Water Quality Assessment and Wastewater Management in Thermal Power Plants

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Introduction

- Water is a prime natural resource and with out that no life on the earth.
- 71% percentage of the earth is covered by water but less than 3% is fresh water and less than 0.3% is available for domestic, agricultural and industrial applications.
- The water resources such as surface and ground water are being polluted by discharge of wastewaters and about 70% of rivers and streams in India contain polluted water.

GLOBAL FRESH WATER RESOURCE GLANCE

- Overall precipitation on the earth provides 5,00,000 BCM of water.
- Land alone gets 1,10, 000 BCM and share of our country is 4000 BCM.
- A Country is 'Water stress' if per capita water availability is less than 1700 m^3/year
- A Country is 'water scarcity' if per capita water availability is less than 1000 m^3/year
- If the per capita water availability is less than 600 m^3/year, it is called 'Absolute scarcity'

NATIONAL WATER RESOURCES AT A GLANCE

Sr.No	Items	Quantity (km^3/yr)	% Rainfall
1	Annual Precipitation (Including snowfall)	4,000	100
2	Lost: Evaporation + GW	2,131	53.3
3	Average Annual Potential flow in Rivers	1,869	46.7
4	Estimated Utilizable Water Resources	1,122	28.1
	4A: Surface Water	690	17.3
	4B: Ground Water	432	10.8
5	Per Capita Water Availability (2001) (2050)	1,820 m^3/yr 1,140 m^3/yr	

1 km^3 = 1 Billion Cubic Metres (BCM)

Source: MOWR

WATER DEMANDS FOR VARIOUS SECTORS IN INDIA

Purpose	Demand (km^3) in the year			No. of times increase w.r.t 1990	
	1990	2000	2025	2000	2025
Domestic Use	25	33	52	1.32	2.08
Irrigation	460	630	770	1.37	1.67
Energy	19	27	71	1.42	3.74
Industrial use	15	30	120	2.00	8.00
Others	33	30	37	0.91	1.12
Total	552	750	1050	1.36	1.90
- Surface water	362	500	700	1.38	1.93
- Ground water	190	250	350	1.32	1.84

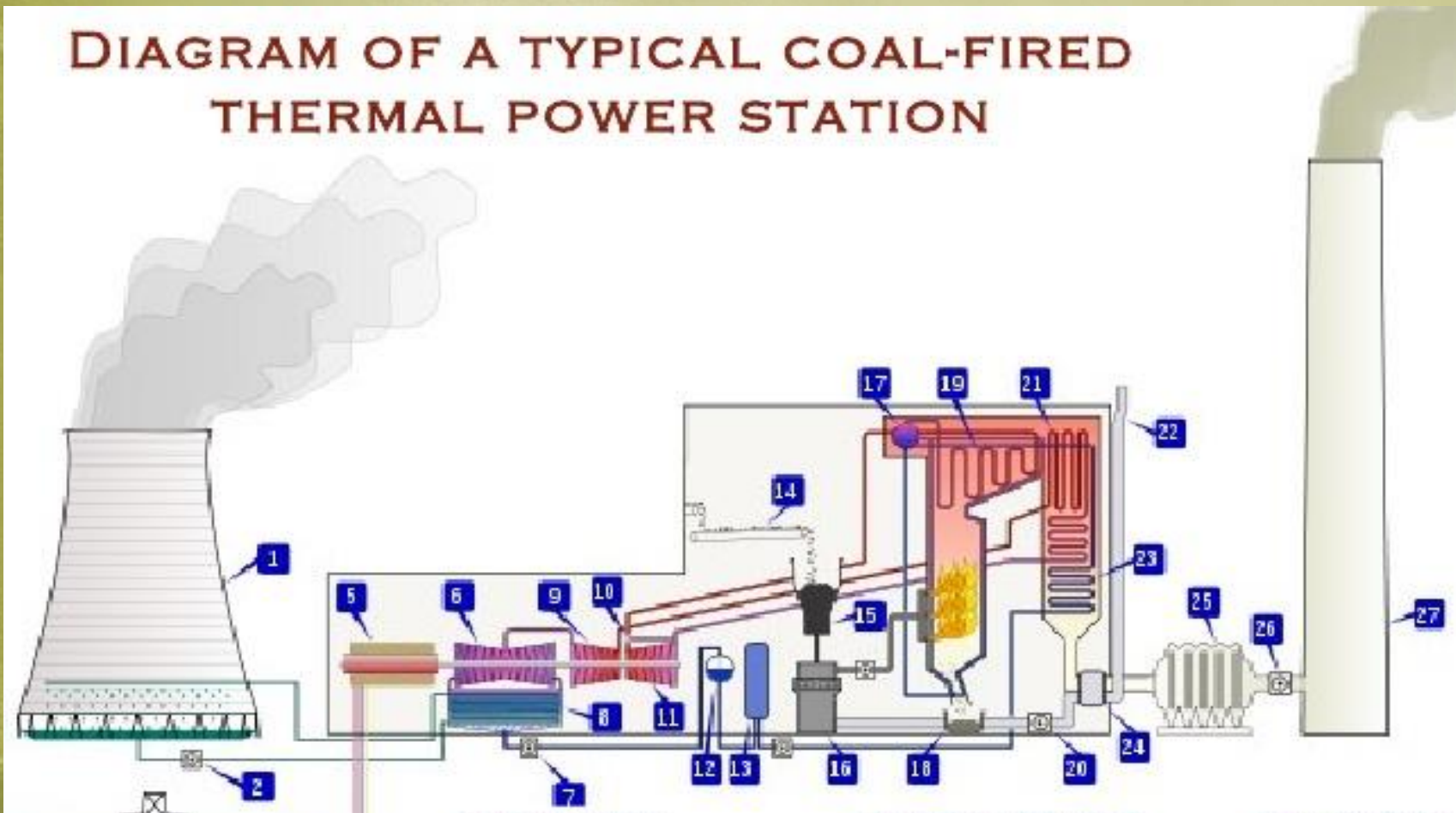
Water Requirement for Thermal Power Plant

- Thermal power plants are predominant Power sectors and its installation capacity of our country has grown up to 2.25 GW/h, in which thermal power alone constitutes around 68%.

- As water is one of the key input requirements in thermal power plants which are used for cooling system, boiler feed and ash disposal along with domestic use and plantation, the demand of water is increasing significantly.

- The consumptive water requirement for power plants with wet ash handling system was 7 m^3/h per MW and for dry ash based 5 m^3/h per MW. In recent years, plants are designed with consumptive water consumption of 3-4 m^3/h per MW.

Diagram of a typical coal-fired thermal power station



1. Cooling tower
2. Cooling water pump
3. transmission line (3-phase)
4. Step-up transformer (3-phase)
5. Electrical generator (3-phase)
6. Low pressure steam turbine
7. Condensate pump
8. Surface condenser
9. Intermediate pressure steam turbine
10. Steam Control valve
11. High pressure steam turbine
12. Deaerator
13. Feed water heater
14. Coal conveyor
15. Coal hopper
16. Coal pulveriser
17. Boiler steam drum
18. Bottom ash hopper
19. Superheater
20. Forced draught (draft) fan
21. Reheater
22. Combustion air intake
23. Economiser
24. Air preheater
25. Precipitator
26. Induced draught (draft) fan
27. Flue gas stack

Water Requirement of Power Plants

- Boiler feed water is deionised water used to absorb the chemical energy of fuel to heat energy.
- Since the boiler water is in circulation and significant loss occurs in the form of evaporation and blow down, only make up water is required. The quantum of blow down water depends on boiler steam parameters and make up DM water.
- The quantity of boiler feed blow down can be calculated using the formula B = E x S/ C-S m^3/h where B is quantity of blow down in m^3/h, S & C are TDS of feed water and boiler drum.

Water Requirements of Power Plants

- Around 80% of water consumption in power plants are taking place in the cooling system.
- For a typical 500 MW coal fired unit, the amount cooling water required is 60,000 m^3/h, with temperature rise across the condenser about 9.5^oC.
- Generally in case of closed cooing cycle system, water loss results in evaporation of 1.5-1.7 % of cooling water flow for heat removal and drift loss amounts to typically 0.05% and 0.35% blow down of the cooling water flow.

Water Quality Requirement

- DM water is used as make up in boiler and its characteristics properties well below the value presented. The specific parameters such as pH (7.5 – 9.6), conductivity (1 µS/cm), dissolved oxygen (0.04 mg/l), alkalinity (carbonate free), hardness (0.3 mg/l), silica (0.5 mg/l) and Oil and grease (free) are desirable for boiler feed water.

- The cooling circulation water should not exceed the corrosion and heat exchange influencing parameters such as pH (6.2-8.2), conductivity (80 µS/cm), chloride (200 mg/l), sulphate (200 mg/l), methyl orange alkalinity (100 mg/l), total hardness 9 200 mg/l), Fe (1 mg/l), Cu (0.3 mg/l), ammonia (0.1 mg/l), residual chlorine (0.3 mg/l) and sulphide (free).

- Domestic water has to meet the prescribed standard.

Effects of Water Quality

S.N	Parameter	Desirable	Permissible	Remarks
1	pH	6.5-8.5		Low pH - corrosion, metallic taste High pH – bitter/soda taste, deposits
2	TDS	500	2000	Hardness, scaly deposits, sediment, cloudy colored water, staining, salty or bitter taste, corrosion of pipes and fittings
3	Total Hardness as $CaCO_3$	300	600	Encrustation in water supply Structure, Scale in utensils and hot water system, soap scum
4	Alkalinity	200	600	Low Alkalinity (i.e. high acidity) causes deterioration of plumbing and increases the chance for many heavy metals in water are present in pipes, solder or plumbing fixtures.
5	Iron, Fe	0.3	1	Brackish color, rusty sediment, bitter or metallic taste, brown-green stains, promotes iron bacteria
6	Sulphate SO_4	200	400	Bitter, medicinal taste, scaly deposits, corrosion, laxative effects, gastro-intentional irritation

S. N	Parameter	Desirable	Permissible	Remarks
7	Magnesium	100		Poor lathering and deterioration of clothes; with sulfate laxative
8	Chloride, Cl	250	1000	High blood pressure, salty taste, corroded pipes, fixtures and appliances, blackening and pitting of stainless steel
9	Chromium	0.05	No relaxation	Skin irritation, skin and nasal ulcers, lung tumors, gastrointestinal effects, damage to the nervous system and circulatory system, accumulates in the spleen, bones, kidney and liver
10	Copper	0.05	1.5	Anemia, digestive disturbances, liver and kidney damage, gastrointestinal irritations, bitter or metallic taste; Blue-green stains on plumbing fixtures
11	Mercury	0.001	No relaxation	Loss of vision and hearing, intellectual deterioration, kidney and nervous system disorders, death at high levels
12	Zinc	5	15	Metallic taste

Effluent Standards

S.No	Parameter	Prescribed limit in mg/l stipulated by Central Pollution Control Board			
		Boiler blow down	Cooling tower blow down	Ash pond water	Once through cooling
1.	pH	-	-	6.5-8.5	6.5-8.5
2.	Temperature	-	-	-	Not more than 5^{o} C of intake water
3.	Suspended Solids	100	-	100	-
4.	Free chlorine	-	0.5	-	0.5
5.	Phosphate	-	5.0	-	-
6.	Oil & Grease	20	-	20.0	-
7.	Fe	1.0	-	-	-
8.	Cu	1.0	-	-	-
9.	Zn	-	1.0	-	-
10.	Total chromium	-	0.2	-	-

Sampling Technique

- Sample containers like wide mouth glass bottles, glass bottles, plastic cans of 1-2 L capacity and BOD bottles are the required items for sampling.
- Cleaning and washing of glassware should be done by using dilute hydrochloric/ nitric acid solutions. Washing power should not be used for samples collected for phosphate analysis.
- Concentrated nitric acid, sulphuric acid, sodium hydroxide and zinc acetate solutions are used for preservation of samples.
- If the samples are brought to the lab within 6 hours, it need not to be preserved otherwise it has to be transported in ice box to maintain the quality of the wastewater.
- If the sampling is planned for different depths, first surface samples have to be collected.
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- Usually 2 L for general parameters, 1 L for sulphuric acid preserved and I L for nitric acid preserved for heavy metals and 0.5 L for Oil and Grease are required.
- Sample preservation and storage is required to minimise physical, chemical and biological changes for which refrigeration and container choices are required.
- The containers have to be selected to avoid vaporization, adsorption/absorption and photo-degradation of the analytes.
- Always the samples should be collected beneath the surface with the mouth directed towards the current whereas for oil and Grease the samples should be collected at the surface.

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- For organic compounds and sulphides, the containers filled without any air space and for microbiological and inorganic parameters air space required for mixing and the mixing should be at least 1% of the container volume.
- Oil and grease sample is half filled in wide mouth glass bottle.
- For ground water sampling, used to remove stagnant water in the borehole for representative sample.
- Labelling for proper sample identification with details such as location, date of sampling, preservative added if any, nature of sample etc.,

Preservation and holding time

S.N	Parameter	Change during storage	Preservation	Container	Holding time
1.	pH	Changes quickly	-	P, G	Immediate
2.	Temperature, ^oC	Changes quickly	-	P, G	In situ
3.	Electrical Conductance, µS/cm		Refrigerate	P, G	Immediate
4.	Total suspended solids, mg/l	Microbial change	Refrigerate	P, G	7 d
5.	Total dissolved solids, mg/l	Microbial change	Refrigerate	P, G	7 d
6.	BOD, mg/l	Microbial change	Refrigerate	P, G	6-48 h
7.	COD, mg/l	Microbial change	Refrigerate	P, G	28 d
8.	Alkalinity, mg/l as CaCO3	Precipitate	Refrigerate	P, G	Immediate
9.	Total hardness, mg/l as CaCO3	Precipitate	Acidify with nitric acid	P, G	6 months
10.	Sulphate, mg/l	Microbial change	Refrigerate	P, G	28 d
11.	Chloride, mg/l	-	None	P, G	28 d
12.	Total phosphate, mg/l	Microbial change	Add H_2SO_4 to pH 2 and Refrigerate	P, G	28 d
13.	Sulphide	Vaporization	Add Zn acetate and use NaOH to raise pH to 9.0	P, G	6-48 h
14.	Silica, mg/l	-	Refrigerate	P	28 d
15.	Oil & Grease, mg/l	Adsorption to plastics	Use wide mouth glass bottles and add H_2SO_4	G	28 d
16.	Heavy metals	Precipitation and adsorption on glass wall	Use nitric acid to reduce pH to 2.0.	P, G	6 months except Hg and Cr (VI)

Analytical techniques (Electro-chemical methods)

- Glass electrode pH Meter is allowed for warm up and calibrated using minimum two buffer solutions.
- Water samples in beaker are kept under the electrodes to measure the pH.

- Specific conductivity is measure of electrical conductance of the water sample under the influence of two electrodes.
- The meter is calibrated using the known concentration of KCl solution and water sample is used to measure.

Analytical techniques (Gravimetric)

- The total dissolved solids are portion of solids that passes through a filter of 2 µm nominal pore size and it is measured by measuring the weight difference of known quantity of water after evaporation and drying to obtain constant weight.
- Suspended solids are measured by the weight difference after filtration using Whatman filter paper after drying to obtain constant weight.
- Oil and Grease also measured by extraction of solvent mixture soluble fraction and completely draining the aqueous phase. The solvent phase is distilled at 85^{o} C to evaporate the solvent and the container is weighed to determine the quantity of O&G.

Analytical techniques (Volumetric methods))

- Parameters such as alkalinity, total hardness, chloride, Sulphide and TKN are measured by volumetric titration methods.
- Alkalinity is determined using standardised acid solution in presence of the indicators like methyl orange and phenolphthalein.
- Total hardness by calcium and magnesium ions is titrated against the standard solution of EDTA in presence of buffer solution and indicator.
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- Chloride ions are determined by reaction against standard silver nitrate solution using potassium dichromate as an indicator at neutral pH.
- Sulphide precipitate is dissolved in dilute HCl and mixed with iodine solution; the unreacted iodine is titrated against standard thiosulphate using in presence of starch indicator.
- The total nitrogen present in the water samples are digested with sulphuric acid in the presence copper sulphate catalyst and potassium sulphate salt. All forms of organic nitrogen are converted to ammonium sulphate and which is distilled in alkaline solution and titrated against standard acid solution.

Analytical techniques (Spectrophotometric methods)

- Phosphate and silica make complex with ammonium molybdate in acidic condition and form colour. The blue colour generated for phosphate and yellow colour generated for silica are measured at the wavelengths of 690 nm and 410 nm, respectively.
- Heavy metals such as Fe, Cu, Zn and Cr are determined using Atomic Absorption Spectrophotometer or ICP.
- The method blank, duplicate/triplicate sample and standard addition methods are followed for AQC. Application of CRM and calibrated glassware and instrument are used to obtain precise and accurate results.

Water Conservation

- Minimization of Boiler blow downs by providing CPU and good boiler and/or it can be treated using DM process/RO process and reused in the process.
- The DM plant regeneration wastewater are neutralised and used for bottom ash removal.
- Closed cycle cooling systems shall be adopted rather than once through cooling. Despite the evaporation and drift loss the blow down quantity are less than 0.035% of the cooling water flows.
- The cooling water blow down can be used for plantations along with treated domestic wastes or suppression of coal dust. Suitability of dry cooling system for condenser is also on going to reduce water consumption.
- Implementation of dry ash collection in the entire fly ash area would reduce water consumption and also water pollution.


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