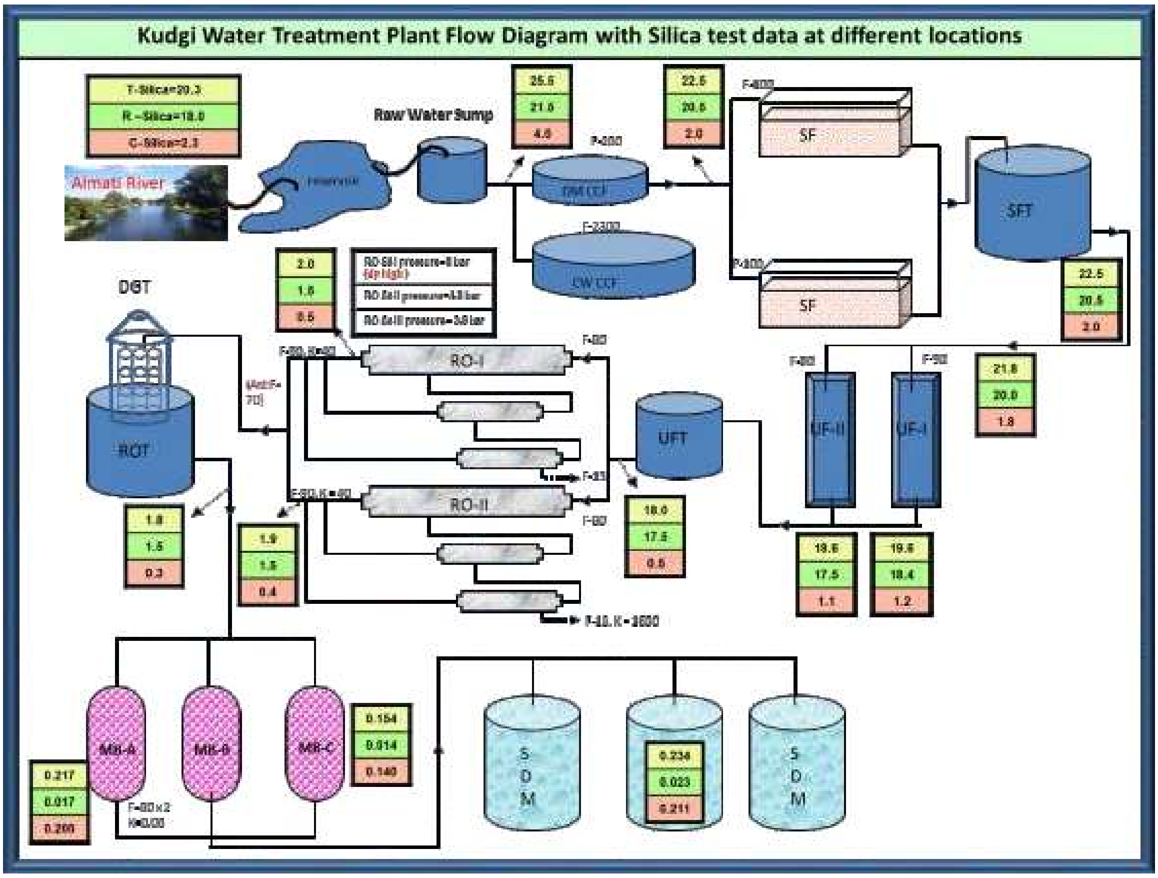
Table-4: TOC Analysis

Sample Description	Almatti Dam	DM Clar Inlet	DM Clarifier Outlet	GSF Outlet	UF Inlet	UF Outlet H-1	UF Outlet H-2	DM Tank- 1	DM Tank-3
Total Organic Carbon (ppm)	1.8	2.9	6.0	6.0	7.1	3.1	2.2	0.82	0.38

Table-5: Analysis of RO outlet and DM water

S. N.	Sample details	Total Silica as SiO2 (ppb)	Reactive Silica as SiO2 (ppb)	Colloidal Silica as SiO2 (ppb)
1	RO Outlet	1910	1320	580
2	DM Tank Outlet	1280	16	1264

Table-6: DM Plant Process



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Case Study: 4

Electro coagulation (EC) system for reduction of Total Silica in pretreatment at Solapur

Introduction:

At Solapur, DM plant was facing problems due to high inlet Silica in raw water, short operating cycle of ion-exchangers, high acid consumption due to frequent regeneration and water loss. Silica design value found less than actual. High Na^+ slippage through cation exchangers due to faults in internals causing internal hydraulic disturbance resulting in flow channeling. Significant reduction in exchange capacity of ion exchange resins observed. Although the faults in the internals could be rectified through design modifications by the supplier but this would not be enough to take care of the high silica problem of the raw water. This issue was tackled in an innovative way through Electro-coagulation by virtue of a lot of literature survey as the conventional pretreatment was unable to address the issue.

Pilot study:

A pilot scale Electrocoagulation (EC) unit of 1 M^3/hr was installed at Faridabad and trial carried out for three months. Trial was conducted to evaluate the unit's performance in treating CW water operated at 5 COC level. Electrocoagulation operates by passing the water across metal electrodes. Trial was conducted using both aluminium or iron electrodes separately. On passing DC current metal dissolve as metal ions from anode (Iron plate), which in turn promotes coagulation and flocculation of the suspended impurities, organic material & other colloidal impurities. These impurities were then separated as a floating, frothy sludge in the downstream sludge separation unit.

The treated liquid effluent was discharged into the CW channel. Approximate cooling water composition was a TDS of 3000-3500 ppm; Silica 60 – 65 ppm and hardness 1000 – 1500 ppm. Two pilot studies/ experiments were carried out, one at Faridabad and another at Kudgi employing Aluminium electrode s and Iron electrodes respectively. Various experiments were carried out in both the pilot studies by altering the variables such as pH (As such, 9.0 & 9.5) with lime addition, Type of Electrode (Aluminum and Iron), Different Coagulant (PAC, Poly-Dadmac, Cationic polymer/Anionic polymer) and Current Density. The experiment was performed in a rectangular, parallel-plate flow-through reactor. The reactor contained ninety-eight electrodes with dimensions of 20 cm x 50 cm x 0.2 cm with inter-electrode gaps of 0.4 cm. The electrodes were oriented vertically and were wetted up fully, yielding a total effective anode area of 1000 cm^2 per electrode (Total surface area was 49000 cm^2). The Water was passed in an up flow direction through the two compartments of parallel channels of ninety-eight-electrodes. Effluent from EC reactor was collected in a tank fitted with agitator and poly-electrolyte dosing system. All tests were performed under galvanostatic control using a direct current

Electrocoagulation System - 1M3/hr Pilot Unit

Bipolar Electrodes with DC supply

power supply. The electrodes were operated in a bipolar stack arrangement with power connections to the first and last electrodes. The current densities ranged from 0.30 to 9.0 mA/cm2. EC chamber was fitted with aeration facility so that deposition of flocs on electrode was averted.

I. Trial study at Faridabad: (Using Aluminum Electrodes)

EC Data Sheet-1

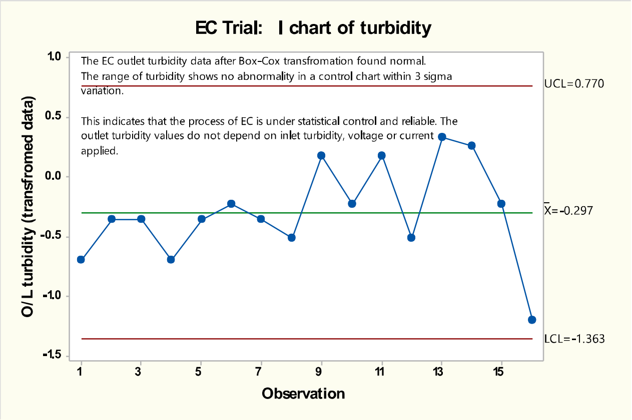
S No	Parameters	Data
1	Area of each electrode (20 cm x 50 cm)	1000 cm2
2	Total no of electrode	98
3	Total Anode Surface area	49000 cm2
4	Max current rate	40 Amp
5	Max current applied per min	2400 C
6	Rate of Fe release per min	720 mg
7	Rate of Al release per min	220 mg
8	Fe requirement per mg of $CaCO_3$ removal	0.28 mg
9	Al requirement per mg of $CaCO_3$ removal	0.18 mg
10	Flow rate	1000 lit/hr (16 lit/min)

Coagulation process

Table-1: Effect on Turbidity (Aluminum Electrodes): Flow: 500 LPH

SN	Voltage (V)	Current (Amp)	pH		Conductivity (µmhos/cm)		Turbidity (NTU)	
			Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
1	64	30	7.6	6.9	3515	3568	6.5	0.5
2	66	29	7.4	6.7	3445	3425	6.0	0.7
3	64	30	7.3	6.1	3652	3608	5.4	0.7
4	90	34	7.1	6.3	3757	3704	6.3	0.5
5	118	39	7.3	6.7	3752	3608	7.3	0.7
6	105	40	7.2	6.7	3375	3311	5.0	0.8
7	104	40	7.2	6.6	3450	3353	6.6	0.7
8	117	44	7.3	6.9	3456	3377	7.0	0.6
9	117	44	7.8	6.8	3524	3452	8.0	1.2
10	140	43	7.3	6.5	3732	3648	6.7	0.8
11	145	43	7.5	7.3	3691	3613	7.3	1.2
12	135	44	7.5	6.6	3619	3480	8.7	0.6
13	152	45	7.4	6.8	3734	3686	8.6	1.4
14	142	44	7.4	6.7	3571	3535	8.1	1.3
15	140	44	7.2	6.2	3600	3515	12.3	0.8
16	118	44	7.5	6.2	3626	3550	10.0	0.3

Observation 1: The performance of EC in respect of reduction of turbidity was found to be quite appreciable i.e., average less than 1 NTU irrespective of inlet water turbidity. The EC process shows very reliable in giving out very low turbidity consistently and the process is under statistical control. It does not depend on inlet turbidity. This is quite better than traditional chemical based coagulation process.



The EC outlet turbidity data after Box-Cox transfromation found normal.
The range of turbidity shows no abnormality in a control chart within 3 sigma variation.

This indicates that the process of EC is under statistical control and reliable. The outlet turbidity values do not depend on inlet turbidity, voltage or current applied.

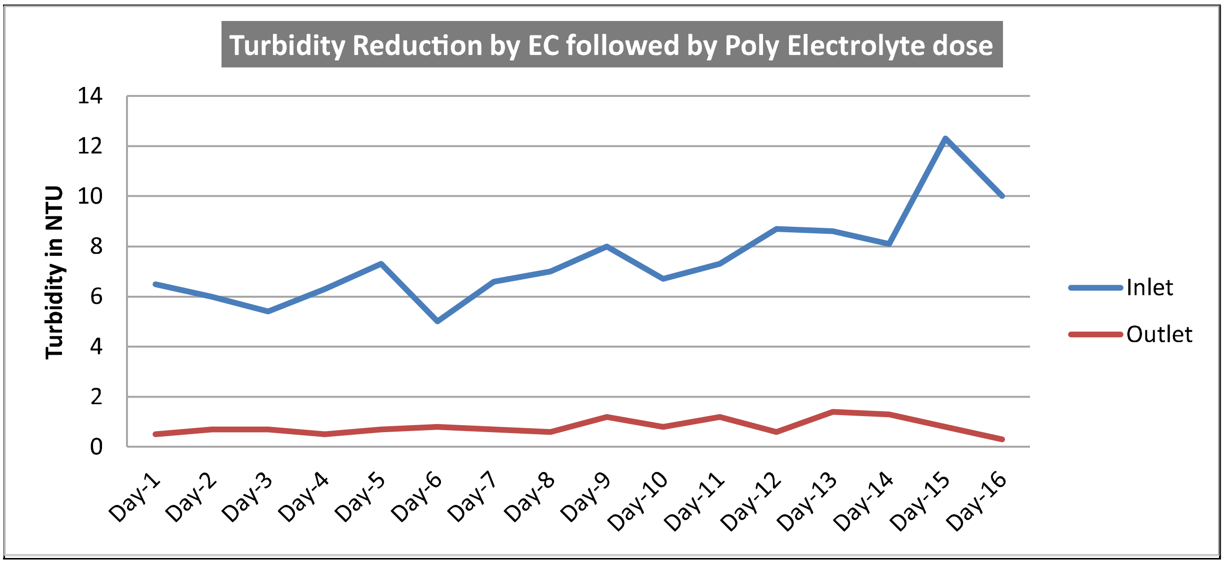


Table-2: Effect on silica (Aluminium Electrodes): Flow : 500 LPH

SN	Voltage (V)	Current (Amp)	pH		Silica		Silica % reduction
			Inlet	Outlet	Inlet	Outlet	
1	64	30	7.6	6.9	65	14	78.5
2	66	29	7.4	6.7	64	22	66.0
3	64	30	7.3	6.1	69	27	61.0
4	90	34	7.1	6.3	64	15	76.5
5	118	39	7.3	6.7	71	30	58.0
6	105	40	7.2	6.7	68	33	51.0

7	104	40	7.2	6.6	63	14	78.0
8	117	44	7.3	6.9	65	10	85.0
9	117	44	7.8	6.8	64	15	98.4
10	140	43	7.3	6.5	68	18	73.5
11	145	43	7.5	7.3	69	35	49.2
12	135	44	7.5	6.6	68	16	76.5
13	152	45	7.4	6.8	65	28	42.0
14	142	44	7.4	6.7	65	27	58.5
15	140	44	7.2	6.2	62	26	58.1
16	118	44	7.5	6.2	64	27	57.8

Observation 2: The rate of silica removal was high in the beginning when electrodes were fresh however, the rate decreased due to scale formation on electrodes as the time passes. Periodic acid cleaning with 5 % HCl concentration ensured removal of scale from electrodes and restored original condition of the electrodes. This demonstrated that online acid cleaning is necessary to achieve effective removal of silica.

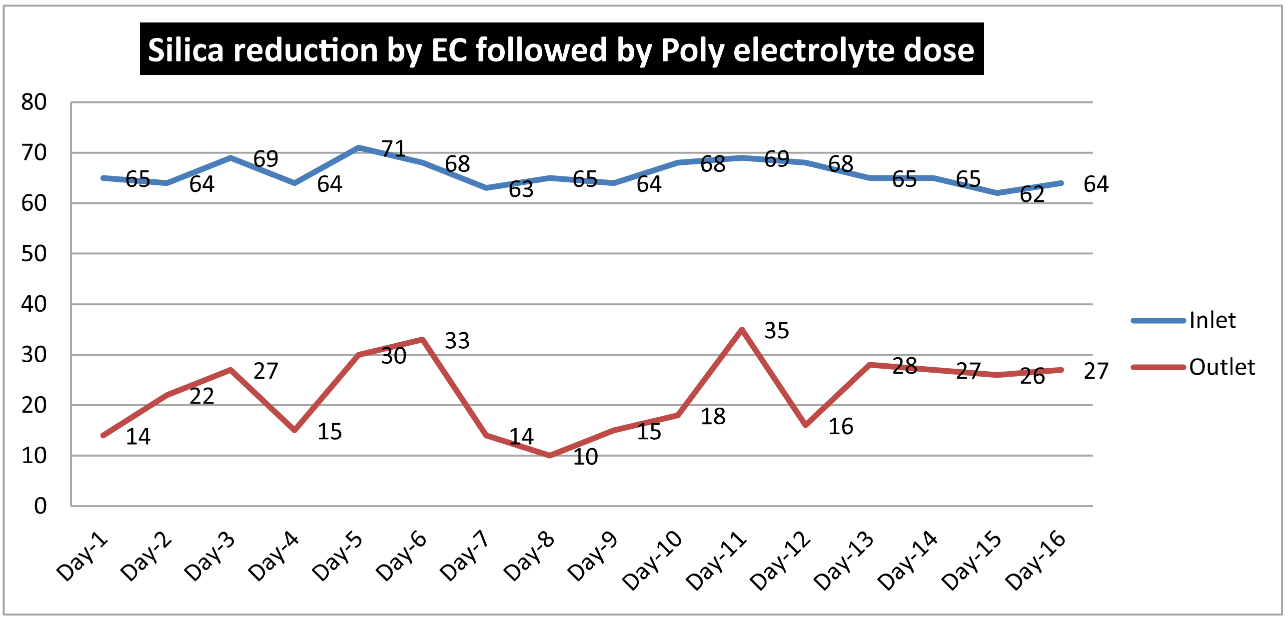
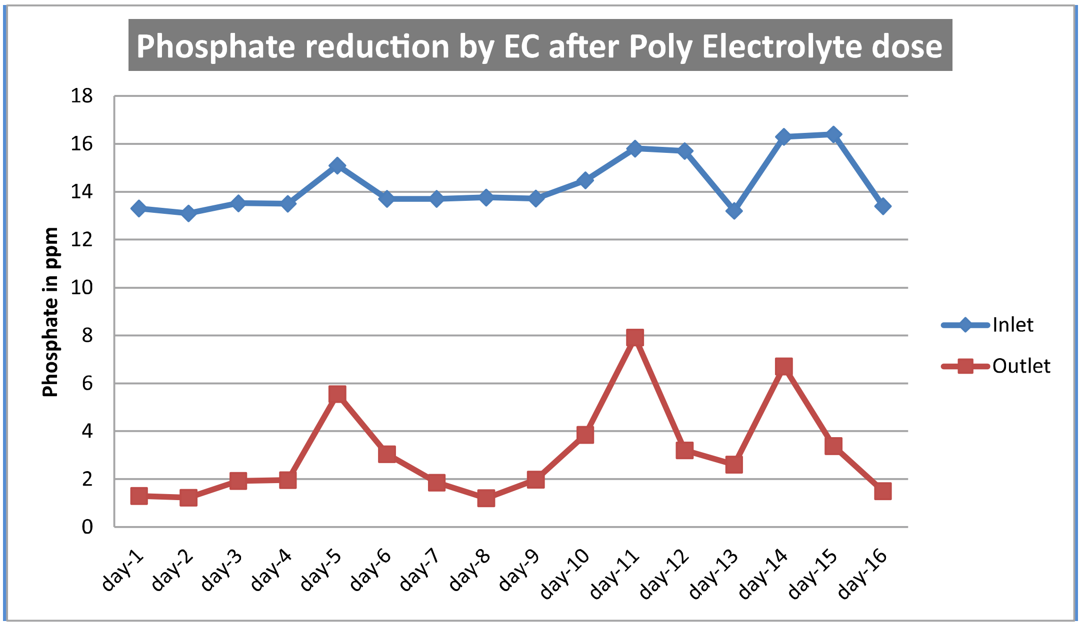


Table-3: Effect on Phosphate (Aluminum Electrodes): Flow: 500 LPH

SN	Voltage (V)	Current (Amp)	pH		Phosphate		Phosphate % reduction
			Inlet	Outlet	Inlet	Outlet	
1	64	30	7.6	6.9	13.3	1.30	90.22
2	66	29	7.4	6.7	13.1	1.23	90.61
3	64	30	7.3	6.1	13.52	1.92	85.80
4	90	34	7.1	6.3	13.5	1.96	85.48
5	118	39	7.3	6.7	15.1	5.56	63.18
6	105	40	7.2	6.7	13.7	3.04	77.81
7	104	40	7.2	6.6	13.7	1.86	86.42
8	117	44	7.3	6.9	13.76	1.21	91.21
9	117	44	7.8	6.8	13.71	1.98	85.56
10	140	43	7.3	6.5	14.48	3.86	73.34
11	145	43	7.5	7.3	15.8	7.92	49.87
12	135	44	7.5	6.6	15.7	3.2	79.62
13	152	45	7.4	6.8	13.2	2.61	80.23
14	142	44	7.4	6.7	16.3	6.71	58.83
15	140	44	7.2	6.2	16.4	3.39	79.33
16	118	44	7.5	6.2	13.4	1.5	88.81



Observation 3: The data from Table-2 reveals that phosphate removal efficiency by EC is also appreciable. Although it was observed that some phosphate gets deposited over electrodes but the same can be taken care of by intermittent acid cleaning. This reduction in phosphate content by EC can also be very helpful during STP water treatment.

II. Trial study at Kudgi: (Using Iron Electrodes)

Table-4: Effect on Turbidity (Iron Electrodes): Flow: 500 LPH

SN	Voltage (V)	Current (Amp)	pH		Conductivity (µmhos/cm)		Turbidity (NTU)	
			Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
1	120	22	8.1	6.6	417	405	5	2
2	180	25	7.89	6.02	416	390	4	2
3	215	29	7.89	9.15	416	330	4	1
4	230	28	7.93	9.29	412	423	4	2
5	250	28	8.02	8.78	407	470	5	2
6	210	28	7.99	8.53	420	385	5	1
7	220	28	8.08	7.6	422	397	4	3
8	232	28	8.1	8.97	424	351	4	3
9	230	26	8.14	8.8	421	339	5	3
10	238	29	8.14	9.2	416	403	4	2

Table-5: Effect on Silica (Iron Electrodes): Flow: 500 LPH

SN	Voltage (V)	Current (Amp)	pH		Silica (NTU)		Silica % reduction
			Inlet	Outlet	Inlet	Outlet	
1	120	22	8.1	6.6	21.0	7.6	64.0
2	180	25	7.89	6.02	20.5	8.7	57.5
3	215	29	7.89	9.15	19.5	5.8	70.3
4	230	28	7.93	9.29	18.0	4.8	73.3
5	250	28	8.02	8.78	20.0	1.0	95.0
6	210	28	7.99	8.53	19.8	1.4	93.0
7	220	28	8.08	7.6	20.2	2.5	87.6
8	232	28	8.1	8.97	21.4	4.4	79.4
9	230	26	8.14	8.8	21.0	3.7	82.4
10	238	29	8.14	9.2	18.4	5.1	72.3

Observation 4: While using Iron electrodes lime addition is required to settle the carried over of iron in outlet water. Approx. 0.1 to 0.2 ppm of Iron was found in outlet. Total Hardness reduced in out let from 160 ppm to 100 ppm. Average Silica removal was found to be 70 to 75 %. Appropriate selection of electrodes either Iron or Aluminum will depend on the nature of downstream water treatment technique i.e., resin based DM plant or RO plant. Iron electrode is preferable where treated water is used in RO plant since aluminum is a known foulant for RO membranes.

Electrodes after one-month operation were removed for cleaning.

Advantages of EC:

- Removal of silica in pretreatment itself will increase OBR of resin beds in the DM plant and in turn reduce the regeneration chemical consumption.
- Near Chemical free pretreatment technique.
- Minimum sludge generation
- It can also be used to reduce BOD, COD and Phosphate from other waste water effluents including STP water.

Outcomes of the pilot studies

- This study shows that EC is effective in reducing silica, turbidity and phosphate to a great extent from inlet water. Approx. 70 - 75 % of Silica reduction by this method is envisaged. As a retrofit to pretreatment EC shall improve the underperformance of DM plant and RO plant due to high silica in inlet water. The discovery of the technology is a solution to a station like, Solapur where raw water has high silica content and the system is under-designed.

- EC can be used along with conventional method of treatment in existing STP's to improve treated water quality.
- It is an environmentally sound technology as it does not require chemicals for treatment and also generates relatively low sludge as compared to other methods of waste water treatment.

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Case Study: 5

Activated Filter Media (AFM) based Tertiary treatment of existing STP to meet NGT norms at Talcher-K

Introduction:

Looking into the present scenario related to water scarcity, NTPC has taken may efforts on water conservation, zero-discharge, and STP water utilization. The matter has taken up more highlight as NGT recently has made norms more stringent related to quality of water on particularly STP.

Current STP performance data

S No	Parameters	STP Inlet (ppm)	STP O/L (ppm)
1	BOD	66	25-35
2	COD	131	50-70
3	Turbidity	87	20-30
4	Total Suspended Solids	112	30-50
5	Dissolved Oxygen	Nil	2-2.5

In general, the STP plants across NTPC have been designed for 20 ppm of BOD and 100 ppm COD. Recently, these parameters are revised by NGT as BOD <10 ppm and COD <50 ppm for STP. Therefore, the existing STP of 4 MLD capacity needed to be supplemented with a scheme to produce the effluent water of the desired quality parameters to meet statutory norms.

In this regard, NETRA explored many new technologies available in this area and found Activated Media Filter can be retrofitted to the existing Activated Sludge Process (ASP) based STP.

While selecting different technologies, it was also thought to reuse the STP treated water for CW makeup or DM plant application so that water conservation is also achieved.

Description of existing Sewage Treatment Plant:

The STP has been designed to treat the sewage generated from Talcher township having following characteristics:

1. Flow : 4000M3/day
2. Average Flow : 167 M3/hr
3. Peak Flow : 500 M3/hr
4. BOD : 20 ppm
5. Suspended solids : 300ppm

New guidelines for STP

S No	Parameters	STP O/L (ppm)
1	pH	6.5 to 9.0
2	BOD as ppm	10
3	COD as ppm	50
4	Total Suspended solids	20
5	Ammonia Nitrogen	5
6	Total Nitrogen	10
7	Fecal Coliform (MPN/100 ml)	< 100

About Activated Filter Media (AFM):

AFM is manufactured by up-cycling post-consumer green glass bottles in a dedicated factory designed and operated just to produce water filtration media. It is an activated amorphous alumina-silicate with +ve charge organic adsorption [OAD] number greater than 10, the activated hydrophilic surface has cation bridging, hydrogen bonding and entropic interactions with organic molecules. It has high surface –ve electrical charge density Zeta Potential > -70 mV as measured by Kinetic Analyser [Kelvin Probe analysis]. It is a mesoporous media and surface area is1 million M^2/ton.

Advantages of AFM: AFM can be recovered and up cycled for reuse again and again for water filtration, or can be directed into high value uses:

(a) Backwash water requirement reduces by up to 50%.
(b) Increased run phase and reduced back wash could give 15% energy savings.
(c) Reduced chemical consumption, chlorine,
(d) ammonia & flocculants
(e) Expected life expectancy is 5 to 10 yrs.

It also rejects bacteria growing and warm-hole channeling, removes heavy metals, Iron, Manganese & Arsenic from water. It reduces BOD & COD from water, removes organic impurities.

Pilot Trial at Talcher-K:

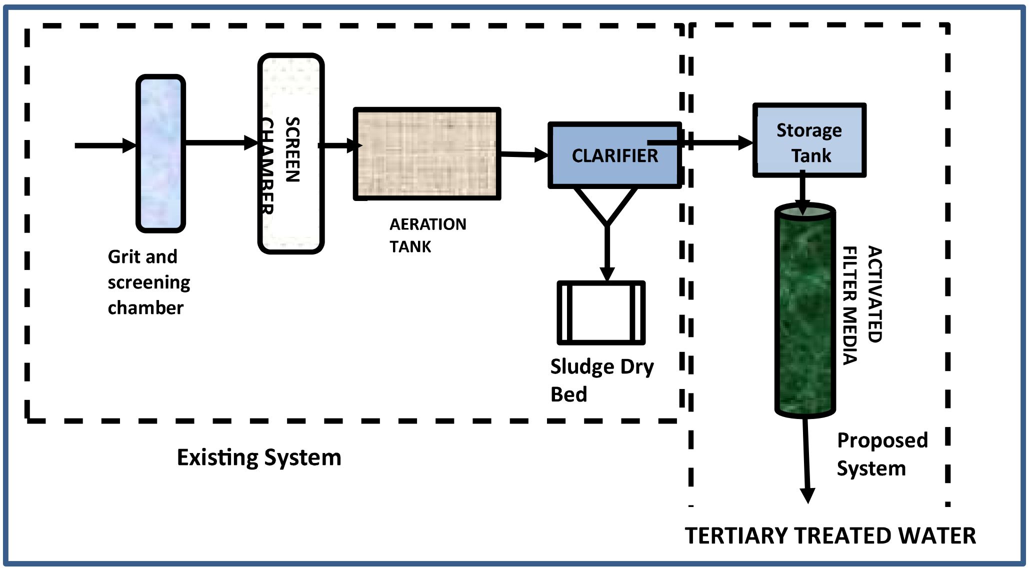
A pilot trial at Talcher-K with 5 M3/hr active filter media was conducted. The outlet parameters were monitored regularly and the data was consolidated and tabulated below.

Result and Discussion:

The results were quite encouraging and the system was compact and suitably retrofitted. BOD and COD were well within the limits. BOD was found to be decreased from 40 ppm to less than 10 ppm, and it was further decreased when ClO2 was dosed. COD came back to below 50 ppm.

Outcomes:

Based on the pilot study it is inferred that there is consistent decrease in BOD, COD, Turbidity, TSS along with ammonical Nitrogen, Total Nitrogen, Phosphate at the outlet of STP by employing Activated Filter Media and the water quality can easily meet the new CTO norms. The new system is under implementation at Talcher (K).



PROPOSED TERTIARY TREATMENT SCHEME IN EXISTING STP OF 4 MLD PLANT AT TALCHER-K

Table-I : Chemical Analysis Data:
Date of Collection:21.03.2017

Pilot plant Performance Data:
Time of Collection : 17:15hrs

S.N.	Parameter	Unit	STP Inlet	STP Outlet	AFM Outlet	AFTER ClO2 Dosing	Clarifier Outlet
1	BOD	mg/ltr	57.6	17.4	8.2	5.7	15.8
2	COD	mg/ltr	124	68	36	26	58
3	Fecal Coliform	(MPN/100ml)	-	1200	ND	-	-
4	Appearance		Dirty	Clear	Clear	Clear	Clear
5	pH		6.9	7.2	7.1	6.9	7.1
6	Conductivity	µs/cm	251	256	280	330	258
7	Turbidity	NTU	87	26	3.4	3.3	22
8	TDS	mg/ltr	135	138	180	215	142
9	TSS	mg/ltr	74	17	2.1	2.4	22
10	P- Alkalinity	mg/ltr as	0	0	0	0	0
11	T-Alkalinity	mg/ltr as	105	120	98	100	92
12	T-Hardness	mg/ltr as	86	86	98	100	128
13	Ca-Hardness	mg/ltr as	61	58	58	59	61
14	Mg- Hardness	mg/ltr as	25	28	33	30	31
15	Chloride	mg/ltr as Cl	64.5	25.5	25.5	80.1	28.2
16	Sulphate	mg/ltr as SO4	15.1	10.5	20.2	21.4	12
17	NH4-Nitrogen	mg/ltr as N	2.23	1.46	0.35	0.35	0.42
18	Total Nitrogen	mg/ltr as N	-	-	-	-	-
19	Silica	mg/ltr as	8.85	9.8	11.3	15.3	9.7
20	Total Iron	mg/ltr as Fe	0.45	0.35	BDL	BDL	0.42
21	Phosphate	mg/ltr as	0.63	0.18	0.12	0.18	0.2

Table-II: ChemicalAnalysisData:
Date ofCollection:09.05.2017

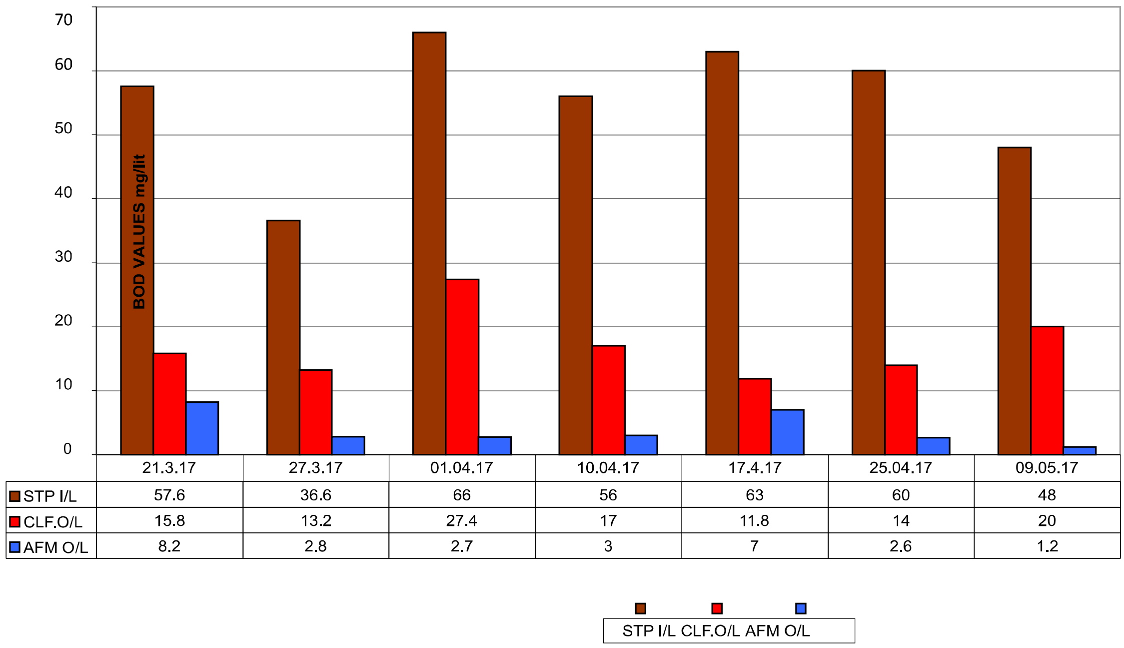
Pilot plant performanceData:
Time of Collection: 10:00hrs

S.N.	Parameter	Unit	STP Inlet	STP Outlet	AFM Outlet	AFTER ClO2 Dosing	Clarifier Outlet
1	BOD	mg/ltr	48	22	1.2	0	20
2	COD	mg/ltr	92	58	10	2	52
3	Fecal	(MPN/100ml)	-	1200	ND	-	-
4	Appearance		Dirty	Clear	Clear	Clear	Clear
5	pH		7.1	7.3	7.0	6.9	7.3
6	Conductivity	µs/cm	254	278	288	292	279
7	Turbidity	NTU	34	12.2	0.8	0.8	10
8	TDS	mg/ltr	165	181	187	190	181
9	TSS	mg/ltr	32	8	BDL	BDL	12
10	P- Alkalinity	mg/ltr as	0	0	0	0	0
11	T-Alkalinity	mg/ltr as	92	98	85	82	98
12	T-Hardness	mg/ltr as	70	78	80	81	84
13	Ca-Hardness	mg/ltr as	48	55	57	58	58
14	Mg- Hardness	mg/ltr as	22	23	23	23	26
15	Chloride	mg/ltr as Cl	22.4	16.8	18.1	30.2	18.2
16	Sulphate	mg/ltr as SO4	18.6	13.9	12.8	12.6	14.8
17	NH4-Nitrogen	mg/ltr as N	6.4	3.8	BDL	BDL	3.6
18	Total	mg/ltr as N	11.5	6.4	BDL	BDL	6.2
19	Silica	mg/ltr as	10.2	10.2	10.9	10.8	10.3
20	Total Iron	mg/ltr as Fe	0.22	0.32	BDL	BDL	0.32
21	Phosphate	mg/ltr as	1.4	0.48	BDL	BDL	0.48

Table: III Comparison of critical parameters at different intervals:

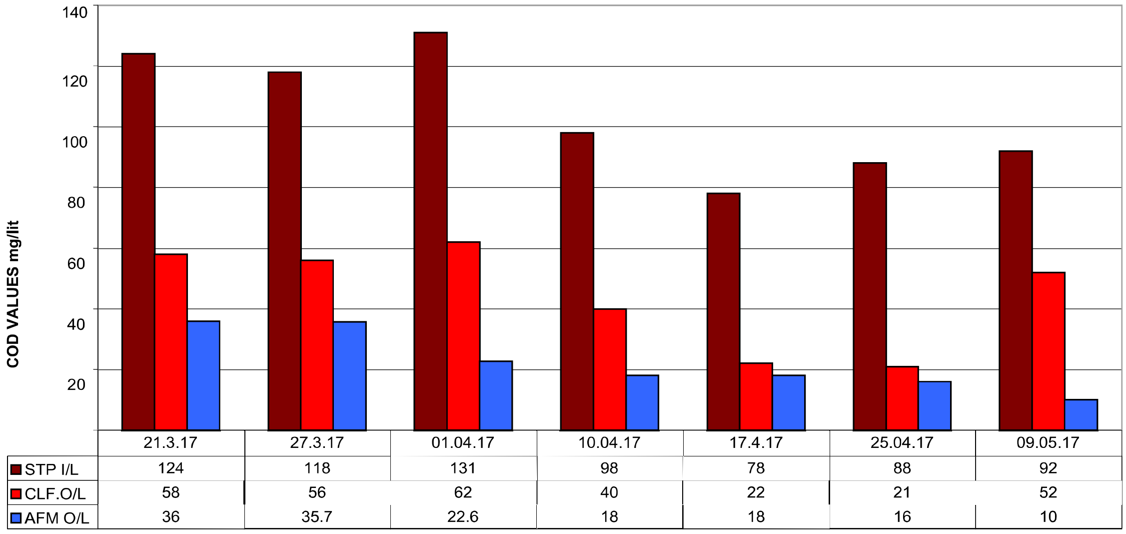
Date	Parameter	STP I/L	STP O/L	AFM O/L	after ClO2 dosing	CLF. O/L
21.03.2017	BOD	57.6	17.4	8.2	5.7	15.8
	COD	124	68	36	26	58
	TURBIDITY	87	26	3.4	3.3	22
	TSS	74	17	2.1	2.4	22
	NH4-	2.23	1.46	0.35	0.35	0.42
	PHOSPHATE	0.63	0.18	0.12	0.18	0.2
01.04.2017	BOD	66	29	2.7	1.8	27.4
	COD	131	73	22.6	16.8	62
	TURBIDITY	78	12	2.6	1.8	14
	TSS	69	12.4	2.6	2.5	13
	NH4-	1.74	1.28	BDL	BDL	0.92
	PHOSPHATE	0.82	0.26	BDL	BDL	0.26
10.04.2017	BOD	56	17	3	1.3	17
	COD	98	46	18	12	40
	TURBIDITY	62	12	2.4	2	10
	TSS	112	18	1.8	1.5	20
	NH4-	4.6	2.2	BDL	BDL	2.0
	PHOSPHATE	0.82	0.26	BDL	BDL	0.26
25.04.2017	BOD	60	18	2.6	0	14
	COD	88	46	16	8	21
	TURBIDITY	36	8.4	1.2	1.1	9.2
	TSS	46	5	BDL	BDL	5
	NH4-	4.2	2.8	BDL	BDL	3.4
	PHOSPHATE	0.8	0.2	BDL	BDL	0.26
09.05.2017	BOD	48	22	1.2	0	20
	COD	92	58	10	2	52
	TURBIDITY	34	12.2	0.8	0.8	10
	TSS	32	8	BDL	BDL	12
	NH4-	6.4	3.8	BDL	BDL	3.6
	Total	11.5	6.4	BDL	BDL	6.2
	PHOSPHATE	1.4	0.48	BDL	BDL	0.48

BOD VAUES of AFM PILOT TRIAL at TALCHER KANIHA STP



	21.3.17	27.3.17	01.04.17	10.04.17	17.4.17	25.04.17	09.05.17
STP I/L	57.6	36.6	66	56	63	60	48
CLF.O/L	15.8	13.2	27.4	17	11.8	14	20
AFM O/L	8.2	2.8	2.7	3	7	2.6	1.2

COD VALUES OF AFM PILOT TRIAL at TALCHER KANIHA STP



	21.3.17	27.3.17	01.04.17	10.04.17	17.4.17	25.04.17	09.05.17
STP I/L	124	118	131	98	78	88	92
CLF.O/L	58	56	62	40	22	21	52
AFM O/L	36	35.7	22.6	18	18	16	10

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Case Study: 6

Research on application dry ion exchange resin to mitigate of high acidity and foaming problem of FRF at Simhadri &Talcher-K

Introduction:

Fire resistant phosphate ester fluids (FRF), commonly used in electrohydraulic control (EHC) systems of steam turbines, are susceptible to hydrolytic breakdown in the presence of water heat, and mechanical impurities. Preventive maintenance of phosphate ester fluids used in EHC systems of steam turbines requires maintaining particulate contamination level, water, acid number (AN) and resistivity within OEM requirements.

The hydrolytic breakdown of the phosphate ester fluid leads to the formation of acidic compounds. To overcome this, conditioning agents which maintain acidity level within acceptable limits are used. One such conditioning agents, Fuller's earth is commonly employed to scavenge acidic compounds formed in the fluid. This works in a side loop, and accumulation of water is minimized through a vapor extraction fan.

Literature shows that while these acid scavengers are effective in removing acids when acid levels are not too high, these are prone/susceptible for leaching metallic impurities such as Ca & Mg with service time. These extractable metal impurities combine with hydrolysis breakdown products to form soaps or salts (Experienced in Simhadri Unit #2 as shown in Case Study-2).

An alternate media, ion exchange resin possesses higher capacity to exchange impurities, like acidity, from FRF. Moreover, they do not release metallic impurities in the medium. However, due to presence of inherent moisture in the resin they release more moisture in the FRF which requires vacuum treatment to dehydrate the fluid.

Various factors that influence the service life and in-service condition of the fluid are: Operating temperature, purification system, ingress of metallic or particulate contaminants and water, FRF tank vapor extraction facility, type of fluid used, and O&M practices.

Problem faced at site:

At Simhadri and Talcher-K FRF was having very high acidity beyond specification limit. There was report of foaming also associated with high moisture, that could not be controlled with the existing process installed. The case was referred to NETRA to find a lasting solution.

Lab Study:

In search of an alternative and effective technology an experiment was undertaken at NETRA using different media and high acidity FRF sample from different stations. The result of the three media is given bellow:

Table-1: Lab scale experimental data

	FRF passed through resin column			FRF passed through activated alumina			FRF passed through Fullers Earth		
	M	A	V	M	A	V	M	A	V
1	1514	0.08	45.0	1222	0.05	46.8	1124	0.247	46.2
2	2091	0.08	43.8	1128	0.05	45.3	472	0.360	47.6
3	2255	0.08	44.6	1123	0.05	44.8	703	0.395	46.8
4	2648	0.08	45.5	1353	0.05	45.1	1094	0.403	45.4
5	1665	0.08	45.0	1380	0.05	44.2	832	0.404	45.3
6	769	0.08	44.5	Vacuum Dehydration (at 50° C & 1 Torr)					
7	1902	0.08	Vacuum dehydration (at 25 °C & 1 Torr)						
8	519	0.08	Vacuum Dehydration (at 25 °C & 10-3 Torr)						

M = Moisture as ppm, A = Acidity as mg KOH/g of oil, V = Viscosity as cst at 40 °C

Sample FRF initial data: Moisture: 1094, Acidity: 0.59, Viscosity: 48.04

The adjoining picture depicts the Laboratory set up used for the trial, it is fitted with a resin column, a heater with magnetic stirrer and vacuum pump to remove water vapour. The column is filled with the different media and contaminated FRF sample was added from the top. Reconditioned oil was collected from the bottom for analysis.

Results & Discussions: From the lab study, it is found that special ion exchange resin is effective in reducing acidity from FRF to <0.1mg KOH/g of oil. However, since resin was used in moist condition the conditioned FRF was found to have high moisture (~2000 ppm), which was not acceptable.

To tackle this problem ion exchange resin was oven-dried at 50-60 ^{0}C and used in a column for passing FRF. This resulted in significant reduction of moisture in treated oil (from 2000 ppm to about 500 ppm). But this procedure of pre-conditioning the resin for removal of moisture was found to decrease the capacity of resin to remove acidity in subsequent processes. It was hypothesized that the high temperature treatment of resin might have damaged the internal structure of resin.

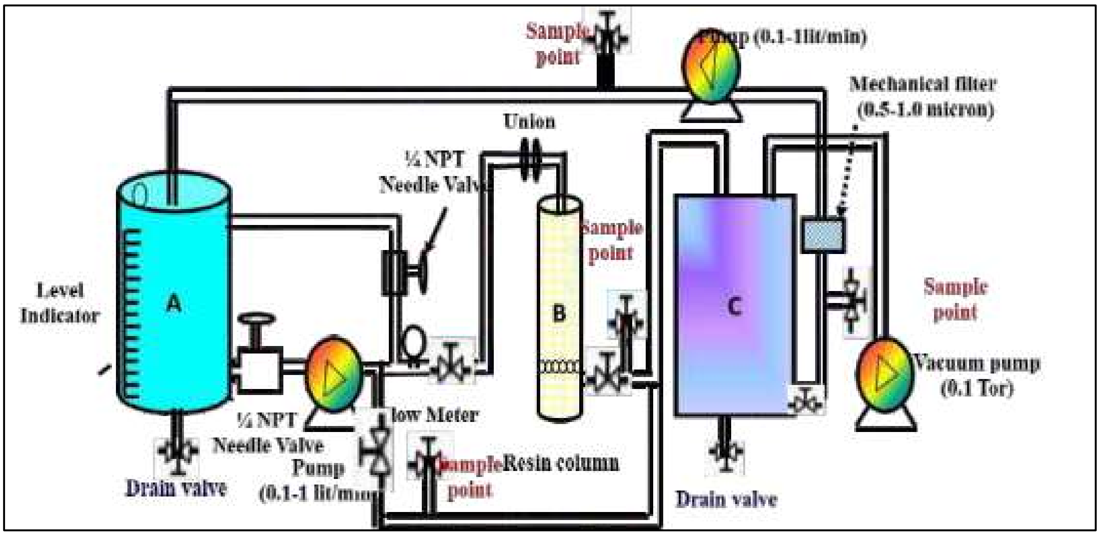
To tackle the above problem, a new method of resin conditioning was developed. The resin was subjected to vacuum drying at lower temperature of about 40 ^{0}C. This modification was found to be effective to reduce both moisture and acidity at the same time, without any other adverse effect.

Development of Pilot set up: Based upon the above research a medium size pilot plant (60 Lts/hr Capacity) was fabricated as shown in Fig-3 (Schematic) and Fig-4 at NETRA. At stations the temperature of the fluid entering the fuller's earth filter is the system temperature which is around 50 ^{o}C. Another set of design of Experiment (DOE) was planned with this pilot set up re-validating all the all the factors and their interactions, at a bigger scale.

Result and Discussion: The pilot study data are tabulated in Table-2. Some of the observations at lab scale were reconfirmed. The acidity of FRF oil was reduced to 0.17 with fuller's earth filter with moisture of 1200 ppm. However, this set up was unable to reduce acidity any further. The most effective approach was found to be resin based with resin dried under vac, and with system vacuum of 0.01 torr (Table-3, Sl no 5). The configuration gave fully acceptable result of acidity of 0.08, moisture of less than 1000 ppm, and took only three-cycle to get the result. To verify all these above observations beyond any doubt, another higher capacity portable pilot set up of capacity 200 Lt/Hr was tried with samples from Vindhyachal. This trial also delivered similar result. The process is now fully validated for application at site.

Table-2

S N	Treatment method	Acidity (mg KOH/g of oil	Moisture
1	FRF Sample as such-Farakka-#4	0.53	950
2	FRF passed through fuller's earth	0.17	1200
3	FRF passed through resin column (initial reading)	0.08	6975
4	FRF passes through resin column after dried at 60°C with system vac 0.1 torr). Resin was dried without vacuum.	0.08	5418
5	FRF passes through resin column (preheated at 50°C with resin vacuum dehydration-40 torr) (3 Cycles). System vacuum was 0.01 torr.	0.08	<1000



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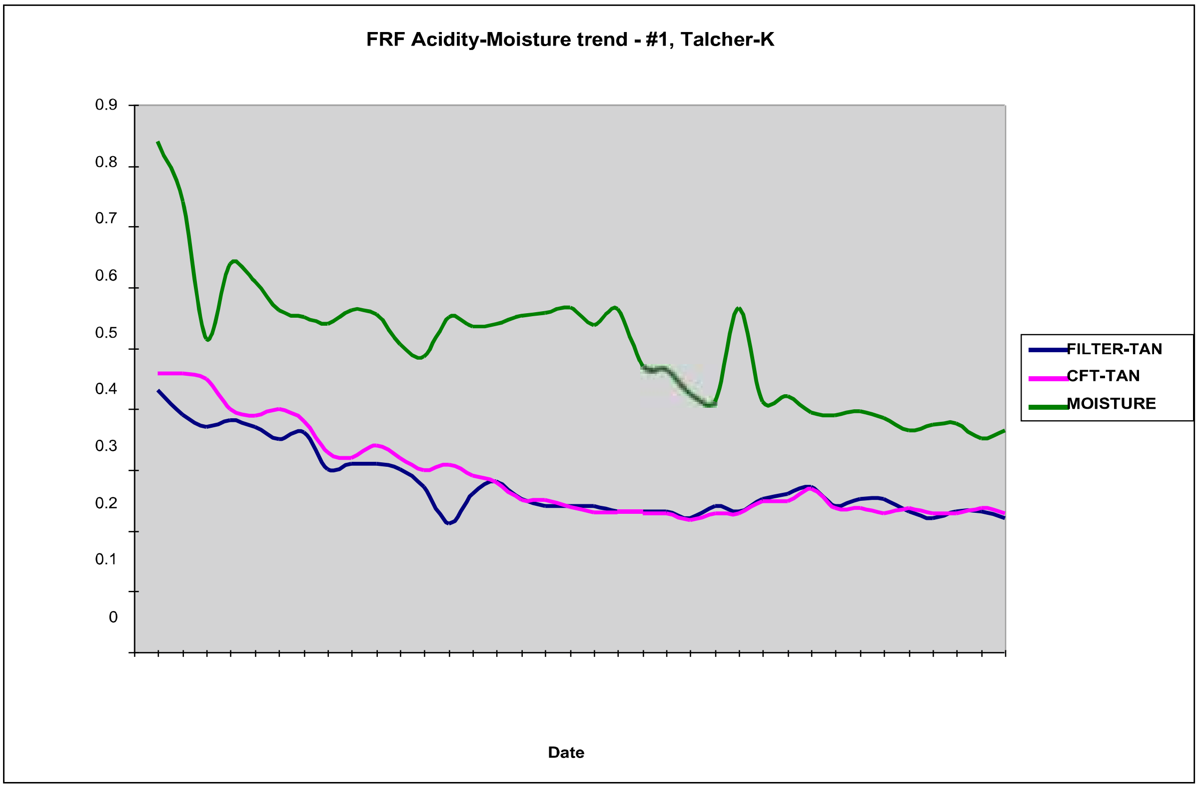
On site Trial: Talcher-K

Problem Description: FRF Acidity in Unit-1 was continuing at 0.46 mg KOH/g of oil, even after repeated replacement of fuller's earth. It was found on visit to Talcher-K.

Planning: Six numbers of cartridge made up of SS metallurgy were fabricated from a vendor. Dry resin (A-2X-MP Tulsion WBA resin) was procured and filled in the cartridges. These cartridges were replaced in place of fuller's earth in the side stream.

Results & Discussion: Trial started on 08/09/2015 and intermittent monitoring of acidity and moisture were being continued for 3 days. After observing downward trend on both acidity and moisture, the process was handed over to site for further monitoring. The data are tabulated in Table-3 & 4. The acidity kept on decreasing till April 2016 and reached a value of 0.26 then started increasing indicating exhaustion of the cartridges in service and these were replaced with fresh cartridges. It took about six months for replacement of cartridges. Ultimately the acidity was maintained at 0.21 and moisture at approx. 350 ppm. Similarly Unit-2 of Talcher-K also taken up for improvement and similar results were obtained.

Date	Time	CFT-TAN	CFT-Moisture	Filter O/L	Filter O/L -Moisture
13.10.2015	1000	0.31	534	0.21	554
21.10.2015	1000	0.24	567	0.24	595
27.10.2015	1000	0.23	463	0.23	482
02.11.2015	1000	0.26	422	0.25	419
10.11.2015	1000	0.25	386	0.23	406
17.11.2015	1000	---	---	0.23	272
09.02.2016	1000	---	---	0.20	831
23.02.2016	1000	---	---	0.20	708
01.03.2016	1000	---	---	0.21	789
08.03.016	1000	---	---	0.24	715
15.03.2016	1000	---	---	0.27	760
22.03.2016	1000	---	---	0.26	765
29.03.2016	1000	---	---	0.33	889
01.04.2016	1000	---	---	0.32	1008
06.04.2016	1000	---	---	0.32	986
12.04.2016	1000	---	---	0.33	814
19.04.2016	1000	**Dry Resin**		0.25	968


FRF Acidity-Moisture trend - #1, Talcher-K
Acidity(mgKOH/goil)-Moisture-ppm
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Date
FILTER-TAN
CFT-TAN
MOISTURE

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On site Trial: Simhadri

Problem Description

At Simhadri, unit-2 FRF was facing sudden increase in acidity along with foaming of about 200 mm above Control Fluid Tank during Nov-2015. Foaming lead to severe hunting problem threatening unit trips and site had to bypass the regeneration system to avoid unit trip.

Remedial Measure: At Simhadri, the system was having basket type of cartridges where directly dry resin could be filled. This also gave similar results and acidity was brought down to 0.15 mg KOH/g of oil and moisture to below 1000 ppm. Here a new observation was that the resin could reduce the foaming behavior of FRF and the problem of pressure hunting was eliminated. Thus the risk of sudden tripping of units is eliminated. It may be noted that fullers earth leaches out Calcium and Magnesium which cause soap formation that led to foaming.

Outcome:

- A new and more effective process was developed in comparison to the existing fullers earth based system
- The FRF oil could be reconditioned to its original value so use of fresh oil was completely avoided.
- A new learning and intrinsic motivation for all the persons involved.

FRF conditioning Baskets

FRF Tank foaming

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CaseStudy: 7

“Molybdate based chemical treatment to prevent pitting corrosion of SS-304 condenser in high chloride environment at Faridabad"

Introduction:

It is known that SS-304, the metallurgy of choice for condenser tubes, is susceptible to pitting corrosion in the environment of high chloride. The present engineering limit is 570 ppm as CaCO3 (200 ppm as Cl^-). We faced a problem of high chloride at Faridabad gas station where due to upstream contamination of the Yamuna river. This threatened integrity of condenser tubes as Chloride in the circulating water approached more 2000 ppm as $CaCO_3$ with a COC of 4 to 5.

Chloride ion limits for different steel grades:
SS 304- 200 ppm as Cl^-
SS 316- 1000
Duplex steel- max 3600

In this situation, to replace present system with any of the above suitable metallurgy would require a complete re-installation of the condenser and tubes and also its suspension system which would have posed a major engineering challenge along with very high cost and time. The steam-water cycle also started getting contaminated with cooling water due to condenser tube seepage.

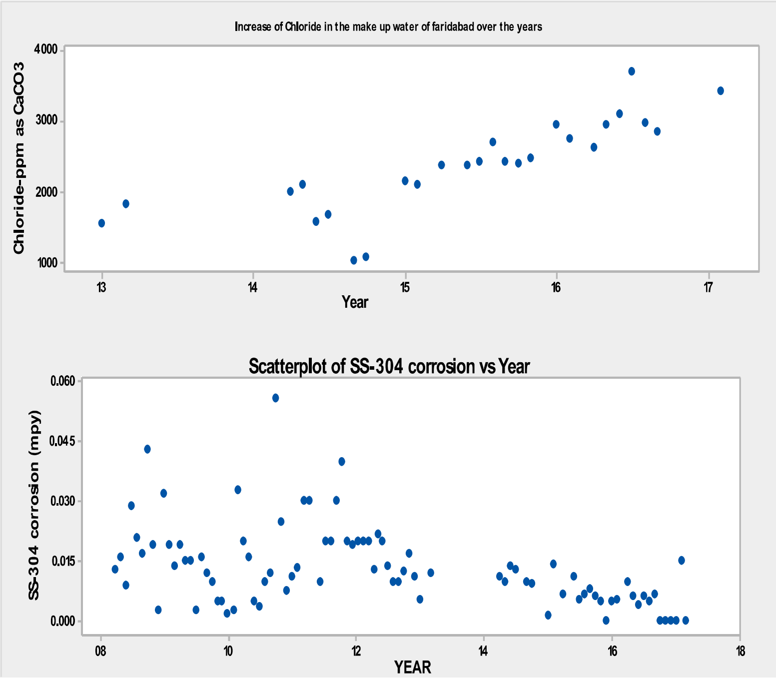
NETRA undertook a research project to mitigate the situation. Extensive laboratory trials with various chemicals and with Potentio-Dynamic study revealed that Molybdate has capability to mitigate the pitting corrosion.

Molybdate treatment started with 4 to 6 ppm as MoO_4 in 2012 after doing thorough evaluation of condenser tubes with eddy current. **The Mechanism:**

The chromium in SS creates a thin oxide layer on the surface and protects the substrate from corrosion. Excessive Chloride breaks the passivated layer and facilitates pitting corrosion.

Molybdate is an anodic inhibitor. Scanning electron microscope (SEM) microprobe studies of mild steel coupons pitted in chloride solution showed molybdate migration to the center of the pit. Very little molybdenum was found outside the pit. This precipitation of molybdate in the most active area of the pit can lead to inhibition of the pitting process under the right conditions. One possible mechanism for this precipitation is that the molybdate ions adsorb on the surface of the iron and form a complex with the ferrous (Fe^{+2}) ions. This complex is not stable, but in the presence of dissolved oxygen the ferrous ions oxidize to ferric (Fe^{+3}) ions which form an insoluble protective barrier of ferric molybdate. This insolubility extends over a fairly wide range of pH (5.5 - 8.5) and seems to be relatively insensitive to temperature. This mechanism also helps explain why molybdate (even at high concentrations) requires the presence of an oxidizing agent to be effective in corrosion protection of steels.

Data Analysis The data was collected from 2012 to 2017 on tube leaks, corrosion, chloride, and COC, contamination to steam water system, and eddy current study both before after the study initiated. The following are the observation:



1. Lowering of corrosion rate of SS -304 condenser tubes in spite of higher chloride in CW water due to the effect of Molybdate treatment achieved after even five years of operation.

2. ACC and Sodium at CEP discharge that there is no evidence of cooling water ingress due to condenser tube failure.

3. The corrosion coupon study shows that the corrosion rate of SS and MS is under limits.

4. Eddy current study conducted by the site in 2014 also reveals that there is no deterioration in tube thickness.

Cumulative Condenser Tube Plug:
2007 to 2011 : 195 nos
2014: 207
After 2014: additional 4 (after eddy current testing)

Cycle Chemistry improvement:
Dec 2011: CEP Na 3.86 ppb
June 2015: it is 0.087 ppb

		MS COUPON	SS COUPON	Deposition Rate
S.No	Month	Corrosion Rate Limit (2.0mpy)	Corrosion Rate Limit (0.100mpy)	<15mg/dm2/ Year
1	Apr-16	0.1500	0.0100	3.5
2	May-16	0.9590	0.0064	6.47
3	Jun-16	1.0520	0.0040	5.2
4	Jul-16	0.5200	0.0064	3.36
5	Aug-16	0.8600	0.0052	4.09
6	Sep-16	0.6200	0.0069	3.64
7	Oct-16	0.0000	0.0000	0.0
8	Nov-16	0.0000	0.0000	0.00
9	Dec-16	0.0000	0.0000	0.00
10	Jan-17	0.0000	0.0000	0.0
11	Feb-17	1.1300	0.0150	9.36
12	Mar-17	1.1100	0.0000	4.37
Avg.		0.533	0.0045	3.33

Outcome: A technology is validated in NTPC that can protect SS 304 metallurgy in high chloride environment. This method is also applicable in case of condenser where unit remain under shut down most of the time, as the technology can protect in stagnant water also.

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Case Study: 8

Condensate Polishing Unit Performance Improvement at Ramagundam

Introduction:

In many of the NTPC stations CPU performance has decreased in terms of Output Between Regeneration (OBR) and premature slippage of chloride and sodium due to improper resin separation during regeneration (cross contamination).

At Ramagundam, Stage-II CPU units were not performing to operate at design OBR. In fact, they were required to operate for 15 days' cycle with the expected OBR of 2 lac M^3. In Stage-II CPU resins, the OBR reduced to 60000 M3 (an approx. 30 % design OBR) due to reduction in regeneration process efficiency. This reduction in OBR increased the number of regeneration requirements and thus increased the water requirement, chemical consumption and higher operator engagement.

The Existing Regeneration Process:

The Regeneration system consist of three number of vessels used for resin separation and regeneration. After back wash, the vessel is subjected to 16% caustic to float out anion resin from cation. However, it was observed that the impurities mainly chloride ions, removed due to the effect of high concentration of caustic was still affecting anion resin by way of reverse contamination and which would later on cause for early chloride seepage during service cycle. Complete removal of these impurities was necessary before going for separation of resins to avoid this phenomenon.

Improvement done in the Process:

After some laboratory simulation, an innovative additional step was introduced in the regeneration process. During regeneration, 6 % NaOH (2 BV) to be injected at the flow rate of 100 lit/min ± 10% for 50±5 min. The temperature of 6% NaOH was maintained at 50±5 °C. The regeneration was carried out in coflow (downflow) regeneration technique. After regeneration 1 BV of DM water (2500 Lts) was passed with the same flow and in same direction. This additional step ensured that all chloride ion from anion resin would go out before starting separation method with higher concentration of NaOH, and there would be any high concentration of chloride impurities that could re-contaminate the anion resin again. The cation resin was double regenerated to bring back it into H-ion form.

Outcome:

- CPU service cycle improved from 8 days to 12 days. No of regeneration per year reduced from 45 to 32 per vessel. Each regeneration requires an approx. 250-300 M3 water. Water saving @ 13 x 350 M3=4550 M3. Cost of treated water @ 45 /M3 will be 2,04,750 per cycle.
- Net Water saving for all 3 vessels per annum = 13650 M3 while cost saving = 6,14,250/-. The above method is in operation since Oct 2016.
- Overall water saving = 34125 M3 while cost saving = Rs. 15,35,625/-

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The author possesses ~35 years' experience in Power Plant Chemistry and has experience in commissioning of 500 MW units, O&M of 2000 MW stations. He also worked as assessor of Business Excellence (EFQM), trained Six Sigma 'Black Belt', and ISO lead auditor. He is currently finalizing the development of 'ChemAnalyser' – a smart software for Power Plant Chemistry. Presently his focus areas are Water Technology, Chemistry readiness for AUSC, validation of non-chemical scale-inhibition method for cooling water system. He has developed a scheme for ICCP of IDCT and a copyright for developing method of selection and specification of coating and painting for power plants.

H. K. Sikri, M.Sc. (Chem), M.Tech. (Chem), IIT Delhi.

Joined NTPC in 1988 and worked in the area of water / boiler chemistry, environmental monitoring and analysis, boiler chemical cleaning, Coal quality monitoring etc. Worked in the efficiency improvement area of the ESP's to reduce the particulate emissions. He was on deputation to Ministry of Power from April 2011 to April 2018, looking after the International Cooperation and Climate Change activities. He was a part of the team which carried out an intense exercise to finalize the Intended Nationally Determined Contributions (INDCs) pertaining to Ministry of Power. The inputs from Ministry of Power were used as the basis for formulating India's INDCs submitted to UNFCCC. As a member of the team lead by Ministry of Environment, Forests and Climate Change, he has also participated in the International Climate Change negotiations under UNFCCC. Presently posted in NTPC- NETRA he is looking after the Water Technology division focusing on non chemical innovative and disruptive technologies.

R Nagarajan, M.Sc. (Chem)

Joined NTPC in 1988 and worked in R&D in different area and has 28 yrs. experience in the field of corrosion, scale problems related to condenser, boiler and turbine of Low and high pressure system. He has involved in many condenser and boiler acid cleaning of both NTPC and other SEB units.

In the area of water chemistry, he is involved in condition monitoring of ion exchange resins both DM plant and Condensate Polishing Units, optimization of steam water chemistry, RO plant performance improvement, Water Balance study and specific water consumption of NTPC stations.

He has developed a patented novel methodology with an innovative approach of measuring colloidal silica using micro wave digestion system. A ChemAnalyzer, online monitoring of water steam cycle has been developed and deployed in Talcher-K and Sipat stations.

Recently, he has introduced resin based cartridge system to solve high acidity and moisture problem besides reduction in foaming issue of Fire Resistant Fluid (Control fluid) used in Turbine governing system.

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	**K Kannan, B.Sc. (Chem)** Joined NTPC in 1983 and worked in R&D in different area and has 35yrs experience in the field of Condition monitoring of DM plant, CPU Ion exchange resins and ACF. He has carried out several studies on rejuvenation of fouled resins, residual life assessment of ion exchange resins. He has been involved in DM plant & pretreatment performance optimization.

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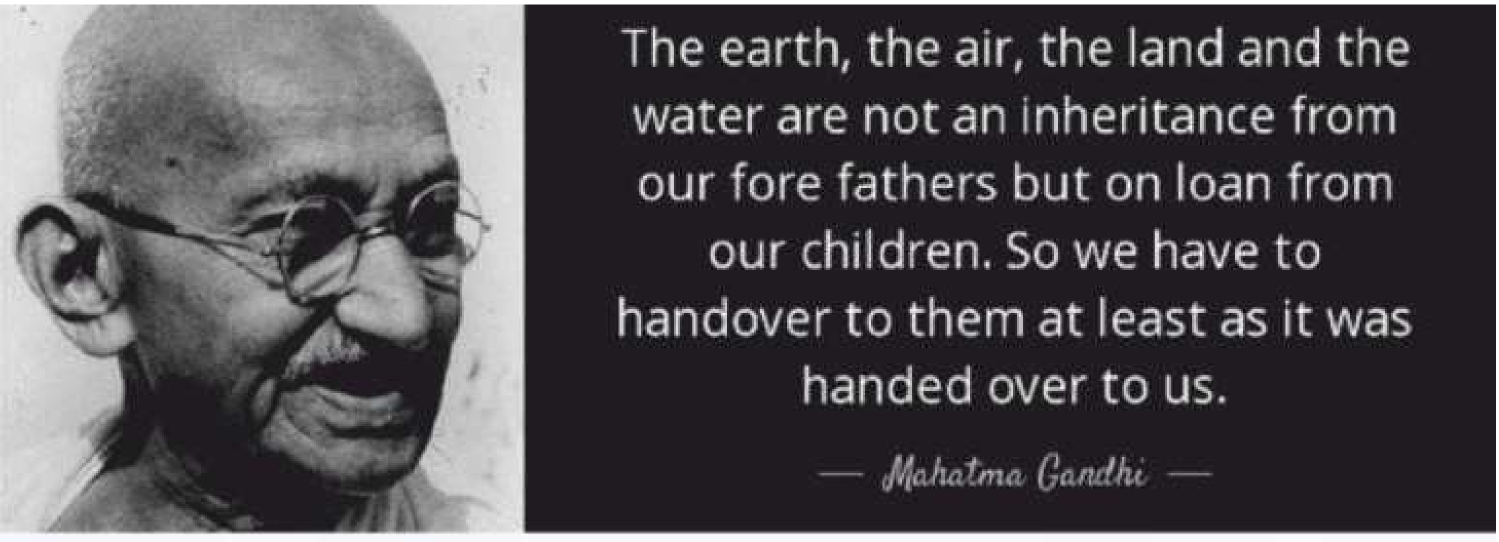
Disclaimer

NTPC Power stations have been facing various kinds of issues with respect to quality of water in the demineralization and circulating water systems in the recent past. Systematic data collection and analysis have unearthed root causes after which remedial actions along with customised technological interventions have been provided by NETRA, some of these issues are described here as Case Studies in the present book, however, it is suggested not to straight away copy the remedial actions in plants having similar issues as every plant may have some other specific issues which also need to be addressed.



> The earth, the air, the land and the water are not an inheritance from our fore fathers but on loan from our children. So we have to handover to them at least as it was handed over to us.
>
> — Mahatma Gandhi —

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