Use of Municipality Sewage Treated water as an alternate water source for Power plants

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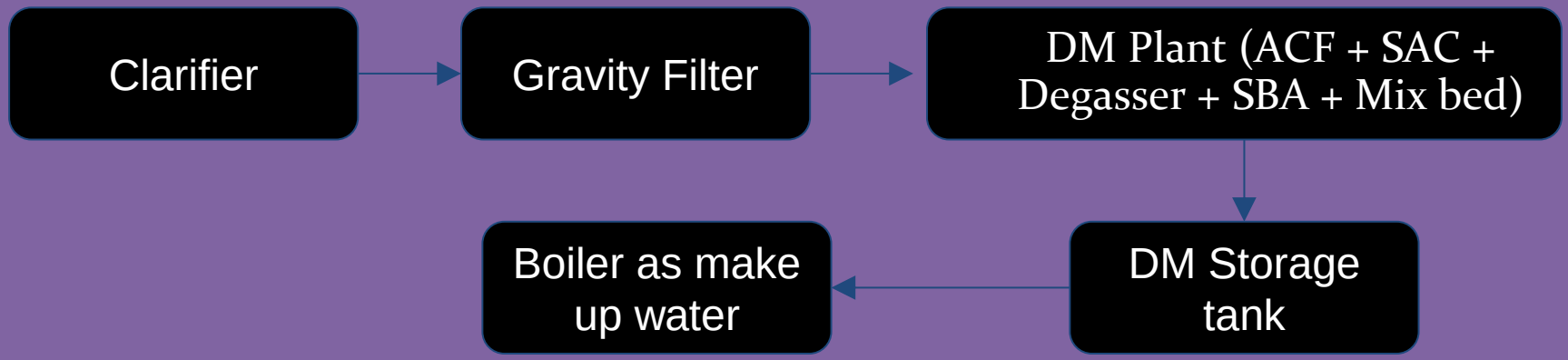
About the author

- M.Sc. (Chemistry) from IIT Delhi & Ph.D. in Chemistry
- Worked in NTPC from 1984 to 2010
- Worked as in-charge of Chemistry & Environment departments of IPGCL-PPCL, New Delhi from 2010 till superannuation in January 2021
- 35+ years experience in Gas as well as Coal based thermal power plants
- Work experience in the field of DM plant, UF plant, RO-DM plant, PT plant, Boiler water Chemistry, cooling water treatment, pre & post chemical cleaning of boilers & condensers, power plant related environmental problems, commissioning of thermal & gas power plants from chemistry side, erection & commissioning DM plant, UF plant & RO-DM plant

Outline

- Makeup water treatment evolution
- Increasing importance of Sewage/waste water treatment
- Problems associated with STP water
- Technology adopted at PPCL to overcome these problems

The Old Days



- More acid and caustic usage due to frequent regenerations.
- No control on TOC in DM water

Makeup Water Treatment Guidelines

As Per EPRI, below are established guidelines for makeup water system :

Parameter	Limit
Sodium	< 3 ppb
Silica	< 10 ppb
Chloride	< 3 ppb
Sulfate	< 3 ppb
TOC	< 300 ppb

Present day Technology

Step 1	Step 2	Step 3
Primary filtration (often micro- or ultra-filtration)	Reverse osmosis (single-pass or two-pass)	Polishing either with ion exchangeable mixed-bed or by electro deionization (EDI)

Factors that influenced use of STP water

- Gazette Notification of Ministry of Power regarding Revised Tariff Policy dated 28th January 2016
- Consent to use fresh river water is not granted to industries including the existing plants located within 50 km radius
- With the growth in India's demand for freshwater, the production of wastewater increases exponentially too
- Disposal of untreated wastewater into already limited freshwater resources – thereby further exacerbating scarcity conditions

More factors influencing the use of STP water

- As per government initiative under Swachh Bharat Abhiyan State Municipal Corporations are encouraged to install STP to treat their sewage water before discharging in river or to use this STP water for industries or non potable water usage
- With improved technology and dramatic reduction in cost, treating sewage water to be used for non-potable purposes is becoming an increasingly viable and practical solution to the looming freshwater crisis

Problems associated with STP water

- Main problem: STP water is highly contaminated
- Most important water quality characteristics are
  - Total Suspended Solids (TSS)
  - Total Dissolved Solids (TDS)
  - Biological Oxygen Demand (BOD)
  - Chemical Oxygen Demand (COD)
  - Nutrients (Nitrates and Phosphates)
- Also, STP water is highly contaminated with ammonical nitrogen, so liquid chlorine which is normally used as oxidizing biocide at pre treatment stage or for condenser cooling water system is not effective.

Problems associated with STP water

- **Inconsistent Quality of Sewage-Treated Water**
  - **Variable Water Quality**: The quality of sewage-treated water can be highly variable due to
    - Differences in sewage treatment processes,
    - Extent of industrial contamination,
    - Seasonal fluctuations in water quality.
  - This variability can affect the efficiency of demineralization and the long-term performance of the treatment systems in power plants.

Problems associated with STP water

- **Inadequate Sewage Treatment**:
  - Treated water may not meet required quality standards for further use in power plants.
  - The absence of comprehensive sewage treatment leads to a high concentration of organic matter and pathogens in the water.
- **Slower Adoption of Advanced Treatment Technologies**:
  - Some power plants are not equipped with the advanced technologies such as reverse osmosis or ultra filtration plant which are essential to make demineralized water suitable for power plants

Typical Chemical analysis of sewage treated water

Parameter	Analysis Value
pH	7.5
Conductivity	1000-1600µs/cm
Turbidity (Physical impurity & debris as well)	50-300 NTU
BOD	45-70 ppm
COD	150-350 ppm
Total Organic Carbon (TOC)	52-67 ppm
$KMnO_4$ No.	90-120 ppm
Chlorine Demand	120-210 ppm

Typical Microbiological Analysis of Sewage Treated Water

Parameter	Analysis value
Total Bacteriological Count	5.0 X 10^6 counts/ml
Total Fungal Count	10 counts/ml
Acid Producing Bacteria	>1600/100ml
Nitrifying Bacteria	20/100 ml
De Nitrifying Bacteria	5/100 ml
Sulphate Reducing Bacteria	> 1600/100ml

TOC problem in STP water

- Sewage water contains a lot of Total Organic Carbon (TOC) as it carries domestic waste, industrial waste and Municipal untreated sewage on its journey
- High pressure boiler requires high purity feed water to limit the effects of Corrosion and deposits that damage steam circuits
- EPRI has also laid a limit of 100 ppb for TOC in boiler feed water

Problem of TOC with old Technology

- Water doesn't clarify upto acceptable level even after enhanced dose rate of Chlorine, PAC/Alum & Polyelectrolyte
- DM water produced with normal pre-treatment:
  - has high TOC in the range of 2.2-3.1 ppm (against the desired limit of 100 ppb as per EPRI guidelines)
  - Has high on line conductivity: 0.4-0.5 µs/cm (desired<0.2 µ s/cm)

TOC in water at Different Stages

- Raw water 19.88 ppm
- Pre-treatment clarifier 16.25 ppm
- ACF outlet 11.45 ppm
- DM plant output 3.1 ppm

EPRI Recommendations

For Main and Reheat Steam Chemistry for Once Through Boilers

Parameter	Target
Cation Conductivity, µS/cm	≤0.15
Silica, ppb	≤10
Sodium, ppb	≤2
Chloride, ppb	≤2
Sulfate, ppb	≤2
TOC, ppb	≤100

Effect of TOC in high pressure boiler

- TOC, the most common forms of organics are characterized in the form of complex acids
- Thermal decomposition of natural or synthetic substances entering the feed water circuits with make up water results in
  - acid formation
  - decrease in pH
  - foaming of water
  - boiler damage as it reaches super heater
- TOC decomposes into organic acids and CO_2, consequently increasing ACC of the steam
- Low pH conditions can cause pitting, corrosion fatigue and stress corrosion cracking problems.

Secondary problems related to High TOC in DM make up water

- Rise in DM water conductivity upon storage in DM storage tank (1.5-4.0 µs/cm upon storage for a week's time)
- Lowering of boiler water pH to 8.5 or below
- Increased ACC of Condensate & Steam samples

Initiatives at PPCL

- Installation of a 330MW gas based power plant near Pragati Maidan, Delhi in 2003 that uses sewage treated water for production of highly purified de-mineralized water & condenser cooling water
- At its planning and development stage, PPCL was denied a freshwater linkage but was given the option to use two 10 MLD-each STPs built atop nearby nullahs which are just 1 and 3 kilometers away

Initiatives at PPCL

- STP treats water to the secondary level with output parameters of BOD <10, COD < 25-30 and TSS <15
- Approximately 15 MLD of STW is pumped to the PPCL power plant where it undergoes lime-softening treatment
- The bulk of the water is utilized in PPCL plant at lime softening level of treatment
- Only a small portion of softened water is further treated for production of DM water using modern techniques
- Another gas based power plant of 1500MW which uses sewage water from Rithala STP has been commissioned by PPCL at Bawana in 2010

Modern Techniques that influenced this Transformation

- Modern filtration systems like micro & ultra filtration systems without clarifiers can often provide the necessary pre-treatment ahead of RO
- RO can remove 99+ percent of the dissolved ions in the water
- Polishing devices such as exchangeable mixed-bed or EDI operate very well with RO-treated influent

Micro- and Ultra- filtration

- Micro and ultra filtration (MF and UF) mechanically remove fine particulates
- MF filtering range: 0.05 to 5 microns
- UF filtering range: 0.005 to 0.1 microns
- While several designs are available, most if not all utilize hollow fiber membranes to filter particulates

Primary Dissolved Solids Removal by RO

- Clarifiers/filters, micro filters, and ultra filters remove suspended solids, but dissolved solids remain
- Prior to commercial development of RO units, ion exchange resins were exclusively utilized to remove the dissolved ions necessary to produce high purity water
- RO is, of course, a membrane process. It is quite reliable if the RO influent has been properly pre-treated, particularly to remove suspended solids.

Two-Pass RO

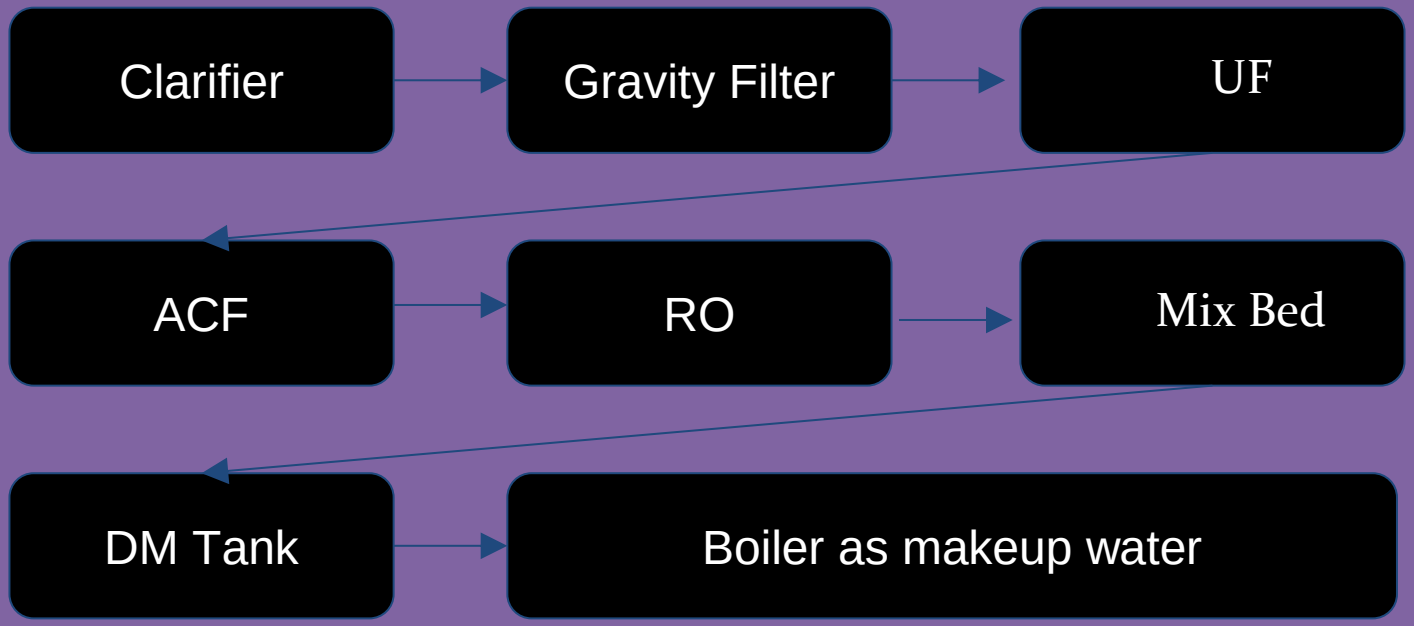
- A quite common application nowadays
- The permeate of the first pass is treated in a second RO pass
- The water from the second pass is pure enough to be only polished further for boiler makeup use

Polishing Choices

Two methods currently predominate for polishing:

- Exchangeable mixed-bed units
- Electro deionization (EDI)

Treatment with UF-RO-MB



TOC measurement at different stages

• STP treated water	19.88 ppm
• Clarified water	16.25 ppm
• ACF outlet	11.45 ppm
• RO permeate	112 ppb
• Mix bed output	105 ppb

Chlorine dioxides

- Sewage water has very high ammonium content. Therefore treating sewage water ClO_2 is preferred over chlorine dosing.

- In submersed / underwater reaction chamber yield is approx. 95 %. Reaction is

$$5NaClO_2 + 4HCl \rightarrow 4ClO_2 + 5NaCl + 2H_2O$$

Use of Chlorine dioxides v/s Chlorine

- No chlorinated by-products
- Chlorine dioxide does not react with ammonia. This is therefore advantageous when ammonium content in the water is high
- Superior disinfection capability in wide range of pH (3-10)
- Can destroy enteroviruses, E. coli and is effective against Cryptosporidium cysts

CONCLUSION

- Membrane technology can deliver the desired results
- The UF-RO membrane in DM plant removes all the TOC in demineralization process and the resultant harmful effect of TOC in boiler feed system
- Thus, there is need to adopt strategy for combination of membrane filtration technique for better control of steam-water cycle in power plant where highly contaminated sewage water is used as raw water
- To overcome ammonical nitrogen problem Chlorine-di-oxide is required instead of Chlorine as oxidizing biocide

Thanks :)

Q/A