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Enhancing water-use efficiency of thermal power plants in India: need for mandatory water audits

CONTENTS

- Introduction 1
- Process water use in power generation 3
- Specific water consumption 3
- Case study of a water audit for a thermal power plant in India: scope for improvement 3
- Cost–benefit: various scenarios 4
- Recommendations 7
- Specific recommendations for power plants 7
- Policy recommendations 8
- Need for establishing water-use benchmarks 8
- Economic viability 9
- Need for a Bureau of Water Efficiency 9
- Third party water audits to be made mandatory 9
- Why third party audits? 9
- Benefits of water audit 10
- Conclusion 10

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Introduction

With its continuously declining per capita water availability (from about 5,177 m^3 in 1951 to 1,654 m^3 in 2007),[1] India stands water stressed[2] and is close to being categorized 'water scarce'.[3] Water demand in India is expected to grow annually by 2.8 per cent to reach 1,500 bcm (by 2030) while the current supply is only about half (viz.,744 bcm).[4]

The Government of India, in its National Water Mission (NWM) under the National Action Plan on Climate Change (NAPCC), has emphasized the need to develop a framework for optimizing water-use efficiency by 20 per cent, through regulatory mechanisms with differential entitlements and pricing. It further emphasizes the need to focus on integrated water resource management through water conservation, wastewater minimization, etc. This would require various sectors, including industries, to optimize their practices ensuring conservation, recycling, and reuse.

Challenges to industrial water use in India

Agriculture is the largest consumer of water in India, and in 2010, it accounted for about 85 per cent of the total demand, followed by industry at 9 per cent, and the domestic sector at 6 per cent.[5]

Water requirements of various sectors of Indian industries had almost doubled during the last decade and are expected to increase more than

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1 Central Water Commission, National Institute of Hydrology. 2008. "Preliminary consolidated report on effect of climate change on water resources". New Delhi: Ministry of Water Resources.

2 A situation of per capita water availability falling below 1,700 m^3.

3 A situation of per capita water availability falling below 1,000 m^3.

4 2030 Water Resources Group. 2009."Charting our water future: economic frameworks to inform decision-making", Executive Summary.

5 Infrastructure Development Finance Company (IDFC). 2011. Water: policy and performance for sustainable development, India Infrastructure Report 2011. New Delhi: Oxford University Press.

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threefold by 2050.[6] Various industries require large quantities of water for their manufacturing processes, while at the same time discharging significant volumes of wastewater. In view of their corporate structure, technical know-how, etc., industries are better placed, compared to other sectors, to improve water-use efficiency and reduce consumption in the short run. Table 1 provides the water consumption pattern of various industrial sectors.

In view of the very high share of water consumption in thermal power plants, this policy brief highlights the water-use scenario in this sector and emphasizes the need for third party/mandatory and regular water audits, along with the setting up of water consumption standards in the power sector.

Power generation scenario in India

The total power generation capacity of India (as on 31 March 2012) was 199,627 megawatts (MW), of which thermal power generation accounted for 66 per cent, followed by hydro (20 per cent), renewable energy sources (12 per cent), and nuclear (2 per cent). Coal accounted for 85 per cent of the total fuel supplied to thermal plants as shown in Figure 1.

Between 1947 and 2012, the total power-generation capacity has increased from 1,362 MW to 199,627 MW. This high growth is expected to continue in the future. It is of significant importance to focus on water-use efficiency of thermal power plants, especially coal-fired power plants, while reforming the power sector in India.

TABLE 1 Industrial water use in India

Sector	Percentage of water consumed
Thermal power plants	87.87
Engineering	5.05
Pulp and paper	2.26
Textiles	2.07
Steel	1.29
Sugar	0.49
Fertilizer	0.18
Others	0.78
Total	100.00

Source Centre for Science and Environment. (Figures based on wastewater discharge data published by Central Pollution Control Board[CPCB] in "Water quality in India (status and trends) 1990–2001". Available online at http://www.cseindia.org/dte-supplement/industry20040215/misuse.htm. Last date of access: 22 October 2012)

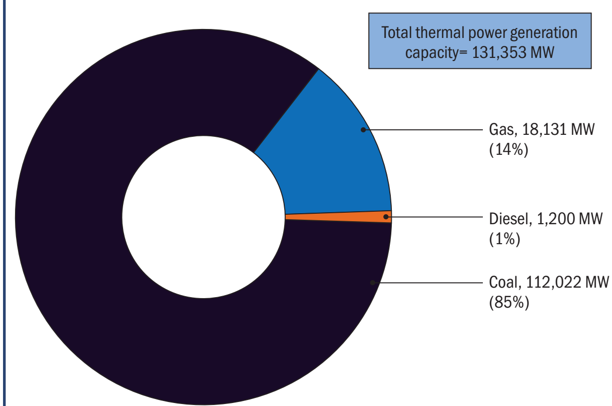

FIGURE 1 Share of fuel (coal, gas, and diesel) in thermal power generation of India
Source Central Electricity Authority (CEA), 2012."All India region-wise generating installed capacity (MW) of power utilities including allocated shares in joint and central sector utilities". Available at http://cea.nic.in; last accessed in March 2012.

BOX 1 Shut down of Chandrapur Super Thermal Power Station

Maharashtra's Chandrapur Super Thermal Power Station (CSTPS), one of the largest power generation plant of Maharashtra State Power Corporation Ltd, was forced to shut down on 15 May 2007 due to an unprecedented scarcity of water.

Chandrapur district was severely hit by insufficient rains during the previous year, leading to a sharp decline in the water level of the Erai dam, which supplies water to the power station, besides also being the source of drinking water for the city and the surrounding villages. The situation led to closure of the power plant.

Water consumption by thermal power plants in India

A rough estimate based on 1999–2001 data from Central Pollution Control Board (CPCB) states that out of a total of about 83,000 million litres per day (MLD) of water discharged by all the industries in India, about 66,700 MLD (~80 per cent) is cooling water discharge from the thermal power plants. During the same period, it was estimated that for every MW of power produced, Indian thermal power plants consumed about 80 m^3 of water as compared to less than 10 m^3 water consumption in developed

[6] Indiastat.com. Also, Central Water Commission, 2008.

nations. This is mainly attributed to the once-through cooling system (open loop system)[7] described later.

Process water use in power generation

Water is used for many purposes in a power plant, such as in the cooling tower, condensers, DM (de-mineralization) plant, drinking water needs, firefighting, coal handling, ash handling, service water, and others.

Specific water consumption

Comprehensive information on the water consumption of power plants in India is not readily available in the public domain. However, a tentative study suggests an example (as shown in Figure 2) of the break-up of specific water consumption of a coal-based thermal power plant with ash water recycling facility.[8]

It can be seen that cooling towers and ash handling are the major water consuming areas and account for about 70 per cent of the water use within the plant.

Case study of a water audit for a thermal power plant in India: scope for improvement

Comprehensive water audits conducted by TERI at some of India's largest thermal power plants revealed significant findings and immense scope of water savings in the cooling towers, and ash handling systems apart from wastewater drainage, township water supply, etc. A summary of observations is discussed below.

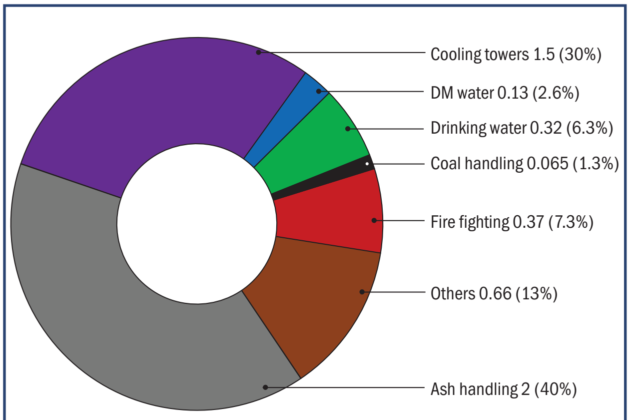

FIGURE 2 Specific water consumption of a coal-based thermal power plant in India (m^3/MW)
Source http://www.energymanagertraining.com

Cooling towers

Cooling towers use a significant volume of water to dissipate the heat of the hot water received from the condensers.

There are two types of cooling systems in conventional, coal-based (steam) thermal power plants: 'once-through' and 'closed-cycle' systems. Once-through systems are water-intensive processes and require continual water flow, which is discharged without recirculation/recycling after heat exchange in the condensers. The water demands of the once-through systems are considered to be about 30 to 50 times more than the closed-cycle systems.[9]

Once-through systems are becoming uncommon in the world; however, in India, many plants still operate the once-through cooling system. A rough estimate by a study suggests that by converting all the thermal power plants in India to closed-cycle cooling systems, about 65,000 MLD of fresh water can be saved.[10]

In a closed-cycle system, water is re-circulated and treated; clarified water is added continuously from the raw water treatment plant to make up for evaporative and drift losses as well as for the loss through the 'blow down' carried out to get rid of high salt content concentrated in water during the process of re-circulation.

Cycles of Concentration (CoC)

Since water is circulated many times in the closed loop, the concentration of dissolved solids increases over a period. The Cycles of Concentration (CoC) is the ratio of dissolved solids in the circulating water to the make-up water.

[7] Center for Science and Environment. 2012. *Down to Earth* supplement. Details available online at http://www.cseindia.org/dte-supplement/industry20040215/misuse.htm; last accessed in May 2012.
[8] The information on the wastewater treatment/recycling for such a plant is not available from the study.
[9] Center for Science and Environment. 2012. Details available at http://www.cseindia.org/dte-supplement/industry20040215/industry-improve.htm; last accessed on 22 October 2012.
[10] Centre for Science and Environment. 2012. Details available at http://www.cseindia.org/dte-supplement/industry20040215/industry-improve.htm; last accessed on 22 October 2012.

Water audit in two thermal power plants revealed that the CoC ranged between 2.0 and 3.5. There is significant scope for improving the CoC initially to around 4–5, and later to maybe something higher (8 or even 10) by various interventions, including the use of stabilizing chemicals and disinfectants, thus saving a large quantity of fresh water needed as make-up.

Ash handling

Apart from cooling towers, generally a large quantity (about 40 per cent of the freshwater intake) is also consumed in the ash handling process. Ash residue is converted to slurry using freshwater and transported to nearby dykes for disposal. The water is often not recycled/partially recycled, leading to wastewater discharge. Recapturing and recycling this water has a significant potential for water savings.

Township water supply (drinking water and other uses)

During the water audits conducted by TERI in the thermal power plants, the treated water supply to township (for drinking and other domestic uses) were observed to be about 2–11 times (~350 lpcd to 1500 lpcd, respectively) higher than the recommended Indian norm of 135 lpcd.[11]

Firefighting

Ideally firefighting water should be used only in the case of a fire emergency. However, it was found that this water was used for sundry other purposes, including floor washing, horticulture, etc.

Wastewater discharge

Through a combination of open channel and closed-conduit measurements during the water audit, it was found that a considerable amount of wastewater was discharged into drains as waste. However, this water had low TDS (total dissolved solids) content and hence, with primary treatment, could be recycled and reused in many processes, such as ash handing units, coal handling processes, recirculation water, etc. The potential for water saving each day was about 18 per cent to about 26 per cent of the intake water, which would in turn also ensure zero discharge within the plant.

Other processes

Water is also lost in other phases of the power-generation process. During the de-mineralization and coal-handling processes, water is lost due to the 'blow down' and other leakages.

However, it is evident from the above explanations that if careful and regular accounting of water consumption is internalized, significant water conservation can be achieved on a regular basis in the cooling towers, ash handling system, firefighting system, drinking water supply, and wastewater discharges. However, in order to achieve this, regular and mandatory water audits of the entire power plant is of foremost importance. Figures 3 and 4 are schematic diagrams showing water flows through a thermal power plant before and after implementation of a water audit.

Cost–benefit: various scenarios

Conversion to closed-cycle systems

Water consumption in a closed-cycle thermal power plant and the associated cost of water would be potentially less than the consumption in an open-cycle system. A comparison is presented in Figure 5; it indicates that the total water consumption in an open-cycle system could be to the tune of 173 million m^3/year[12] as compared to an observed 123.5 million m^3/year in a closed-cycle plant (of about 3,000 MW capacity) with an associated cost of ₹69.1 crore/year and ₹49.4 crore/year, respectively.

Recycling drain wastewater

Water audit of closed-cycle thermal power plants (of about 3,000 MW capacity) reveals that an immediate intervention of recycling drain wastewater can save

[11] Central Public Health and Environmental Engineering Organization (CPHEEO). 1999. *Manual on water supply and treatment*. New Delhi: CPHEEO, Ministry of Urban Development (MoUD).
[12] At an assumed water consumption of about 40 per cent more than the closed-cycle system.

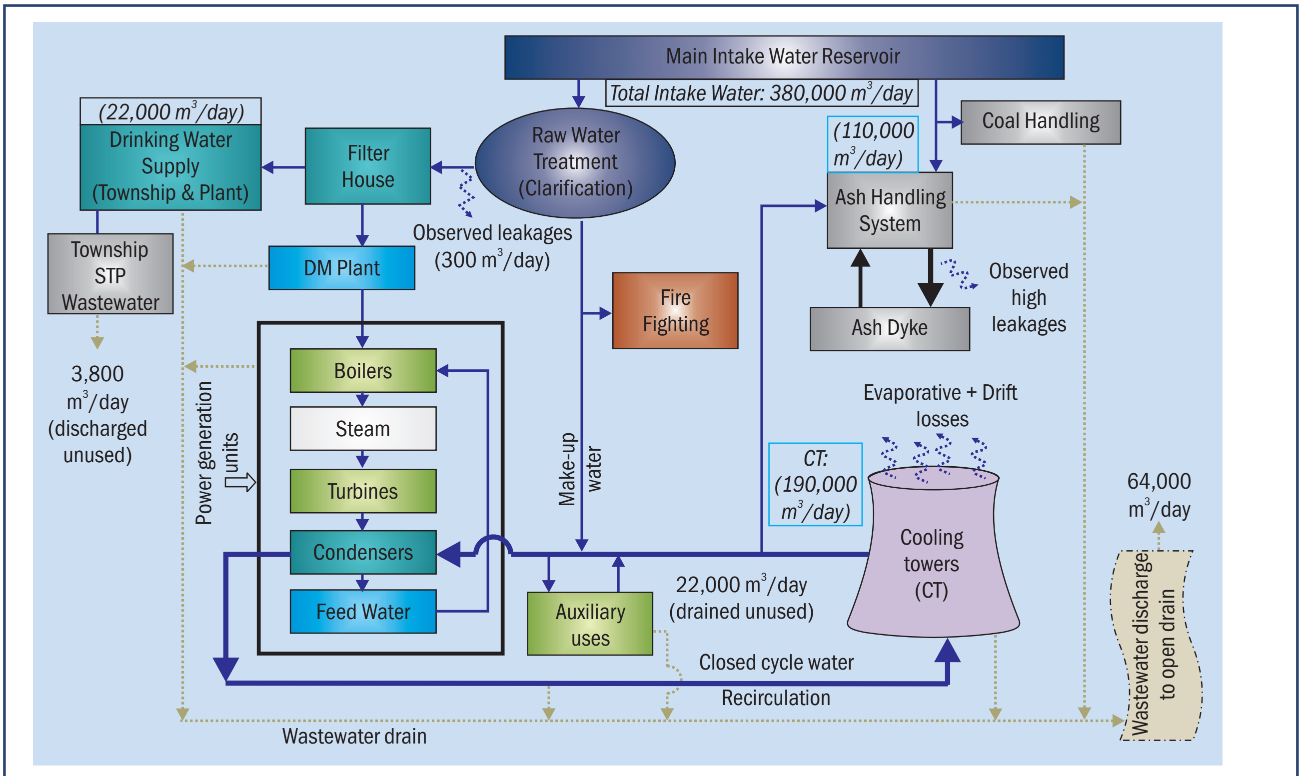

FIGURE 3 State of water use before water audit

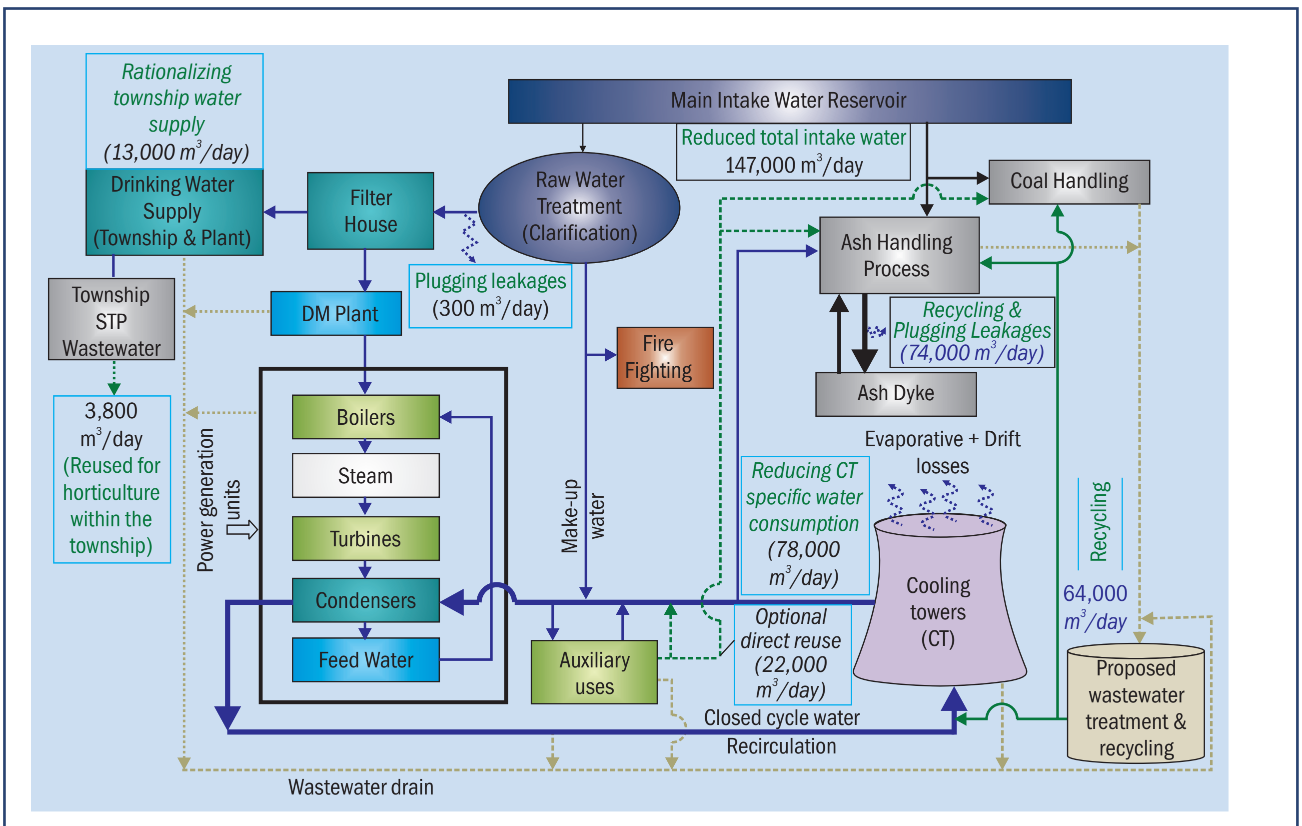

FIGURE 4 Potential water saving areas identified after water audit

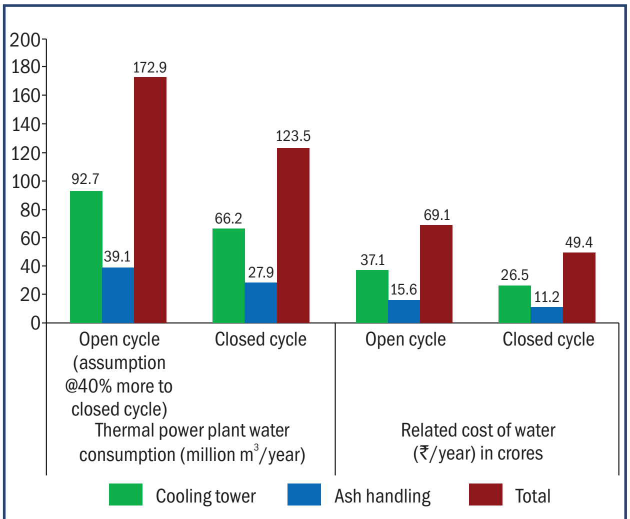

FIGURE 5 Open-cycle versus closed-cycle: Major water consumption areas and associated cost in a coal-based thermal power plant (capacity 3,000 MW)

Note Values are indicative and in case of open-cycle systems,values are assumed to be about 40 per cent more than the closed-cycle system

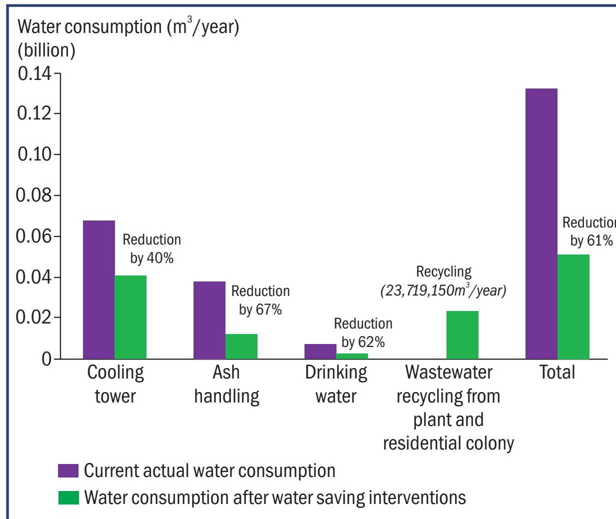

FIGURE 6 Potential reduction in water consumption

about 17.9 million m³/year with an associated financial saving of about ₹7.2 crore/year.

Recycling of water used in ash handling and reduction in cooling tower water consumption

In the long term, including recycling of water used for ash handling as well as reduction in specific water consumption of the cooling tower, a total of about 65 million m³/year could be potentially saved with an associated financial saving of about ₹26 crore/year (Figure 6 and Table 2).[13]

With reference to item 3 from Table 2, a simple cost–benefit analysis of recycling the wastewater (at a conservative 80 per cent of about 60,000 m³/day of the wastewater generated) was carried out as given below:

- Rate of fresh water procured from irrigation department = ₹4/m³
- Capital cost for setting up a 60-MLD recycling plant = ₹13 crore[14]
- Annual operation and maintenance (O&M) cost (including cost of chemicals, manpower, and electricity) = ₹168 lakh (say ₹1.7 crore)
- Annual savings on cost of procuring fresh water (by recycling the wastewater discharged through drain) = ₹7.2 crore.

Payback period

The payback period for the proposed wastewater treatment and recycling system (ETP) = Capital

TABLE 2 Financial benefits of water conservation interventions

S. No.	Identified interventions	Potential water saving volume (million m³/year)	Potential savings in cost* (in ₹ crore/year)
1	Potential saving if specific consumption of water in cooling towers is reduced from 2.5 to 1.5	21.9	8.7
2	Potential saving if water lost in ash handling is recycled (about 70 per cent)	20.6	8.3
3	Recycling wastewater from major drains of plant *(adopting zero discharge)*	17.9	7.2
4	**Total** *(including plugging leakages and recycling township STP wastewater)*	65.2	26.1

Note:* *At the rate of current cost of procurement of freshwater intake*

[13] Actual figures may vary depending upon the technical feasibility from plant to plant.
[14] Indicative cost. Actual cost may vary with different manufacturers.

cost of proposed ETP (b)/ {Annual savings on cost of freshwater (d) – Annual O&M cost(c)}

i.e., the payback period = 13/(7.2 –1.7)= 2.36 years, i.e., less than 3 years.

Benchmarking and specific water consumption

The overall specific water consumption of the audited thermal power plant was found to be around 4.8 m^3/MW. However, with the observed scope of water saving potential in areas, such as ash handling systems, wastewater recycling, rational water supply, and leakage management, a target benchmark of about 3 m^3/MW was likely for the plant.

Water audit outcomes from the audited plants indicate that there is ample scope for improvement in water-use efficiency. The need, though, is to initiate mandatory water audits for the larger benefit of the entire power sector. Such benchmarking and audits should be regularly conducted for further improvements.

Recommendations

It is evident from the above discussions that while thermal power plants are the largest consumers of water in the industrial sector, the scope for water conservation is high if a combination of interventions is implemented. Most of the National Thermal Power Corporation (NTPC) thermal power plants have adopted closed-circulation-based cooling system, which reduces water consumption. Despite this, the expenditure by NTPC on water charges, cess, etc., has increased to almost five times as the figures in Table 3 show.

Table 3 NTPC water charges (₹/crore)

	Water charges	Water and environmental protection cess
2007–08	65.1	22.8
2008–09	93.2	25.5
2009–10	137.9	26.2
2010–11	307.0	38.6

Source National Thermal Power Corporation (NTPC), *Annual Reports*, 2007–08; 2008–09; 2009–10; 2009–10.

From a national perspective, where a large number of power plants other than NTPC still function on the once-through cooling system, there is considerable scope to improve water-use efficiency and conserve water resources.

Specific recommendations for power plants

Cooling system

- A once-through system of water usage in cooling systems should be changed to closed-cycle systems.
- CoCs in cooling towers should be increased through interventions, such as chemical treatment (anti-sludging, anti-sepsis, acidification, etc.), periodic maintenance of cooling tower (CT), etc.[15] The possibility of using dry or hybrid cooling technologies to replace traditional wet cooling towers should be explored in order to reduce water consumption in a few specific cases.[16]

Ash handling

- Overflows should be recycled, leakages plugged, and wastewater reduced. An estimate suggests that for every one per cent of reduction in ash-water ratio, there is a potential saving of 60 m^3/hr of water.[17] Recycled ash-water could be utilized for gardening, firefighting, and dust suppression in the coal-stacking yard.
- Wet ash handling through slurry should be shifted to dry ash handling by use of 'hydro bins' where water is separated from the ash slurry within the plant and the dry lumps are conveyed to the ash dykes through conveyer belts. This would significantly reduce the amount of water consumed in ash handling units.

Firefighting water

Firefighting water must not be used for any other purpose. It should be retained under pressure in fire hydrants and pipelines for emergencies.

[15] Mian Xing. 2010. "Study on the water conservation management measures in thermal power plants". *International Journal of Business and Management*. **5**(3), March.

[16] United States Department of Energy. 2006. *Energy Demands on Water Resources*, Report to Congress on the interdependency of energy and water.

[17] "Estimate for a 210 MW thermal power plant". Details available at http://www.energymanagertraining.com; last accessed on 22 October 2012.

Township water supply (drinking water and other uses)

The per capita water consumption has to be rationalized in residential colonies and norms for supply and tariffs set.

Wastewater

Wastewater should be treated and recycled to achieve zero discharge and save on freshwater intake. Township STP discharge water should be reused, ensuring adherence to zero discharge. Figure 7 represents one of the possible treatment, and recycling systems as an example.

Water audits

Regular water audits should be conducted as a matter of corporate policy. To start with, a periodic annual water audit can be initiated.

Automation

Automation should be introduced in water quality and flow monitoring with a centralized control system and management information system.

Policy recommendations

The 2002 National Water Policy emphasizes the principles of water-use optimization, but does not establish standards or provisions for its enforcement. While there is a clearly set goal of improving water-use efficiency by 20 per cent, this is not supported by existing standards for water consumption. Industry-specific wastewater discharge guidelines need to be revised by an independent body and adequate implementation ensured by third party audits through independent agencies. Water use standards that incorporate the projected growth of the thermal power plant industry and the rise in demand for water must be established.

Need for establishing water use benchmarks

The Central Pollution Control Board (CPCB) has set water quality standards for liquid effluents from condenser cooling, boiler 'blow down', and cooling tower 'blow down'. However, there are no standards for water consumption. Water-use benchmarks that take into consideration technical feasibility,

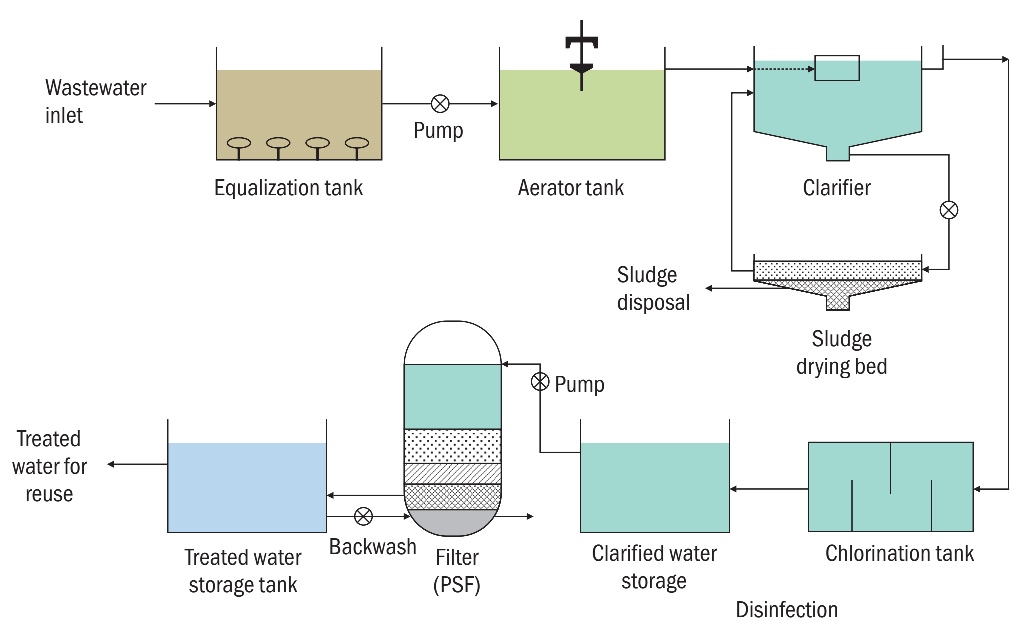

FIGURE 7 Example of a possible wastewater treatment and recycling system

economic feasibility, and present social constructs must be established. This is to be preceded by extensive water audits to enhance understanding of all the systems.

Water balance studies

In order to establish technically feasible benchmarks, the current scenario of water use in thermal power plants needs to be carefully studied on a priority basis. Detailed information on existing raw water use, manufacturing processes, and type and quantity of wastewater generated in the power generation process needs to be collected through initial water balance studies through water audits. Once this information is available, the sources where most of the water loss occurs can be identified.

Economic viability

Once the sources have been identified, various water-saving methods and wastewater treatment alternatives can be proposed. Their applicability should be studied through a detailed cost–benefit analysis. This will help ensure that established water-use benchmarks are economically viable for the industry.

It is important that water be charged to all the power plants at feasible rates to promote water conservation.

Social viability

Comprehensive water use benchmarks must also consider social viability. Thermal power plants must provide adequate effluent treatment to protect their surrounding environment and neighbouring population, and to ensure provision of safe drinking water to workers.

It is also important that the established benchmarks factor in freshwater availability, so that thermal power plants are able to regulate their water use without causing or exacerbating water scarcity in the area.

Need for a Bureau of Water Efficiency

Water-use efficiency essentially should lie within the purview of the Ministry of Water Resources. However, since the functioning of power plants in India is under the Ministry of Power, the task of ensuring water audits and improving water-use efficiency in power plants could be initially with the Ministry of Power. In order to improve water-use efficiency in the entire water sector (agriculture, domestic, and industrial), one of the requisite key reforms would be to set up a central monitoring agency, viz., Bureau of Water Efficiency. Drawing on the experiences from the Bureau of Energy Efficiency, such an agency should train and certify water auditors to carry out performance assessment of water-use efficiency in all sectors and place the reports and findings in the public domain.

Third party water audits to be made mandatory

Once benchmarks for water use in the thermal power plant industry are established, Third Party Water Audits (TPAs) should be made mandatory for all thermal power plants to ensure compliance with the set water-use standards.

Trained and experienced water auditors who are concurrently familiar with international best practices and aware of local circumstances should conduct these water audits to address the data gap on supply, demand, and utilization. This monitoring of water usage in thermal power plants can also help the plants enhance their productivity whilst maximizing natural resource availability, as TPAs can provide guidance regarding technologies and measures, which could improve efficient water usage.

Why third party audits?

The need for efficient water management has to take centrestage in business planning by the industries. Regular water auditing is essential for quantifying the water use by industries in general and power plants in particular, at various stages of production. It is a critical tool to avoid water losses/wastage as well as to identify, prioritize, and strategize areas of water conservation and management.

Regulatory bodies and thermal power plants are currently not equipped with trained professionals who have the expertise to regularly conduct such water audits. Another advantage of TPAs is that they can create a platform to share knowledge, best practices, and benchmarks in other parts of the world.

Benefits of water audits

Water audits, thus, help in the development of an integrated industrial water management strategy, which optimizes efficient use of water, improves water productivity, reduces losses, and helps in identifying alternative methods of water conservation. It reduces specific water consumption and helps in setting benchmarks.

There are three other benefits:

Policy relevance

- Improving water-use efficiency helps contribute to the overall objectives of the National Water Policy and National Water Mission.
- Mandating regular water audits through a policy directive would ensure dynamic assessment of the water-use efficiency in the sector and help regulate and improve the water usage in the power sector on a real-time basis.

Financial benefits

- Interventions identified through water audits will require capital investments. However, in most of the cases, such investments will result in considerable savings in the cost of procurement of freshwater with short payback periods, thus, making it an excellent financially sensible proposition.
- Plants with prior informed and incremental investment in water-efficient policies and technologies will benefit more compared to others.

Co-benefits

The most manifest co-benefit of water audits is the conservation of energy and consequent monetary savings, given that water is a critical part of the energy value chain.

Conclusion

Given the grim water scarcity scenario in India, water intensive industries, such as thermal power plants, must focus on reducing water consumption and improving water-use efficiency. Thermal power plants have a very large potential and a corporate responsibility in this regard. There is, therefore, a pressing need for setting up a Bureau of Water Efficiency and making third party water audits mandatory as early as possible.

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