COST EFFECTIVE GREEN SOLUTION FOR ZERO DISCHARGE FOR GAS POWER STATIONS

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[**ABSTRACT:** Unlike coal based power stations, achieving zero discharge is a very difficult and expensive. In coal based power stations cooling water blow down which constitute a major portion of effluent can be used for ash handling requirements. But in gas stations it is not possible. Use of ultra filtration, reverse osmosis , multi effect evaporator and crystalliser can provide zero discharge solution. But it is very expensive solution and will add to power generation cost. This paper explores how **cost** effectively we can explore zero discharge in gas based power station . We can reuse of waste water in clarifier and cooling system like HVAC ,Air washers after further treatment directly . Sewage effluent can also used after further treatment in cooling water system. Another important area of reuse is irrigation of lawns, trees and landscape in the premises after ensuring quality requirement and assessing the quantity of water than can be used for the purpose. Irrigation of greenery will enhance plant growth and will increase carbon dioxide removal rate . This paper is exploring various recycling schemes that can be implemented, treatment required for the purpose, quality criteria for using irrigation of landscape and the quantity of water that can be used for irrigation while sharing some experience in Auraiya power station]

INTRODUCTION

Thermal power plants account for 85% of total water consumed by industry. Increasing population puts pressure on water resources. In power tariff policy, power stations should sewage plant effluent water available from municipalities located in 50KMS. As per Environment protection rule (amendment) 2015 , Zero discharge has been given as target for new power station and water intake quantity has fixed as 3.5M3/MWHr and 2.5M3/MWHr for old and new power stations respectively . NTPC as proactive measure has decided to achieve zero discharge in old power stations

Every gas based power station generates waste water from plant effluent from different sources and effluent from sewage effluent from sewage treatment plant. To assess quantity and quality of effluent generated the data of Auriya gas power station is given below in Table 1

Table 1

S.no	Effluent	Quantity generated (M^3/day)	% of total effluent
1	Filter Back Wash Effluent	125	2.7
2	Clarifier sludge water	165	3.5
3	Boiler ,turbine Area effluent	168	3.6
4	DM Plant regeneration Effluents	150	3.2
5	Cooling Tower Blow Down	2640	56.0
6	Softening Plant regeneration Effluents	1014	21.5
7	Salt lagoon effluent	10	0.2
8	Township STP effluent	430	9.1
9	Plant sewage effluent	10	0.2
	TOTAL	4712	100.0

Basic approach to achieve zero discharge involves

- Reduction of water consumption and effluent discharge
- Reuse waste water generated
- Recycle waste water for other applications

To achieve cost effective zero first step is to explore reuse of waste water within plant and its premises using this philosophy .

1. **REUSE OF WATER TREATMENT PLANT EFFLUENT**
   Gravity Filter and pressure filter rinse water can be collected in separate pit and can fed back to filter for reuse Clarified water blow down and pressure filter and Gravity filter back wash effluent has considerable amount of solid sludge (upto 3-5%) Rinse water can be recycled to own reservoir if

one has after settling in primary and secondary settling pits . If there is no reservoir ,silt from water can be separated by simple drying bed and water separated can be reused in clarifier

2. **REUSE OF COOLING WATER BLOW DOWN**

Gas Turbine Cooling water blow down can be recycled to ST CW channel as normally COC for GT circulating water will be lower than steam turbine cooling water in view of high cavity temperature of gas turbines

ST CW blow down cab reduced by effectively using the same for the following purposes

a. Fire water make up
b. Make up for cooling tower in HVAC system . HVAC CT basin can be replaced by FRP. Chemical treatment feeding CT basin will be required apart from annual cleaning of condensers with inhibited acid to ensure its usage without any impact
c. Make up in air washer system

3. **REUSE OF SEWAGE EFFLUENT**

Effluent from sewage treatment plant can be disinfected by chlorination and can used for irrigation of landscape flowerbeds grass and trees. Effluent from septic tanks requires further secondary and tertiary treatment before using in irrigation of landscape flowerbeds grass and trees.Exploring reuse of sewage effluent is important in view of the recent notification of Ministry of environment and forest in stipulating limits for specific water consumption. Industrial reuse of treated sewage includes the following:

- Cooling in air handling unit, desert coolers, air washer units
- Cooling water make up in CW system
- Dimineralisation plant
- Non-human contact process water like scrubbers
- Irrigation of landscape around plant

The Central Public Health and Environmental Engineering Organisation under the Ministry of urban development has come out with guidelines for reuse of sewage effluent and Table 2 gives the quality required for reuse of sewage water for various applications mentioned in their manual.

Table 2 Rrecommended norms for treated sewage quality for reuse for various applications

	Parameter	Toilet flushing	Fire protection	Floor washing	Non-contact use (e.g scrubbers)	Landscaping, horticulture& agriculture			
						Horticulture / parks	Non edible crops	edible crops eaten in	
								Raw form	cooked form
1	Turbidity(NTU)	<2	<2	<2	<2	<2	AA	<2	AA
2	SS	NIL	NIL	NIL	NIL	NIL	30	NIL	30
3	TDS	2100							
4	pH	6.5 TO 8.3							
5	Temperature	Ambient							
6	Oil& grease	10	NIL	NIL	NIL	10	10	NIL	NIL
7	Minimum res cl	1	1	1	0.5	1	NIL	NIL	NIL
8	Total kjeldahl N	10	10	10	10	10	10	10	10
9	BOD	10	10	10	10	10	20	10	20
10	COD	AA	AA	AA	AA	AA	30	AA	30
11	Dissolved P	1	1	1	1	2	5	2	5
12	Nitrate nitrogen	10	10	10	5	10	10	10	10
13	Faecal coliform in 100 ml	NIL	NIL	NIL	NIL	NIL	230	NIL	230
14	Helminthic Eggs/liter	AA	AA	AA	AA	AA	<1	<1	<1
15	Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
16	Odour	Aseptic which means not septic and no foul odour							

All units in mg/litre and limits for maximum unless specified . AA- As arising when other parameters are satisfied. Ref : CPHEEO sewage treatment manual

Treatment through Bio-digester and reed bed can be used as additional treatment for sewage effluent from septic tanks to achieve the parameters prescribed by Central Public Health and Environmental Engineering Organisation and ensure its safe use in irrigation. These technologies have very low capital cost and very low maintenance cost and technology is eco friendly

Some of recycling schemes implemented already in Auraiya gas power station and water reuse achieved are detailed below in table 3

Table 3

S No	Water recycling reuse measure	Volume of water conserved in M^3 2015-16
1.	Gravity Filter Backwash water recycling	63322
2.	GT Circulating water blowdown Rerouting to ST CW system	166798
3.	GF Rinse water Recycling back to gravity filter	9267
4.	Fire water pumps seal/cooling water recycling	22240
5.	using ST CW blowdown for Fire water make up	123554
6.	using ST CW blowdown for Salt solution make up	15444
7.	Recycling DM plant filter Backwash water to reservoir	17772
8.	Recycling of clarifier blow down water to reservoir	13900
9.	Sewage water reuse for horticulture	9000
	Total	441296
	Raw water intake	3077630
	% of recycled water used out of total water drawn	14.34

4. REUSE OF WASTE WATER FOR IRRIGATION

Irrigation plays a vital role in increasing growth of vegetation and increase ability to remove carbon dioxide. In arid and semi-arid regions, irrigation is essential for economically viable, while in semi-humid and humid areas, it is often required on a supplementary basis. The following basic conditions should be met to make irrigation a success:

- the required amount of water should be applied;
- the water should be of acceptable quality;
- water application should be properly scheduled;
- appropriate irrigation methods should be used;
- salt accumulation in the root zone should be prevented by means of leaching;
- the rise of water table should be controlled by means of appropriate drainage; - plant nutrients should be managed in an optimal way. The above requirements are equally applicable when the source of irrigation water is treated wastewater. Nutrients in sewage effluent water and treated effluents are a particular advantage of these sources over conventional irrigation water sources and supplemental fertilizers are sometimes not necessary. However, additional environmental and health requirements must be taken into account when treated wastewater is the source of irrigation water.

4.1 Quality Of Irrigation Water

The quality of irrigation water is to be evaluated in terms of degree of harmful effects on soil properties with respect to the soluble salts it contains in different concentrations and vegetation growth. To evaluate the quality of Irrigation water, Indian standard has been prepared as a guideline which is detailed below
The suitability of an irrigation water depends upon several factors, such as, water quality, soil type, plant characteristics, irrigation method, drainage, climate and the local conditions. The integrated effect of these factors on the suitability of irrigation water (SI) can be expressed by the relationship given below.

SI (suitability for irrigation) = ƒQSPCD Where

Q	quality of irrigation water, that is, total salt concentration, relative proportion of cations, etc;
S	soil type, texture, structure, permeability, fertility, calcium carbonate content, type of clay minerals and initial level of salinity and alkalinity before irrigation;
P	salt tolerance characteristics of the plant being grown, its variety and growth stage;
C	climate, that is, total rainfall, its distribution and evaporation characteristics; and
D	drainage conditions, depth of water table, nature of soil profile, presence of hard pan or lime concentration and management practices

These factors act interactively such that a single suitable criteria is hard to be adopted for widely varying conditions. However, a general broad guideline has been, developed here.

Besides these factors, the presence of potassium and nitrate ions in water, is favourable for plant /grass/tree growth, as water of more salinity can be used in presence of these ions. In a particular climate, all the factors enumerated are likely to vary and interact either positively or negatively in relation to salt accumulation and degree of harmful effect on soil properties and plant /grass/tree growth.

The following chemical properties shall be considered for developing water quality
criteria for irrigation:
a. Total salt concentration,
b. Sodium adsorption ratio,
c. Residual sodium carbonate or bicarbonate ion concentration, and
d. Boron content.

4.1.1 Total Salt Concentration—It is expressed as the electrical conductivity (EC). In relation to hazardous effects of the total salt concentration, the irrigation water can be classified into four major groups as given in Table 5.

Table 5 water quality rating based on the total salt concentration

Sl no.	Class	Range of ec (micromhos/cm)
(a)	Low	Below 1 500
(b)	Medium	500-3 000
(c)	High	3 000-6 000
(d)	Very high	Above 6 000

4.1. 2 Sodium Adsorption Ratio (SAR)—shall be calculated from the following formula:

$$\mathbf{SAR = Na^{+} / \sqrt{\{(Ca^{2+} + Mg^{2+})/2\}}}$$

Where

SAR	sodium adsorption ratio √(millimole / litre)
Na	sodium ion concentration, me/1
Ca	calcium ion concentration, me/1
Mg	magnesium ion concentration, me/1

NOTE— me/l = milliequivalent/litre.

In relation to the hazardous effects of sodium adsorption ratio, the irrigation water quality rating is given in Table 6.

Table 6 Water quality rating based on sodium adsorption ratio

SL NO.	CLASS	SAR Range in √(millimole / litre)
i)	Low	Below 10
ii)	Medium	10-18
iii)	High	18-26
iv)	Very high	Above 26

4.1.3 Residual sodium carbonate (RSC) shall be determined by the equation:

$$RSC = (CO_3^{2-} + HCO^{3-}) - (Ca^{2+} + Mg^{2+})$$ Where

RSC	residual sodium carbonate (me/l),
CO_3^{2-}	carbonate ion concentration (me/l),
HCO_3^{2-}	bicarbonate ion concentration (me/l),
Ca2+	calcium ion concentration (me/l), and
Mg2+	magnesium ion concentration (me/l).

NOTE—me/l = milliequivalent/litre.

In relation to the hazardous effects of high bicarbonate ion concentration expressed as residual sodium carbonate, the irrigation water quality rating is given in Table 7.

TABLE 7 Water quality rating based on residual sodium carbonate

SL NO.	CLASS	RSC RANGE (me/1)
i)	Low	Below 1.5
ii)	Medium	1.5-3.0
iii)	High	3.0-6.0
iv)	Very high	Above 6.0

4.1.4 Boron Content—Boron, though a nutrient, becomes toxic if present in water beyond a particular level. In relation to boron toxicity, the irrigation water quality rating is given in Table 8.

Table 8 Water quality rating based on boron content

Sl no.	Class	Boron (ppm)
i)	Low	Below 1.0
ii)	Medium	1.0-2.0
iii)	High	2.0-4.0
iv)	Very high	Above 4.0

Though all the chemical characteristics have been classified separately, they are present in each irrigation water, and the chemical characteristics of a particular class of water is independent of the chemical characteristics of different classes of water. For example, a water of high EC may or may not have high SAR or RSC or boron. These chemical characteristics interact with each other and cause hazardous effects on soil properties and plant /grass/tree growth.

4.1.5. Water quality rating in relation to soil type and Plant tolerance to salts

Keeping in view the soil types and quality of ground water, the upper permissible limit of electrical conductivity (EC), sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and boron content for the semi-tolerant and tolerant plants are given in Table 9

Table 9 suitability of irrigation water for semi-tolerant and tolerant plants in different soil types

SL No.	Soil textural group	Upper Permissible Limit for plant /grass/tree growth.							
		Salinity(EC)(micromhos/cm)		Sodicity √(millimole/ 1)		RSC (me/1)		Boron (ppm)	
		Semi-tolerant	Tolerant	Semi-tolerant	Tolerant	Semi-tolerant	Tolerant	Semi-tolerant	Tolerant
i)	Above 30 Percent Clay Sandy clay clay loam, silty clay loam, silty clay, clay	1500	2000	10	15	2	3	2	3
ii)	20-30 Percent Clay Sandy clay loam, loam, silty loam	4000	6000	15	20	3	4	2	3
iii)	10-20 Percent Clay Sandy loam, loam, silty loam	6000	8000	20	25	4	5	2	3
iv)	Below 10 Percent Clay Sand, loamy sand, sandy loam, silty loam, silt	8000	10000	25	30	5	6	1	2

Characteristics of various effluents of Auraiya gas power station for comparison with IS limit for Clay content in the range of 10-20% for semi tolerant plants is given below in table 10

Table 10

PARAMETER		CW blow down	STP effluent	Softenig plant effluent (max)	Main plant effluent	Salt lagoon effluent (max)	DM plant effluent (max)	Maximum permitted in irrigation water IS
PH		8.06	7.25	8.5	7.24	9.3	8.39	6.0-8.5
Conductivity	US/CM	1122	551	274500	1337	26000	1380	
Total hardness ppm	ppm as CaCO3	60	154	20000	160	458	1481	
Ca.Hardness ppm	-do-	28	100	16080	96	306	921	
Mg .Hardness ppm	-do-	32	54	3920	64	152	560	
P-Alkalinity ppm	-do-	NIL	0	10	NIL	86	40	
M-Alkalinity ppm	-do-	150	110	150	120	54	100	
Sodium ppm	ppm as Na	175	26	76000	842	6534	1920	
SODIUM eq	millie eq /litre	7.6	1.1	1520	36.6	130.7	38.4	
Ca meq/litre	-do-	0.56	2	321.6	1.92	6.12	18.42	
Mg meq/litre	-do-	0.64	1.08	78.4	1.28	3.04	11.2	
Ca+Mg meq/litre	-do-	0.6	1.54	400	1.6	9.16	29.62	
HCO3 meq/litre	-do-	3	2.2	3	2.4	1.08	2	
Salinity	US/CM	1122	551	274500	1337	26000	1380	<6000
Sodium absorption ratio		9.82	0.91	76.00	28.94	43.18	7.06	<20
Residual sodium carbonate		1.8	-0.88	-397	-0.8	-8.08	-27.62	<4
Boron content		0.8	0.27	0.27	0.33	0.27	0.27	<2

As can be seen from the table 10, effluent from softening plant and salt lagoon are exceeding limits permitted for irrigation water. In order to make usable for irrigation, Auraiya station will have go for CW treatment for using hard water directly for cooling purpose so that softening process and salt lagoon system can be abandoned. This will reduce exorbitant cost required to remove salinity through RO evaporator and crystalliser system

4.2 Amount of water to be applied

It is well known that more than 99 percent of the water absorbed by plants is lost by transpiration and evaporation from the plant surface. Thus, for all practical purposes, the water requirement is equal to the evapotranspiration requirement. Evapotranspiration is mainly determined by climatic factors and hence can be estimated with reasonable accuracy using meteorological data. In order to efficiently apply water to the root zone, estimate the water demand based on soil type, precipitation, plant needs and soil moisture retention. The process for developing an irrigation schedule is described below.

 Determine your soil type. Soil characteristics help determine effective irrigation application rates, durations and frequencies. For instance, sandy soils may require more frequent but shorter duration applications.
 Determine weekly precipitation amounts from weather monitoring system
 Determine each flower bed/grass/lawn/trees water quantity needs**.**
 Monitor soil moisture to determine whether irrigation is necessary. If the soil moisture content is adequate for the plant's water quantity needs, no additional water application is required.
 Measure the output from your irrigation devices. Use flow meters or gauged water pans to measure the output of sprinklers and drip irrigation heads.
 Combine the five pieces of information above to determine a week-by-week irrigation schedule. Update the schedule as weather and soil moisture conditions change.
 Recheck soil moisture 1-2 days after irrigation to determine depth of applied water and uniformity. If water penetration is too deep, too shallow, or spotty adjust your irrigation schedule to correct it.

Quantity water that can be used for Auraiya station at present was estimated based on different types of green coverage , area of coverage , peak water requirement and the details are given below in table 4

Table 4

Required Quantity of Treated Wastewater of Auraiya power station for Irrigation

Sr. No.	Site Name	Area, Sqm	Acre	Peak Water Req per mm/Day /Sqm	Requird Water, M3/day	Litre/Sec for managing irri in 8 hrs
1	Total lawn area A Type of Plant	5987.22	1.48	6	35.92	1.25
2	Total lawn area B Type of Plant	9627.36	2.38	6	57.76	2.01
3	Grass area of Plant	62079.33	15.34	6	372.48	12.93
4	Flower bed area of plant	2030.62	0.50	6	12.18	0.42
5	Hedge area of plant	2291	0.57	6	13.75	0.48
6	Rose flower bed area	300	0.07	6	1.80	0.06
7	Road side Berm area of Plant	20316	5.02	20	101.58	3.53
8	D Type lawn of township	1235	0.31	6	7.41	0.26
9	C Type lawn of township	458.72	0.11	6	2.75	0.10
10	Guest house, Sarveshwer Temple	5585	1.38	6	33.51	1.16
11	Township other area. Park, St joseph Qtr, Jayanti park, godawon load.	20692	5.11	6	124.15	4.31
12	B type Lawn, Green Park, Flower Bed B type Hostel, Guest House,	55003.52	13.59	6	330.02	11.46
13	Area of Trees of more than 7 year old	28902	7.14	6	173.4	
	Total Area	214507.8	53		1264.71	37.96

At present we can use 1264 M3 of waste water for watering the greenery. Given the fact that there is enough area and scope of increasing the green coverage by planting Vetiver grass, a type of plant used for purification of waster water , quantity of waste water that can used can be further increased

5. **ROAD MAP FOR COST EFFECTIVE ZERO DISCHARGE IMPLEMENTATION**

Based on study of effluents of Auraiya gas power station, road map for cost effective eco-friendly zero discharge solution can be drawn as follows in table 11

Table 11

	Effluent	Reuse /recycling/Reduction measure	Add system required
1.	Filter Back Wash Effluent	Recycling to clarifier after silt removal	Drying bed for removal of silt
2.	Clarifier sludge water	Recycling to clarifier after silt removal	Drying bed for removal of silt
3.	Boiler and turbine effluent	Reuse for irrigation of landscape after quality study	Irrigation pipe net work with sequential opening of valves
4.	DM Plant regeneration Effluents	Reuse for irrigation of landscape after quality study	Irrigation pipe network with sequential opening of valves in the network
5.	Cooling Tower Blow Down	1. Reduction by increasing COC by 25% 2. Reduction by reusing blow down water in HVAC and air washer , and fire water make up 3. Reuse for irrigation of landscape after quality study	HVAC CT basin to be replaced by FRP . Chemical treatment of cooling water . Vetiver grass plantation to increase green coverage in possible areas
6.	Softening Plant regeneration Effluents	Elimination with CW treatment/ scale ban	Installation of CW treatment plant
7.	Township STP effluent	Reuse for horticulture after disinfecting with chlorination	Effluent collection tank with Irrigation piping network with sequential opening of valves in the net work
8.	Plant area sewage effluent from septic system	Reuse for horticulture after further treatment	Primary treatment with biodigestor, and secondary treatment with reed bed system

6.CONCLUSION

Each station can assess quality and quantity of waste water that can used for watering greenery and explore reuse and recycling to reduce cost of zero discharge solution substantially