DRAFT BACKGROUND DOCUMENT

Assessment of Urban Pollution in the Hindon River Basin including Recommendations for Measures

Development and Implementation Support to the India-EU Water Partnership (IEWP)

Contract number: PI/2017/386-557

Partnership Instrument 2016 Annual Action Programme

Implemented by:

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Preamble:

This document holds an assessment of the current pollution load from human settlements in the Hindon basin and expected trends, aimed at establishing current gaps and future management and treatment needs.

The content of this document should be seen as a proposal that will be coordinated between the EU, 2030 WRG and Indian stakeholders including relevant representatives of Uttar Pradesh.

CONTENT

1 INTRODUCTION

This document holds an assessment of the current pollution load from human settlements in the Hindon basin and expected trends, aimed at establishing current gaps and future management and treatment needs.

2 DEMOGRAPHY OF HINDON RIVER BASIN

2.1 Current population

The population has been estimated based on Census 2011 for all the districts that have territory in the Hindon basin. Population is broken down in 3 components:

1. population in major cities (class I and II cities).
2. other urban population.
3. rural population.

Table 1. Urban and rural population in Hindon basin (2011)

District (2011)	Population (2011)	Rural	Urban	% of District Area in the Basin	Hindon population in major cities	Hindon population in urban areas (others)	Hindon rural population	Total Hindon population
Uttar Pradesh								
Baghpat	1,303,048	1,028,023	275,025	12.00%	103,764	20,551	123,363	247,678
Ghaziabad	4,681,645	1,519,098	3,162,547	6.00%	2,196,839	57,942	91,146	2,345,927
Muzaffarnagar	4,143,512	2,952,200	1,191,312	24.00%	500,034	165,907	708,528	1,374,469
Saharanpur	3,466,382	2,399,856	1,066,526	35.00%	802,515	92,404	839,950	1,734,868
Gautam Buddha Nagar	1,648,115	673,806	974,309	10.00%	830,515	14,379	67,381	912,275
Meerut	3,443,689	1,684,507	1,759,182	5.00%	1,363,681	19,775	84,225	1,467,681
Sum	**18,686,391**	**10,257,490**	**8,428,901**		**5,797,348**	**370,959**	**1,914,592**	**8,082,899**
Uttarakhand								
Hardwar	1,890,422	1,197,328	693,094	10.00%	171,171	52,192	119,733	343,096
Sum	**1,890,422**	**1,197,328**	**693,094**		**171,171**	**52,192**	**119,733**	**343,096**
Total	**20,576,813**	**11,454,818**	**9,121,995**		**5,968,519**	**423,151**	**2,034,325**	**8,425,995**

Source: own elaboration with data from Annexure I of Tapi Basin Report [http://cleanganga.info/hindon/finaldmin/main.php] *and* http://censusindia.gov.in/

Hindon basin is a densely urbanized and populated area. Major cities located within or close to the limits of the basin have been identified and their inhabitants considered in the assessment, which means that there is probably an overestimation of the population discharging wastewaters into the Hindon basin. Other urban population and rural one has been approached based on the fraction of the district pertaining to the Hindon basin.

Under these assumptions, it has been estimated that 6.31 million people lived in urban areas, above 75% of total basin inhabitants in 2011 (8.43 million). Major cities accommodated 5.97 million (70.83% of the basin population) while other urban areas house 0.43 million people (5.02%) and rural areas de remaining 2.03 (24.14%). Most of the population (8.08 million, 95.63%) lived in Uttar Pradesh.

The main urban agglomerations in the Hindon basin are presented in the following table.

Table 2. Main cities and agglomerations in the Hindon Basin (population 2011)

State / District		City/Town	Population
Uttar Pradesh			
Baghpat	Class I	Baraut (NPP)	103,764
Gautam Buddha Nagar	Class I	Noida (CT)[1]	637,272
Gautam Buddha Nagar	Class I	Greater Noida (CT)	102,054
Gautam Buddha Nagar	Class II	Dadri (NPP)	91,189
Ghaziabad	Class I	Ghaziabad (M Corp)	1,648,643
Ghaziabad	Class I	Hapur (NPP)	262,983
Ghaziabad	Class I	Khora (CT)	190,005
Ghaziabad	Class II	Muradnagar (NPP)	95,208
Meerut	Class I	Meerut (M Corp)	1,305,429
Meerut	Class II	Sardhana (NPP)	58,252
Muzaffarnagar	Class I	Muzaffarnagar (NPP)	392,768
Muzaffarnagar	Class I	Shamli (NPP)	107,266
Saharanpur	Class I	Saharanpur (M Corp)	705,478
Saharanpur	Class II	Deoband (NPP)	97,037
Uttarakhand			
Hardwar	Class I	Roorkee (NPP)	118,200
Hardwar	Class II	Manglaur (NPP)	52,971

Source: http://censusindia.gov.in/

2.2 Future population

State level projection estimates can be found in «*India's Demography at 2040: Planning Public Good Provision for the 21st Century*», chapter 7th of the Report «*Economic Survey 2018-2019*» by the Ministry of Finance (the original source is the International Institute for Population Sciences (IIPS)[2].

Table 3. Annual Population Growth Rate (in per cent) for India and Major States

States	2001-11	2011-21	2021-31	2031-41
INDIA	1.77	1.12	0.72	0.46
Uttar Pradesh	2.02	1.48	0.93	0.73
Uttarakhand	1.88	1.30	0.70	0.50

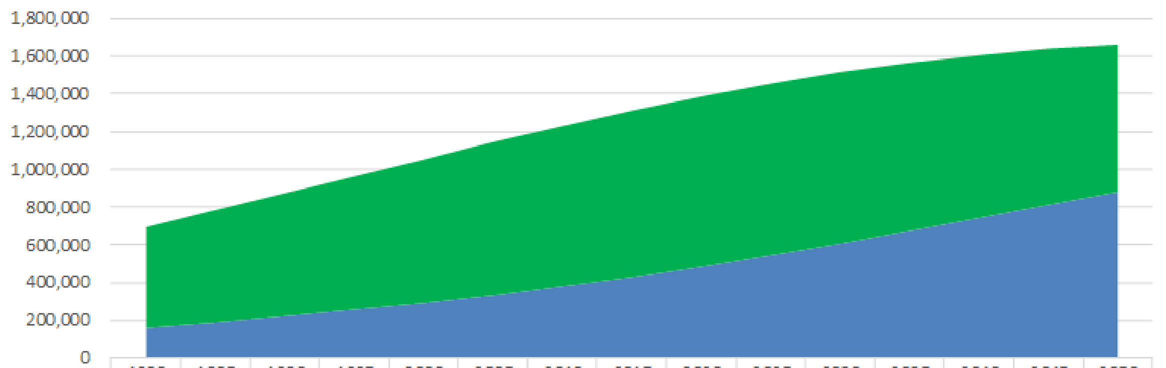
Source: Census, IIPS projections (taken from Economic Survey 2018-2019*)*

In turn, the World Urbanization Prospects 2018 prepared by the United Nations Department of Economic and Social Affairs provide a nation-wide estimation of urban and rural population dynamics. It can be seen how the rural population would begin to decrease in 2025 although it is necessary to wait until 2050 for the urban one to be predominant.

1 Noida, short for the New Okhla Industrial Development Authority, is a satellite city of Delhi and is part of the National Capital Region of India. Also Greater Noida and Dadri

2 http://www.iipsindia.ac.in/

Table 4. Population at Mid-Year, 1980-2050 (thousands)

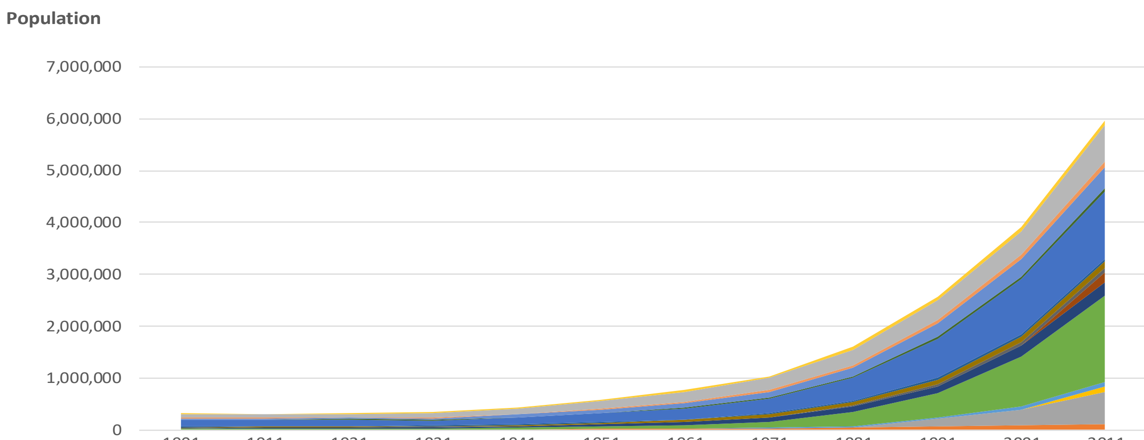


	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Rural	535,842	591,345	647,837	704,924	761,701	809,639	850,236	879,985	900,099	909,086	905,643	889,114	860,975	824,747	782,365
Urban	160,942	190,322	222,297	255,559	291,350	334,479	380,745	429,069	483,099	542,743	607,342	675,456	744,380	811,749	876,613

Source: own elaboration from data and estimates by United Nations Department of Economic and Social Affairs [3]

Finally, a more detailed assessment can be made on the evolution of the population living in the major cities in Hindon during XX and XXI centuries as well as the district populations.

Table 5. Population Growth in major cities of Hindon Basin[4]

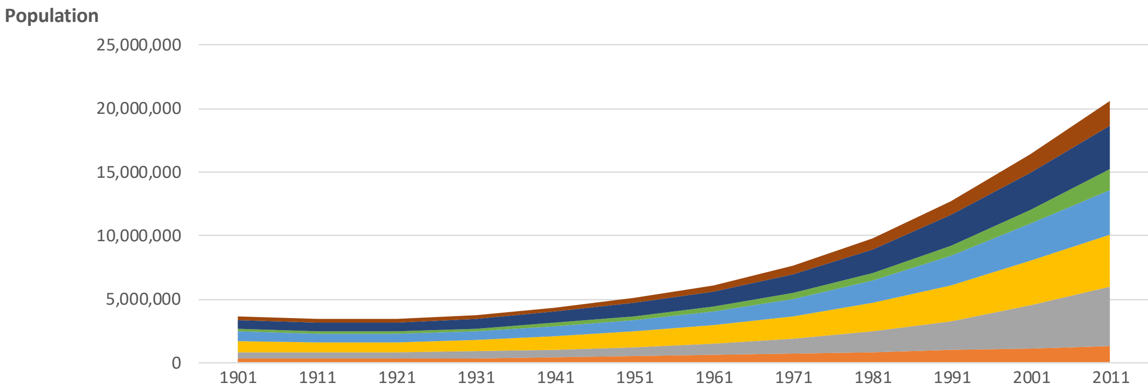


	1901	1911	1921	1931	1941	1951	1961	1971	1981	1991	2001	2011
Deoband	20,167	18,614	17,891	22,126	24,662	25,916	29,980	38,194	51,270	66,208	81,641	97,037
Saharanpur	66,254	62,850	62,261	78,665	105,622	148,435	185,213	225,396	295,355	374,945	455,754	705,478
Shamli	7,478	7,312	8,425	8,940	12,416	17,986	26,397	36,959	51,850	70,853	90,055	107,266
Muzaffarnagar	23,444	23,811	23,937	35,347	46,758	64,213	87,622	114,783	171,816	247,624	331,668	392,768
Sardhana	12,467	9,242	9,524	10,265	12,607	12,556	16,563	22,083	30,138	42,980	48,314	58,252
Meerut	122,981	121,477	126,996	97,580	129,309	167,315	211,326	286,345	442,405	753,778	1,068,772	1,305,429
Manglaur	10,763	9,282	8,852	10,044	11,093	13,751	15,206	19,723	25,724	34,161	42,584	52,971
Roorkee	17,148	16,584	16,716	13,944	17,334	23,239	33,657	47,561	61,851	80,262	97,516	118,200
Muradnagar	4,659	5,298	4,955	4,904	5,529	6,194	8,258	13,985	26,047	44,395	74,151	95,208
Khora												190,005
Hapur	17,796	19,142	20,388	25,116	33,756	49,266	55,248	71,266	102,837	146,262	211,983	262,983
Ghaziabad	11,275	11,304	12,343	18,831	23,834	38,217	63,190	118,836	275,815	454,156	968,256	1,648,643
Dadri			3,092	4,036	4,419	6,668	8,693	13,061	19,723	32,883	57,416	91,189
Greater Noida												102,054
Noida										146,514	305,058	637,272
Baraut	7,703	7,776	9,304	9,390	11,464	16,928	22,818	31,264	46,292	67,705	85,708	103,764

Source: own elaboration from Census of India[5]

3 https://population.un.org/wup/Download/
4 Data for the new entities of Greater Noida and Khora are provided only for 2011 and. Noida from 1991.
5 http://censusindia.gov.in/DigitalLibrary/Tables.aspx#

Table 6. Population Growth in Hindon Districts



	1901	1911	1921	1931	1941	1951	1961	1971	1981	1991	2001	2011
Hardwar	329,839	311,436	296,103	329,914	373,042	427,574	504,582	670,764	890,260	1,124,488	1,447,187	1,890,422
Meerut	675,150	666,027	663,961	709,677	840,218	1,010,618	1,201,058	1,492,928	1,897,593	2,397,099	2,973,877	3,443,689
Gautam Buddha Nagar	204,084	201,453	194,556	207,635	242,431	281,621	331,688	406,847	514,037	770,367	1,105,292	1,648,115
Saharanpur	728,601	687,620	653,460	727,731	822,231	942,849	1,132,537	1,414,231	1,821,543	2,309,029	2,896,863	3,466,382
Muzaffarnagar	867,177	799,331	786,187	885,877	1,046,382	1,209,771	1,429,961	1,781,579	2,248,483	2,842,543	3,543,362	4,143,512
Ghaziabad	495,100	488,479	483,558	516,681	609,878	728,149	883,370	1,149,313	1,594,768	2,256,089	3,314,070	4,681,645
Baghpat	347,045	342,354	341,292	364,792	431,893	519,483	606,642	701,493	852,462	1,030,399	1,163,991	1,303,048

Source: own elaboration from Census of India[6]

Based on these various estimates, the projection of the population in Hindon basin in 2021, 2031 and 2041 has been made with the methodology explained below:

1. For major cities, the average among UN urban prospects, IIPS projections (State level) and a projection based on past trend (4th degree polynomial regression on the observed evolution).
2. For the rest urban population, the average between UN urban prospects, IIPS State projections and districts' projection based on past trends.
3. For the rural population, the average between UN rural prospects, IIPS State projections and districts' projection.

In the case of minor cities and rural areas, UN prospects have been weighted double to better reflect the expected internal migration patterns. Growth rates are presented in Table 7 and population results summarized in Table 8.

Table 7. Estimated annual population growth rates in Hindon Basin

Spatial unit	2011-2016	2016-2021	2021-2026	2026-2031	2031-2036	2036-2041
Baraut	1.87%	1.85%	1.45%	1.41%	1.03%	0.96%
Noida	2.60%	2.59%	2.32%	2.28%	2.01%	1.95%
Greater Noida	2.60%	2.59%	2.32%	2.28%	2.01%	1.95%
Dadri	2.84%	2.83%	2.48%	2.44%	2.13%	2.06%
Ghaziabad	2.98%	2.97%	2.57%	2.53%	2.18%	2.11%
Hapur	2.27%	2.26%	1.92%	1.88%	1.63%	1.56%
Khora	2.48%	2.47%	2.19%	2.15%	1.89%	1.82%
Muradnagar	2.40%	2.39%	1.96%	1.92%	1.60%	1.54%
Meerut	2.48%	2.46%	2.09%	2.03%	1.63%	1.53%
Sardhana	1.82%	1.80%	1.49%	1.42%	0.91%	0.81%
Muzaffarnagar	2.24%	2.21%	1.90%	1.84%	1.45%	1.35%
Shamli	1.98%	1.95%	1.65%	1.59%	1.14%	1.04%

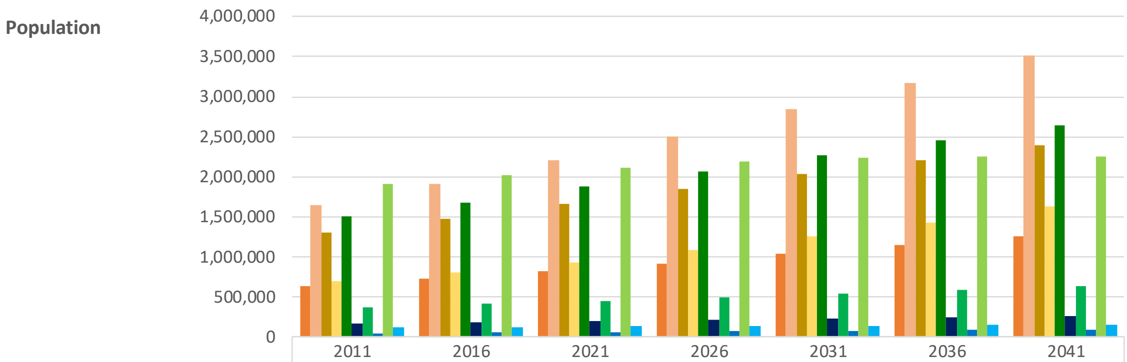
6 http://censusindia.gov.in/2011census/PCA/A2_Data_Table.html

Table 7. Estimated annual population growth rates in Hindon Basin

Spatial unit	2011-2016	2016-2021	2021-2026	2026-2031	2031-2036	2036-2041
Saharanpur	2.91%	2.89%	2.97%	2.91%	2.66%	2.57%
Deoband	2.08%	2.06%	1.84%	1.78%	1.43%	1.33%
Roorkee	1.70%	1.68%	1.34%	1.29%	0.91%	0.84%
Manglaur	2.04%	2.02%	1.76%	1.71%	1.48%	1.41%
Baghpat urban (others)	1.80%	1.78%	1.52%	1.46%	1.12%	1.02%
Ghaziabad urban (others)	2.46%	2.44%	2.21%	2.15%	1.86%	1.76%
Muzaffarnagar urban (others)	2.02%	2.00%	1.75%	1.69%	1.40%	1.30%
Saharanpur urban (others)	2.04%	2.02%	1.78%	1.72%	1.42%	1.32%
Gautam Buddha Nagar urban (others)	2.55%	2.53%	2.31%	2.25%	1.95%	1.85%
Meerut urban (others)	1.97%	1.94%	1.68%	1.62%	1.30%	1.20%
Hardwar urban (others)	2.14%	2.12%	1.92%	1.85%	1.58%	1.48%
Baghpat rural	0.83%	0.70%	0.35%	0.20%	-0.18%	-0.28%
Ghaziabad rural	1.49%	1.36%	1.04%	0.89%	0.55%	0.46%
Muzaffarnagar rural	1.05%	0.92%	0.58%	0.43%	0.09%	0.00%
Saharanpur rural	1.07%	0.94%	0.60%	0.46%	0.12%	0.02%
Gautam Buddha Nagar rural	1.58%	1.45%	1.14%	0.99%	0.64%	0.55%
Meerut rural	0.99%	0.87%	0.50%	0.36%	-0.01%	-0.10%
Hardwar rural	1.22%	1.09%	0.80%	0.65%	0.34%	0.24%
Total Hindon	**2.23%**	**2.21%**	**1.94%**	**1.89%**	**1.59%**	**1.54%**

Source: own elaboration from sources described in main text

Table 8. Population projection (2011-2041) for Hindon Basin



	2011	2016	2021	2026	2031	2036	2041
Noida	637,272	724,681	823,480	923,727	1,034,054	1,142,335	1,257,867
Ghaziabad	1,648,643	1,909,535	2,210,109	2,508,986	2,842,457	3,165,759	3,514,430
Meerut	1,305,429	1,475,380	1,665,636	1,847,059	2,041,934	2,213,566	2,387,928
Saharanpur	705,478	814,415	939,151	1,087,214	1,254,776	1,431,104	1,624,335
Uttar Pradesh - other major cities	1,500,526	1,679,352	1,878,103	2,068,274	2,272,391	2,456,390	2,645,501
Uttarakhand - major cities	171,171	187,176	204,540	220,014	236,192	249,394	262,519
Uttar Pradesh urban (others)	370,959	411,595	456,223	499,790	545,884	587,594	629,474
Uttarakhand urban (others)	52,192	58,035	64,461	70,881	77,700	84,036	90,446
Uttar Pradesh rural	1,914,592	2,020,162	2,118,303	2,184,270	2,236,144	2,250,599	2,254,381
Uttarakhand rural	119,733	127,194	134,274	139,727	144,352	146,792	148,555

Source: own elaboration

3 ASSESSMENT OF DOMESTIC POLLUTION LOADS

3.1 Assessment of the sewage volume generated in the Hindon basin

3.1.1 Sources of information

3.1.1.1 Central Pollution Control Board

The last India-wise assessment on water supply and wastewater discharge in main Indian cities was released by CPCB in the publication «*Status of Water Supply, Wastewater Generation and Treatment in Class-I Cities & Class-II Towns of India*» *(CPCB, 2009)*[7]. The information regarding Hindon is summarized in Table 9.

Table 9. Water supply and sewage generation in cities and towns in the Hindon Basin

District	City	Population in Year 2008	Total Water Supply (in MLD)	Per capita water supply (LPCD)	Total Sewage (in MLD)	Per Capita sewage (LPCD)
Uttar Pradesh						
Baghpat	Baraut	99,900	11.99	120.02	9.59	96.02
Gautam Buddha Nagar	Noida	361,510	235.00	650.05	188.00	520.04
Gautam Buddha Nagar	Dadri	66,880	8.03	120.07	6.42	96.05
Gautam Buddha Nagar	Greater Noida			127.77		102.22
Ghaziabad	Ghaziabad	1,191,280	199.54	167.50	159.63	134.00
Ghaziabad	Hapur	260,740	43.68	167.52	34.94	134.02
Ghaziabad	Muradnagar	86,230	*1.26*	14.61	1.01	11.69
Ghaziabad	Khora			174.82		139.86
Meerut	Meerut	1,321,300	221.31	167.49	177.05	134.00
Meerut	Sardhana			127.77		102.22
Muzaffarnagar	Muzaffarnagar	389,240	89.04	228.75	71.23	183.00
Muzaffarnagar	Shamli	104,600	12.55	119.98	10.04	95.98
Saharanpur	Saharanpur	557,100	*75.88*	*136.21*	60.70	108.96
Saharanpur	Deoband	95,110	11.41	119.97	9.13	95.97
Uttarakhand						
Hardwar	Roorkee	112,980	15.96	141.26	12.77	113.01
Hardwar	Manglaur			163.26		130.61
Maharashtra	Class II average	2,503,080	267.18	106.74	431.78	172.50

Source: extracted and elaborated from CPCB 2009

This report Includes an estimation of total sewage and per capita sewage generation for population centres classified as Class I or II in the Census 2001. State' weighted average (light blue) is used for the towns and cities not included in the report. The general criterion is that 80% of water supply is eventually discharged.

3.1.1.2 Uttar Pradesh State Water Resources Agency

The State Water Resources Agency (SWaRA) provides an estimate of wastewater discharges at block level. These data aggregated by State are presented in Table 10. It can be noticed that per capita discharges estimated by SWaRA are lower than those reported by CPCB.

---

7 http://www.indiaenvironmentportal.org.in/content/295129/status-of-water-supply-wastewater-generation-and-treatment-in-class-i-cities-class-ii-towns-of-india/.

Table 10. Urban and rural wastewater discharges in Hindon districts

District	Wastewater discharge, MCM			Population			per capita discharge (l/d)		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
Saharanpur	31.78	14.46	46.26	900,432	1,238,879	2,139,311	96.70	31.98	59.24
Muzaffarnagar	20.55	15.78	36.35	640,885	1,351,321	1,992,206	87.85	31.99	49.99
Meerut	1.94	4.56	6.51	94,797	389,786	484,583	56.07	32.05	36.81
Baghpat	0.81	5.56	6.37	39,432	475,533	514,965	56.28	32.03	33.89
Ghaziabad	82.92	3.18	86.09	1,996,522	272,611	2,269,133	113.79	31.96	103.94
Gautam Buddha Nagar	6.54	2.07	8.61	225,797	175,938	401,735	79.35	32.23	58.72
Shamli	6.47	5.81	12.26	216,442	496,956	713,398	81.90	32.03	47.08
Sum	**151.01**	**51.42**	**202.45**	**4,114,307**	**4,401,024**	**8,515,331**	**100.56**	**32.01**	**65.14**

Source; own elaboration from SWaRA data

3.1.1.3 Uttar Pradesh STP monitoring System

The STP Monitoring System http://www.jalshodhan.com/data.php powered By Uttar Pradesh Urban Directorate provides information on current STPs capacity and operation, as well as monitoring data (see sections 3.1.1.3 and). Information is summarized in Table 11, where STPs are systematically coded: initials of State name (UP) + Census code for the agglomeration + name of the plant.

Table 11. STPs in the agglomerations of the Tapi basin

STP Code - Name	Agglomeration	Technology[8]	Sewerage Capacity (MLD)	Sewerage reaching STP (MLD), average)	Population reaching STP (estimated)[9]
UP800734_Dudaheda-1	Ghaziabad	UASB	56.00	56.00	417,910
UP800734_Dudaheda-3	Ghaziabad	UASBR	70.00	71.70	535,075
UP800734_Govindpuram	Ghaziabad	UASB	56.00	9.72	72,520
UP800734_Indirapuram-1	Ghaziabad	SBR	74.00	67.77	505,757
UP800734_Indirapuram-2	Ghaziabad	SBR	56.00	55.85	416,806
UP800734_Indirapuram-3	Ghaziabad	SBR	56.00	49.18	366,990
UP120347_Badalpur	Greater Noida	SBR	2.00	1.63	15,932
UP120347_Ecotech-2nd	Greater Noida	SBR	15.00	1.90	18,587
UP120347_Ecotech-3rd	Greater Noida	SBR	20.00	5.73	56,007
UP120347_Kasna	Greater Noida	SBR	137.00	34.88	341,176
UP120227_Sector-123	Noida	SBR	35.00	33.74	64,881
UP120227_Sector-168	Noida	SBR	50.00	35.40	68,068
UP120227_Sector-50-1	Noida	SBR	25.00	19.19	36,898
UP120227_Sector-50-2	Noida	SBR	34.00	30.62	58,885
UP120227_Sector-54-2	Noida	SBR	33.00	28.67	55,125
UP120227_Sector-54-3	Noida	SBR	54.00	47.45	91,252
UP800716_Ganga Nagar	Meerut	ASP	10.00	4.53	33,769
UP800716_Lohia Nagar	Meerut	ASP	10.00	4.85	36,202
UP800716_Major Dhyan Chand	Meerut	NA	7.00	2.64	19,701
UP800716_Modipuram Tiraha	Meerut	NA	5.00	4.20	31,343
UP800716_Pallavpuram-1	Meerut	ASP	7.00	6.71	50,083
UP800716_Pallavpuram-2	Meerut	WSP	11.00	7.49	55,879

8 ASP: Activated Sludge Process; UASB: Upflow Anaerobic Sludge Blanket; SBR: Sequencing Batch Reactors; WSP: Waste Stabilization Ponds; OP: Oxidation Pond; MBBR: Moving Bed Bio Reactors; NA: Others or unspecified

9 The population whose sewage is treated in the plant is estimated based on CPCB per capita wastewater generation.

Table 11. STPs in the agglomerations of the Tapi basin

STP Code - Name	Agglomeration	Technology[8]	Sewerage Capacity (MLD)	Sewerage reaching STP (MLD), average)	Population reaching STP (estimated)[9]
UP800716_Pandav Nagar	Meerut	WSP	3.00	2.58	19,216
UP800716_Rakshapuram	Meerut	ASP	6.00	4.55	33,955
UP800716_Saardapuri-Phase2	Meerut	SBR	6.00	5.73	42,786
UP800716_Sainik Vihar	Meerut	NA	6.00	6.00	44,776
UP800716_Saardapuri-Phase1	Meerut	ASP	6.00	5.76	43,004
UP800716_Shatabdi Nagar	Meerut	ASP	15.00	4.59	34,235
UP800716_Ved Vyaspur	Meerut	NA	15.00	4.50	33,582
UP800716_Village Kamalpur	Meerut	ASP	72.00	24.54	183,107
UP800652_Kidwai Nagar	Muzaffarnagar	WSP	32.50	29.03	158,617
UP800630_Mlahipur	Saharanpur	UASB	38.00	38.52	353,513
Sum			**1,022.50**	**705.62**	**4,295,638.24**

Source: Jal Shodan 2019

Even though there are no direct estimates of the wastewater generation per capita, the information seems to be globally consistent with CPCB per capita wastewater generation as reflected in the last column where the population whose sewage is treated in the plant is approached based on CPCB ratios. When both sources are compared, the effort of expanding treatment capacity in Hindon basin in recent years becomes evident.

Table 12. Comparison od sewage treatment situation 2008 vs 2019 for class I and II cities in Tapi basin

District	CPCB 2008			Jalshodan 2019		
	Sewage Generation (MLD)	Installed Treatment Capacity (MLD)	%	Sewage Generation (MLD)	Installed Treatment Capacity (MLD)	%
Saharanpur	69.83	38.00	54.42%	113.76	38.00	33.40%
Muzaffarnagar	81.27	32.00	39.37%	126.99	32.50	25.59%
Meerut	177.05		0.00%	469.47	179.00	38.13%
Baghpat	9.59		0.00%	14.43		0.00%
Ghaziabad	195.58	126.00	64.42%	461.36	368.00	79.76%
Gautam Buddha Nagar	194.42	70.00	36.00%	540.12	405.00	74.98%
Uttar Pradesh in Hindon	**727.75**	**266.00**	**36.55%**	**1,726.13**	**1,022.50**	***59.24%***

Sources: own elaboration from CPCB 2009 and Jalshodan 2019

3.1.2 Criteria adopted for assessing sewage generation in Hindon basin

The wastewater discharge in the reference year 2011 has been assessed by adopting the following criteria:

- For major cities and towns, CPCB ratios have been privileged since they are consistent with installed sewage treatment capacity.
- For other urban areas, the average of CPCB and SWaRA estimates per district have been used.
- For rural areas, SWaRA estimates are used. The discharge is affected by a coefficient of 0.9, considering that the percentage of water supplied that returns is higher in the absence of sewerage infrastructure.

3.1.3 Assessment of current and projected water supply and wastewater generation

The volumes for current situation -assimilated to the 2021 horizon to maintain the census reference- and for the future horizons 2031 and 2041 has been made based on demography projections and applying some considerations on the future evolution of per capita consumption.

The Government of India norms propose the following urban water supply ratios (litres per capita day)[10]:

(i) *150 lpcd for metro cities (which are all equipped with sewerage systems)*
(ii) *135 lpcd for non-metro towns and cities equipped with a sewerage system*
(iii) *70 lpcd for towns and cities not equipped with a sewerage system*
(iv) *40 lpcd for the population relying on public standpipes.*

Regarding rural communities, the « *Strategic Plan (2011-2022) Ensuring Drinking Water Security in Rural India* »[11] establishes three standards of service depending on what communities want:

- *Basic piped water supply with a mix of household connections, public taps and handpumps (designed for 55 lpcd) -with appropriate costing as decided by States taking affordability and social equity into consideration*
- *Piped water supply with all metered, household connections (designed for 70 lpcd or more) - with appropriate cost ceilings as decided by States taking affordability and social equity into consideration.*
- *In extreme cases, handpumps (designed for 40 lpcd), protected open wells, protected ponds, etc., supplemented by other local sources – preferably free of cost.*

According to the above criteria, the following water supply rates will be adopted[12]:

	metro-cities	non-metro towns and cities (urban)	rural
2011	CPCB 2009 (lpcd)	CBCB 2009 (lpcd)	--
2021	CPCB 2009 or 135 lpcd	CPCB 2009 or 70 lpcd	40 lpcd
2031	150 lpcd	135 lpcd	55 lpcd
2041	150 lpcd	135 lpcd	70 lpcd

The water supply for Noida (650.05 lpcd) is clearly out of range. There are different reasons that might explain this anomaly, such as significant industrial consumption integrated with domestic, high network losses or connection of other agglomerations to Noida STPs. In the expectation of a better understanding of the case, a provision of 450 lpcd in 2041 has been assumed, compatible with an urban area with a high service and industry component.

To assess the sewage generation in towns and cities, it has been considered that 80% of the water supply to cities and towns returns to the aquatic environment, following the criteria established on CPCB 2009. For rural areas supplied with less than 70 lpcd, a higher 90% coefficient has been applied.

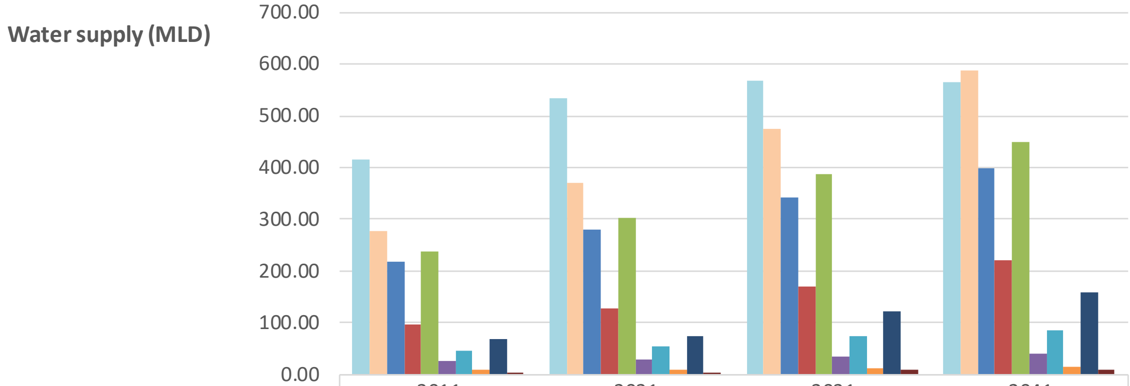
Per capita ratios are applied to the inhabitants projected for each spatial unit in the previous section to approach the urban water supply and wastewater generation in 2021 and future scenarios. Summary results are presented, respectively in Table 12 (water supply) and Table 13 for (wastewater generation).

10 *State of Urban Water Supply in India 2018*. https://www.wateraidindia.in/publications/state-of-urban-water-supply-in-india-2018.

11 Ministry of Drinking Water and Sanitation- Rural Drinking Water. http://www.ielrc.org/content/e1104.pdf

12 It must be noted that States can adopt higher quantity norms, such as 100 lpcd, and follow their own strategies and phased timeframes to achieve these goals.

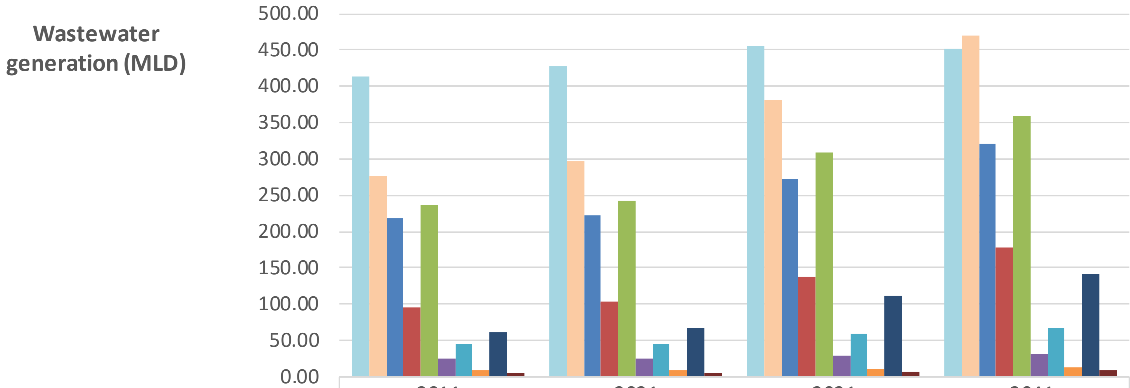
Table 13. Water supply projected for Hindon basin



	2011	2021	2031	2041
Noida	414.26	535.30	568.73	566.04
Ghaziabad	276.15	370.19	476.11	588.67
Meerut	218.65	278.98	342.00	399.95
Saharanpur	96.09	127.92	170.91	221.25
Uttar Pradesh - other major cities	236.90	303.08	386.88	450.12
Uttarakhand - major cities	25.34	30.32	35.06	39.04
Uttar Pradesh urban (others)	44.64	54.96	73.69	84.98
Uttarakhand urban (others)	8.52	10.52	12.69	14.77
Uttar Pradesh rural	68.07	75.31	122.99	157.81
Uttarakhand rural	4.26	4.78	7.94	10.40

Source: own elaboration

Table 14. Wastewater generation projected for Hindon basin



	2011	2021	2031	2041
Noida	414.26	428.24	454.98	452.83
Ghaziabad	276.15	296.15	380.89	470.93
Meerut	218.65	223.18	273.60	319.96
Saharanpur	96.09	102.34	136.73	177.00
Uttar Pradesh - other major cities	236.90	243.31	309.50	360.09
Uttarakhand - major cities	25.34	24.25	28.05	31.23
Uttar Pradesh urban (others)	44.24	43.97	58.96	67.98
Uttarakhand urban (others)	8.52	8.42	10.15	11.81
Uttar Pradesh rural	61.26	67.78	110.69	142.03
Uttarakhand rural	3.83	4.30	7.15	9.36

Source: own elaboration

3.2 Assessment of raw pollutant loads

3.2.1 Assessment based on typical generation and treatment rates

3.2.1.1 Pollution generation rates

The estimation of pollutant loads is indebted to two publications:

- «*GHG platform India 2005-2015 State Estimates - 2019 Series*»[13]
- «*Biological Wastewater Treatment: Principles Modelling and Design*»[14]

The first document, prepared by ICLEI South Asia under the phase-III of the GHG Platform India[15] initiative, explains the process followed in calculating the India level emissions for the Waste Sector for the period 2005 to 2015. In this context BOD and N production from wastewater sector are calculated at district level, following a thorough compilation and exploitation of the information available.

The second one provides extensive information for the characterization of domestic and urban wastewater, including ranges of variation under different assumptions and circumstances. Thus, once BOD and nitrogen loads are calculated, the rest of the components (phosphorus, COD, suspended solids) can be approached.

Table 15. Typical composition of raw municipal wastewater with minor contributions of industrial wastewater

Parameter	High	Medium	Low
COD total	1,200	750	500
COD soluble	480	300	200
COD suspended	720	450	300
BOD	560	350	230
VFA (as acetate)	80	30	10
N total	100	60	30
Ammonia-N	75	45	20
P total	25	15	6
Ortho-P	15	10	4
TSS	600	400	250
VSS	480	320	200

Source: 2008 Mogens Henze

The main data and methodological explanation of the assessments are summarized below:

- **Biological Oxygen Demand (BOD)**. BOD generation per capita is estimated in 39.0 and grams per day both in Uttar Pradesh and Uttarakhand[16]. Based on the Second National Communication

[13] Kolsepatil, N., Subramaniyam, A., Sekhar, A., Chaturvedula, S., (2019). Greenhouse Gas Emissions from Waste sector in India (subnational estimates). Version 3.0 dated September 20, 2019, from GHG platform India: GHG platform India-2005-2015 Sub-National Estimates - 2019 Series: http://ghgplatform-india.org/data-and-emissions/waste.html

[14] 2008 Mogens Henze. Biological Wastewater Treatment: Principles Modelling and Design . Edited by M. Henze, M.C.M. van Loosdrecht, G.A. Ekama and D. Brdjanovic. ISBN: 9781843391883. Published by IWA Publishing, London, UK. https://ocw.un-ihe.org/pluginfile.php/462/mod_resource/content/1/Urban_Drainage_and_Sewerage/5_Wet_Weather_and_Dry_Weather_Flow_Characterisation/DWF_characterization/Notes/Wastewater%20characterization.pdf

[15] The GHG Platform – India is a collective civil-society initiative providing an independent estimation and analysis of India's greenhouse gas (GHG) emissions across key sectors such as Energy, Waste, Industry, Agriculture, Forest and Other Land Use. The platform includes notable institutions such as the Council on Energy, Environment and Water (CEEW), Center for Study of Science, Technology & Policy (CSTEP), ICLEI South Asia (Local Governments for Sustainability), Vasudha Foundation, and World Resources Institute India (WRI India).

[16] Original source: *Inventorization of Methane Emissions from Domestic & Key Industries* Wastewater – Indian Network for Climate Change Assessment, NEERI, 2010.

for India[17] and the IPCC Guidelines[18], a factor of 1.25 is applied for collected wastewater and 1 for uncollected wastewater respectively. This criterion has been applied by using 1.25 factor for urban discharges and 1.00 for rural ones.

- **Nitrogen**. Total nitrogen in the sewage is calculated based on protein intake:

State/Union Territory	Protein Intake (kg/capita/day) 2004-05		Protein Intake (kg/capita/day) 2009-10		Protein Intake (kg/capita/day) 2011-12	
	Urban	Rural	Urban	Rural	Urban	Rural
Gujarat	57.30	53.30	54.85	55.00	55.20	52.25
Madhya Pradesh	58.20	58.80	56.55	60.55	60.55	63.40
Maharashtra	52.10	55.70	55.75	58.20	58.20	58.35

Original source: National Sample Survey Office (NSSO) surveys

Starting for these data, the following methodology (GHG 2019) is applied:

$N_{effluent}$ = Protein x F_{NPR} x $F_{NON\text{-}CON}$ x $F_{IND\text{-}COM}$ * N_{HH}

Protein = annual per capita protein consumption, kg protein/person/yr

F_{NPR} = fraction of nitrogen in protein, default = **0.16** kg N/kg protein

$F_{NON\text{-}CON}$ = factor for nitrogen in non-consumed protein disposed in sewer system, kg N/kg N. See new Table 6.10a. (**1.02 for India**)

$F_{IND\text{-}COM}$ = factor for industrial and commercial co-discharged protein into the sewer system, kg N/kg N (**default value of** 1.25 **used as per 2006 IPCC guidelines for wastewater**)

N_{HH} = additional nitrogen from household products added to the wastewater, default is **1.1** (some country data are in new Table 6.10a). (**1.13 for India**)

- **Phosphorus**. Total phosphorus in the sewage is not estimated by GHG platform India. Alternatively, Mogens – Henze estimates are used:

P total / N total			
High	Medium	Low	Average
0.25	0.25	0.20	0.23

- **Chemical Oxygen Demand (COD)**. COD is approached based on BOD concentration, based on average typical ratio:

COD / BOD			
High	Medium	Low	Average
2.14	2.14	2.17	2.15

- **Total Suspended Solids (TSS)**. Total phosphorus in the sewage is not estimated by GHG platform India. Alternatively, Mogens – Henze estimates are used:

P total / N total			
High	High	Medium	Low
0.25	1.07	1.14	1.09

3.2.1.2 Results

For each agglomeration or area (rest of urban and rural population per district), pollutant loads can be calculated based on the bibliographic sources mentioned in the previous section:

17 India - Second National Communication to the United Nations Framework Convention on Climate Change. Ministry of Environment & Forests Government of India 2012. https://unfccc.int/resource/docs/natc/indnc2.pdf

18 Bartram, D., Short , M.D., Ebie, Y., Farkaš, J., Gueguen, C., Peters, G.M., Zanzottera, N.M., Karthik, M. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_6_Ch06_Wastewater.pdf

BOD_5 load (Kg/day) urban = Population x (g BOD_5/day x 1.25) / 1,000 g/Kg

BOD_5 load (Kg/day) rural = Population x (g BOD_5/day x 1.00) / 1,000 g/Kg

N load (Kg/d) urban = Population x (g N/day x 1.25) / 1,000 g/Kg

N load (Kg/d) rural = Population x (g N/day x 1.00) / 1,000 g/Kg

P load (Kg/d) urban = Population x (g P/day x 1.25) / 1,000 g/Kg

P load (Kg/d) rural = Population x (g P/day x 1.00) / 1,000 g/Kg

COD load (Kg/day) urban = Population x (g COD/day x 1.25) / 1,000 g/Kg

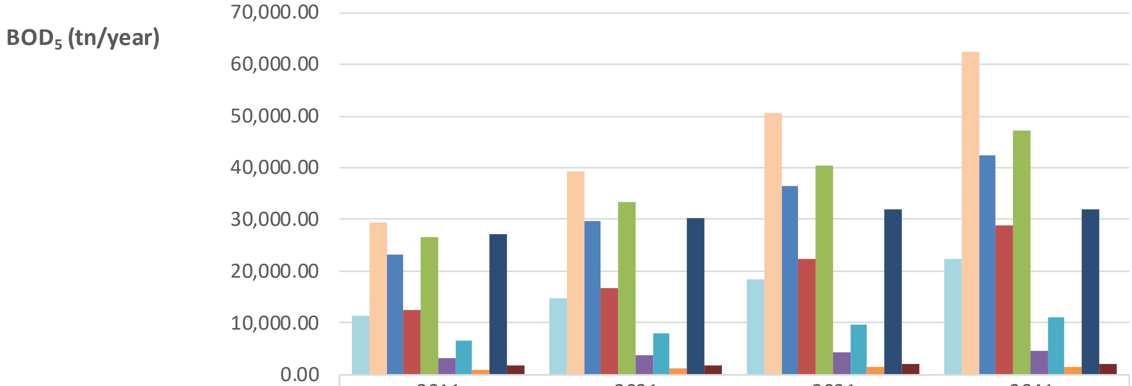
COD load (Kg/day) rural = Population x (g COD/day x 1.00) / 1,000 g/Kg

TSS load (Kg/d) urban = Population x (g TSS/day x 1.25) / 1,000 g/Kg

TSS load (Kg/d) rural = Population x (g TSS/day x 1.00) / 1,000 g/Kg

The results of raw pollution generation for the different time horizons are presented in the tables below.

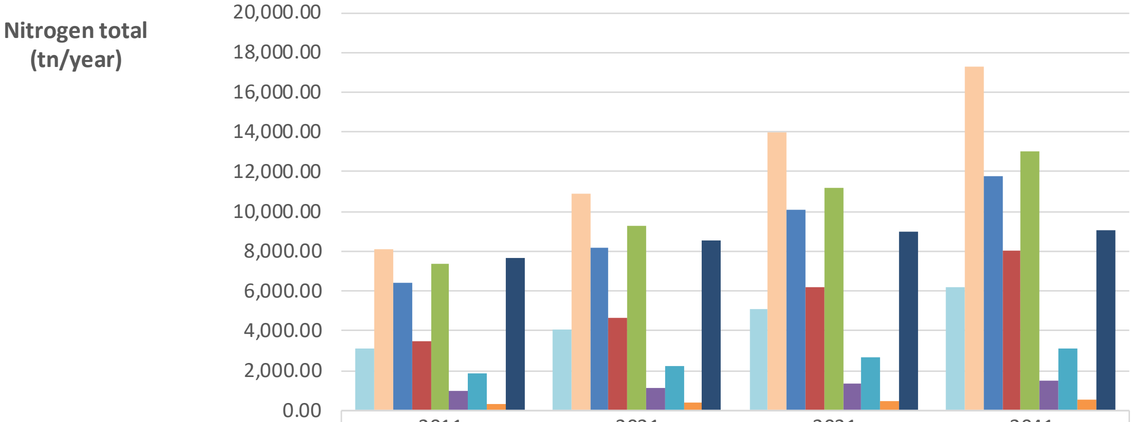
Table 16. BOD_5 estimated raw discharge from urban and rural areas of the Hindon basin



	2011	2021	2031	2041
Noida	11,339.46	14,652.80	18,399.70	22,382.17
Ghaziabad	29,335.54	39,326.13	50,577.97	62,534.89
Meerut	23,228.48	29,637.91	36,333.66	42,490.19
Saharanpur	12,553.10	16,711.02	22,327.17	28,903.01
Uttar Pradesh - other major cities	26,699.98	33,418.50	40,434.36	47,073.38
Uttarakhand - major cities	3,045.77	3,639.53	4,202.74	4,671.20
Uttar Pradesh urban (others)	6,600.75	8,117.92	9,713.32	11,200.70
Uttarakhand urban (others)	928.70	1,147.00	1,382.57	1,609.37
Uttar Pradesh rural	27,254.22	30,154.04	31,831.51	32,091.11
Uttarakhand rural	1,704.40	1,911.39	2,054.85	2,114.68

Source: own elaboration

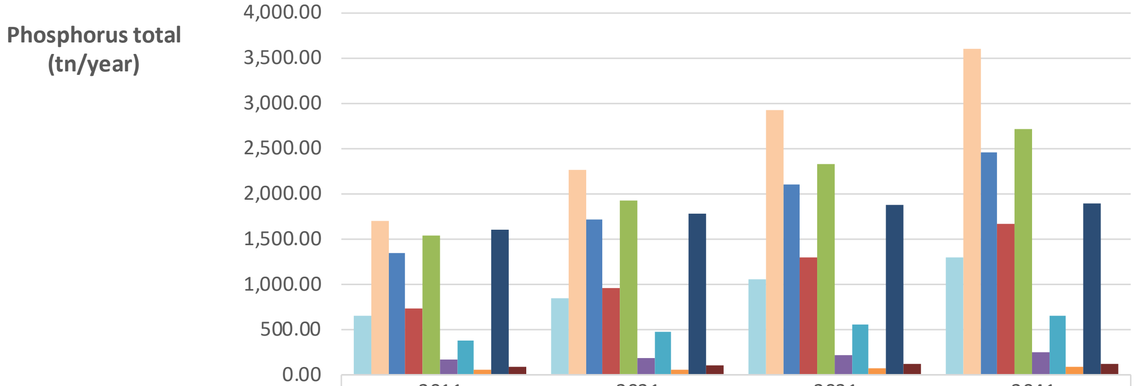
Table 17. Nitrogen estimated raw discharge from urban and rural areas of the Hindon basin



	2011	2021	2031	2041
Noida	3,137.00	4,053.62	5,090.18	6,191.91
Ghaziabad	8,115.53	10,879.37	13,992.14	17,299.96
Meerut	6,426.04	8,199.18	10,051.52	11,754.70
Saharanpur	3,472.75	4,623.02	6,176.70	7,995.87
Uttar Pradesh - other major cities	7,386.42	9,245.06	11,185.96	13,022.61
Uttarakhand - major cities	956.16	1,142.56	1,319.37	1,466.43
Uttar Pradesh urban (others)	1,826.06	2,245.78	2,687.14	3,098.62
Uttarakhand urban (others)	291.55	360.08	434.03	505.23
Uttar Pradesh rural	7,696.56	8,515.46	8,989.18	9,062.49

Source: own elaboration

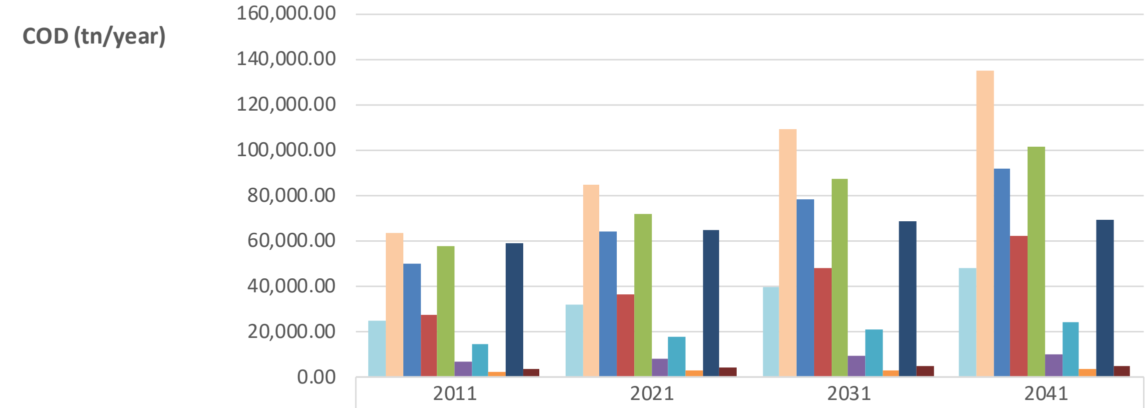
Table 18. Phosphorus estimated raw discharge from urban and rural areas of the Hindon basin



	2011	2021	2031	2041
Noida	653.54	844.50	1,060.45	1,289.98
Ghaziabad	1,690.74	2,266.54	2,915.03	3,604.16
Meerut	1,338.76	1,708.16	2,094.07	2,448.90
Saharanpur	723.49	963.13	1,286.81	1,665.81
Uttar Pradesh - other major cities	1,538.84	1,926.05	2,330.41	2,713.04
Uttarakhand - major cities	157.83	188.60	217.78	242.06
Uttar Pradesh urban (others)	380.43	467.87	559.82	645.55
Uttarakhand urban (others)	48.12	59.44	71.64	83.40
Uttar Pradesh rural	1,603.45	1,774.06	1,872.75	1,888.02
Uttarakhand rural	92.03	103.21	110.96	114.19

Source: own elaboration

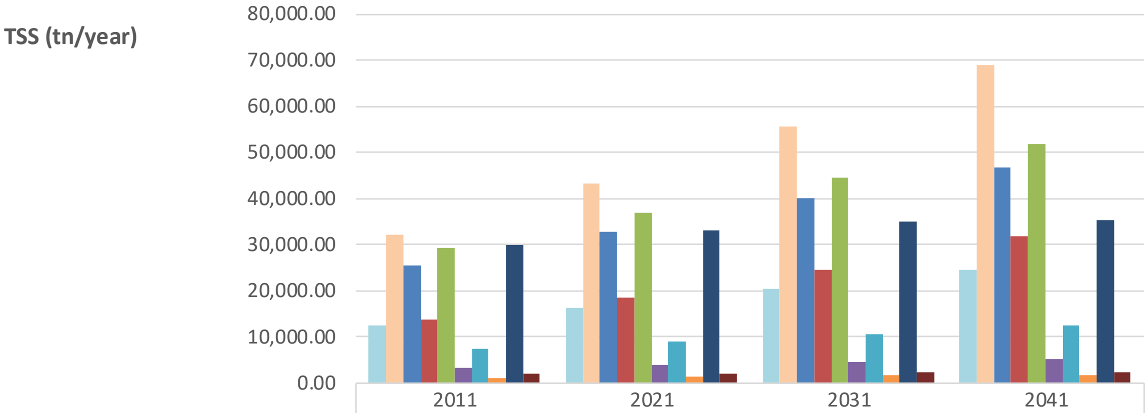
Table 19. COD estimated raw discharge from urban and rural areas of the Hindon basin



	2011	2021	2031	2041
Noida	24,416.23	31,550.54	39,618.40	48,193.49
Ghaziabad	63,165.55	84,677.37	108,904.94	134,650.69
Meerut	50,015.77	63,816.62	78,233.97	91,490.27
Saharanpur	27,029.45	35,982.32	48,075.07	62,234.23
Uttar Pradesh - other major cities	57,490.65	71,957.01	87,063.63	101,358.84
Uttarakhand - major cities	6,558.19	7,836.68	9,049.38	10,058.06
Uttar Pradesh urban (others)	14,212.79	17,479.58	20,914.82	24,117.46
Uttarakhand urban (others)	1,999.68	2,469.74	2,976.97	3,465.32
Uttar Pradesh rural	58,684.03	64,927.96	68,539.90	69,098.88
Uttarakhand rural	3,669.92	4,115.62	4,424.52	4,553.35

Source: own elaboration

Table 20. TSS estimated raw discharge from urban and rural areas of the Hindon basin



	2011	2021	2031	2041
Noida	12,478.10	16,124.14	20,247.29	24,629.66
Ghaziabad	32,281.24	43,275.02	55,656.71	68,814.27
Meerut	25,560.94	32,613.97	39,982.07	46,756.81
Saharanpur	13,813.61	18,389.04	24,569.13	31,805.28
Uttar Pradesh - other major cities	29,381.04	36,774.18	44,494.54	51,800.21
Uttarakhand - major cities	3,351.61	4,004.99	4,624.76	5,140.25
Uttar Pradesh urban (others)	7,263.56	8,933.07	10,688.68	12,325.41
Uttarakhand urban (others)	1,021.95	1,262.18	1,521.40	1,770.98
Uttar Pradesh rural	29,990.93	33,181.93	35,027.84	35,313.51
Uttarakhand rural	1,875.54	2,103.32	2,261.19	2,327.02

Source: own elaboration

3.2.2 Comparison with monitoring data

Jalshodan app provides data for inlet and outlet BOD and TSS for the STPs operating in the basin (see list in Table 11)[19]. Inlet concentrations -as the average of all the STPs treating major city sewage- can be compared which those estimated for raw pollutant load generation in the main cities in Hindon basin:

BOD_5 (mg/l) = BOD_5 load (tn/year) [section 3.2.1.2] / (Wastewater generation (MLD) [section 3.1.3] x 365 days / year)

TSS (mg/l) = TSS load (tn/year) [section 3.2.1.2] / (Wastewater generation (MLD) [section 3.1.3] x 365 days / year)

Agglomeration	BOD_5 inlet from monitoring (mg/l)	BOD_5 raw load from estimates (mg/l)	TSS inlet from monitoring (mg/l)	TSS raw load from estimates (mg/l)	TSS / BOD_5 from monitoring	TSS /BOD_5 from estimates
Ghaziabad	218.45	363.81	386.40	400.34	1.77	1.10
Greater Noida	163.98	476.93	332.81	524.82	2.03	1.10
Meerut	183.58	363.82	186.92	400.36	1.02	1.10
Noida	172.41	93.74	335.97	103.16	1.95	1.10
Saharanpur	147.19	447.39	285.94	492.31	1.94	1.10
Weighted average	**193.00**	***264.27***	***336.51***	***290.81***	1.74	1.10

From the observation of these data, two main conclusions can be drawn:

- There is more variability in the estimations than in observed data. This variability emerges entirely from the diverse sewage generation per capita (lpcd), which is quite evident for Noida, where high discharge per capita (650 lpcd) translate into particularly low concentrations.
- Setting Noida aside, observed BOD_5 concentrations are significantly lower than estimated ones but it is not possible to establish the reasons behind the differences. BOD loads may be effectively lower than the theoretical ones but also volume of wastewater generation being higher could show similar effect. For the moment, data of the number of inhabitants that are connected to each STP that would be useful for proper diagnosis is missing. Finally, it must be noted that the concentrations resulting from the estimates are, in general, higher than those suggested for STP design[20], what would also support the idea that estimated absolute loads are likely to be overestimated.
- The ratio TSS / BOD_5 taken from Mogens-Henze 2008 seems to be quite low for the Hindon.
- Considering the analysis above, the estimates have been revised by implementing the following criteria:
  1. BOD_5 loads will be corrected by a factor based on basin-wise weighted averages:

     (monitoring + estimate) / estimate = 0.87
  2. COD, whose calculation is dependant on BOD_5, will be corrected in the same proportion.
  3. TSS / BOD5 ratios will be replaced by observed ones where available while factor based on weighted average will be adopted for the rest of the basin.

     (monitoring + estimate) / estimate = 1.29
  4. Nitrogen and phosphorous estimates are not affected.

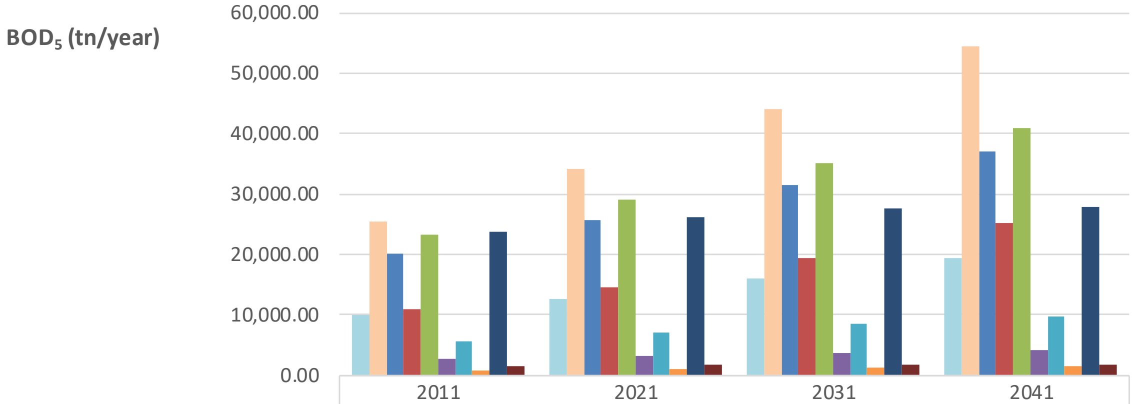
19 Data reported in the period from January to May 2019 have been considered.

20 For instance, the «STP Guide - Design, Operation and Maintenance» (Dr. Ananth S. Kodavasal, published by the Karnataka State Pollution Control Board 2011) proposes that design BOD should be 250 mg/l (equalized sewage) since empirical value, for typical Indian domestic sewage BOD may range form 200-250 mg/l.

3.2.3 Results adjusted from the observed data

The revised results (BOD_5, COD and TSS) are presented in the following tables.

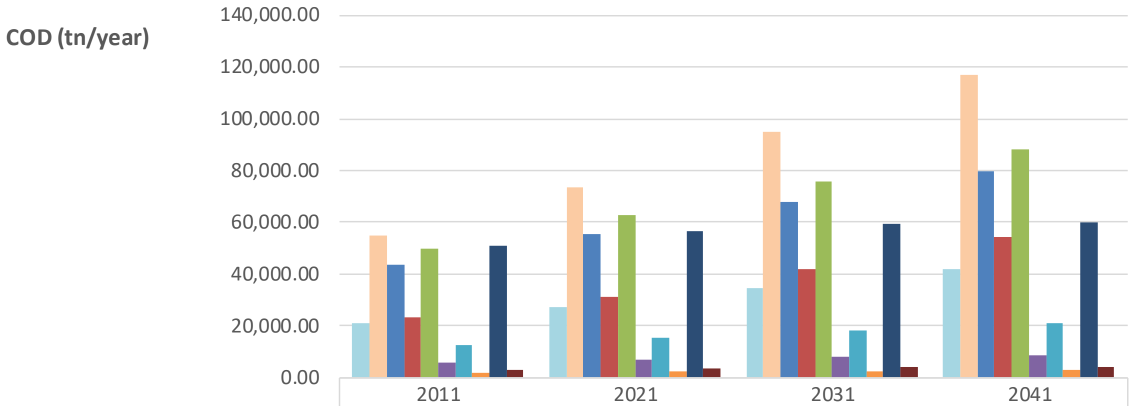
Table 21. BOD_5 revised discharge from urban and rural areas of the Hindon basin



	2011	2021	2031	2041
Noida	9,865.33	12,747.93	16,007.74	19,472.49
Ghaziabad	25,521.92	34,213.73	44,002.83	54,405.35
Meerut	20,208.78	25,784.98	31,610.29	36,966.47
Saharanpur	10,921.20	14,538.59	19,424.64	25,145.62
Uttar Pradesh - other major cities	23,228.99	29,074.09	35,177.89	40,953.84
Uttarakhand - major cities	2,649.82	3,166.39	3,656.39	4,063.94
Uttar Pradesh urban (others)	5,742.65	7,062.59	8,450.59	9,744.61
Uttarakhand urban (others)	807.97	997.89	1,202.84	1,400.15
Uttar Pradesh rural	23,711.17	26,234.02	27,693.41	27,919.27
Uttarakhand rural	1,482.82	1,662.91	1,787.72	1,839.77

Source: own elaboration

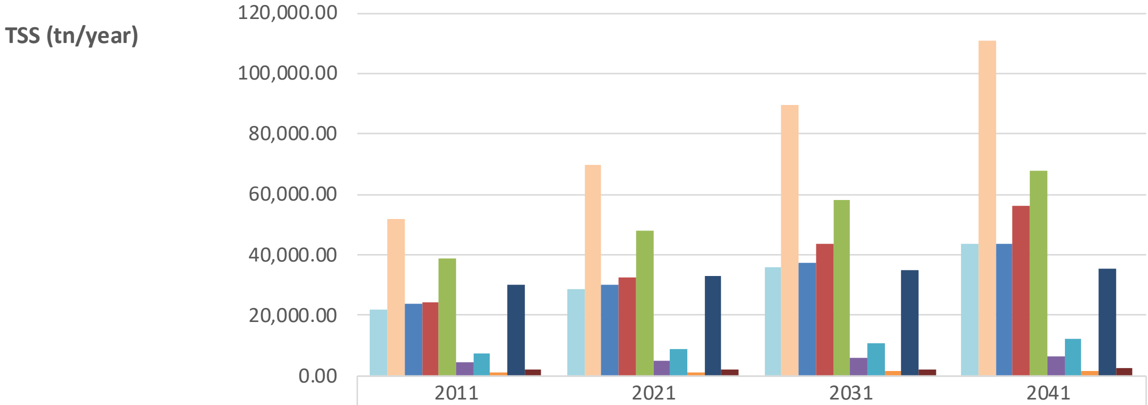
Table 22. COD revised discharge from urban and rural areas of the Hindon basin



	2011	2021	2031	2041
Noida	21,242.12	27,448.97	34,468.01	41,928.34
Ghaziabad	54,954.03	73,669.32	94,747.30	117,146.10
Meerut	43,513.72	55,520.46	68,063.56	79,596.54
Saharanpur	23,515.62	31,304.62	41,825.31	54,143.78
Uttar Pradesh - other major cities	50,016.87	62,602.60	75,745.36	88,182.19
Uttarakhand - major cities	5,705.62	6,817.91	7,872.96	8,750.52
Uttar Pradesh urban (others)	12,365.13	15,207.23	18,195.89	20,982.19
Uttarakhand urban (others)	1,739.72	2,148.67	2,589.97	3,014.83
Uttar Pradesh rural	51,055.11	56,487.33	59,629.71	60,116.02
Uttarakhand rural	3,192.83	3,580.59	3,849.34	3,961.41

Source: own elaboration

Table 23. TSS revised discharge from urban and rural areas of the Hindon basin



	2011	2021	2031	2041
Noida	22,086.24	28,539.74	35,837.70	43,594.49
Ghaziabad	51,972.80	69,672.79	89,607.30	110,790.98
Meerut	23,771.68	30,331.00	37,183.33	43,483.83
Saharanpur	24,450.08	32,548.60	43,487.36	56,295.35
Uttar Pradesh - other major cities	39,000.59	48,182.39	58,372.07	68,063.44
Uttarakhand - major cities	4,323.58	5,166.44	5,965.93	6,630.92
Uttar Pradesh urban (others)	7,263.56	8,933.07	10,688.68	12,325.41
Uttarakhand urban (others)	1,021.95	1,262.18	1,521.40	1,770.98
Uttar Pradesh rural	29,990.93	33,181.93	35,027.84	35,313.51
Uttarakhand rural	1,875.54	2,103.32	2,261.19	2,327.02

Source: own elaboration

3.3 Assessment of actual pollution

3.3.1 Sewage Treatment in the Hindon basin

STPs operating in the Hindon have been already presented in Table 11. This treatment infrastructure will substantially reduce the pollution load from main cities.

For assessing the quality of wastewater discharges into the environment, two methodologies have been used:

1. For those quality parameters where observed data of actual plants is available BOD_5, TSS), the corresponding reduction rates have been used, either specific of the agglomeration or weighted average when not available.

Table 24. Observed influent and effluent water quality in Hindon STPs (average January to March 2019)

uwwCode	Agglomeration	Sewerage Reaching STP (MLD)	pH inlet	BOD inlet (mg/l)	TSS inlet (mg/l)	pH outlet	BOD out-let (mg/l)	TSS outlet (mg/l)
UP800734_Dudaheda-1	Ghaziabad	56.00	6.93	242.50	396.25	7.21	13.50	17.50
UP800734_Dudaheda-3	Ghaziabad	71.70	7.53	191.25	426.25	7.35	48.88	90.75
UP800734_Govindpuram	Ghaziabad	9.72	7.51	74.67	92.23	7.66	8.23	13.23
UP800734_Indirapuram-1	Ghaziabad	67.77	7.31	265.86	316.86	7.22	5.86	5.57
UP800734_Indirapuram-2	Ghaziabad	55.85	7.20	200.80	434.00	7.08	46.16	87.20
UP800734_Indirapuram-3	Ghaziabad	49.18	7.12	213.83	417.00	7.26	9.03	9.92
UP120347_Badalpur	Greater Noida	1.63	7.54	165.43	317.14	7.33	8.40	8.97
UP120347_Ecotech-2nd	Greater Noida	1.90	7.74	151.00	306.60	7.24	11.00	11.20

Table 24. **Observed influent and effluent water quality in Hindon STPs (average January to March 2019)**

uwwCode	Agglomeration	Sewerage Reaching STP (MLD)	pH inlet	BOD inlet (mg/l)	TSS inlet (mg/l)	pH outlet	BOD outlet (mg/l)	TSS outlet (mg/l)
UP120347_Ecotech-3rd	Greater Noida	5.73	7.87	167.75	326.50	7.40	9.13	8.63
UP120347_Kasna	Greater Noida	34.88	7.89	164.00	336.00	7.29	10.88	10.13
UP120227_Sector-123	Noida	33.74	7.36	177.44	274.06	7.61	7.89	7.44
UP120227_Sector-168	Noida	35.40	7.48	200.65	297.24	7.51	8.47	8.53
UP120227_Sector-50-1	Noida	19.19	7.45	164.11	369.56	7.52	8.78	6.89
UP120227_Sector-50-2	Noida	30.62	7.46	162.44	378.50	7.51	8.28	5.94
UP120227_Sector-54-2	Noida	28.67	7.69	154.94	353.89	7.62	8.06	7.61
UP120227_Sector-54-3	Noida	47.45	7.43	168.11	357.06	7.42	8.22	6.94
UP800716_Ganga Nagar	Meerut	4.53	7.00	162.89	206.67	7.37	19.11	22.00
UP800716_Lohia Nagar	Meerut	4.85	6.81	196.44	188.22	7.32	23.89	56.89
UP800716_Major Dhyan Chand	Meerut	2.64	6.62	190.00	182.40	7.44	25.60	61.20
UP800716_Modipuram Tiraha	Meerut	4.20	6.09	204.22	252.78	6.86	15.11	20.67
UP800716_Pallavpuram-1	Meerut	6.71	6.67	187.00	191.89	7.53	21.89	60.33
UP800716_Pallavpuram-2	Meerut	7.49	6.77	187.33	191.78	7.56	13.78	42.89
UP800716_Pandav Nagar	Meerut	2.58	6.74	186.50	182.50	7.53	15.63	44.50
UP800716_Rakshapuram	Meerut	4.55	6.74	199.70	183.50	7.40	22.80	61.00
UP800716_Saardapuri-Phase2	Meerut	5.73	6.89	205.56	185.67	7.50	15.33	48.44
UP800716_Sainik Vihar	Meerut	6.00	6.13	200.63	242.00	6.75	17.25	39.38
UP800716_Saardapuri-Phase1	Meerut	5.76	6.85	187.00	178.13	7.60	15.75	47.25
UP800716_Shatabdi Nagar	Meerut	4.59	6.83	193.11	188.67	7.44	21.67	59.00
UP800716_Ved Vyaspur	Meerut	4.50	6.71	188.56	187.11	7.47	23.67	56.00
UP800716_Village Kamalpur	Meerut	24.54	6.94	162.44	159.02	7.35	17.36	18.30
UP800652_Kidwai Nagar	Muzaffarnagar	29.03	NA	NA	NA	NA	NA	NA
UP800630_Mlahipur	Saharanpur	38.52	7.30	147.19	285.94	7.75	29.50	47.38
Hindon weighted average		**705.62**	**7.29**	**193.00**	**336.51**	**7.37**	**18.64**	**30.34**

Source: own elaboration from Jalshodan data

2. Typical pollution reduction ratios from literature for the rest of parameters. Regarding nutrients, the removal efficiency reflected in Table 25 have been considered. For secondary treatment, COD reduction is estimated 10% lower than BOD_5.

Table 25. **Typical efficiency of domestic wastewater treatment**

Treatment level	BOD_5	Nitrogen	Phosphorus
Primary Treatment	30%	10%	13%
Wetlands or Stabilization Ponds	80%	58%	40%
Secondary Treatment (mechanical biological)	90%	30%	25%
Advanced Treatment with P removal	94%	30%	88%
Advanced Treatment with N removal	94%	84%	25%
Advanced Treatment with N & P removal	94%	84%	88%
P removal	4%	0%	63%
N removal	4%	54%	0%
N & P removal	4%	54%	63%

Source: Blue 2 Project[21]

[21] Benitez Sanz, C., Wolters, H., Martí B. and Mora B. (2018): "EU Water and Marine Measures Data base". Deliverable to Task B2 of the BLUE2 project "Study on EU integrated policy assessment for the freshwater and marine environment, on the economic benefits of EU water policy and on the costs of its non-implementation". Report to DG ENV. https://ec.europa.eu/environment/blue2_study/pdf/BLUE2_B2_FINAL_REPORT.pdf

Summarizing the above criteria, the removal efficiency for each agglomeration is presented in Table 26. When more than one STP is operating, weighting average percentages have been obtained for each agglomeration (BOD_5, TSS), while typical secondary ratios of N, P and COD removal are assumed. The exception is Muzaffarnagar, where no observed data are provided and typical stabilization pond' ratios are used.

Table 26. Removal efficiency in STP_S in Hindon agglomerations

	Treatment level	BOD_5	COD	N	P	TSS
Ghaziabad	Secondary	89%	79%	30%	25%	89%
Greater Noida	Secondary	94%	83%	30%	25%	97%
Noida	Secondary	95%	85%	30%	25%	98%
Meerut	Secondary	90%	80%	30%	25%	79%
Muzaffarnagar	Stabilization ponds	80%	71%	58%	40%	91%
Saharanpur	Secondary	80%	71%	30%	25%	83%

Source: own elaboration following methodology explained in main text

Previously to the application of these coefficients, a comparison of the sewage reaching the STPs in the agglomeration and the generation assessment (2019) has been made. The conclusion is that both Ghaziabad and Greater Noida would be treating volumes above generation; respectively 30.92 MLD and 31.32 MLD. Different explanations are possible, including any kind of combination of underestimation of generation rates and/or population and STPs treating sewage from neighbor cities. These apparent inconsistencies should be investigated in the drafting of the Programme of Measures of the Hindon Basin. In the meantime, the surplus has been distributed among the rest of the agglomerations of Ghaziabad and Noida.

Finally, the following reduction ratios have been used.

Table 27. Reduction of wastewater pollution per agglomeration

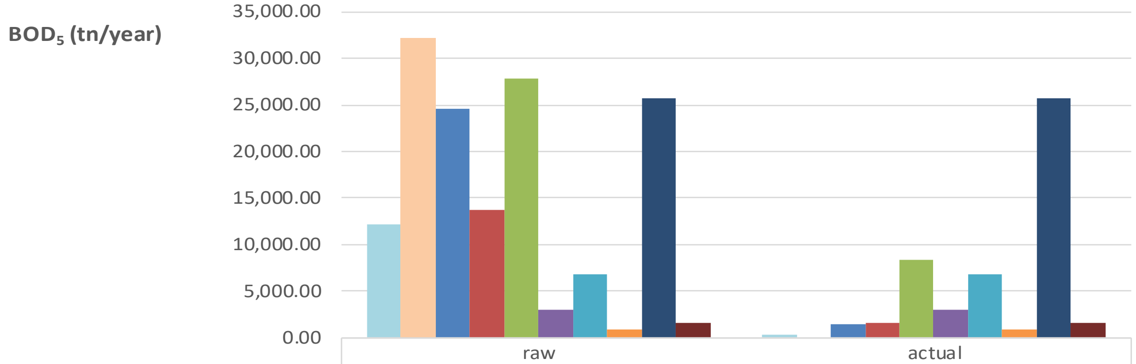
Agglomeration	Sewage produced (MLD)	Sewage treated (MLD)	Surplus distribu-tion	% treated sewage	Removal efficiency				
					BOD	COD	N	P	TSS
Baraut	11.55			0.00%					
Noida	406.84	195.07	29.78	55.27%	95%	85%	30%	25%	98%
Greater Noida	12.81	12.81		100.00%					
Dadri	10.96		1.54	14.06%	94%	83%	30%	25%	97%
Ghaziabad	279.29	279.29		100.00%	89%	79%	30%	25%	89%
Hapur	42.16		15.53	36.84%	89%	79%	30%	25%	89%
Khora	32.32		11.90	36.84%	89%	79%	30%	25%	89%
Muradnagar	9.47		3.49	36.84%	89%	79%	30%	25%	89%
Roorkee	15.28			0.00%					
Manglaur	8.13			0.00%					
Meerut	212.57	88.66		41.71%	90%	80%	30%	25%	79%
Sardhana	6.87			0.00%					
Muzaffarnagar	85.71	29.03		33.86%	80%				
Shamli	12.03			0.00%					
Saharanpur	96.64	38.52		39.86%	80%	71%	30%	25%	83%
Deoband	10.97			0.00%					

Source: own elaboration

3.3.2 Assessment of actual urban pollution in the Hindon basin

For each agglomeration, pollutant loads are reduced by applying the coefficients of Table 27, while no alteration is made for the rest of urban and rural areas. The comparison of raw and actual pollutant loads in current situations is presented in the tables below.

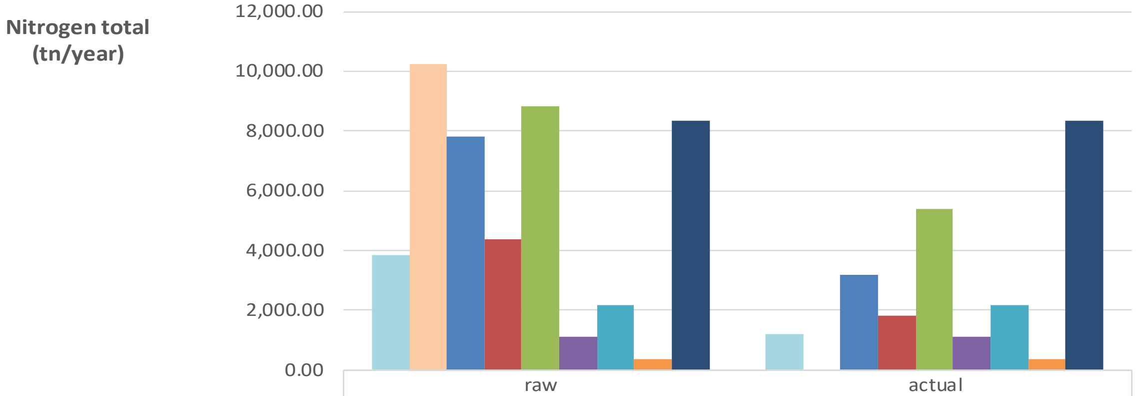
Table 28. Comparison of raw and actual BOD_5 discharge from urban and rural areas of the Hindon basin



	raw	actual
Noida	12,110.84	270.87
Ghaziabad	32,265.84	0.00
Meerut	24,558.48	1,431.54
Saharanpur	13,730.04	1,651.56
Uttar Pradesh - other major cities	27,796.50	8,373.37
Uttarakhand - major cities	3,055.53	3,055.53
Uttar Pradesh urban (others)	6,776.12	6,776.12
Uttarakhand urban (others)	956.63	956.63
Uttar Pradesh rural	25,708.40	25,708.40
Uttarakhand rural	1,625.22	1,625.22

Source: own elaboration

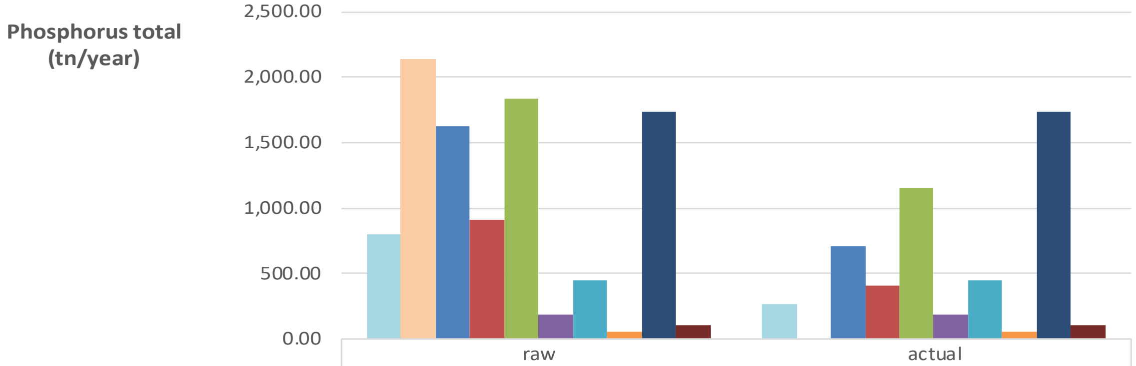
Table 29. Comparison of raw and actual Nitrogen discharge from urban and rural areas of the Hindon basin



	raw	actual
Noida	3,851.04	1,205.85
Ghaziabad	10,259.98	0.00
Meerut	7,809.17	3,186.44
Saharanpur	4,365.91	1,838.08
Uttar Pradesh - other major cities	8,838.80	5,403.26
Uttarakhand - major cities	1,102.56	1,102.56
Uttar Pradesh urban (others)	2,154.69	2,154.69
Uttarakhand urban (others)	345.19	345.19
Uttar Pradesh rural	8,344.85	8,344.85

Source: own elaboration

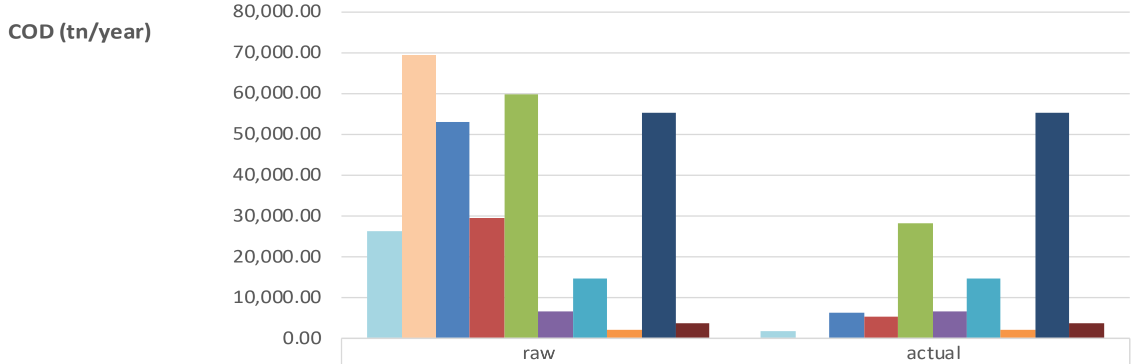
Table 30. Comparison of raw and actual Phosphorus discharge from urban and rural areas of the Hindon basin



	raw	actual
Noida	802.30	269.16
Ghaziabad	2,137.50	0.00
Meerut	1,626.91	711.26
Saharanpur	909.57	410.29
Uttar Pradesh - other major cities	1,841.42	1,152.10
Uttarakhand - major cities	181.99	181.99
Uttar Pradesh urban (others)	448.89	448.89
Uttarakhand urban (others)	56.98	56.98
Uttar Pradesh rural	1,738.51	1,738.51
Uttarakhand rural	100.87	100.87

Source: own elaboration

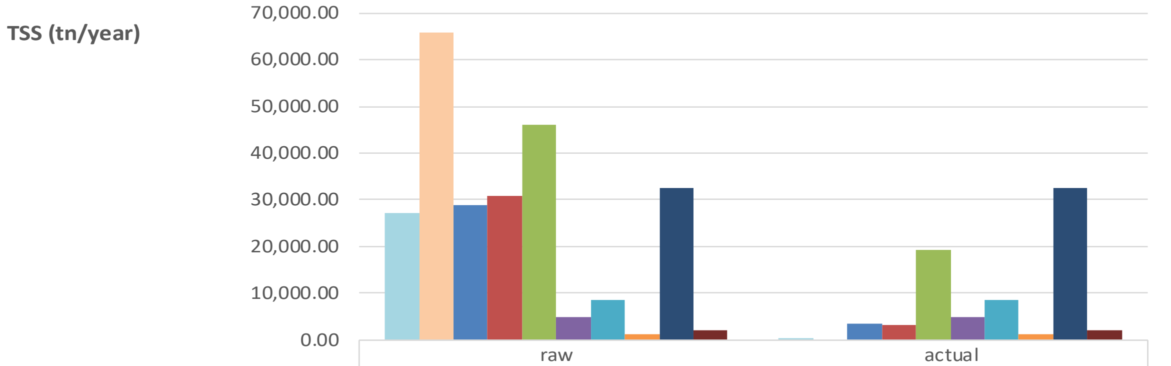
Table 31. Comparison of raw and actual COD discharge from urban and rural areas of the Hindon basin



	raw	actual
Noida	26,077.16	1,749.72
Ghaziabad	69,475.11	0.00
Meerut	52,879.54	6,164.83
Saharanpur	29,563.65	5,156.41
Uttar Pradesh - other major cities	59,851.67	28,040.42
Uttarakhand - major cities	6,579.20	6,579.20
Uttar Pradesh urban (others)	14,590.39	14,590.39
Uttarakhand urban (others)	2,059.83	2,059.83
Uttar Pradesh rural	55,355.55	55,355.55
Uttarakhand rural	3,499.44	3,499.44

Source: own elaboration

Table 32. Comparison of raw and actual TSS discharge from urban and rural areas of the Hindon basin



	raw	actual
Noida	27,113.42	242.57
Ghaziabad	65,706.11	0.00
Meerut	28,888.25	3,536.26
Saharanpur	30,738.45	3,142.84
Uttar Pradesh - other major cities	46,171.01	19,315.33
Uttarakhand - major cities	4,985.56	4,985.56
Uttar Pradesh urban (others)	8,570.73	8,570.73
Uttarakhand urban (others)	1,209.99	1,209.99
Uttar Pradesh rural	32,517.10	32,517.10
Uttarakhand rural	2,055.65	2,055.65

Source: own elaboration

3.3.3 Sewage treatment gap

The current sewage treatment gap has been assessed under three different assumptions (scenarios):

1. The treatment gap is identified strictly at the agglomeration level. Thus,
2. Apparent surplus of sewage produced that is reaching STPs in Ghaziabad and Greater Noida is distributed to neighbour cities, as assumed in the pollution assessment.
3. The idle treatment capacity (treatment capacity – sewage reaching STPs) is distributed to cover, as far as possible, the treatment deficits of neighbouring cities.

Results are presented in the Table 33.

Table 33. Assessment of current treatment gap in Hindon basin under different assumptions

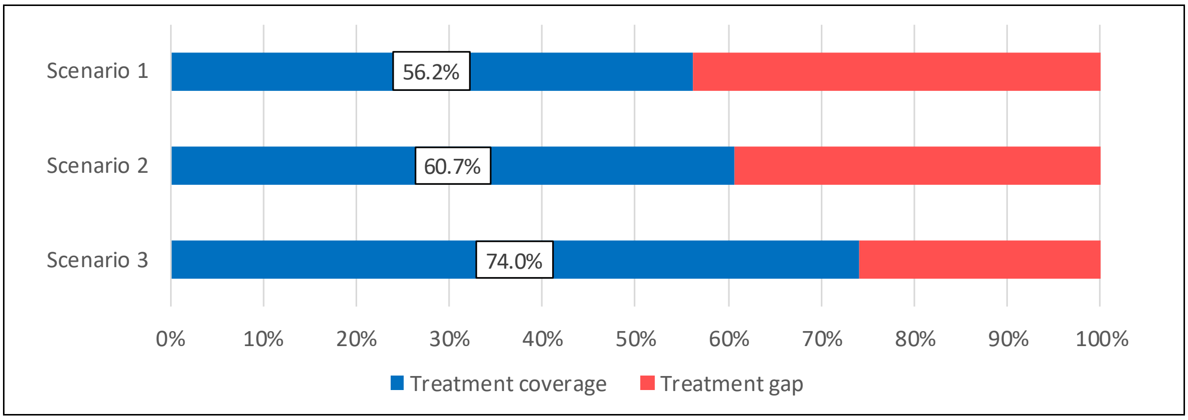
City /Area	Treatment needs	Treatment capacity	Sewage reaching STP(s)	Treatment gap 1	Treatment gap 2	Treatment gap 3
Baraut	11.55	0.00	0.00	11.55	11.55	11.55
Noida	406.84	231.00	195.07	175.84	146.06	22.58
Greater Noida	12.81	174.00	44.13	0.00	0.00	0.00
Dadri	10.96	0.00	0.00	10.96	9.42	3.03
Ghaziabad	279.29	368.00	310.22	0.00	0.00	0.00
Hapur	42.16	0.00	0.00	42.16	26.63	0.00
Khora	32.32	0.00	0.00	32.32	20.41	0.00
Muradnagar	9.47	0.00	0.00	9.47	5.98	0.00
Roorkee	15.28	0.00	0.00	15.28	15.28	15.28
Manglaur	8.13	0.00	0.00	8.13	8.13	8.13
Meerut	212.57	179.00	88.66	33.57	33.57	33.57
Sardhana	6.87	0.00	0.00	6.87	6.87	6.87

Table 33. Assessment of current treatment gap in Hindon basin under different assumptions

City /Area	Treatment needs	Treatment capacity	Sewage reaching STP(s)	Treatment gap 1	Treatment gap 2	Treatment gap 3
Muzaffarnagar	85.71	32.50	29.03	53.21	53.21	53.21
Shamli	12.03	0.00	0.00	12.03	12.03	12.03
Saharanpur	96.64	38.00	38.52	58.64	58.64	58.64
Deoband	10.97	0.00	0.00	10.97	10.97	10.97
Baghpat urban (others)	1.88	0.00	0.00	1.88	1.88	1.88
Ghaziabad urban (others)	7.60	0.00	0.00	7.60	7.60	7.60
Muzaffarnagar urban (others)	18.49	0.00	0.00	18.49	18.49	18.49
Saharanpur urban (others)	10.79	0.00	0.00	10.79	10.79	10.79
Gautam Buddha Nagar urban (others)	1.60	0.00	0.00	1.60	1.60	1.60
Meerut urban (others)	1.83	0.00	0.00	1.83	1.83	1.83
Hardwar urban (others)	8.07	0.00	0.00	8.07	8.07	8.07
Baghpat rural	4.20	0.00	0.00	4.20	4.20	4.20
Ghaziabad rural	3.26	0.00	0.00	3.26	3.26	3.26
Muzaffarnagar rural	24.51	0.00	0.00	24.51	24.51	24.51
Saharanpur rural	29.10	0.00	0.00	29.10	29.10	29.10
Gautam Buddha Nagar rural	2.45	0.00	0.00	2.45	2.45	2.45
Meerut rural	2.91	0.00	0.00	2.91	2.91	2.91
Hardwar rural	4.20	0.00	0.00	4.20	4.20	4.20
Noida	406.84	231.00	195.07	175.84	146.06	22.58
Ghaziabad	279.29	368.00	310.22	0.00	0.00	0.00
Meerut	212.57	179.00	88.66	33.57	33.57	33.57
Saharanpur	96.64	38.00	38.52	58.64	58.64	58.64
Uttar Pradesh – other major cities	234.85	206.50	73.16	189.54	157.08	97.66
Uttarakhand – major cities	23.40	0.00	0.00	23.40	23.40	23.40
Uttar Pradesh urban (others)	42.17	0.00	0.00	42.17	42.17	42.17
Uttarakhand urban (others)	8.07	0.00	0.00	8.07	8.07	8.07
Uttar Pradesh rural	66.42	0.00	0.00	66.42	66.42	66.42
Uttarakhand rural	4.20	0.00	0.00	4.20	4.20	4.20
Total Hindon	**1,374.46**	**1,022.50**	**705.62**	**601.86**	**539.62**	**356.72**

Source: own elaboration

Table 34. Treatment coverd vs treatment gap under the three scenarios



Source: own elaboration

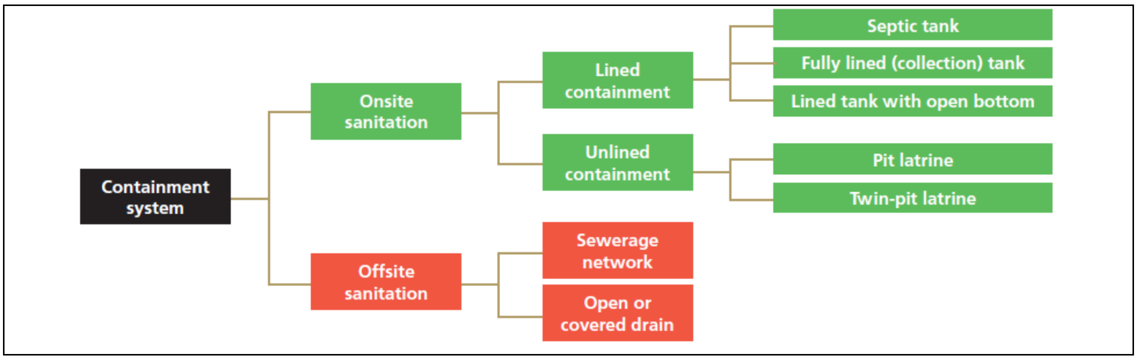
3.3.4 Assessment of excreta management in Uttar Pradesh

The Centre for Science and Environment has published in 2018 and 2019 in-depth analysis of how human excreta is managed in cities of Uttar Pradesh[22]. Focusing on Hindon, detailed factsheets are elaborated for Ghaziabad, Muzaffarnagar, Saharanpur, Shamli, Baraut, Meerut and Modinagar.

Three different components / steps of the management process are described:

1. **Containment system**, to which toilet is connected to.
2. **Emptying**, the process of extracting faecal sludge/septage from onsite sanitation systems.
3. **Transport** of faecal sludge/septage and wastewater/sewage to the treatment/disposal site
4. **Treatment and disposal** of wastewater, faecal sludge and supernatant

Figure 1. Type of containment systems



Source: CSE 2019

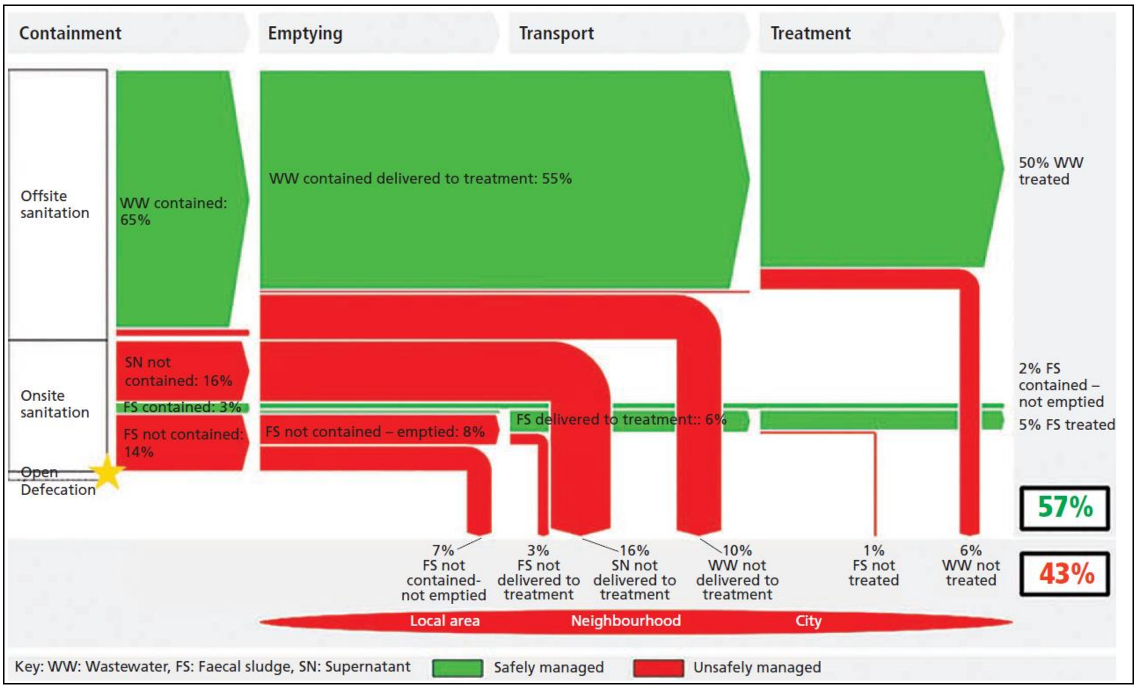
Analysis are presented graphically in the form of the so-called excreta flow diagram, also often described as Shit Flow Diagram (SFD)[23]. SFD is intended to be a *tool to readily understand and communicate how excreta physically flows through a city or town*.

SFD represents how the different components of excreta flow trough the system, indicating the percentage under each management option thar are qualified as safe or unsafe with green / red colour code (see Figure 2).

[22] Suresh Rohilla, Bhitush Luthra et al 2019. *Managing Septage in Cities of Uttar Pradesh: An Analysis of the sanitation chain in 66 cities through SFDs*, Centre for Science and Environment, New Delhi. https://www.cseindia.org/managing-septage-in-cities-of-uttar-pradesh-9268
Suresh Rohilla, Bhitush Luthra et al 2019. Assessment of Excreta Management — Factsheets for 66 cities in Uttar Pradesh, Centre for Science and Environment, New Delhi. https://www.cseindia.org/assessment-of-excreta-management-9269

[23] https://sfd.susana.org/

Figure 2. Example of SFD. Ghaziabad



Source: CSE 2019

The information contained in the report on the different stages of excreta management in Hindon cities is summarized in the following tables.

Table 35. Containment systems in cities of Hindon basin

City/Town	Ghaziabad	Muzaffarna-gar	Saharanpur	Shamli	Baraut	Meerut	Modinagar
Toilet discharges directly to a central-ised combined sewer	69%						
Toilet discharges directly to a central-ised foul/separate sewer		5%	2%				
Toilet discharges directly to open drain or storm sewer	1%	2%	15%	7%	2%	9%	22%
Toilet discharges directly to open ground	1%						
Piped sewer system					5%	39%	
Septic tank connected to drain or storm sewer open	27%	46%		38%	34%	14%	30%
Septic tank connected to a centralised foul/separate sewer			24%				
Fully lined tank (sealed) connected to an open drain or storm sewer		46%	47%	54%	50%	31%	43%
Fully lined tank (sealed) connected to open ground							2%
Lined tank with impermeable walls and open bottom					6%	6%	
Unlined pit, no outlet or overflow, (sig-nificant risk of groundwater pollution)	2%						
Open defecation		1%	12%	1%	3%	1%	3%

Source: CSE 2019

Table 36. Proportion of wastewater, faecal sludge and supernatant under different safe and unsafe management options in cities of Hindon basin

City/Town	Ghaziabad	Muzaffarna-gar	Saharanpur	Shamli	Baraut	Meerut	Modinagar
WW treated	50%	3%	22%			32%	
FS contained – not emptied	2%	7%	9%	10%	2%	1%	2%
FS treated	5%		1%				
SN treated		14%	12%				
Open defecation		1%	2%	1%	2%	1%	3%
FS not contained not emptied	7%	7%	10%	13%	5%	8%	3%
FS not delivered to treatment	3%	32%	16%	23%	38%	20%	33%
SN not delivered to treatment	16%	17%	25%	46%	45%	23%	37%
WW not delivered to treatment	10%	1%	3%	7%	8%	12%	22%
FS not treated	1%						
SN not treated		14%					
WW not treated	6%	4%				3%	

WW: wastewater. FS: faecal sludge. SN: supernatant

Source: CSE 2019

Table 37. Treatment systems in cities of Hindon basin

City/Town		Ghaziabad	Muzaffarnagar	Saharanpur	Shamli	Baraut	Meerut	Modinagar
Treatment and disposal - sewage	Treatment facility present - Sewage	Yes	Yes	Yes	No	No	yes	No
	Type of facility - Sewage	STP	STP	STP	Oxidation pond	No	STP	NA
	Generated - Sewage (MLD)	312	49.00	93.00	12.86	10	179	14.00
	Treated - Sewage (MLD)	281	32.50	38.00	No	0	82.6	0.00
	Designated disposal site - Sewage	Yes	Drain	STP	Open drain	NA	No	Open drain
Treatment and disposal - sludge	Treatment facility present - Faecal sludge	Yes	No	No	No	No	No	No
	Type of facility - Faecal sludge	Co-treatment at STP	NA	NA	NA	NA	NA	NA
	Generated - Faecal sludge (KLD)	202	201.00	286.00	61	32	230	55.00
	Treated - Faecal sludge (KLD)	10	No	No	No	0	0	No
	Designated disposal site - Faecal sludge	Yes	Open drain	Open drain and fields	Solid waste dump yard	No	No	Open drain & dumping site

Source: CSE 2019

4 PROGRAMME OF MEASURES

4.1 Proposal of the Centre for Science and Environment

CSE has devised a 5 year' Plan of Action for Uttar Pradesh cities, following the mandate of the 2017 National Policy[24] that establish the needs to formulate Faecal Sludge and Septage Management (FSSM) strategy for states and urban local bodies. The Plan raises a sequence of actions that range

24 https://smartnet.niua.org/content/8e184ef5-2232-4f0d-a5af-78876c96aff8

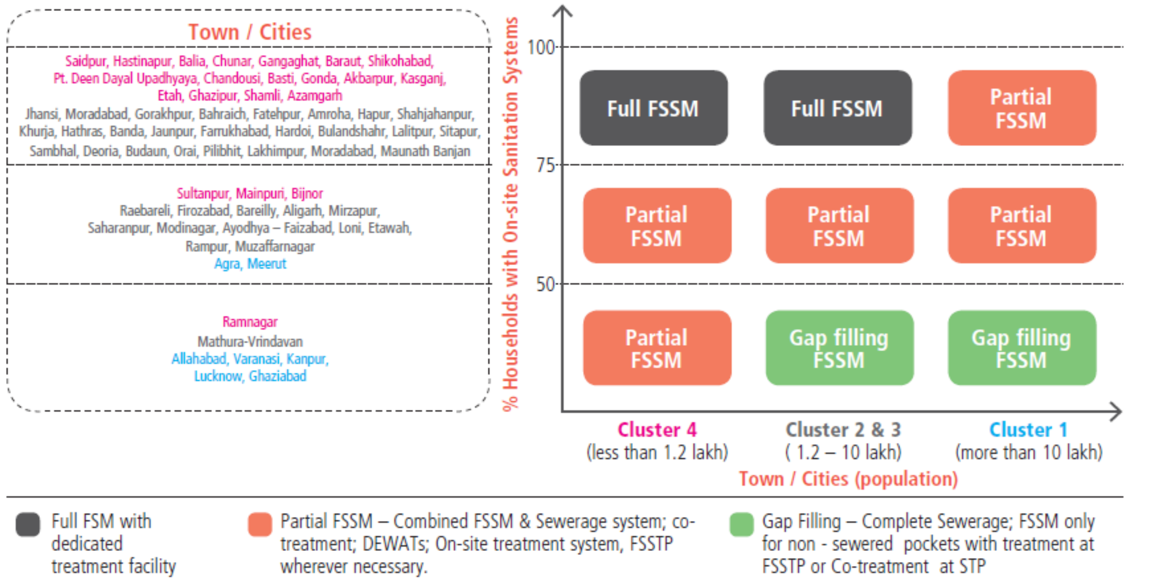
from the compilation of data to the design of a Sanitation Plan and its implementation and incorporate training and legal enforcement measures.

Depending on the starting situation and population size, Uttar Pradesh cities are divided into four clusters (plus a fifth one for cities along main Ganga) where different level of ambition is set:

- **Gap filling FSSM**: complete sewerage coverage (FSSM for non - sewered pockets
- **Partial FSSM**: combination of sewerage systems and FSSM:
- **Full FSM**, with specific treatment facility.

The proposal is summarized in the schema below.

Figure 3. Proposed FSSM approach for urban areas in Uttar Pradesh



Source: CSE 2019

Focusing on Hindon cities, the following strategies are proposed:

Gap filling - FSSM	Ghaziabad (cluster 1)
Partial FSSM	Meerut (cluster 1)
	Saharanpur, Loni (cluster 2)
	Modinagar, Muzaffarnagar (cluster 3)
Full FSSM	Moradabad (cluster 2)
	Baraut, Shamli (cluster 4)

It must be noted that some cities that have been taken into account in the pollution assessment (section 3) are not considered in this Action Plan. This is the case of Noida and Greater Noida -probably because of being part of the National Capital Region of India- bat also of Dadri and Deoband.

4.2 Recommendations

- The Plan of Action proposed by CSE is well founded and structured Shock Plan to optimize the impact of limited financial resources in the short term.
- However, more ambitious goals (Gap filling strategy) can be generalized in the medium-long term. A national (or State policy) setting specific objectives for different time horizons like EU 91/271 Directive. Size of population and quality objectives for receiving waters, depending of

flow availability to assimilate polluted discharges or environmental vulnerability, can be elements for a mid-term strategy.

- FSSM in non-sewered areas can be a permanent element of the strategy, provided that the level of environmental protection achieved is satisfactory. The option of co-treatment in STP or FSSTP[25], as suggested by CSE, can be helpful in this regard.
- Current planning by Uttar Pradesh Jal Nigam[26] and local Governments (municipal corporation, nagar nigam, nagar palika prishad …) should be factored into the decision process regarding the Sanitation Plan.
- Appropriate cost recovery policies of FSSM services must be established in parallel to the financing and implementation of the infrastructure to ensure proper maintenance of treatment installations and sewerage networks.
- The extension of the strategy to towns and villages, in a second step, is also needed. India-EU co-financed projects[27] under the EU - India Joint Call on Research and Innovation for Water can be of interest in this regard. The selected projects will develop new and/or adapt the most suitable existing innovative and affordable solutions in wastewater treatment and reuse for Indian conditions.
- The potential role of water reuse as part of low-cost integrated solutions (wetlands or irrigation) or as a provision of sage and secure water for industrial purposes must be further explored in the framework of the Programme of Measures for Hindon.
- Apparent inconsistencies in the assessment of urban pollution, highlighted in section 3 should be clarified in direct contact with competent authorities. The most relevant ones are listed below:
  - The volume of sewage reaching the STPs of Ghaziabad is higher of sewage generation estimates. Moreover, according to CSE SFD for this city, sewerage coverage is relevant but not complete.
  - In Greater Noida sewage treatment capacity is also quite high in relation to the estimated sewage production.
  - Sewage generation per capita in Noida (650 lpcd) is well above standard. Probably, relatively high industrial component and/or significant irrigation of municipal green areas may be behind this abnormal value.

25 https://www.youtube.com/watch?v=WZgT2Vwfvwc
26 http://jn.upsdc.gov.in/page/en/sewerage
27 https://eeas.europa.eu/delegations/india/58099/eu-india-jointly-fund-seven-research-and-innovation-projects-tune-eur-40-million-tackle-urgent_en