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Increasing Pollution Level in River Yamuna—A Challenge to Sustainable Development of an Urban Centre, Delhi, India

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Abstract: Water quality degradation is a serious and rapidly growing problem in expanding cities of India where unprecedented and unplanned urbanization accompanied by rapid industrial development are the major causal factors. Delhi, the capital city of India, is facing the problem of water pollution since the last few decades. In the present study different physico-chemical and biological parameters (i.e. COD, BOD, DO, TKN, AMM, WT, TC and FC) of water are analysed to assess the changing quality of water over the period of twelve years (1995–2006) and to evaluate the impact of Yamuna Action Plans on water quality. With the help of time series analysis method changing trend of pollutants is estimated, and value for the future is also calculated. The primary data collected are from 1896 households to examine the relationship between outdoor and indoor pollution levels. The analysis reveals that despite the implementation of Yamuna Action Plan I and II, the pollutants are well above the standard limit set by Central Pollution Control Board (CPCB). For the mitigation and management of this problem in the sustainable urban development perspectives certain relevant measures are also suggested.

Key words: Delhi, pollution, urbanization, CPCB, Yamuna Action Plan.

Introduction

Water is, literally, the bearer of life. The history of human civilization reveals that human habitations from times immemorial evolved and developed near a good source of water. The alteration in water quality that started with the first advanced civilizations of Mesopotamia, Egypt, India, China, Persia, Greece and Rome continues till date. Unfortunately, the importance of clean water was not understood until the second half of the nineteenth century, a relatively recent development. As the industrial revolution accompanied with urbanization progressed, water pollution became a major crisis. Discharge from households and factories have found water sources, especially rivers, a convenient means of waste disposal.

In the contemporary world, due to alarming growth of urban population not only the demand of fresh water to meet the domestic requirement has enhanced but also the discharge of waste water, having a cumulative effect of deteriorating the water quality in receiving bodies has increased manifolds. On an average 90% to 95% of all domestic sewage and 75% of all industrial waste are discharged into surface water without any treatment (Allaoui, 1998; Carty, 1991). It is estimated that each year roughly 450 km^3 of waste water is discharged into rivers, streams and lakes (Shiklomanove, 1997). To dilute and transport this polluted water, before it can be used again another 6000 km^3 of clean water is needed—an amount equal to about two-thirds of the world's total annual usable fresh water runoff (Shiklomanove, 1997). According to an estimate made by the United Nations Food and Agriculture Organization (UNFAO, 1990), if the current trends were to continue, the world's entire stable river flow would be needed just for pollutant

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transport and dilution by the middle of this century. Consequently, fresh water is emerging as one of the most critical natural resource issues facing humanity, globally.

In developing countries, where population is growing rapidly, development demands are great, and government has other investment priorities, water pollution is a vexing problem. India which has 16% of the world's population and 4% of world's water resources is already heading towards a state of water crises. Almost 14 major rivers in India are polluted and together they transport 50 million cubic metres of untreated sewage into coastal water every year (Harrison, 1992; Niemczynowicz, 1996). Consequently, some 200 million Indians do not have access to safe and clean water (Bansal, 2004). With pipes running empty, Indian cities are turning into villages served by tankers. Even in metropolitan cities such as Chennai, Bangalore, Mumbai and Delhi water is being rationed. In fact, from being a necessity, water has now become a luxury in these metropolises.

Degrading water quality of river Yamuna is the biggest crisis facing Delhi that seems to be going from bad to worse. The river is the most conspicuous feature (Figure 1) and the main source of drinking water supply (i.e. approximately 37% of the total supply) in Delhi (Economic Survey of Delhi, 2007–08). Due to perennial increase of urban population accompanied by enhanced urban activities that are placing exigent pressures on the use of fresh water and are enhancing the discharge of municipal waste, industrial effluents and agricultural residue into the river containing all sorts of toxic chemicals and pollutants, the water quality of river Yamuna is degrading each day. Therefore, it is necessarily implied to understand the nature of the problem through in-depth study and to identify the real causes of the problem. The objective of the study is to evaluate the changing level of pollutants in river Yamuna with special reference to physico-chemical and biological parameters. We also tried to assess the relationship between outdoor

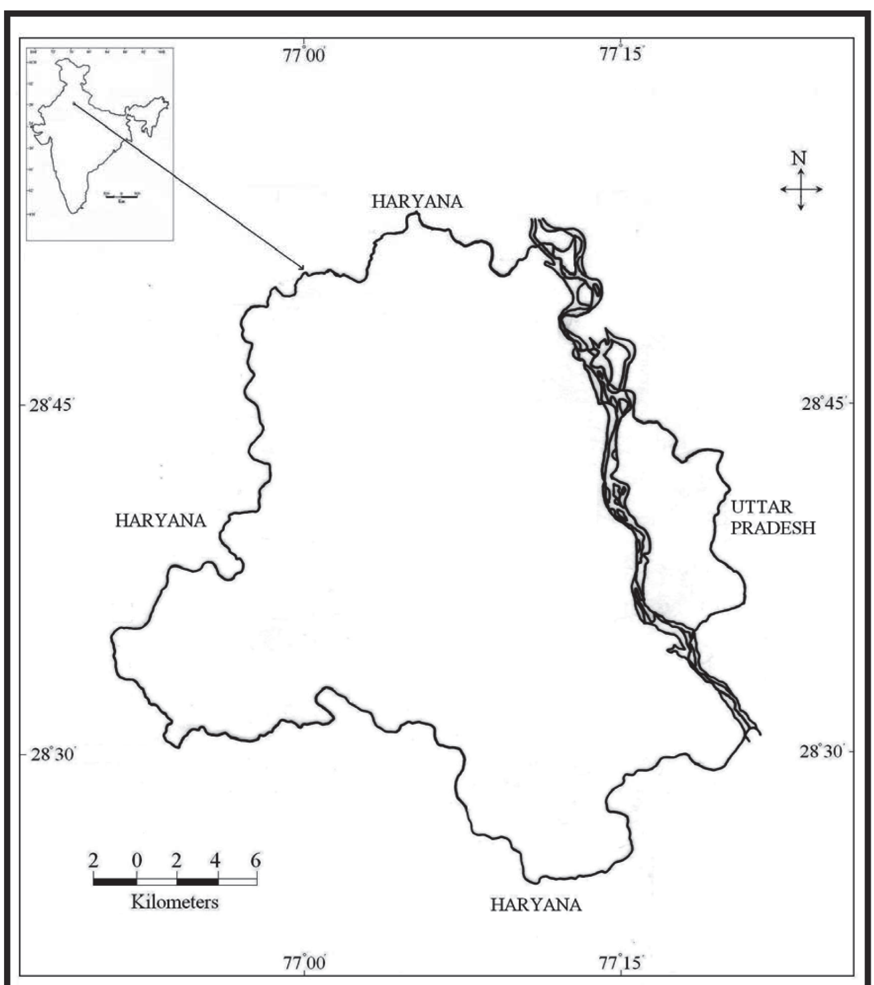

Figure 1: Location of river Yamuna in Delhi.

and indoor pollution at household level. The impact of Yamuna Action Plans on water quality of river Yamuna was also critically evaluated. Finally, remedial measures to reduce further degradation of water bodies and to recover them through enforced and time-bound implementation of policies is discussed.

Data Base

The present analysis is based on both primary and secondary sources of data. The latest available secondary data are collected from Central Pollution Control Board (CPCB). Primary data are obtained from cross-sectional field survey conducted during the months from May to August 2009 with the help of a questionnaire. For the selection of wards, a multi-stage sampling method is applied as it is likely to be more representative of the existing problems. At the first stage, zones of the study area, i.e., twelve in number, are taken into consideration and divided into four categories on the basis of density of population. This method is applied because the population density in the study area is highest among all the states and union territories in the country. From each of the selected zone, 25% of wards are selected with the help of purposive random sampling method. The study has been limited to the heads of the households as it is assumed that the head of the family would be an ideal subject for measuring the different aspects of the problems concerning water quality. The questionnaire includes the basic information of the respondents (i.e., sex, age, education level, family size, occupation), sources of water supply (i.e. piped water, tube well, hand pump and others), uses of water (only domestic, drinking and domestic) and quality of water (good, average and poor). In all 1896 heads of the household were interviewed from 21 wards.

Methodology

The collected data are organized, classified and analysed with statistical technique, viz., time series analysis (trend line by least square method) as well as visual presentation in the form of graphs, maps and diagrams. It is one of the best ways of obtaining trend value for the entire time period. With this method, a straight line trend is obtained. The equation of straight line is $Y = a + bX$ where 'a' and 'b' are constants. This equation of straight line establishes a functional relationship in X and Y series and as such can be used to forecast future value.

Results

Figure 2 shows the mean level of Chemical Oxygen Demand (COD). The mean COD values were found to vary from 31 mg/l to 76 mg/l over the entire observational period. The highest COD value, i.e., 76 mg/l was recorded in the years 1988 and 2004 whereas the lowest value, i.e., 31 mg/l was observed in the year 1995. The average annual growth rate was observed at 1.89 mg/l and expected to reach up to 76.61, 87.07 and 95.52 mg/l by 2010, 2015 and 2020 respectively. Whereas the mean level of Biological Oxygen Demand (BOD) over the entire observational period was recorded at 16.66 mg/l showing 1.29 mg/l average annual growth rate (Figure 2). It varies from 7 mg/l to 24 mg/l in 1998 and 2004 that fall beyond the prescribed standard limit (3 mg/l or less) set by ISI (Indian Standards Institute, Government of India, 1984). The values calculated for the years 2010 (30.19 mg/l), 2015 (36.64 mg/l) and 2020 (43.09 mg/l) was also found far beyond the limit. The concentration of dissolved free ammonia (AMM) in the river water also shows an increasing trend with the value varying from 4.60 mg/l (1995) to 20.66 mg/l (2004) and fall beyond the standard limits (1.2 mg/l or less) in most of the years. The mean level of AMM over the observational period was recorded at 12.05 mg/l with the average annual growth rate of 1.42 mg/l. The expected values for the years 2010, 2015 and 2020 were recorded at 25.93 mg/l, 33.03 mg/l and 40.13 mg/l, respectively. Similar trend was observed in Total Kjeldal Nitrogen (TKN) concentration. The lowest concentration of TKN was observed in 1998 (4.97 mg/l) and highest in 2004 (28.88 mg/l). The values seem to be moving upward and in the near future also it is expected to reach up to 36.37 mg/l, 46.82 mg/l and 57.27 mg/l for the years

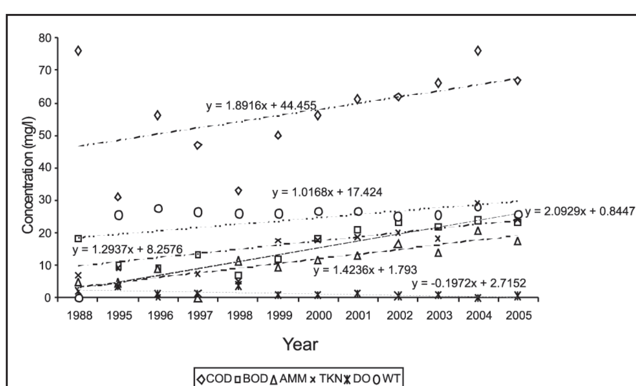

Figure 2: Physico-chemical characteristics of river water of Yamuna (1998-2006).

2010, 2015 and 2020, respectively. Figure 2 indicates the mean level of Dissolved Oxygen (DO) that recorded at 1.43 mg/l during the entire period of the study. The annual average of DO varied from 3.8 mg/l (1998) to 0.0 mg/l (2004) against the standard limit of 5.0 mg/l or more. Water Temperature (WT) of the river ranged between 25°C and 28°C. The lowest temperature was recorded in 1995 (25.3°C) and highest (28.1°C) in 2004 with the average temperature of 26.21°C. After 1995 it shows an upward trend and then follows a declining trend.

Like the physico-chemical parameters, the biological parameters, i.e., Total Coliform (TC) recorded at 22742798.83/100 ml throughout the observational period is well above the standard limit (5000 MPN/100 ml or less). The minimum TC count were found in 1997 (44918/100 ml) and maximum in 2003 (102508333/100 ml). In general, it follows an increasing trend with average annual growth rate of 6660054.19/100 ml especially after 1998 and expected to reach up to 133768474.6/100 ml, 167068745.60/100 ml and 200369016.50/100 ml in the years 2010, 2015 and 2020, respectively (Figure 3). Similarly, the annual mean number of Fecal Coliform (FC) recorded at 3868107.66/100 ml over the entire study period showing 1079478.94/100 ml average annual growth rate. The value has been continuously increasing especially after 1998. It varied between 25807/100 ml (1998) and 19411250/100 ml (2004) and fall beyond the prescribed limit in most of the year. The projected value for the years 2010 (21319647.45/100 ml), 2015 (26717042.15 ml) and 2020 (32114436.85/100 ml) are also quite high.

A detailed study of selected wards of Delhi regarding the sources, uses and quality of water supply has been undertaken as the river Yamuna is the main source of drinking water supply. Information regarding physical and aesthetic aspects such as turbidity, colour, taste and

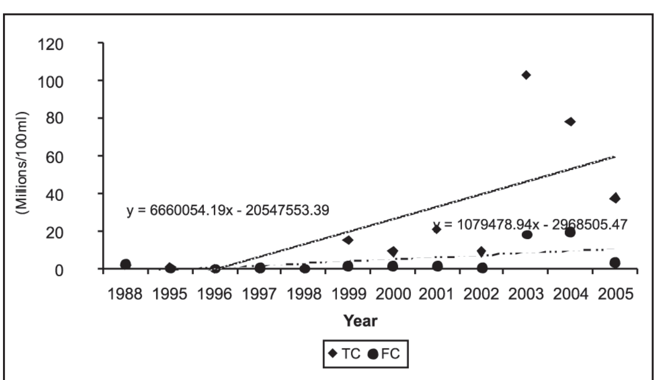

Figure 3: Bacteriological characteristics of river water of Yamuna (1998-2006).

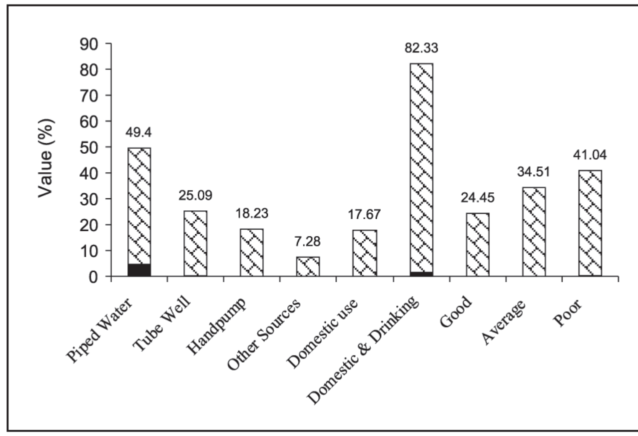

Figure 4: Quality characteristics of water available in the respondent's house (2008).

odour has been collected. Figure 4 indicates that nearly 50% of the respondents have access to piped water connection whereas 25.09%, 18.23% and 7.28% rely on tube well, hand pump and other sources (tankers and roadside water connection), respectively. Regarding the uses of water, 17.67% of respondents use it for domestic purposes only, and 82.33% use it for both domestic and drinking purposes. As far as the quality of water is concerned, only 24.45% of the household has reported for good quality of water, the average and poor quality is observed by 34.51% and 41.02%, respectively.

Discussion

River Yamuna is a lifeline of Delhi and is the main source of water supply to the city. The 48 km stretch of the river in Delhi is heavily polluted and has become extremely critical from a water quality and public health standpoint (Annual Report – CPCB, 2003–2004). This is one of the first studies to assess the changing water quality of river Yamuna and impact of various policies undertaken recently on changing level of pollution in the river. This study will provide an important background for additional research on changing physico-chemical characteristics of ground water and lake or reservoir in the wake of urbanization. The analysis reveals that water quality of Yamuna, instead of improving, has deteriorated over the observational periods despite the expenditure of Rs 871.67 crores since 1994 (Rs 284.98 crores until 1998–99 and Rs 586.69 crores during 1999–2004) Rs 439.60 crores by Delhi Jal Board (DJB) and Rs 147.09 crores by the Delhi State Industrial Development Corporation (DSIDC) under the network of Yamuna Action Plans (YAPs).

The core of Delhi's water problem lies in its cumulative effects of unprecedented and unplanned urban development, phenomenal growth of population, and lack of efficient waste treatment facilities. Delhi being the national capital and the third largest urban centre of India is facing rapid growth in population. No other city has grown so phenomenally as Delhi in the recent past. From a population of barely 0.4 million in 1901, it increased to 13.89 million in 2001 recording decadal growth rate of 51.93% during 1991–2001 (Figure 5). Alarming growth of population has not only increased the demand of fresh water to meet the domestic requirements but also increased the discharge of waste water in receiving bodies. Consequently, the domestic waste has become the major source of pollution. It is estimated that about 85% of the total pollution load is generated by domestic source. Moreover, numerous unauthorized colonies exist in various parts of Delhi. Due to non-availability of sewerage system in these colonies, the night soil, domestic waste, and other discarded materials are dumped directly into the river without any treatment. It is estimated that about 50% of the total pollution load is contributed by unsewered areas. Besides, the embankments of a few major storm water drains such as Najafgarh drain, Barapulla drain, etc., is heavily populated with jhuggi and jhopri clusters (slums) where the sanitary facilities are either not existing or not developed. These slum dwellers use open areas around their units for defecation. In this way, the entire human waste generated from these units along with the additional wastewater generated from their unit is discharged untreated into the river contributing both pathogenic and organic contamination to the river water (MINARS/20/2001–2002). It is estimated that Delhi has experienced nine-fold increase in the generation of sewage over the last thirty-three years. The quantity of waste increased from 329 million litres per day (MLD), 522 MLD, 916 MLD, 1616 MLD to 3267 MLD for the years of 1961, 1971, 1981, 1991 and 2003, respectively (DESR, 2008).

In addition, there are several medium and small-scale industries which are immensely contributing to the generation of pollution loads. In the post-independence period, Delhi emerged as a major industrial and commercial sector with phenomenal growth in manufacturing, trading, and transportation and communication activities. During the past five decades the number of industries increased from 8000 (1951) to 129,000 (2001) (Figure 5). Most of the industries have an inefficient treatment system that leads to generation of pollution loads, which is toxic and varied in nature and highly concentrated in terms of space and time. Some pollutants being refractory become very difficult to either destroy or remove once they have entered into the water body. The domestic and industrial sectors were observed the major pollution load generating sources in different sewerage zones (Figure 6). The domestic waste got the highest value, i.e., 1630 MLD followed by other sources (i.e., commercial activities, service shops, institutional areas, offices and floating population) discharge (371.29 MLD) and industrial discharge (81.40 MLD).

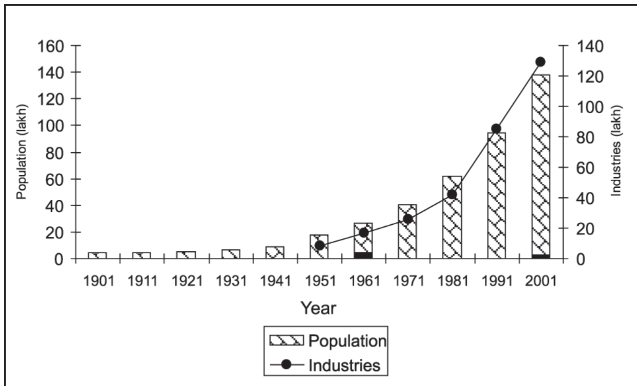

Figure 5: Growth of population and industries in Delhi (1901–2001)

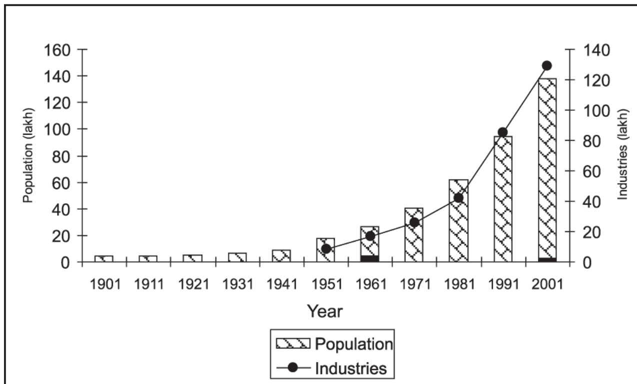

Figure 6: Pollution load discharge from different sewerage zones of Delhi.

Other substantial source of pollution is dairy farming. There are large numbers of unauthorized dairies and ten authorized clusters of dairy farms are located along the river that directly discharge the cattle dung and liquid wastes into the river. It is estimated that in 12 different zones of MCD, there are 21 unauthorized dairy clusters with over 2811 unauthorized dairy units with more than 40,000 cattle which generate about 380 tonnes/day dung (YAP Report). Over three-fourths of waste generated at these diary clusters finds its way into the river through the local surface drains corresponding to a BOD pollution load of over 48 tonnes/day. Besides, waste from slaughter houses, washing cloth, mass bathing, offering of flowers and sweets, cremation of dead bodies, release of burned and half burned bodies and submergence of idols into the river further degrade the water quality.

Regarding pollution at household level it is observed that the ordinary consumer judges the water quality by its physical characteristics. The provision of drinking water that is not only safe but also pleasing in appearance, taste and odour is a matter of high priority. The supply of water that is unsatisfactory in this respect is undermining the confidence of consumers. Most of the respondents claimed for turbid, poor taste and odour and sometime coloured water. Turbidity in drinking water is caused by particulate matter that may be present as a consequence of inadequate treatment or from resuspension of sediment in distribution system. It may also be due to the presence of inorganic particulate matter in some ground water. Colour in drinking water may be due to the presence of organic matter such as humic substances, metals such as iron and manganese and highly coloured industrial wastes. Taste problems in drinking water supplies are often the largest single cause of consumer complaints. Changes in the normal taste of a public water supply may be due to changes in the quality of the raw water source or deficiencies in the treatment process. Odour in water is mainly due to the presence of organic substances. Some odours are indicative of increased biological activity while others may originate from industrial pollution and poor sanitary system. A direct relationship is observed between outdoor and indoor pollution.

Recognizing the gravity of the problem, the Government of India (GOI) launched a massive plan, i.e., Yamuna Action Plans for pollution abatement but due to certain reasons these plans have not proved effective and the problem continues till date. First, against the estimated domestic sewage generation of 719 million gallon per day (MGD) in Delhi, the Government has created capacity for treatment of only 512 MGD until March 2004. Only 335 MGD out of the estimated domestic sewage of 719 MGD is being treated before discharge into the river (Table 1). The balance 384 MGD outfalls into the river untreated. Second, the sewage treatment plant (STP) capacity created by the Delhi Government remained under-utilized to the extent of 25%–45% because of severe limitations like construction of STPs in areas without adequate sewage load, non-synchronization of construction of trunk sewer lines and sewage pumping stations. As a result, untreated sewage continued to flow into the river through a series of storm water drains. Third, when YAP-I schemes were being designed, the wastewater discharge standards did not mandate STP effluents to comply with any bacteriological water quality standards. Consequently, the STPs did not include effluent disinfection systems and even the treated effluent was contributing to the deterioration in water quality. Fourth, out of the 15 Common Effluent Treatment Plants (CETPs) required for treatment of 42 MGD industrial sewage, only 10 are completed and of which only four were commissioned as of March 2004. Even the commissioned plants are not put to optimum utility. Consequently, almost the entire industrial sewage was falling into the river without treatment. Last but not the least the strategy in YAP-I did not adequately address non-point sources of pollution such as dairy farms, dhobighats, slaughter houses, etc. (Report of GNCTD, 2005).

Table 1: Sewerage treatment plants in Delhi

S. No.	*STPs*	*Capacity as on 31 March 2006 (MGD)*	*Actual treatment as on 31 March 2006 (MGD)*
1	Coronation Pillar	46	26.0
2	Delhi Gate	2.2	2.4
3	Ghitorni	5	-
4	Keshopur	72	68.6
5	Kondli I, II, III, IV	45	43.50
6	Mehrauli	5	1.50
7	Najafgarh	5	0.2
8	Nilothi	40	5.10
9	Narela	10	2.3
10	Okhla	140	119
11	Papankalan	20	8.2
12	Rithala	80	42.0
13	Rohini	15	-
14	Dr.Sen N.H.	2.2	2.5
15	Yamuna Vihar I, II	20	7.6
16	Vasant Kunj	5	4.10
	Total	512.40	333.00

From the above discussion it is amply clear that urban activities have profoundly affected the surface water quality that has led to a spiral of environmental decline. River Yamuna in Delhi is like an open sewer. The quality of water in the river is in extremely deteriorated condition and is not suitable for any designated use. Although many policies were implemented under YAP-I and YAP-II but an integrated approach with many essential components are required. Increasing the strength of waste water collection system, and treatment capacity of STPs considering the quantum of waste water generated in future, equip sewage treatment plant with disinfection system, and reducing gap between wastewater generation and its treatment. Clearance to new residential colonies should be given only after ensuring the treatment facilities for the waste water generated by them, and decentralize the sewage treatment facilities by providing this facility at residential colony levels that will not only reduce the waste water transportation cost but also provide treated water for gardening and will reduce the abstraction of ground water. Toilet facilities connected with sewer lines should be provided in jhuggi and jhopri colonies and disposal of garbage, solid and semi-solid waste into river and drains should be prohibited. The industries should maintain and operate their ETPs adequately to meet the specific waste water discharge norms and should be operated to their full capacity and optimum efficiency. All the small scale industries should be connected with the CETP. Avoid mixing of industrial effluents with domestic wastewater for the effective functioning of STPs. Mass awareness should be generated through various programmes. One of the public outreach programme *Aao Jamuna Mein Jaan Daalain* (Let's revive Yamuna) is the best example of involving the masses in the cleaning operation.

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