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Transforming Ganges to be a Living River through Waste Water Management

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Abstract**—**By size and volume of water, Ganges River basin is the biggest among the fourteen major river basins in India. By Hindu's faith, it is the main *'holy river'* in this nation. But, of late, the pollution load, both domestic and industrial sources are deteriorating the surface and groundwater as well as land resources and hence the environment of the Ganges River basin is under threat. Seeing this scenario, the Indian government began to reclaim this river by two Ganges Action Plans I and II since 1986 by spending Rs. 2,747.52 crores ($457.92 million). But the result was no improvement in the water quality of the river and groundwater and environment even after almost three decades of reclamation, and hence now the New Indian Government is taking extra care to rejuvenate this river and allotted Rs. 2,037 cores ($339.50 million) in 2014 and Rs. 20,000 crores ($3,333.33 million) in 2015. The reasons for the poor water quality and stinking environment even after three decades of reclamation of the river are either no treatment/partial treatment of the sewage. Hence, now the authors are suggesting a tertiary level treatment standard of sewages of all sources and origins of the Ganges River basin and recycling the entire treated water for nondomestic uses. At 20million litres per day (MLD) capacity of each sewage treatment plant (STP), this basin needs about 2020 plants to treat the entire sewage load. Cost of the STPs is Rs. 3,43,400 million ($5,723.33 million) and the annual maintenance cost is Rs. 15,352 million ($255.87 million). The advantages of the proposed exercise are: we can produce a volume of 1,769.52 million m^3 of biogas. Since biogas is energy, can be used as a fuel, for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat. It is possible to generate about 3,539.04 million kilowatt electricity per annum from the biogas generated in the process of wastewater treatment in Ganges basin. The income generation from electricity works out to Rs 10,617.12million ($176.95million). This power can be used to bridge the supply and demand gap of energy in the power hungry villages where 300million people are without electricity in India even today, and to run these STPs as well. The 664.18 million tonnes of sludge generated by the treatment plants per annum can be used in agriculture as manure with suitable amendments. By arresting the pollution load the 187.42 cubic kilometer (km^3) of groundwater potential of the Ganges River basin could be protected from deterioration. Since we can recycle the sewage for non-domestic purposes, about 14.75km^3 of fresh water per annum can be conserved for future use. The total value of the water saving per annum is Rs.22,11,916million ($36,865.27million) and each citizen of Ganges River basin can save Rs. 4,423.83/ ($73.73) per annum and Rs. 12.12 ($0.202) per day by recycling the treated water for nondomestic uses. Further the environment of this basin could be kept clean by arresting the foul smell as well as the 3% of greenhouse gages emission from the stinking waterways and land. These are the ways to reclaim the waterways of Ganges River basin from deterioration.

Keywords**—**Holy Ganges River, lifeline of India, wastewater treatment and management, making Ganges permanently holy.

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I. Introduction

INDIA is drained by more than 12 major river basins with a catchment area of more than 2,500,000 square kilometer (km^2). These river systems are grouped into four broad categories: The Himalayan Rivers, the Peninsular Rivers, the Coastal Rivers and the Inland Rivers. In addition to the Ganges, Fig. 1, the Himalayan river system includes the Indus and Brahmaputra River basins [1].

Fig. 1 Ganges River [2]

The Ganges River is fed by runoff from a vast land area bounded by the snow peaks of the Himalaya in the north and the peninsular highlands and the Vindhya Range in the south. Bhagirathi is the source stream of Ganges and it emanates from Gangotri Glacier at Gaumukh at an elevation of 3,892 m. Many small streams comprise the headwaters of Ganges. The important among these are Alaknanda, Dhauliganga, Pindar, Mandakini and Bhilangana. The other important streams/ tributaries are the Yamuna, the Ramaganga, the Gomti, the Ghagra, the Sone, the Gandak, the Burhi Gandak, the Kosi and the Mahananda. At Devprayag, where Alaknanda joins

Bhagirathi, the river acquires the name Ganges. At Farakka in West Bengal, the river divides into two arms namely the Padma which flows to Bangladesh and the Bhagirathi – Hooghly which flows through West Bengal, Fig. 2 [3].

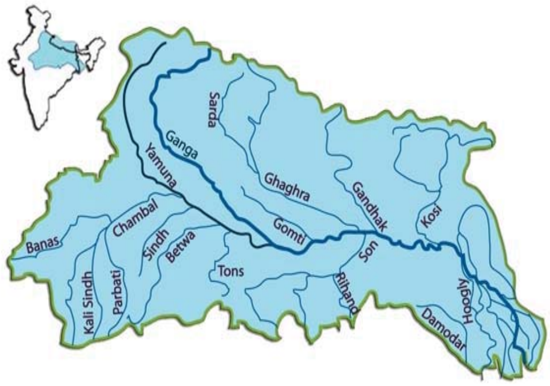

Fig. 2 Ganges River Basin [4]

The Ganges basin encompasses an area of 1,186,000 km^2 spread over four countries: India, Nepal, Bangladesh and China. With 8,61,404 km^2 within India itself, the Ganges basin is the largest river basin in India covering approximately 26.4% of India's total geographical area, 30% of its water resources and more than 40% of its population. It is the world's most populous river basin with more than 500million in India alone. The annual average rainfall in the basin varies between 39 cm to 200 cm; with an average of 110 cm. Eighty percent of the rainfall occurs from June to October, the monsoon months. Because of large temporal variations in precipitation over the year, there is wide fluctuation in the flow characteristics of the river. The average annual discharge of the Ganges River basin is 4,93,400 million cubic metres (MCM)/493.40 km^3 of water.

Groundwater potential of Ganges basin has been assessed by adopting the average annual groundwater fluctuation behavior and specific yield of the aquifers of different geological formations of various origins of this basin. Out of the net 187.42 km^3 of the annual groundwater availability, the groundwater usage for irrigation in the States falling under Ganges basin exceeded 104.7 km^3 per year as of 2008 and accounted for nearly 50% of the groundwater irrigated area of the entire country. The extent of groundwater utilization per year for irrigation is highest in Uttar Pradesh (45.36 km^3), followed by Madhya Pradesh (16.08 km^3), West Bengal (10.84 km^3) and Rajasthan (11.6 km^3). The mean annual replenishable groundwater in India as a whole has been assessed at 433 km^3 per year, of which about 202.5 km^3 (46.8%) lies in the States of the Ganges basin. The demands for domestic and industrial uses are expected to increase to 14.99 km^3 per year in the Ganges basin States by the year 2025. Some 60% of this groundwater potential has already been utilized.

Ganges basin with rich surface and groundwater potential is the '***lifeline of India'*** to produce enough food grain and to generate sustainable hydropower for domestic and industrial growth of the nation. Over 40% of the India's Gross Domestic Product (GDP) is generated in the Ganges River basin. Now due to the domestic sewage and industrial effluents coupled with solid wastes, both the surface and groundwater quality as well as the environment are deteriorating which is likely to further reduce the fresh water resources and in turn the food grain production of the Ganges basin. Therefore, the main objectives of this paper are to treat and recycle the sewage of all origins and protect the freshwater resources and environment and rejuvenate the waterways of Ganges River basin permanently *'living rivers'*.

II. Materials and Methods

In the present context of physical and economic water scarcity as well as the human influenced pollution of freshwater and environment in many nations, water management practices are being adopted to bridge the water supply and demand gap. Among the water management practices, treating and recycling the sewage for many nondomestic uses, and conserving the freshwater resources along with protection of the environment play a big role now in many nations. In the water scarce nations like Israel (treats and recycles more than 80% of its wastewater, using it primarily for agriculture, making it a world leader in that field) and in the Western States of USA, Australia etc., the treated sewage is mainly used for irrigation and other nondomestic uses and in this way the water scarcity is arrested and the environment is protected. Therefore, the present study aims at to treat and recycle the entire sewage in the Ganges River basin similar to the above nations and protect the freshwater and the ecosystems.

To decide the treatment plants the quantity of the domestic and industrial pollution load is necessary. The domestic sewage load is calculated at the rate of 100litres per capita per day for the present population of this basin and industrial effluent load of the 764 industries. Eighty percent of the water use for both these purposes is taken as the sewage load and for this quantity-the STPs are decided, each at 20MLD capacity. The surface and groundwater resources and their quality of the Ganges River basin are also discussed in this paper. Further, in this research paper, the reclamation of the Ganges River basin by wastewater treatment and recycling-the benefits such as the volume of biogas and sludge production, electricity generation from biogas, quantity of freshwater conservation and its economic importance are explained. Quantification of the total quantity of wastewater generation, number of STPs needed to treat the sewage and their installation and maintenance costs are the other salient points of this research paper.

III. Objective of the Study

The water resources of the 14 major river basins in India are being used for human and national developmental activities. Among them the Ganges River basin, the transboundary as well as an interstate river, is the most important by water resources, agricultural production, hydropower etc. It is joined by a large number of tributaries on both the banks in the course of its total run of 2,525km before it outfall into the Bay of Bengal. The Ganges also serves as one of India's holiest rivers whose cultural and spiritual significance transcends the boundaries of the basin.

As per the Comprehensive Mission Document, 2008, Ministry of Water Resources **[5]** the annual surface water potential of this basin has been assessed as 525 km^3. The groundwater potential is 187.42 km^3. The basin provides more than one-third of India's surface water, 90% of which is used for irrigation. The hydropower potential of the basin has been assessed as 10,715 megawatt (MW) at 60% load factor.

The Ganges river basin is one of the most densely populated regions of the world and its population density 520 persons per km^2 is higher than average density 312 for the entire country (2011 census) of India. The main reason for the high density population in the Ganges River basin is the fertile land, uninterrupted water supply, sustainable agriculture and industries.

Though Ganges River in India is considered as the holy river, but of late the domestic and industrial wastewater generated within Ganges basin is polluting the holy river and as a result of this the Ganges River and its tributaries have already become sick, dying or dead. *Hence, now Ganges River is holy only by faith and not by purity.* So, the freshwater in many waterways in the Ganges River basin is deteriorating and became unfit for human consumption. If the present pollution trend is not arrested, all the waterways in the Ganges River basin are likely to be sick and dying similar to Yamuna River, one of the important tributaries of the Ganges within few decades. Hence, the new Indian Government is initiating action to reclaim the Ganges River first.

Already there has been reclamation in the Ganges River in different reaches. Rs. 2,7467.52 crores ($ 457.92 million) was spent in the two Ganges Action Plans (GAPs) over the last 30 years since 1986. Though there is wastewater treatment in some reaches of a few waterways of this basin including the Ganges River, the treated water quality standard has not improved either due to allowing the wastewater without treatment or partial treatment. That is why; the waterways of Ganges basin are stinking in many reaches including at Varnashi the '*holiest place'* of Ganges. An interim report of the Ganges River Basin Management Plan prepared by a Consortium of seven Institutions of Technology said, *attempt to keep the river clean through conventional pollution control methods have proved ineffective* [6]. If the water quality deterioration trend of the waterways of the entire Ganges River basin is not arrested, they are likely to become unfit for human uses. Therefore, the main objective of the present exercise is to reclaim the Ganges River permanently holy, not only by faith but also by purity and transform it 'ever living'.

IV. Ganges River Pollution Scenario

Rapidly increasing population, rising standards of living and exponential growth of industrialization and urbanization have exposed water resources, in general, and rivers, in particular, to various forms of degradation. As a result of this, the rivers are no longer, only a source of water but are also a channel, receiving and transporting urban wastes away from the towns. The mighty and holy Ganges River is no exception to the above scenarios.

Both the point and non-point sources of pollutions are high in the Ganges River basin. The point sources pollutions are 1. Municipal sewage about 1. 3billion litre per day with organics, nutrients and coliform and 2. Industrial wastes of 260million liters per day from food processing, fertilizer manufactures, pharmaceutical companies, electroplating, textile and paper industries, tanneries, oil refineries and petrochemicals, sugar and distilleries, chlor-alkali (an industrial process for the electrolysis of sodium chloride) comprising of liquid effluents like Polychlorinated biphenyls (PCBs), salts, cyanide, Hydro Choleric Acid, pesticides e.g.; dichlorodiphenyltrichloroethane (DDT), bleachers and dyes, heavy metals, ammonium sulfide and absorbable organic halidies (AOX). The non-point sources of pollution are run off from rural settlements, fertilizers and pesticides from agricultural run-off containing residues of harmful pesticides and fertilizers, dumping of animal carcasses, disposal of dead bodies (cremation on wood pyres leaves partially burnt and unburned bodies, 40,000 cremations are performed annually in Varnasi and the dead bodies are thrown as it is due to un-affordability of cremation), floral offerings, solid wastes, Dhobhi Ghats and cattle wallowing and mass bathing. Further, the open defecation on the banks by the low-income people and mass bathing and ritualistic practices are also polluting the river. In many locations the solid garbage is thrown directly into the river.

In the recent past, due to the rapid progress in communications and commerce, there has been a swift increase in the urban areas along the river Ganges and hence today, one third of the country's urban population lives in the towns of the Ganges River basin. Out of the 2,300 towns in the country, 692 are located in this basin, and of these, 100 are located along the Ganges River bank itself. The industrial pockets in the catchments of Ramganga and Kali Rivers and in Kanpur city are significant sources of industrial pollution. The major contributors are tanneries in Kanpur, distilleries, paper mills and sugar mills in the Kosi, Ramganga and Kali river catchments [7]. Hence, in some stretches of the Ganges, particularly during lean seasons, the polluted water became unfit even for bathing as a result of the discharge of sewage from large number of towns and industries there. In addition to industrial and domestic sewage-the organic wastes, trash, polyethylene cans, cloths and food also deteriorate the water quality of Ganges River and other waterways of this river basin. But, the major sources of pollution in river Ganges are discharge of untreated/partially treated sewage from urban centers and industrial units. Seventy five per cent of the pollution load was from untreated municipal sewage and 88% of the municipal sewage was from the 25 Class I towns on the main Ganges River. Only a few of these cities have sewage treatment facilities and these are very inadequate and often not functional. All the industries accounted for 25% of the total pollution load and in some areas such as Calcutta and Kanpur; the industrial effluents are very toxic and hard to treat.

It has been assessed that more than 80% of the total pollution load [in terms of organic pollution expressed as biochemical oxygen demand (BOD)] arises from domestic sources from the settlements along the river course. The above pollution scenario of Ganges River suggests, that the belief, the Ganges river is 'holy' has not, however, prevented over-use, abuse and pollution of the river. Therefore, the immediate impacts of the polluted surface and groundwater of Ganges River basin are the major sources of deterioration of water quality, non-availability of fresh water for various human uses, foul smell of the waterways and stinking environment, greenhouse gases emission, environmental degradation and waterborne diseases (due to the polluted river and groundwater consumption).

In addition to the above pollution scenarios, the threat of the glacial melt on Ganges flow due to the human induced climate change, and the impacts of some infrastructural projects on the upper reaches of the river to the downstream sides raise issues that need a comprehensive response.

Water Quality Assessment

To know the present pollution status of Ganges River basin, the water quality of both surface and groundwater are discussed below.

Surface water quality study done by the Central Pollution Control Board (CPCB) [8] in four reaches of Ganges River in three States Uttar Pradesh, Bihar and West Bengal shows that in all four reaches the BOD, Faecal Coliform are high; indicating the water is unfit for human use and in some locations it is not suitable even for irrigation also.

A. Water Quality Assessment in Uttar Pradesh State

Water quality assessment has been done at two reaches in the upper stretch from Garhmukteshwar to Kanpur and in the lower stretch from Dalmau to Trighat. The first reach study from Garhmukteshwar to Kanpur shows the Biochemical Oxygen Demand (BOD) ranges from 1.6-9.6 mg/L. The maximum value of BOD measured at all monitoring locations is exceeding the water quality criteria notified for bathing. BOD does not comply with the standards at most of the locations for the period of 2006-2011 and in general an increasing trend of BOD is observed during this period of study. Faecal Coliform value ranges from 70-93000 most probable number (MPN)/100 ml and not meeting the water quality criteria for bathing from downstream of Kannauj. The second reach water quality study from Dalmau to Trighat shows the BOD ranges from 2.3-10.5 mg/L. The maximum value of BOD has been measured at Indhyachal (Mirzapur). All the monitoring locations are exceeding the water quality criteria notified for bathing. BOD does not comply with the standards at most of the locations for the period of 2006-2011, and it is the highest at Varanasi. Faecal Coliform values range from 40-46000 MPN/100ml and not meeting the water quality criteria for bathing at all in the monitoring locations. Similarly, the total coliform is also higher than the criteria at most of the locations, while the highest value is always observed at Varanasi.

B. Water Quality Monitoring in Bihar State

Water quality monitoring from Buxar to Khalgaon in Bihar shows the BOD ranges from 2.6-9.0 mg/L and not meeting the water quality criteria notified for bathing at all monitoring locations in all occasions. Faecal coliform values range from 700-9000 MPN/100ml. Total Coliform values range from 1400-90,000 MPN/100ml not meeting the water use standard almost in all of the water quality monitoring locations.

C. Water Quality Observation in West Bengal State

Water quality observation in West Bengal shows the Dissolved Oxygen varies from 4.3-13.4 mg/L and not meeting the water quality criteria notified for bathing at Tribeni, Howrah-Shivpur, Garden Reach and Uluberia. BOD ranges from 0.3-8.2 mg/L and not meeting the water quality criteria notified for bathing at most of the monitoring locations except Tribeni and Palta. An increasing trend of BOD is observed at Serampore, Dakshineshwar, Howrah-Shivpur, Uluberia and Diamond Harbour. Similarly, the average value of BOD was also observed higher than the normal standard at Dakshineshwar, Howrah-Shivpur, Garden Reach, Uluberia, Palta and Diamond Harbour. Faecal coliform value ranges from 700-11,00,000 MPN/100 ml and it is higher than the criteria at all monitoring locations. Faecal Coliform and total coliform value ranges 900-25,00,000 MPN/100 ml is not meeting the desired criteria at all for water use in the monitoring locations of the Ganges in West Bengal.

From the above water quality study, it can be seen that the BOD is higher than 2 mg/L and the total Coliforms Organism MPN/100 ml is more than 500 MPN/100 ml in all reaches and hence the surface water quality is deteriorating in the Ganges River due to the mixing of sewage. The low value of BOD 1.6 mg/L is due to the mixing of heavy seasonal rain water over and above the sewage in this reach.

In overall analysis, the River Ganges is polluted with respect to organic and coliform pollution in all stretches of study in Uttar Pradesh, Bihar and West Bengal states. In general, once the water is polluted in some reaches of the river it is polluting the water in other reaches also since the polluted reaches are continuously being replenished by the pollution load.

D. Groundwater Quality

In general, due to the sewage load of the industries and domestic sources, the groundwater quality is gradually under deterioration globally. To know the impact of these sources of pollution in the Ganges basin aquifer, Dr.C.K.Jain and M.K.Sarma [9] carried out groundwater quality study in the Yamuna River reach located near Delhi and they found higher concentration of total dissolved solids (TDS), electrical conductivity, nitrate, sulphate and sodium. The presence of total coliforms in this region indicates the bacterial contamination in groundwater. The presence of heavy metals in groundwater is also recorded in many samples. In general, the groundwater quality standards have been violated for TDS, nitrate, sulphate, and sodium in the Yamuna River region aquifers located near Delhi metropolitan city, the capital of India.

The groundwater quality is also being monitored by the Central Ground Water Board once a year (April/May) through a network of observation wells located all over the country including in Ganges River basin. The hot spots for groundwater in districts coming under this basin States are identified on the basis of six main parameters: salinity (EC>3000 µS/cm/micro-Siemens per centimeter), chloride, fluoride (>1.5 mg/L), iron (>1.0 mg/L), arsenic (>0.05 mg/L) and nitrate (>45 mg/L). The States of Bihar, Uttar Pradesh and West Bengal is affected by arsenic (where the concentration is greater than the permissible limit of 0.05 mg/L as per IS: 10500), fluoride, iron & nitrate. Groundwater pollution due to salinity, fluoride and chloride have been identified in Haryana, Delhi, Himachal Pradesh, West Bengal, Uttar Pradesh, Rajasthan and Madhya Pradesh [10].

High bacterial population and BOD values of the river Ganges may be attributed to discharge of untreated effluents in the Varuna at Varanasi. The qualitative analysis of the water of river Varuna, a minor tributary of Ganges shows that its water cannot be used even for irrigation purposes due to the complete deterioration in most of its stretches. The impact of the polluted surface water in the Varanasi city along its stretches can very well be related to increased contamination level in groundwater resources. Increased hardness and presence of even toxic trace metals indicate the degradation of groundwater quality of the region. The carpet cluster of Bhadohi, Varanasi Saree cluster, mushrooming electroplating and other hazardous industries are contributing to this woe.

V. Pollution Load to the Ganges River

It has been estimated that about 1.4×10^6 m^3 of domestic wastewater per day and 0.26×10^6 m^3 of industrial sewage per day are going into the Ganges River. So, by domestic sewage about 18.05 thousand million cubic feet (TMC) and by industrial effluent about 3.35 TMC of water is entering into the Ganges River every year as per the study carried out by [11]. In addition to this, a huge quantity of domestic sewage from villages before entering into the river dries up or stagnating and polluting both the surface and groundwater resources and land including the rural environment of the Ganges basin.

As per Vishal Gandhi et al., (2013)**[12]** the study done by CPCB, 138 drains are discharging 6,087 MLD of wastewater which works out to 78.46T MC/2.17 km^3 per annum and the resultant-BOD load is 999 tonnes/day into the Ganges River. In Uttrakhand, 14 drains are discharging 440 MLD of industrial and domestic wastewater directly/indirectly into river Ganges. In Uttar Pradesh 3,289 MLD of industrial and domestic wastewater discharges through 45 drains into this river. In the State of Bihar, 25 drains are discharging 579 MLD of wastewater into the river Ganges. The 54 drains in West Bengal discharges 1,779 MLD of wastewater into the river Ganges. In the Ganges basin approximately 12,000 MLD sewage (per annum 154.68 TMC/4.38 km^3) is generated, for which presently there is a treatment capacity of only around 4,000 MLD as per official document. Approximately 3000 MLD of sewage is discharged into the main stem of the river Ganges from the Class I & II towns located along the banks, against which treatment capacity of about 1000 MLD has been created till date. The contribution of industrial pollution is 2400 MLD (20 per cent of 12,000 MLD) which works out to 30.94 TMC/876 MCM per annum, but due to its toxic and non-biodegradable nature, this has much greater significance among the other sources of pollution.

There are 764 grossly polluting industries discharging wastewater into the main stem of River Ganges (either directly or through drains) and its two important tributaries Kali-east and Ramganga in Uttarakhand, Uttar Pradesh, Bihar and West Bengal States [13]. Out of 764 industries, 687 are located in Uttar Pradesh. The 764 industrial units (Chemical 27, Distillery 33, Food, Dairy & Beverage 22, Pulp & Paper 67, Sugar 67, Textile, Bleaching & Dyeing 63, Tannery 444 and others 41) in five States of the Ganges basin Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal consumes 1,123MLD (annual consumption 14.48 TMC/410 MCM) of fresh water and generates 501MLD sewage (annual generation 6.44 TMC/182.36 MCM) [14]. This is 45% (approximate) of total water consumed. In terms of number of industrial units, tannery sector is dominating, whereas in terms of wastewater generation Pulp & paper sectors dominate followed by chemical and sugar sectors. It is observed that in Bihar, a minimum wastewater (19%) is generated in terms of water consumed whereas West Bengal generates a maximum wastewater, 75.5% in terms of water consumed. This is followed by Uttarakhand (56.7%) and Uttar Pradesh (39%). In the riverine system, Ramganga carries maximum industrial wastewater followed by main stream of river Ganges and Kali-East respectively. In general, most of the effluents from tanneries are violating the pollution norm [15].

Delhi uses about 45.37 TMC/1.2847 km^3 of domestic water per annum at the per capita per day rate of 160litres (per day water use is 0.124 TMC/3.52 MCM) and generates about 36.31 TMC/1.03 km^3 [16] of domestic sewage per annum. This pollution load of this city enters into the Yamuna River either partially treated or untreated and hence this river, one of the tributary of Ganges has been almost turned into a dead waterway now. Therefore, the pollution load is very grim once the holy Ganges and its tributaries also.

Central Pollution Control Board (CPCB) [12] inspected 51 STPs installed under the catchment area of Ganges River in 2013. Total installed capacity of the STPs is 1,009 MLD and actual utilization is 602 MLD which is 59%. Among the 51 STPs, 9 are violating BOD standard and 1 STP exceeded the chemical oxygen demand (COD) standard and 14 STPs are found non-operational and the remaining plants are also not able to function continuously due to mechanical failures. It was observed from the findings, that the plants need immediate attention to utilize them to the full capacity of the pollution load in West Bengal. All the non-functional STPs need to be made functional in this State. The STPs at Bhatpara, Titagarh, Bandipur need further improvements in the plants. With respect to Uttar Pradesh, Jajmau, Dinapur, Bhagwanpur needs improvement in its water treatment performances. In case of Bihar, treatment plant at Chapara, Patna needs to be made functional. The STP at Lakkarghat in Uttrakhand needs improvement in its water treatment performances. Comparing the sewage generation and treatment capacity, overall there is a gap of 1,515 MLD as per the CPCB study. Therefore, the study carried out by CPCB shows 1. There is a gap between sewage generation and treatment 2. There is no retreatment and 3. Partial treatment of the sewage and is the main reason for the poor water quality of the polluted reaches of the Ganges River basin, even though the sewage treatment commenced about 3 decades ago by two Ganges Action Plans.

VI. Ganges Pollution and Waterborne Diseases

A 2006 measurement of pollution in the Ganges revealed that the river water monitoring over the previous 12 years had demonstrated faecal coliform counts up to 100,000,000 MPN per 100ml and BOD demand levels averaging over 40mg/L in the most polluted part of the river in Varanasi. The overall rate of waterborne/enteric disease (a disease of the intestine caused by any infection) incidence, including acute gastrointestinal disease, etc., and was estimated to be about 66% [17].

A study conducted by the National Cancer Registry Program (NCRP) under the Indian Council of Medical Research in 2012, suggested, "those living along Ganges's banks in Uttar Pradesh, Bihar and Bengal are more prone to cancer than anywhere else in the country" [18] There has been an enormous impact on the wildlife and marine life due to the mixing of the polluted water from the Ganges along the river as well as in sea. The results of mercury analysis in various specimens collected along the basin indicated that some fish muscles tended to accumulate high levels of mercury. Of it, approximately 50–84% was organic mercury which is fatal to any living being. Due to the consumption of the polluted water of both surface and groundwater in Ganges River basin, the water borne diseases like cholera, hepatitis, typhoid, amoebic dysentery, gall bladder disease is leading to 80% of all health problems and one third of deaths in this holy river basin. Due to the heavy pollution, Ganges has been declared as the sixth most polluted river in the world [19].

VII. Status of the Ganges River Reclamation

After seeing the threat of pollution on the water and land resources of Ganges basin, Indian Government thought of rejuvenating this river, before the river is dead, by Ganges Action Plans I and II (GAP). The GAP-I commenced in June 1986 and completed in March 2000 with an outlay of Rs. 462.04 crores ($77.01 million) and GAP-II started in steps between 1993 and 1996, finally implementation commenced in April1, 2001 with an outlay of Rs. 2,285.48 crores ($380.91 million). But, by the time GAP-I was brought to a close, the sewage generation increased substantially, from 1340 MLD (annual generation 25.78 TMC/730 MCM) to more than 2000 MLD (annual generation 17.27 TMC/489 MCM). The programme was delayed considerably due to the problems on the land acquisition front, litigations filed in the courts, but mainly due to poor planning and lack of experience in implementation. The installed infrastructure failed to close the gap on the sewage generated in the basin**.** To make matters worse, operations and maintenance of the commissioned plants was marred by lack of uninterrupted electricity or dedicated power supply, resulting in reduced treatment efficacy. More importantly, erroneous positioning of treatment plants mostly in the peripheries ensured that most STPs operated well below capacity, while some were overwhelmed with sewage flows where majority of sewage received was bypassed untreated.

In this phase, GAP-II, the Yamuna, Gomati and Damodar, tributaries that directly discharge into the Ganges were taken up to reduce incoming pollution load. To deal with the untreated sewage in the main stem of the river, 223 MLD capacity funded by GAP-II has been commissioned, increasing the total installed capacity to 1,092 MLD. The total expenditure incurred so far by GAP I and II, on conservation of river Ganges is Rs. 2,747.52 crores/$457.92 million (The Times of India, May 28, 2014) [20]. The assessment shows that there is also a massive gap between the generation and treatment capacity in the main stretch of the Ganges. The current treatment capacity lags behind at 1208.80 MLD, far less than half of what is required. Operation and maintenance of existing plants and sewage pumping stations is not satisfactory, as nearly 39% plants are not conforming to the general standards prescribed under the Environmental (Protection) Rules for discharge into streams as per the CPCB survey report. Therefore, the net result of GAP I & II is a failure due to the lack of power supply, below capacity of the treatment plants, incomplete treatment and allowing sewage into the river without treatment, fund shortage and lack of attention.

Now in the budget tabled in Parliament on 10 July 2014, the Union Finance Minister Arun Jaitley announced an integrated Ganges development project titled 'Namami Ganges' (obeisance to the Ganges) and allocated Rs. 2,037 crores ($339.50 million) for this purpose [21]. As a part of the programme, Government of India ordered the shutdown of 48 industrial units around Ganges. The Government's efforts to clean and protect the Ganges got a big financial boost of Rs. 20,000crores ($3,333.33million) which the Centre will spend to rejuvenate the national river in the next five years. The Union Cabinet, chaired by Prime Minister Narendra Modi, approved this fund in May 2015 for the government's flagship programme 'Namami Gange' which was launched in 2014 [22]. However, the Challenges ahead are 1. Maintaining the serenity and cleanliness of Ganges without hurting the sentiments of pilgrims 2. Protecting and conserving the marine and wildlife from the pollution load 3. Convincing the people to reduce the pollution along the banks and coordinating with them to clean the river and 4. Controlling the increasing pollution rate besides the cleanup campaigns. History shows the Ganges Action Plans I&II did not help to improve the water quality of this river, which was considered as the big agenda of the previous governments. If the same traditional methodology of treating and recycling the sewage is followed, the new allotment earmarked for this purpose now by the New Indian Government might not improve the water quality of the Ganges River and it could be an infructuous expenditure.

There is no doubt that the earlier approaches have not given any desired result on water quality but the new approach by the new Indian Government should give results to the desired level, only by either arresting all types of sewages and solid wastes falling/dumping into the Ganges River and by tertiary level treatment standard and recycling the entire treated water of the Ganges River basin for appropriate uses. Hence, in this paper the authors are suggesting to the 'New Indian Government' to treat and recycle the entire pollution load of 18.52 km^3 per annum or 50,740 MLD by a tertiary level sewage treatment standard through 'An Action Plan' to get full benefits of reclamation instead of practicing the old conventional treatment methods. They are also suggesting to reuse the treated water to appropriate nondomestic purposes and wishing, let the real treatment and recycling of all sewages of different origins of Ganges River basin begin at least by the New Indian Government after 69 years of independence from 2015. This is the only way to make the Ganges 'permanently holy' by faith and purity.

VIII. Sewage Treatment Plants Needed for Reclamation of Ganges River Basin Waterways

The pollution load which we have explained above is the quantity of sewage entering in different reaches into the Ganges River in different years from the pollution sources of domestic and industrial sources from cities located adjacent to the river. But there is sewage generation in towns and villages also, away from the waterways which are not reaching the rivers. Even the GAP I & II did not have quantified the entire volume of the sewage generation from different sources in the entire river basin of Ganges. This is also the reason for the failure to address the pollution and reclamation of the Ganges River even after 30 years. Hence, all sewage loads of all origins in the entire Ganges basin should be also accounted for and treated at least now. Therefore, the domestic wastewater generation per annum by the preset population of 500 million people in the entire Ganges River basin and the industrial effluents by 764 industries are taken as the total water use and for this quantity the pollution load of the Ganges River basin is calculated now. At the average rate of 135 litre per capita per day (lpcd) norm [23] the domestic water supply per annum to the present population in Ganges basin is 24,637.5 MCM/870.06 TMC/24.64 km^3. But this much quantity of per capita water supply is not provided even today to every citizen in this basin. Therefore, on the safer side 100 lpcd is taken as the domestic water supply and this quantity work out to 50,000 MLD, (18,250 MCM/644.49 TMC/18.25 km^3 per annum) and for this quantity the domestic sewage load is calculated. In 2015, the Ministry of Water Resources [24] estimated that roughly 501 MLD/0.5 MCM (annual discharge 6.45 TMC) of industrial discharge flows into the river from 764 industries. The bulk of these industries, about 90% operate in the stretch of the Ganges River that flows through the State of Uttar Pradesh. Therefore, the total water use per annum for domestic and industrial purposes in the Ganges basin is 650.94 TMC/18.43 km^3, or 50,500 MLD (domestic use 644.49 TMC+industrial use 6.45 TMC). But in the total water use, only 80% turns into sewage, and hence the pollution load from these two sources is 40,400 MLD/40.40 MCM. Hence, the total sewage generation per annum is 520.75 TMC/14.75 km^3. At 20 MLD capacity of a STP we need 2,020 tertiary level standard treatment plants to treat the present pollution load in the Ganges basin.

For the successful reclamation of the Ganges basin waterways, the sewage from each village and town has to be brought to the nearby plants and treated and in this way all sources of sewage of different origins should be treated and recycled. In case of more sewage generation than the above estimate, additional STPs are also to be installed along with the above 2020 plants with the same capacity or higher depending upon the quantity of sewage generation after through field investigation. However, special type of treatment is necessary for the effluents of chemical industries and hospital sewage before they are let into the common domestic sewage treatment plants.

IX. Fund Needed for Sewage Treatments Plants

At Rs. 170 million per STP ($2.81 million), total cost of the 2020 plants is Rs. 3,43,400 million ($5,723.33 million), for infrastructure, machinery etc. At Rs. 7.6 million ($1,26,666.67), per STP, the annual maintenance cost of the 2020 STPs is Rs. 15,352 million ($255.87 million). The cost of the plant is likely to increase depending up on the year of commissioning and transporting cost of the sewage load from villages and towns to the STP (In this estimate the recycling cost of the treated water for nondomestic uses is not included).

X. Benefits of the Ganges River Basin Waterways Reclamation

Now, numerous technologies are used to recycle wastewater, depending on the purity we need and the purposes. The sewage is now brought to the standard of drinking by preliminary, primary, secondary, tertiary and advanced stages of treatment through microfiltration, reverse osmosis and Ultra Violet (UV) light. By the time it leaves the plant, it is distilled water. Now Singapore (NEWATER), Australia, Namibia and few States California, Virginia and New Mexico in USA are already drinking recycled water, demonstrating that purified wastewater by a STP can be safe and clean, and help to ease shortages [25]. California's Orange County Water District (OCWD) has a plant that recycles the used water and returns it to the drinking water supply. It is expanding production to 100 million gallons per day, enough for 8,50,000 people [26]. The World Water Council projects [27] that recycled sewage will be a normalized source of drinking water in cities around the world within 30 years, and much of the infrastructure and technology is already in place.

Though the water treated by advance methods can be consumed, the authors are not suggesting using the treated

Ganges River basin water for domestic use. However, consuming the treated water by an advanced standard of treatment is going to be a reality in future, in the present context of spreading of freshwater scarcity. By the present study, the authors have identified the following benefits to the Ganges River basin due to treating and recycling the entire sewage load 1. Foul smell of air will be arrested 2. Freshwater, land and the environment of the entire river basin will be protected 3. Generations of about 3% greenhouse gases emission being generated from the stinking environment will be arrested 4. We can produce a volume of about 48,48,000 m^3 of biogas (methane) per day and the annual production from the 2,020 plants would be 1,769.52 million m^3 at the rate of 2,400 m^3/day per STP. It can be directly used for cooking through pipes 5. We can generate about 17, 52,000 kWh of electricity per annum per plant and from all plants about 3,539.04 million kWh electricity (at the rate of about 4,800 khw/day per plant at 2 kwh electrify per m^3 of biogas) [28] and [29]. The income generation from electricity (at Rs. 3 per kwh, Tamil Nadu State, India power tariff rate) works out to Rs 10,617.12 million ($176.95 million) per annum, Table I. This power can be used to bridge the supply and demand gap in the power hungry villages where 300 million people are without electricity in India even today (Aniruddha Sharma, 2015) [30], and to run the STPs 6. The 664.18million tons of sludge generated in sewage treatment can be used in agriculture as manure with suitable treatment 7. If groundwater is polluted due to the raw sewage, it will affect the present 67% area of irrigation by this source of water in Ganges River basin. By arresting the pollution after treatment, 187.42km^3 groundwater potential [1] of this basin could be protected from deterioration and 8. By recycling the treated sewage for appropriate uses, the basin can conserve about 520.75TMC/14.75 km^3 of fresh water per annum. Total value of the fresh water conservation per annum at Rs. 1,800 ($29.75) per 12,000 litres of a lorry load of water in Tamil Nadu State, India is Rs. 22,11,910million ($36,865.17million) and each citizen of Ganges basin can save Rs.4,423.82/($73.73) per annum.

The purpose of tertiary level sewage treatment in the Ganges River basin is to provide a final treatment stage to raise the effluent quality to the desired level and utilize the treated water for nondomestic urban landscape, agricultural irrigation, industrial cooling, recreational uses, and groundwater recharge and even for indirect augmentation of drinking water supplies. In various combinations, these processes coagulation, sedimentation, filtration, reverse osmosis and extending secondary biological treatment to further stabilize oxygen-demanding substances, or removing nutrients can achieve any degree of pollution control desired. As wastewater is purified to higher and higher degrees by such advanced treatment processes, the treated water can be reused for drinking water supplies also [26].

A treatment scheme for a 20MLD sewage treatment plant is provided, Fig. 3. The different units of the treatment plant would have the following dimensions: Inlet chamber: 3 m x 2 m x 6 m depth; Detritus tank: 10 m x 10 m x 0.92 m; Primary clarifier: 21.4 dia/2.4 m depth; Primary digester: 21.4 mdia/6.1 m height; Secondary digester: 21.4 m dia/6.1 m height; Aeration tank: 40 m x 10 m x 3.8 m depth; Sludge drying bed: 30.5 m x 11.6 m; Secondary clarifier: 24.4 m dia x 2.4 m depth.

TABLE I
BENEFITS OF SEWAGE TREATMENT AND RECYCLING IN GANGES RIVER BASIN

Sewage Treatments plants =2020, Capacity 20 MLD each		
By products from sewage treatment	Volume in million m^3	Cost Rs. in million
Biogas (Methane)	1769.52	-
Converting biogas into electricity, at 2 kwh per m^3	3539.04 million kwh	10,617.12 ($176.95 million)
Sludge	664.18 million tons	Free of cost
Water saving from treating and recycling the sewage (total water saving per annum 520.75TMC/14.75km^3)		
From toilet flushing at 35 lpcd for 500 million people (Using treated sewage for toilet flushing)	225.57 TMC (6.39km^3) per annum	Rs.9,58,125 million ($15,968.75 million) at Rs. 1,800 ($29.75) per 12,000 litres a lorry load of water per annum
Using the treated water for non-domestic urban, landscape, and agricultural irrigation, industrial cooling and processing, recreational and recharge	295.18TMC (8.36km^3) per annum	Rs.12,53,791million ($20,896.52 million) at Rs. 1,800 ($29.75) per 12,000 litres a lorry load of water per annum

After primary and secondary treatment, the wastewater will be subjected to tertiary treatment involving microfiltration (MF) (pore size: 0.2 (micro metre) um) for the removal of fine particles and microbes and then demineralized in 5MLD Reverse Osmosis (RO) plants for 80% recovery. Chlorine may be added before and after MF treatment. The RO permeate is disinfected by ultra violet irradiation using UV units in series equipped with UV lamps, Fig. 3.

For organic pollution, the treatment efficiencies that define a tertiary treatment are the following: organic pollution removal of at least 95% for BOD and 85% for chemical oxygen demand (COD), and at least one of the following: 1. Nitrogen removal of at least 70% 2. Phosphorus removal of at least 80% 3. Microbiological removal achieving a faecal coliform density less than 1000 in 100 mL and 4. Colour removal. Thus the treated sewage characteristics could be brought to: BOD mg/L (5 days at 20ºC) <20, COD mg/L <100, TSS mg/L 30, Oil and grease mg/L 10.

Technology is available now to reclaim the sewage with inorganic and organic pollution load. Hence, the authors would like to request the New Indian Government, to start cleaning the Ganges River basin waterways first, with a strong *'political will'* and take up other river basins one by one on priority basis and clean all the Indian waterways by a time bound action plan with the existing nonconventional sewage treatment technology. Globally, India continues to be the country with the highest number of people (597million people) practicing open defecation. If toilet facility is provided in each house to these people and treat the sewage, more than 50% of water pollution will be arrested. In the entire annul 62.43km^3 domestic water supply as per the WHO norm to the Indian population [31] (1,267 million in July 1, 2014), the domestic sewage generation at 80% of domestic water supply is 49.95km^3. If the domestic sewage and an additional load of industrial effluent which may be 20% of domestic water use are allowed without proper treatment, the entire utilizable surface and groundwater resources of 1,086 km^3 (surface water 690 km^3 and groundwater 396 km^3 per year) [32] in all the 14 major Indian River basins as well as the land and environment are under threat.

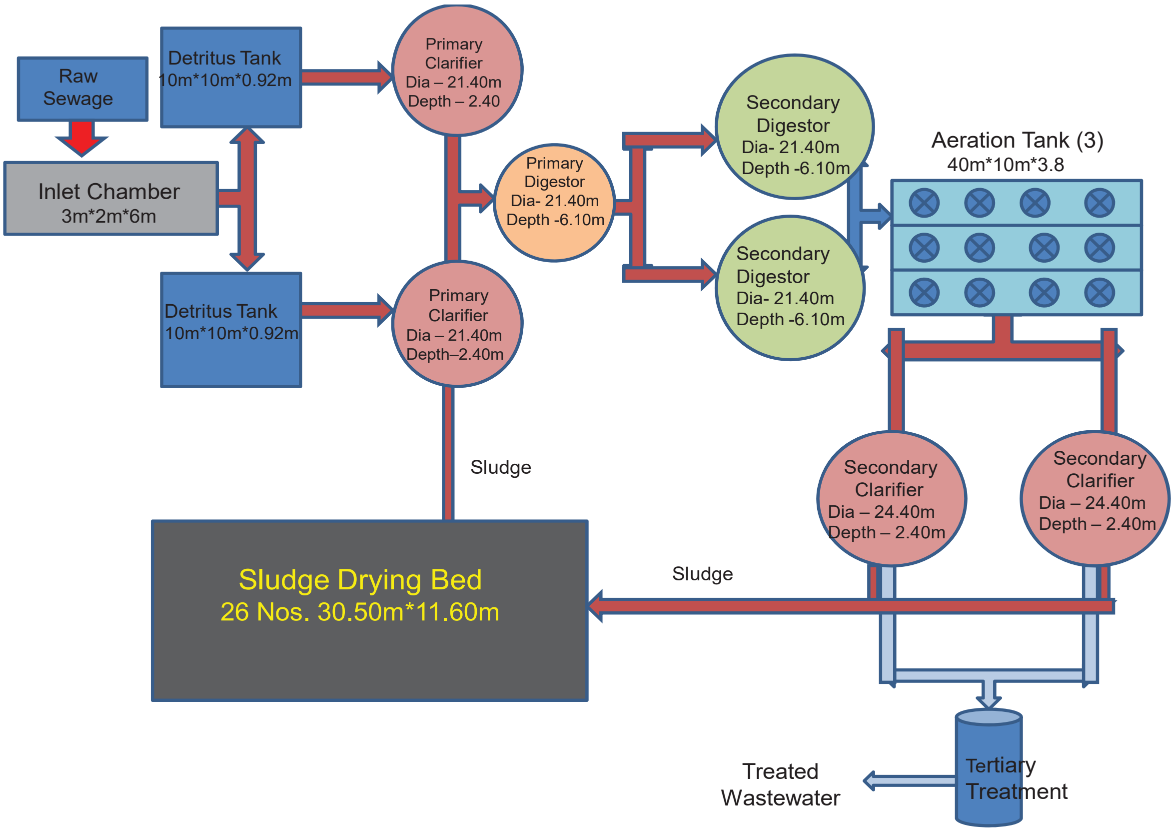

Fig. 3 Flow Chart Showing the Primary, Secondary and Tertiary Treatment of Raw Sewage

XI. Conclusions

Since Ganges is considered as the Holy River, Government of India started GAP I and II to protect the river from pollution. But the results are the BOD, COD and other chemical parameters are not able to be brought to the desired level in many reaches, not only in Gages River but also in other waterways particularly in Yamuna River of this river basin. In the religious bathing areas also the pollution load is dangerously high even after the completion of the two Ganges Action Plans. The BOD is as high as 25 mg/L at the confluence of Ganga and Varuna. The fecal coliform varied from 70,000 MPN/100 ml to 1.5 million/100 ml. Even in the treated sewage coming out from many STPs, the BOD is dangerously high at 50 mg/L against a maximum permissible value of 20 mg/L. Therefore, the water quality is unfit for human uses in many reaches even after treatment. According to environmentalists, about 90% of pollution into the holy river is caused due to the perennial flow of the domestic and industrial sources of sewages, while only about 5% to 6% can be blamed on bathing and other activities. Hence, it is necessary to treat and recycle the entire sewage load of all origins in all waterways in the entire Ganges River basin by tertiary level treatment, since the conventional methods are ineffective.

Since wastewater is being generated everywhere in every second in the world, it is suggested to reclaim it first to a desired standard and then only it should be allowed into the environment. The treated water should be used for appropriate nondomestic purposes within the basin and ease the water stress of the adjacent basins where there is water scarcity by diverting the freshwater from the water rich basins. This is possible in the Ganges River basin, since this basin has appreciable quantity of freshwater. By utilizing the treated water within the Ganges River basin for nondomestic uses, about 14.75 km^3 of freshwater can be saved in this basin and this much quantity of freshwater from this basin can be diverted to any one of the water scarcity States in India including Tamil Nadu where there is huge water scarcity now. But, without proper treatment of the sewage and recycling, it is impossible to bring all the waterways, villages, towns, cities and the entire environment of the Ganges River Basin clean, and get full benefits like arresting the stinking of the waterways and bringing the environment of this basin to a hygienic standard permanently, and above all to arrest the water miseries of this basin totally. Hence, the authors of this paper would like to suggest to the new Indian Government to treat and recycle the wastewater of all origins by the tertiary level sewage treatment standard and recycle it for appropriate nondomestic uses. This is the way to transform the 'Ganges River permanently holy' and disprove "holy Ganges is a utopia'. Further, for the sustainable water and food securities of not only to the people living in the Ganges River basin but also in the entire Indian nation in general, and famers' 'livelihood security' in particular, as well as to lead a healthy life without water borne diseases, treating and recycling the sewage as a model case study first in the Ganges basin and one by one in every Indian river basin by *"An Action Plan"* is need of the hour. The authors are requesting the New Indian Government, to seriously think on the aspect of treating and recycling the sewage in the prevailing context of water scarcity, water miseries, water conflicts, and water wars in India.

The new Indian government is aiming at to provide water, energy and toilet to every home of India before 2022. If the surface and groundwater is polluted by the human generated wastewater of different sources, as it is happening now in the Ganges and in other river basins in India, it may not be possible at all to keep up the above ambitious plans. Further, the Second United Progressive Alliance Indian Government's 'Food Bill' to provide food at a cheaper rate to the economically poor could fail. In the present human induced global warming and climate change context, the perennial Ganges River is likely to become seasonal, because of glacier retreat, perhaps around 2100. If the carbon emission trend continues at the present level, the water resource is likely to vary due to both glacier retreat and change in the normal behaviour of the hydrologic cycle that is also altering the precipitation pattern. To compensate and sustain water supply against these factors, not only in the Ganges River basin but also in all Indian river basins, and globally also, treatment and recycling the sewage are perhaps the main options necessary now and future. Therefore, let every nation commence to treat and recycle the sewage, to successfully bridging the present and future water supply and demand gap to a maximum extent. Without these options, keeping clean environment is a dream.

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