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| RESEARCH ARTICLE

Assessment of Drinking Water Quality and the Efficiency of the Two Water Treatment Plants in UP, India

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| ABSTRACT
This study presents the analysis of the water quality and efficiency of two water treatment plants (370 MLD Palra Reservoir and 310 MLD Conventional Water Treatment Plant). These facilities are catering the water demand of Agra city, having a population of about 2.5 million people. Results have shown that the canal water in Pahansu at Bulandshahr District from the Ganga River has mainly two physical concerns; turbidity and total suspended solids. Other parameters like TDS (Total Dissolved Solids), Hardness, Alkalinity, ORP (Oxidation Reduction Potential) and E.C (Electrical Conductivity) were also measured, but their concentration met the BIS recommended values for mentioned water quality parameters. During the study, it was found that the average TSS concentration at Palra reservoir is 468 mg/l, and the same is removed by about 50% with the help of the sedimentation process. The initial turbidity level is about 10.55 NTU, whereas, after sedimentation, it is 9.12 NTU. After primary treatment, the raw water is conveyed to the 310 MLD Conventional Water Treatment Plant at Sikandara Agra through an under-gravity pipeline traversing 134kms. The Conventional Water Treatment Plant involves Coagulation, Flocculation, Sedimentation, Filtration and Disinfection Processes. Raw water at the inlet has turbidity and TSS around 16.9 NTU and 187 mg/l, respectively. About 50% turbidity removal and 70% TSS removal occur in the clari-flocculator, and the remaining get removed during the rapid sand filtration process, thus, giving final water free from turbidity and TSS. Other parameters of the treated water, like pH, Alkalinity, Hardness, TDS etc., are well within the prescribed limits.

| KEYWORDS
Treatment Plant, Water Quality Index (WQI), Disinfection, Turbidity, Hardness, TSS

| ARTICLE INFORMATION
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1. Introduction
Collectively, industrial-scale operations known as "water treatment" work to improve the quality of water so that it can be used for drinking, manufacturing, or medical purposes. The original goal of water treatment was to enhance the aesthetics of drinking water. As early as 4000 B.C., techniques for enhancing the flavour and smell of drinking water were documented. Physical procedures like settling and filtering, as well as chemical processes like disinfection and coagulation, may be used to separate sediments from drinking water to provide a safe source of water supply. The maintenance of life on earth depends entirely on water. But this precious resource is still being contaminated by our civilization.

Population increase, industrialisation, and urbanisation are all blamed for pollution. Unsafe drinking water is a factor in a number of health issues (Meghana and Manjunath, 2017). Drinking water ought to be essentially devoid of pathogenic bacteria; however, this is frequently not the case. Especially in developing nations, a sizable share of the global population consumes water that has been contaminated by microbes (Sobsey, 2000).

According to Arshad et al. (2012), it is crucial for consumer health that surface water treatment plants regularly check the quality of the water they are treating as well as assess the effectiveness of their individual unit operations and processes. Turbidity and coliform are typically eliminated by water treatment facilities. Water would acquire the necessary quality during the treatment. The point of consumer usage should be included in the evaluation of its quality rather than being restricted to the end of the treatment facilities. According to Eaton et al. (2005), pre-chlorination, aeration, coagulation, coagulant aids, sedimentation, filtration, desalination, and disinfection are all used in conjunction to treat municipal drinking water around the world. This study focuses on assessing the performance of a water treatment system that has been installed for Agra city in India, sourcing water from the major river of Ganga. In order to achieve the aim of the study, some tasks have been carried out like investigating the raw water quality at the source and every stage of the treatment process on a regular basis, determination of the overall efficiency of the facility and its comparison with the Indian drinking water quality standards and the investigate operational problems of the water treatment processes/plants if any. The data achieved from lab experiments and the water quality index shows that the treatment process is sufficient enough to make the product with excellent water quality, which is completely fit for drinking.

2. Description of the Study Sites

The present study was carried out at two sites. The first site is Palra in District Bulandshahr, which is located 134 km from Agra. A reservoir was constructed at this site which receives canal water. The canal water is tapped, treated in this reservoir cum sedimentation tank and then conveyed to the water treatment plant in Agra. The total length of the conveyance line is 134 km. The canal is connected to the river Ganga in the upper reaches that runs full throughout the year. This was one of the main reasons for collecting the water from this canal and conveying it through a 2000mm diameter pipeline under gravity up to Agra. The total head available between the tapping point of the canal and the water treatment facility at Agra is 24m. After tapping the canal, primary treatment is given right at this place for the removal of debris, objects and suspended solids.

The other two sites are situated within the same premises in Agra. The conventional water treatment plant of capacity 310 MLD is an old facility. This receives water from the above canal. A brief description of these two study sites is given below.

2.1 Palra Reservoir

It is located in Pahansu, District Bulandshahr, which is 134 kms from Agra. The canal runs full throughout the year, and this was one of the reasons to select the site for constructing a reservoir cum sedimentation tank. The reservoir contains three sedimentation tanks with a total capacity of 370MLD. Each tank is 80m in length and 40m in width. The Palra reservoir is being used for the pretreatment of water collected from the Ganga canal, as shown in **Fig. 1.** A view of the Palra reservoir is given in **Fig. 2.**

Fig. 1. View of the Ganga Canal at Palra, District Bulandshahr

Fig. 2. View of the Reservoir Cum Sedimentation Tank at Palra, District Bulandshahr

The effluent of the sedimentation tank is conveyed to Agra for further treatment at the existing conventional water treatment plant. The total distance between Palra and Agra is 134 kms.

The reservoir has the following components of Intake channel with intake screen, Influent system, Three sedimentation tanks (2 duty and 1 standby), Effluent system (including weir, launder, outlet channel, outlet chamber, and screen), RCC ramps (one for each tank, By-pass channel andTank decanting system.

2.2 Conventional Water Treatment Plant

This is an old treatment facility of about 310 MLD capacity. The scheme includes coagulation, sedimentation, filtration, and chlorination. The treatment scheme is shown in **Fig. 3**. The canal water from Palra has been connected with this treatment plant. The facility was refurbished in 2016 and is now operational to cater for the demand of Agra. A few pictures of the WTP are given below (**Fig. 4** and **Fig.5**).

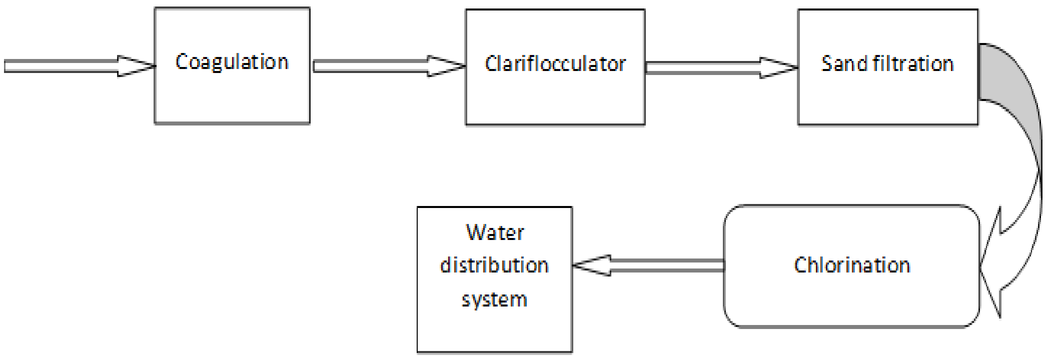


Fig. 3. Flow sheet of the Conventional WTP

Fig. 4. View of the Clari-flocculator

Fig. 5. Filteration Unit

3. Water Quality Index

The water quality index is calculated to reflect the composite influence of different parameters to explain the overall quality status of the water (BOUSLAH et al., 2017). Traditional methods to assess water quality are based on a comparison of water quality values to available normative standards, which is unable to provide a summarized status on spatial trends (Fu et al., 2014). Different water quality indices have been developed to present the overall water quality status from a large variety of water quality data. The weighted arithmetic water quality index used in this study was proposed by Horton (1965) and then developed by Brown et al. (1970), Dojlido et al. (1994), McClelland (1974), and Pesce & Wunderlin (2000). The present study has used eight water quality parameters and IS recommended values in WQI calculation. The steps of WQI calculation are given below.

3.1 Calculation of unit weight (Wn)

The calculation of unit weight (Wn) for water quality parameters is inversely proportional to the recommended standards Sn for the corresponding parameters.

Wn = K/Sn (1)

where: Wn = unit weight for the nth parameters; Sn = standard value for nth parameter; K = constant for proportionality,

3.2 Calculation of sub index of quality rating (qn)

(n) shows the water quality parameter, and (qn) represents the quality rating or sub index corresponding to the nth parameter. The (qn) is a number which reflects the concerned value of this parameter in polluted water with respect to its permissible quantity. The following expression is used for the calculation of (qn).

qn = 100 [(Vn – Vi0) / (Sn – Vi0)] (2)

Where: qn = quality rating for the nth water quality parameter; Vn = estimated value of the nth parameter at a given sampling station; Sn = standard permissible value of the nth parameter; Vi0 = ideal value of nth parameter in pure water.

The (Vi0) value for all parameters for drinking water is taken as zero except the PH, where it is 7 and dissolved oxygen is equal to 16.6mg/l.

3. 3 Calculation of WQI

WQI is calculated from the following equation:

WQI = ΣqnWn/ΣWn (3)

The overall water quality index was calculated by aggregating the quality rating with unit weight linearly.

Table 1. Water quality index (WQI) range, status and possible usage of the water sample

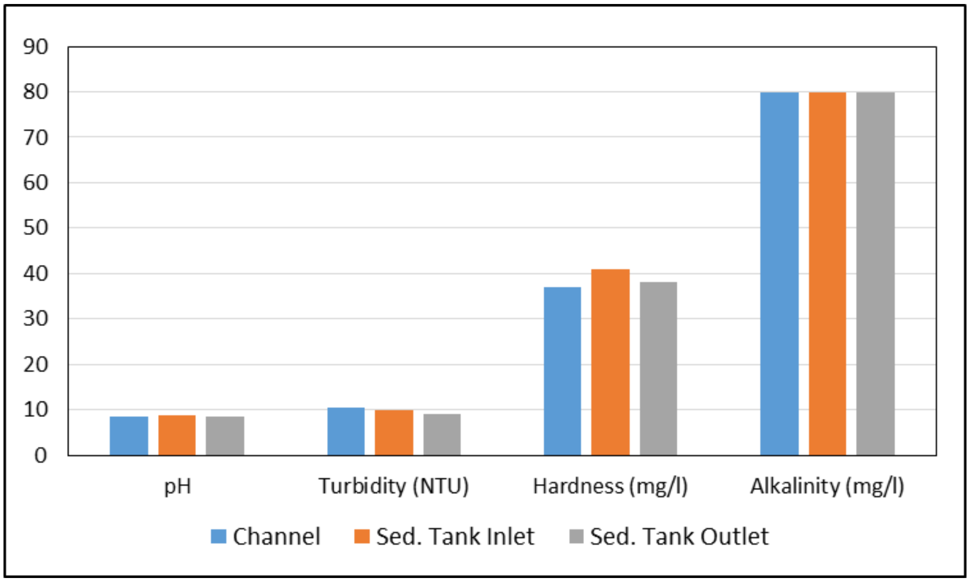
WQI range	**Water quality status**	**Possible usage**
0-25	excellent water quality	drinking, irrigation and industrial
26-50	good water quality	drinking, irrigation and industrial
51-75	poor water quality	irrigation and industrial
76-100	very poor water quality	irrigation
>100	unsuitable for drinking and propagation of fish culture	proper treatment required before use

4. Results and Discussion

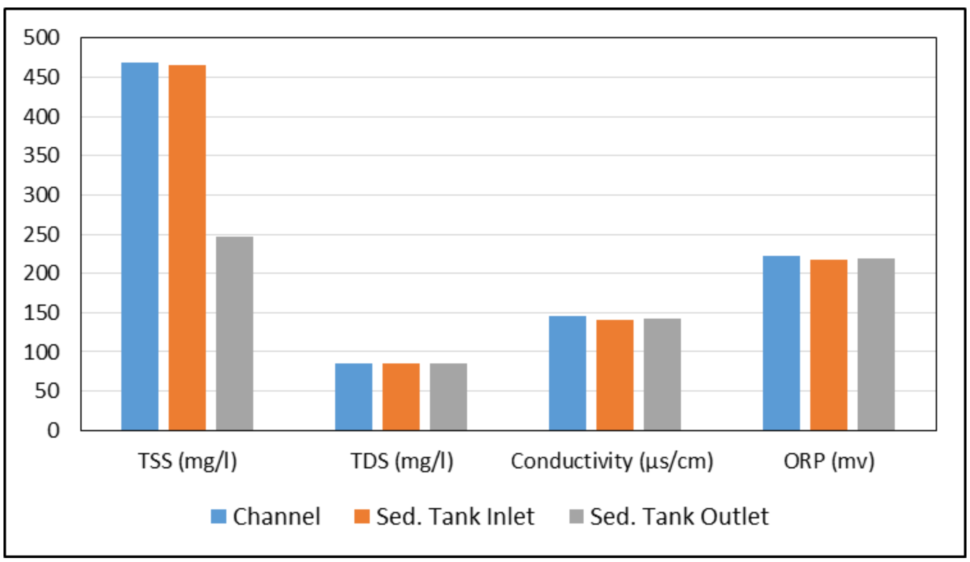
Within the objectives of the study, a reservoir at Palra and a conventional WTP at Agra have been monitored and analyzed for various water quality parameters for assessment of the water quality and efficiency of these water treatment facilities. The monitoring data and results have been discussed in the subsequent sections.

4.1 Monitoring of Reservoir cum Sedimentation Tank

The reservoir at Palra, Bulandshahr, is a reservoir cum sedimentation which receives the Ganga river water through a canal and serves the purpose of pre-treatment for the incoming water. Mainly, floating materials and suspended solids are removed here and supplied to a conventional WTP at Agra for further treatment and to meet the drinking water demand of the local population. Physico-chemical characteristics of the samples collected from different points of the reservoir are shown in **Fig. 6 (a) and (b)**. It is evident from Fig. 7 (b) that the TSS at the inlet of the sedimentation tank is about 468 mg/l, and nearly 50% reduction occurs in the sedimentation process, thus justifying the significance of the Palra reservoir cum sedimentation tank. Other parameters like pH, turbidity, alkalinity, hardness, TDS etc., remain almost the same at the inlet and outlet of the sedimentation tank; no significant changes have been observed, confirming only the physical treatment of the incoming water.



(a)



(b)

Fig.6. Physico-chemical characteristics of water at different points of the reservoir at Palra

4.2 Monitoring of Conventional Water Treatment Plant

The conventional WTP at Agra receives the Ganga water from the reservoir located at Palra. The Ganga river water has low turbidity water, and a conventional treatment scheme consisting of coagulation, flocculation, sedimentation, filtration, and disinfection has been found sufficient to make it fit for drinking purposes as per IS 10500 (2012). Water quality achieved after different treatment processes/operations is shown in **Fig 7 and 8**. The raw water at the inlet of the WTP has a pH of about 6.8±0.6, and the pH of the water after the treatment process remains almost the same. The treated water has a pH of about 6.9±0.8which agrees with the desired standard for pH ranging from 6.5 to 8.5. Turbidity at the inlet is found to be 16.9±4.5 NTU during the monitoring period. About 50% turbidity reduction is achieved in the clari-flocculator, and the colloidal and suspended impurities which escape the clari-flocculator are removed in the rapid sand filtration unit. The treated water has a turbidity of less than 1 NTU; hence, the WTP efficiently removes the turbidity from the Ganga water and fulfils the desired turbidity criteria for potable uses. Hardness and alkalinity in the Ganga water are well below the desired levels, and a significant difference in their levels in raw water and treated water is not observed. The hardness of the raw water collected from the inlet of the WTP is found to be 39±7 mg/l, and that in treated water is found to be about 30±4 mg/l. Alkalinity is, however, greater than the hardness showing the presence of noncarbonate hardness in the Ganga water. The alkalinity of the inlet sample is measured to be about 85±9 mg/l, and treated water has a slightly higher alkalinity of 91±15 mg/l but below the desired alkalinity level as per IS 10500 (2012).

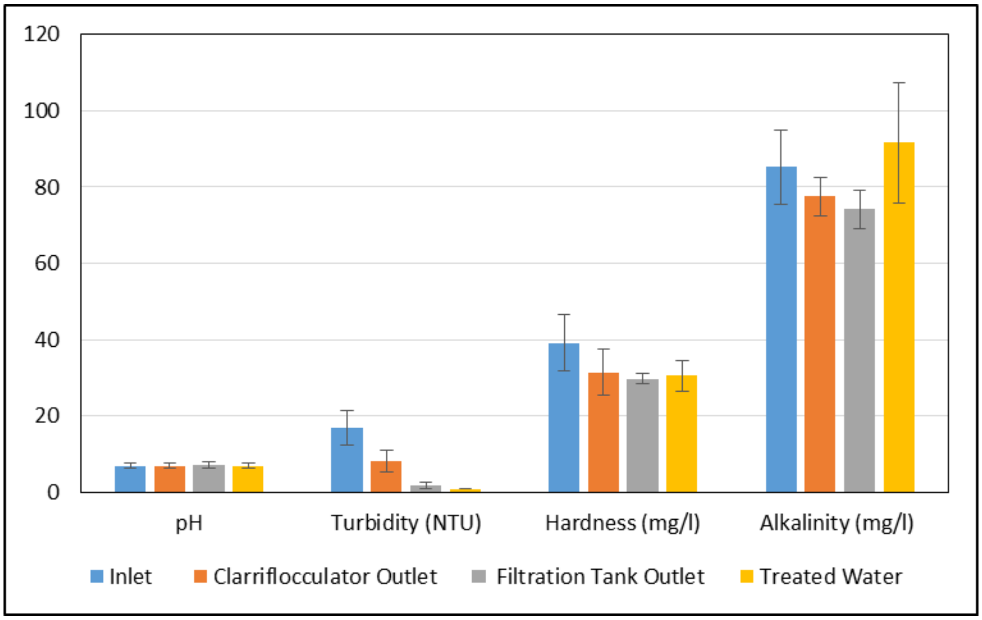


Fig. 7. pH, Turbidity, Hardness and Alkalinity at different sampling points

Raw water has TSS around 187±32 mg/l, and more than 70% TSS removal is achieved in the clari-flocculation process, and the remaining TSS is removed in the filtration process. Treat water has nearly no TSS and is thus fit for drinking purposes. Parameters like TDS, electrical conductivity and oxidation-reduction potential (ORP) of the raw water do not have any significant change and remain almost the same in treated water. These parameters are also below the desirable limits; the TDS of the samples collected from the inlet and that of the samples after chlorination are about 85±4 mg/l and 87±5 mg/l, respectively. The Ganga water received at the WTP is of fairly good quality, and except for turbidity and TSS, the criteria for other parameters are fully satisfied. With the application of a conventional treatment process, the WTP is efficiently removing turbidity and TSS from the Ganga water and making it fit for potable supplies to the local population at Agra and thus, contributing significantly to catering for the water demand in Agra.

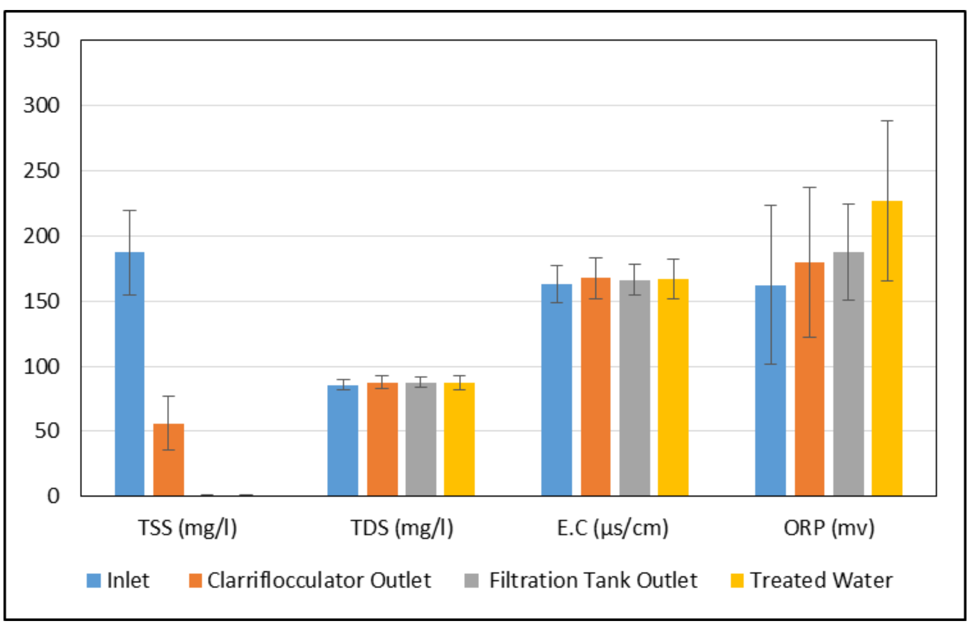


Fig.8. TSS, TDS, Electrical Conductivity and Oxidation-Reduction Potential of different samples

4.3 Water Quality Index

WQI has been calculated using seven water quality parameters data earned through laboratory experiments from representative samples of raw and treated water. WQI calculation is presented in table 2 and table 3 for raw water and treated water correspondingly.

Table 2. WQI of raw water (Ganga Canal)

NO.	Parameter	Observed value	Standard value	Wn	Quality rating *Qn*	Weighted value *Wn · Qn*
1	TSS	468	500	0,150039716	9360	1404,371745
2	SDT	86	5	0,001500397	17,2	0,025806831
3	YTIDIBRUT	11	300	0,750198582	1100	825,2184402
4	HARDNESS	38	3	0,003750993	19	0,071268865
5	ALKALINITY	80	8.5	0,003750993	40	0,150039716
6	E.C	148	45	0,002500662	49,33333333	0,123365989
7	PH	7,2	5	0,088258657	13,33333333	1,176782089
				$\sum Wn$ = 1		2231,137449
WQI = ΣQnWn / ΣWn = *2231,137449*						

Table 3. WQI of treated water (product of 310 MLD conventional WTP)

NO.	Parameter	Observed value	Standard value	Wn	Quality rating *Qn*	Weighted value *Wn · Qn*
1	TSS	0	500	0,150039716	0	0
2	TDS	95,5	5	0,001500397	19,1	0,028657586
3	TURBIDITY	0	300	0,750198582	0	0
4	HARDNESS	40,5	3	0,003750993	20,25	0,075957606
5	ALKALINITY	98	8.5	0,003750993	49	0,183798653
6	E.C	167	45	0,002500662	55,66666667	0,139203515
7	PH	6,8	5	0,115415166	40	4,616606658
				$\sum Wn$ = 1		$\sum Wn \cdot Qn$ =5.044
WQI = ΣQnWn / ΣWn = *5.044*						

5. Conclusion

The study aimed to evaluate the performance of water treatment systems which are installed to cater for the water demand for Agra City, India, which sourced water from the Ganga and Yamuna Rivers. To achieve this goal, tasks such as regularly monitoring raw water quality at the source and throughout the treatment process, determining the facility's overall efficiency and comparing it to Indian drinking water quality standards, and investigating any operational issues with the treatment processes were carried out. The data obtained from lab experiments and the water quality index indicated that the treatment process effectively produced water of an excellent quality suitable for drinking. Within the mentioned objectives, the scope was limited to, Identification of the study sites (Palra Reservoir and Conventional WTP), develop an understanding of the overall scheme of these sites and purposes, the collection of samples from the study sites and analysis of raw water to determine the initial concentration of impurities or contaminants present in the raw water, sampling and analysis of every stage of the treatment process to find out removal efficiency and compare the results with drinking water quality standards from a compliance point of view.

In Palra Reservoir at Pahansu, Dist. Bulandshahr, The raw water quality which gets water from the Canal (Ganga River), contains turbidity and suspended solids. The concentration of solids is about 468 mg/l, whereas average turbidity is observed to be around 10 NTU. The Palra reservoir is a sedimentation tank, and therefore removal of suspended solids is found to be about 50%. In the conventional Water Treatment Plant, Agra, The raw water received has a turbidity of around 17 NTU; however, after a series of treatment processes, the turbidity of treated water is found to be less than 1 NTU. The average TSS concentration at the inlet of the conventional water treatment plant is found to be 187 mg/l, and the final water after treatment is free from TSS. Other water quality parameters such as pH, alkalinity, hardness and TDS of the treated water also satisfy the desired standards for drinking water. The conventional water treatment facility at Agra is, thus, found to perform well in this study and produce water fit for potable supplies to meet the water demand of local people at Agra. For the Water Quality Index for Ganga Canal and Product of 310 MLD Conventional WTP at Sikandar, Agra, the quality status of raw water falls under the fifth category, which is not usable without proper treatment, while the treated water is defined as excellent water quality and is suitable for drinking, irrigation and industrial uses.

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