Avicenna J Environ Health Eng. 2018 June;5(1):8-14 http://ajehe.umsha.ac.ir

Original Article

doi 10.15171/ajehe.2018.02

Sewage Generation and Treatment Status for the Capital City of Uttar Pradesh, India

Rajneesh K. Gautam[1*], Saumya Verma[2], Islamuddin[1], Nandkishor More[3]

[1]Department of Civil Engineering, UIET, Babasaheb Bhimrao Ambedkar University, Lucknow-India
[2]Department of Statistics, Lucknow University, Lucknow –India
[3]Department of Environmental Science, Babasaheb Bhimrao Ambedkar University, Lucknow-India

***Correspondence to**
Rajneesh K. Gautam
Email:
gautamenviro@gmail.com

Published online June 17, 2018

Abstract
The piped water supply in Lucknow was introduced in 1892 to serve the population of 2 Lacs. However, the population has risen exponentially since then from 2.1 million in 2001 to 2.86 million in 2011 according to the census data of the Government of India. In this paper, statistical analysis was done and it was projected that the population of Lucknow will be as high as 4.2 million in 2025 followed by 6.42 million in 2040. Since the water demand is proportional to the population, it is projected that present water demand of 550 million liters per day (MLD) would rise to the maximum of 1300 MLD in the year 2040 which is twice more than the present volume. The major concern of Lucknow city is the poor efficiency of wastewater treatment facilities which are deteriorating the quality of underground water and surface sources. The major concern lies in Gomti River. The wastewater generation in 2025 would be as high as 700 MLD while for the year 2040 it would be 1100 MLD. To meet the given figures a well-planned and effective wastewater treatment system has to be designed and implemented which may include centralized and decentralized treatment facilities in accordance with the need of the particular division followed by up-gradation of the present water supply and sewerage system. Care should be taken while discharging the sewage into river Gomti and other natural streams as it should strictly follow the prescribed standards by central state pollution control boards, also there should be the least disturbance of aquatic ecosystem. Furthermore, deterioration of the water quality must be minimized to a large extent.
Keywords: Wastewater, Aquatic Ecosystem, Decentralized Treatment System, Water Quality, Gomti River

Received March 20, 2018; **Revised** May 10, 2018; **Accepted** June 2, 2018

1. Introduction

1.1. Overview of Sewage Generation in India

India is a country with rich and varied heritage and enormous cultural beliefs. The civilization is proved to be originated at the bank of the river. The past civilization such as Harappa has the historical proof that the civilizations have blossomed at the site of the river. The past scenario of the river water quality varies drastically as per the present scenario. The rapid urbanization and industrialization have led to a plethora of environmental problems offsetting the benefits of modernization and development. Energy, water and food securities are emerging as increasingly important and vital issues for India and the world. Current and future freshwater demand could be met by enhancing water use efficiency and demand management (1,2). An estimated 38 354 million liters per day (MLD) sewage is generated in major cities of India (3), but the sewage treatment capacity is only 11 786 MLD. Similarly, 60% of industrial wastewater, mostly large scale industries, is treated. Performance of state-owned sewage treatment plants, for treating municipal wastewater, and common effluent treatment plants, for treating effluent from small-scale industries, is also not complying with prescribed standards. As per center for Public Health and Environmental Engineering Organization (CPHEEO) Delhi, about 70%-80% of total water supplied for domestic use is estimated to be generated as wastewater. The per capita wastewater generation in the class-I cities and class-II towns, representing 72% of urban population in India, has been estimated to be around 98 LPCD (3).

Around 3296 MLD of sewage is dumped in the River in Delhi, Capital of India. Delhi generates approximately 2 271 247 080 liters of sewage per day (600 MGD), while it has an installed capacity to treat only 1 938 130 841 L (512 MGD) of wastewater. Almost 58% of the total sewage

generated by the city is dumped in the Yamuna, emptied into the river by 22 drains between Wazirabad Barrage and Okhla Barrage (5).

1.2. Geographical Location of Lucknow City

The geographical location of Lucknow is between 26.8467° N and 80.9462° E. Lucknow is located at an elevation of 123 m above sea level. It is surrounded on the eastern side by Barabanki district, on the western side by Unnao, on northern side by Sitapur and on southern side by Raebareli.

1.3. Demography of Lucknow

Lucknow (Fig. 1) is the capital of the state Uttar Pradesh. It is known for its uniqueness and varied heritage. Lucknow is one of the fastest growing cities in the north India after Delhi (1). It continues to be an imperative focal point of administration, organization, business, education, tourism, music and verse. It is the political and administrative headquarter and is known as the city of Nawabs which has preserved its own historical importance. According to the 2011 census, the city had a population of 2 815 601 from which about 1 470 133 were men and 1 345 468 were women. More than 36.38% of the aggregate population live in rural areas, leaving scarcely around 63.23% made out of the urban population. These were high figures when contrasted with the state as a whole, where the urban population just constituted around 21.2% of the aggregate population. The sex proportion in the city remained at 915 females to 1000 males in 2011 as contrasted with 2001 evaluation figure of 888. The average national sex proportion in the country is 940 as indicated by the 2011 census. The city, additionally, boasts a literacy level of 84.72% contrasted with 56.3% for the state. The population density of the city is 1815 persons per square kilometer. The total number of inhabitants in Lucknow urban agglomeration exceeded one million in 1981 while the 2001 evaluation assessed it to be ascended to 2.24 million. This included around 60 000 individuals in the Lucknow Cantonment and 2.18 million in Lucknow city and additionally had an increase of 34.53% over the 1991 figure. As reported by the census of India in 2011, the city had a population of 2 815 602 from which around 1 471 133 were men and 1 345 4687 were women. This figure showed an increase about 25.36% contrasted with the 2001 figures. Somewhere around 1991 and 2001 the population enrolled growth of 32.03%, essentially lower than 37.14% which was enlisted somewhere around 1981 and 1991 (1,6).

1.4. Sources of Water Supply

The formation of Lucknow municipal board took place in 1882, while as the water supply demand is fulfilled by tube wells, river Gomti, Sharda Sahayak feeder canal, aquifers, and so on, the maximum source of intake is Gomti which is geographically distinguished as Cis and Trans Gomti. The Cis Gomti side is comparatively lower than the area on Trans Gomti side. Since the city is located on alluvial aquifers of Indo-Gangetic plain, where due to easy accessibility, private tube well construction activity is going on unchecked, especially in residential colonies and multi-storeyed buildings, and this is the reason why the private tube wells/borings have almost mushroomed in this capital city. This has led to heavy pumpage/continuous abstraction of groundwater resources, widespread depletion of aquifers and as a result, going down of groundwater levels drastically to almost unsustainable levels, from where it seems very difficult that the depleted conditions of ground water could ever improve (6). The water supply network depends on sources like tube wells, river Gomti and the Sharda Sahayak feeder canal. The distribution of water supply has a very vast network and it is reported to be 2884 km. The rate of water supply is assumed to be 150 LPCD and water demand is calculated accordingly (7). The availability of water, as reported by Jawaharlal Nehru national urban and rural mission

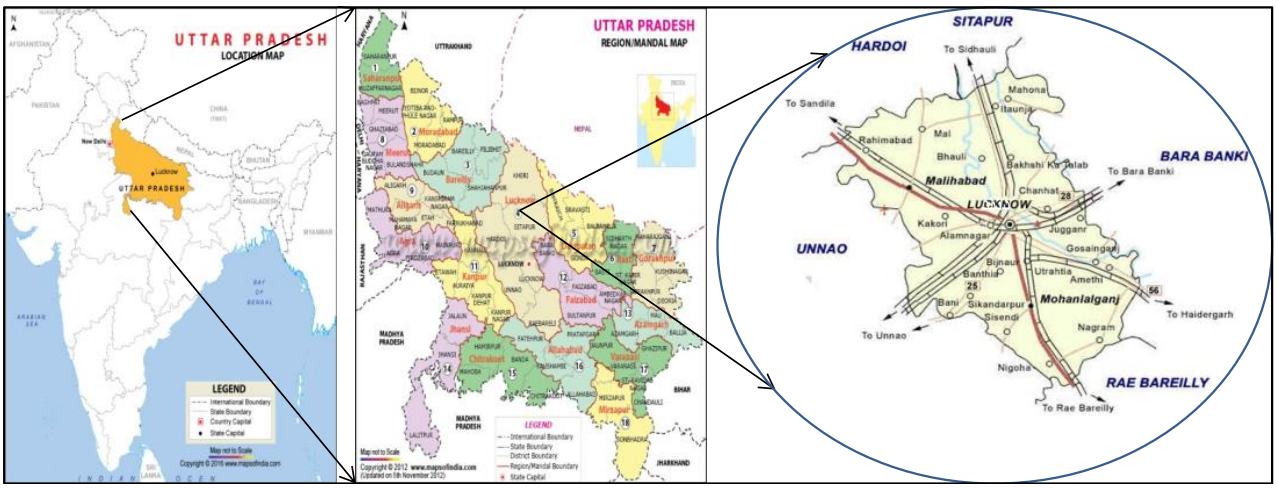

Fig. 1. Maps of India, Uttar Pradesh and Lucknow (Source: http://www.indiainmaps.com/maps/uttar-pradesh-location-map.jpg (4).

(JNNURM) on November 2016, was 619 MLD from various sources (7), however, it keeps fluctuating as the city is more vulnerable to migration from other parts of the state.

1.5. Status of Wastewater Treatment

The sewerage system of Lucknow is divided into four separate sewerage districts, which are further divided into zones. These zones are further divided into several sewer sub-catchment areas. The entire city is divided into 4 different sewerage districts, namely I, II, III, and IV as shown in Fig. 2. It is reported in the Lucknow development plant (8) that 100% sewer lines have been laid for the districts I and III, while the sewerage system for the district IV has become defunct due to lack of maintenance and old system. Furthermore, district II lacks sewerage system completely. Around 500 MLD sewage is generated in Lucknow, which is treated at various centralized effluent treatment plants viz Daulatganj STP (56 MLD) and Bharwar STP (346 MLD). Twenty-six different drains join the river Gomti, out of which 14 are from Cis side and 12 are from Trans side. The Cis Gomti drains are 14 in numbers, 12 of which are located on upward Stream (U/S) and 2 are on the downward stream (D/S) of the barrage. There is a deficit of 90 MLD in wastewater treatment which is disposed of in the natural streams, deteriorating the water quality which is a major environmental constraint.

As the population of the city is growing exponentially, the water demand and the wastewater generation would be more than the calculated value and it may surpass the projected value. The objective of this research was to estimate the population of future decades for the city of Lucknow from the known decades, thereby calculating the overall water demand from its sources, highlighting the system of supply and deficit likely to occur over future decades. Moreover, this research aimed to emphasize overall wastewater generation in the city, method of wastewater treatment, efficiency of wastewater treatment and future recommendations with respect to the obtained statistical data. This paper presented a deep statistical analysis of water demand, supply and wastewater generation from the demographic projection of population by various statistical tools.

Fig. 2. Different Districts of Wastewater Treatment in Lucknow (Source: http://jklmc.gov.in/map.aspx (9).

2. Materials and Methods

2.1. Method for Projection of Population

The population of Lucknow is known for the years 1901, 1911, 1921, 1931, 1941, 1951, 1961, 1971, 1981, 1991, 2001, 2011 and is projected for the years 2021, 2031, and 2041 respectively. The population is calculated by various methods and compared to the previous growth rates and it has been found that the geometrical increase method is the most suitable one for projection of the present population. The method of population projection or forecasting involves statistical and mathematical techniques viz arithmetic increase method, geometric increase method, incremental increase method, decreasing rate method and logistic curve method.

2.1.1 Geometric Increase Method

Assuming the growth rate (r) to be constant, the increase in the population is compounded over the existing population every decade. This method is also known as uniform increase method, though the population of Delhi has decadal variation in its growth rate. The calculated value is acceptable as compared to other forecasting methods. The population is collected from the NSSO, Govt. of India for the preceding years, from 1951 to 2011, and the available population is compounded for the succeeding decades, from 2021 to 2051, by geometrical increase method.

$P_1 = P_0 + (r/100)*P_0$; P_1 = population after one decade
$P_2 = P_1+(r/100)*P_1$; P_2 = population after 2 decades
$P_1 (1+r/100)$; r = percentage growth in population

2.2. Calculation of Water Demand

The water demand is calculated in accordance with the population, the higher the population is, the greater the water demand will be. It is also dependent on various other factors such as lifestyle of the individuals, type and nature of the intake, size of the city, metering system, and so on (1). The calculation of water demand is based on the norms of 60 gallon per capita per day (GPCD) as per the Ministry of Urban Development, Government of India and Central Public Health and Environmental Engineering Organization (CPHEEO) norms, however at present the average per capita water supply in Lucknow is 150 LPCD, whereas it fluctuates between 100 and 200 LPCD in 110 different wards. The total requirement of water in March 2011 was found to be 486 MLD. The water demand is calculated by multiplying the population by the per capita demand in addition to 15% for leakage and thefts. Various types of water demand, which a city has,

may be broken down into various classes such as domestic demands, institutional demands, industrial demands, fire demands, public use demands, loss, and theft demands. The amount of domestic water consumption per person shall vary according to the living conditions of the consumers. As per IS: 1172-1993, the minimum domestic consumption of a town or city with the full flushed system should be taken as 200 LPCD, although it can be reduced to 135 LPCD for economically weaker section and lower income groups (LIG) depending upon the prevailing condition. The Lucknow development authority (LDA) has taken a figure of 150 LPCD.

2.3. Calculation of Wastewater Demand

According to reports, 80%-90% of water turns into wastewater. Hence the water demand is calculated and then converted into wastewater by taking the percentage into consideration, as mentioned by CPHEEO manual India. The wastewater generation is then projected for the financial year 2040 which is based on the quantity of water needed. Wastewater indicates the liquid waste originating from the domestic uses of water. It includes sullage, discharge from toilets, urinals, wastewater generated from commercial establishments, institutions, industrial establishments, as well as groundwater and storm water that may enter into the sewers. Its decomposition produces large quantities of malodorous gases, and contains numerous pathogenic or disease-producing bacteria, along with high concentration of organic matters and suspended solids (10). The net quantity of produced sewage can be estimated by considering the addition and subtraction over the accounted quantity of water, supplied by water authority as bellows:

Net quantity of sewage = A+B+C-D-E

Where A = Accounted quantity of water supplied from the waterworks, B= Addition due to unaccounted private water supplies, C= Addition due to infiltration, D= Subtraction due to water losses, E= Subtraction due to water not entering the sewerage system.

3. Results and Discussion

From the calculations and investigations above mentioned, it could be stated that fluctuation has been observed in the initial decades and the rate has been constant thereafter. The growth rate is calculated by calculating the increment and then applying the geometrical increase method to obtain the growth rate for projected years. It was also found that the population is rising in the future decades. This rise in the population is exponential as there is constant migration of people to the state capital region from all over the country. The mathematical data obtained after statistical correlation is mentioned in Table 1 and represented graphically in Fig. 3 and Fig. 4.

As demonstrated in Table 1, the growth rate for each decadal year for Lucknow is continuously increasing.

Table 1. Population Forecast With Growth Rate

Year	Population	Increment	Growth Rate
1951	496900		0.198
1961	595400	98500	0.367
1971	814000	218600	0.238
1981	1007604	193604	0.657
1991	1669204	661600	0.345
2001	2245509	576305	0.293
2011	2902601	657092	0.32
2021	3831433	928832	0.32
2031	5057491	1226058	0.32
2041	6675889	1618398	0.32
2051	8812174	2136285	0.32

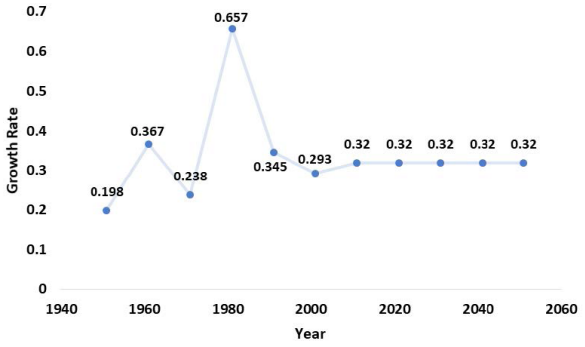

Fig. 3. Graphical Representation of Growth Rate With Time for the City of Lucknow From the Year 1951 to 2051.

The growth rate is calculated from 1951 to 2051 which is found to be increased by 1.6 times as calculated by the method of geometrical increase. In the year 1991, the population was 496 900 according to the census of India (11,12) which may reach by 8 812 174 in 2051 as calculated by geometrical method. The population in 2051 would be almost 17 times the year 1951. The growth rate was reported to be 0.198 in 1951 which shows an exponential growth rate in the next three decades, which are 0.367 in 1961, 0.238 in 1971, and 0.657 in 1981, thereafter it is decreased for the next decades and since 2011 the rate would be decreasing and the population is calculated at constant value of 0.32.

Fig. 3 is the graphical representation of growth rate with time for the city of Lucknow. The graph is neither exponential nor logarithmic as continuous fluctuation is seen in the previous years and the estimated growth rate is seen to be constant. In the year 1991, the growth rate is recorded maximum which is 0.675. Thereafter the estimated growth rate is seen to be constant.

Fig. 4 is the graphical representation of the population for the projected years which has been calculated using correlating growth rates for previous years, obtained by geometrical increase method.

According to the norms of Lucknow JAL Board (8),

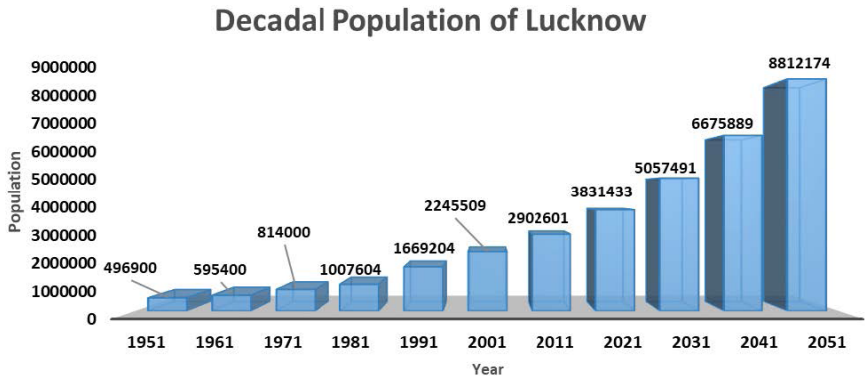

Fig. 4. Graphical Representation of Population for the City of Lucknow From the Year 1951 to 2051.

150 LPCD is taken as the baseline for calculating water demand, however, the per capita demand keeps varying among different zones of Lucknow due to undefined settlements (7). The water demand is seen to be increasing exponentially due to rise in the population as seen in the Fig. 5 and same has been calculated and projected for the future decades in Table 2. The water demand is seen to be increasing exponentially due to the population increase. The water demand as per Lucknow Jal Board was 74 MLD in the year 1951 against the population of 496 900 which was increased to 336 MLD in the year 2001 and 500 MLD in 2011 (8). The projected water demand as mentioned in Table 3 is calculated on the basis of per capita demand in LPCD. The per capita demand for the years 2021 and 2031 is taken as 200 LPCD and for the years 2041 and 2051 is taken as 225 LPCD due to a significant increase in the number of users. The population growth rate is assumed to be constant from 2011 to 2051 but the water demand is increasing continuously and it would reach to a maximum value of 1762 MLD in the year 2051 which is about 24 times the water demand in the year 1951.

Table 2. Projected Water Demand

Year	Population	Water Demand (in MLD)
1951	496900	74
1961	595400	89
1971	814000	122
1981	1007604	151
1991	1669204	250
2001	2245509	336
2011	2902601	500
2021	3831433	766
2031	5057491	1011
2041	6675889	1335
2051	8812174	1762

The correlation between water demand and wastewater can be seen in Fig. 6. The wastewater generation has been calculated against the water demand as 80%-85% of water turns into wastewater (13) and the wastewater generation is proportional to the water demand. Since the water demand was continuously increasing from 1951 to 2011 and till present hence the wastewater generation was also increasing from 62.9 MLD in 1951 to 369.75 MLD in 2011 which would be as high as 1500 MLD in 2051. The treatment capacity of wastewater treatment plant as reported by Lucknow municipal corporation (LMC) (14) was found to be 265 MLD in 2011, having a deficit of 20 MLD. The total sewage generation on January 2015 was 490 as reported in the city development plan of Lucknow (14). The treatment efficiencies of the plants running in Lucknow is only 58% which is again a major concern, as untreated wastewater is either released on land or dumped in Gomti River deteriorating the water quality of Gomti. The treatment efficiencies of the wastewater treatment plants should be increased for better treatment and disposal of wastewater into Gomti and other nearby streams. Therefore, the old machineries of wastewater treatment plants located in various zones of Lucknow should be replaced, since most of the treatment plants in Lucknow are relying on activated sludge process (ASP),

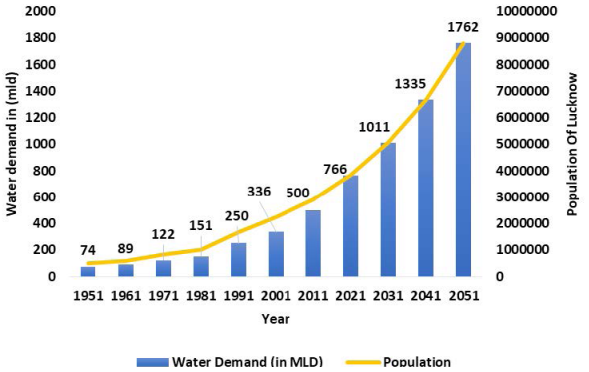

Fig. 5. Graphical Representation of the Present and Projected Water Demand for the City of Lucknow.

Table 3. Correlation Between Population, Growth Rate, Water and Wastewater Generation

Year	Population	Increment	Growth Rate	Water Demand (MLD)	Wastewater Generation (MLD)	W.W Treatment capacity (MLD)	W.W Treatment Gap (MLD)
1951	496900		0.198	74	62.9	-	
1961	595400	98500	0.367	89	75	-	
1971	814000	218600	0.238	122	103.7	-	
1981	1007604	193604	0.657	151	128	-	
1991	1669204	661600	0.345	250	212.5	-	
2001	2245509	576305	0.293	336	285.6	265	220
2011	2902601	657092	0.32	500	369.75	465	363.81
2021	3831433	928832	0.32	766	651	700	-
2031	5057491	1226058	0.32	1011	859	900	-
2041	6675889	1618398	0.32	1335	1134	1200	-
2051	8812174	2136285	0.32	1762	1500	1700	-

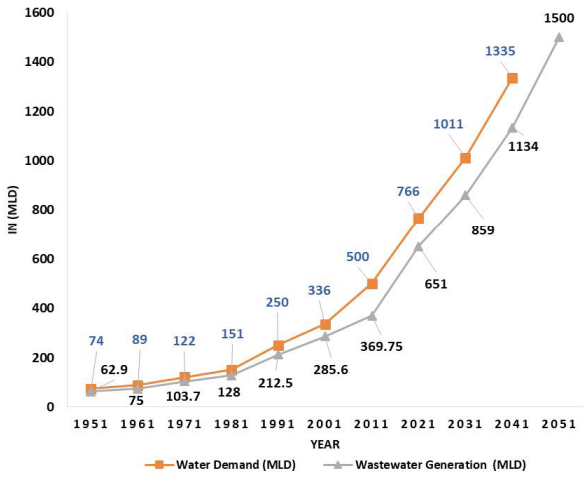

Fig. 6. Graphical Representation of Correlation Between Population, Growth Rate, Water and Wastewater Generation.

which may be replaced by sequential batch reactors (SBR) (2) in order to attain maximum treatment efficiency. The untreated effluent discharge is major concern as most of the Indian rivers are turning into sewer due to uncontrolled and untreated discharge of wastewater into natural bodies especially rivers (15).

4. Conclusion

The water demand of Lucknow is continuously increasing year by year due to constant migration of people from other cities and its fast growing status, availability of all needed resources like hospitals, world class education platforms, transportation system, and so on. There are few other reasons like thefts, losses, undefined metering system, and undefined settlements like JJ Clusters in few areas of Lucknow, behind the increased demand of water. The basic sources of water supply in Lucknow are surface and underground sources. The underground sources include tube wells which are nearly 400 MLD followed by 475 MLD from surface sources such as Sharda Sahayak feeder canal and River Gomti which are getting polluted day by day by industrial and municipal effluents. The normal per capita water supply in Lucknow is 150 LPCD, though it varies in the vicinity of 100 and 200 LPCD in 110 different wards which would increase to a level of 250 LPCD in future decades. The aggregate prerequisite of water in year 2011 was observed to be 486 MLD which has increased to 680 MLD in 2018. Water supply is not a major concern in Lucknow as it has ample quantity of water in its surface and underground sources. The major concern of the city is wastewater treatment as the city is already having a deficit of nearly 200 MLD of wastewater treatment, and poor efficiency of wastewater treatment facilities installed at different zones of Lucknow, which is only 58%. The wastewater treatment plants should be upgraded and different sustainable approaches like decentralized wastewater treatment facilities (16) should be adopted in the areas where centralized treatment facilities are not feasible. The decentralized treatment system may also be commissioned and mediatized at governmental organizations, hospitals, schools, and so on to motivate and spread awareness related to water reuse, reduction, and recycling for a sustainable future.

Conflict of Interest Disclosures

The authors declare that they have no conflict of interests.

References

1. Gautam R. Sewage Generation and Treatment Status for the City of Delhi, its Past, Present and Future Scenario- A Statistical Analysis. Int J Res Appl Sci Eng Technol. 2017;5(5):926-33.
2. Gautam R, Islamuddin VFS, More N. Sequential Batch Reactor Technology and Role of Aerobic Granular Sludge in Biological Treatment of Wastewater. Int Res J Eng Tech. 2016;3(11):1210-4.
3. CPCB. Performance status of common effluent treatment plants in India. India: Central Pollution Control Board; 2005.
4. Maps of India, Uttar Pradesh and Lucknow, http://www.indiainmaps.com/maps/uttar-pradesh-location-map.jpg.
5. Kumar A, Sharma RC, Rathore B. Determination of WQI of

River Yamuna Between Mathura and Agra Region. J Ultra Chem. 2012;11(1):7-14.
6. Chaurasia PR, Sinha RS, Saxena NC, Zaidi MA, Saraswat AK, Yadav S. Lucknow city- under ground water stress. Government of Uttar Pradesh; 2015.
7. Lucknow water supply, an insight to third water works, JNNURM http://cdn.cseindia.org/userfiles/AK%20Gupta-Lucknow%20Water%20Supply.pdf,
8. Revised CDP (City development plan), Lucknow city 2040, lmc.up.nic.in/pdf/nnfinal.pdf.
9. Different districts of wastewater treatment in Lucknow. http://jklmc.gov.in/map.aspx.
10. Ghangreker MM. Industrial water pollution control, IIT Kharakpur; 2005.
11. http://indiapopulation2017.in/population-of-lucknow-2017.html
12. Census. (2011). Census of India. Retrieved from http://www.censusindia.gov.in/
13. World Health Organisation. Operation and maintenance of water supply systems. CPHEEO, New Delhi: Ministry of Urban Development; 2005.
14. Revised city development plan- Lucknow 2040. Lucknow Municipal Corporation; 2015.
15. CPCB. Report on Water Quality Status of Yamuna River 1999-2005. India: Central Pollution Control Board; 2006.
16. Gautam R, Singh A. Decentralized Low Cost Wastewater Treatment Plant Based on Phytoremediation and natural filtering media. Int J Sci Res. 2016;5(2):1097-100.