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Assessment of Physicochemical Characteristics of Water Quality along Balua Ghat, Yamuna River in Prayagraj Metropolitan City, India

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ABSTRACT

Water is one of the most precious resources on the earth and with the increasing population and reckless use it's becoming scarce day by day. Most of the populous cities of India are facing this problem with a higher to a lesser degree of its intensity. Allahabad the ancient historical city of India situated on the confluence of the Ganga and its tributary the Yamuna also facing the problem of clean and potable water. To examine the water quality and its various features analysed the physicochemical characteristics of the Yamuna river at Balua Ghat, Allahabad. For this purpose Landsat satellite images of the year, 2009 and 2019 were used and analysed through Arc GIS. Parameters like BOD, COD, pH and temperature were analysed to understand the plight of water quality, which is also substantiated with the inputs of the local people of the study area. The study shows that along the course of the river Yamuna built-up area is increasing at an unprecedented rate and open space is shrinking very rapidly. Various parameters of water show that the water quality is under great stress. Dumping of drainage waste in the river and unplanned slum settlements along the river are basically responsible for deteriorating water quality.

Introduction:

The whole world is facing the challenge of Covid-19, which has drastically impacted the world on the economic, socio-cultural and psychological accounts. But there is another side of this crisis in a positive way that is environment and its components are healing itself. Rivers have become clean and healthy as well as air. There is low emission of greenhouse gasses. The water quality of various rivers in India has become better including Yamuna river. As we know water is the prime substance of life. In the present time, the waterbody is distorted by human as well as natural activities. The anthropogenic activities deteriorate the water quality by disposal of organic and inorganic waste such as industrial, agricultural and domestic (Sharma et al. 2020).On the other hand, the natural source of water pollution is climatic change and lithological influence on topology as well as hydrological hazards. (Uddin et al. 2021). The world's urbanization prospects (Guohua et al. 2019) suggested that 70,000 lakh people will be living in the citiesby2050. This population requires a huge amount of water. The great amount of pollutant discharge into the rivers, reduce the water quality and threat to the ecosystem (Wulong et al. 2020). The study of the relationship of landscape, population, and water parameters for sustainable water resource development is very essential. Land-use change is one of the main driving forces of global environmental change (Jingan et al. 2005), and agriculture activities also put pressure on water resources by high demand and using hazardous chemicals to increase crop yield (Sharma et al. 2004). Yamuna river banks have witnessed haphazard urban development that makes

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this river one of the most polluted rivers in the world. Also, due to heavily populated and expeditious industrial growth (Sharma et al. 2020). The total length of the Yamuna river is 1,376 km long and it's the largest tributary of Ganga.

Over the last few years, the water quality of Yamuna has deteriorated despite huge expenditures and efforts put by the government of India and other authorities (Sharma et al. 2021). One of the potent effects of polluted water is the occurrence of heavy metals, which are harmful and high concentration of toxic affecting aquatic animals and the human population. The river has suffered severe degradation of its water quality and the primary cause is rapidly changing of land use pattern and over-exploitation of water resources in irrigation or domestic use, approximately 90 per cent of water resources are utilized for this sector, nearly all the water received at Hathnikund barrage. Domestic and industrial water utilization is leading to low-flow conditions in the Yamuna River. Discharge of untreated wastewater from growing urban centers, discharge of organic wastes from agriculture-based industries and other factors are tourist activity, poor sewage, and wastewater management system along the Yamuna river (Sharma and Kansal 2011).

2. Study Area :

Prayagraj(Allahabad) is an administrative and educational city and now emerging as one of the urbanized cities of Uttar Pradesh. The total geographic area of Allahabad city is 70.05 kilometres and there are 97 administrative wards. According to the census of India, 2011, The entire district is divided into three parts (a) Trans-Ganga (b) The Doab and (c) Trans Yamuna. The total population of the city is 1,168385 and population density is 1,086 persons per sq kilometre. The geographical location of this area is at 25°28'N latitude and 81°54'E longitude and the mean elevation at sea level is 98 meters. The Allahabad town is located in the Doab region and it is well known for the confluence of three rivers Ganga, Yamuna and hidden Sarasvati is famously called Sangam. The city is well known for its rich cultural and religious profile around the world. The average annual rainfall is 934 mm. Climate is subhumid and is characterized by hot summer and pleasant monsoon and cold seasons. About 90 per cent of rainfall takes place from June to September. During the monsoon surplus water is available for deep percolation to groundwater. The district is mainly characterized by Ganga, Yamuna alluvial plain and Vindhyan Plateau. In Allahabad mainly four types of soils are found: 1) Black and coarse grey soil, which is clay loam to sandy loam in 48% area of the District in Manda, Meja blocks. 2) khaddar and alluvial is rich in Loam and sandy Loom and cover 10 % area of the district especially Jasra, Karchhana, Chaka. 3) Ganga low land and sodic (Gangapar Soil is rich in sandy loam to sodic soil and covered 15 % of the area namely the block Pratappur, Handia, Phulpur. 4) In the Ganga plain area Sandy loam & clay are dominant and cover 27% of the district namely the blockPhulpur, Saidabad and Soraon (Census of India2011).

3. Database and Methodology:

In this research paper both primary and secondary data are used. The Primary data is acquired through the questionnaire and interviewing the local people and government stakeholders to get in-depth knowledge about the study area. A total of 60 samples were collected though random sampling method from the Balua Ghat. The collected primary data was tabulated, cross-checked, and represented with the help of Ms Excel. Secondary data is collected from numerous government departments like Allahabad Municipal Corporation, Allahabad Development Authority, Central Pollution Control Board and scientific reports, Census of India 2011 and Slum free city plan of Action for Allahabad city. Data on water pollution was acquired for different years from the Central Pollution Control Board portal. Change detection analysis along the Yamuna river was performed through unsupervised classification in ERDAS imagine software with the help of Satellite images of Landsat 5 &8 of the years 2009 and 2019. For the mapping and representation of data as well as land use and land cover maps, Arc GIS software is used. For creating a multi year longitudinal profile of the water quality at Balua ghat, different water quality parameters such as Bicomical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, Conductivity were used.

4. Result and Discussion :

The result is dived into three parts(a) Demographic change and land use change detection (b) Longitudinal profile of BOD, COD, pH and temperature and (c) Ground truth.

4.1 Demographic Change and Landuse Change Detection:

Allahabad tahsil is one of the most populated areas and the total population for the year 2001 is 1,198,150

and is 1,395,816 people in 2011. The percentage decadal variation from 2001 to 2011 of Allahabad tahsil is 16.49760. The urban population in 2001 is 1,042,229 which change into 1,214,420 in the year 2011 and the percentage decadal variation is 16.52 (Table:1).

Table, No 2 shows that Allahabad (M.Corp) and Allahabad (CB) have a total population of the slum is 27044 and 265 that is 2.31 and 0.98 Percentage of the slum population to total population respectively, mostly situated along the river Yamuna.

agriculture area is also reduced by 17.12 to 11.67 sq. km. due to urbanization.

The land use and land cover of the 4 km. buffer zone of the Yamuna river near Allahabad city has been highlighted (Figure 1), where the main land use is built-up area. It is one of the holiest places in India and have several ghats on the river bank of Yamuna. Here Yamuna river is also connected with the Ganga river on the northeast side. It is visible that there a huge outburst in the built-up area of Allahabad city.

Table 1: Decadal Change in the population of Tahsil by residence,2001-2011

Population of Allahabad Tahsil						Percentage Decadal variation 2001-2011		
2001			2011					
Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban
1198150	155921	1042229	1395816	181396	1214420	16.50	16.34	16.52

Source: Census of India, 2011

Table 2: Proportion of slum population,2011

S. No	Towns	Total population	Slum population	Slum population %
1	Allahabad (M corp. +OG)	1168385	27044	2.31
2	Allahabad (CB)	26944	265	0.98

Source: Census of India, 2011

Changing land use and land cover over the year 2009 to 2019:

Table 3 shows the statistical calculation of land use and land cover data of the 4 km. buffer zone of Allahabad beside Yamuna River and the unsupervised classification of landuse and landcover change is demonstrated in Fig.1 by using the Landsat satellite images of 2009 and 2019. With the help of image classification it's very clear the builtup area is dramatically enhanced by 25.9047 to 41.1354 sq. km. from 2009 and 2019 which shows the human domination along the river (Richaet al.2021).Open space is reduced by 13.92 to 3.47 sq. km. from 2009 to 2019 due to the high demand of land for anthropogenic activities such as urbanization. The

4.2 Longitudinal profile of water parameters:

The Multi year's longitudinal profile of physicochemical parameters of water quality of Yamuna river at Allahabad from 2006 to 2019 is shown in (Figure 2) with the help of parameters like Biochemical Oxygen Demand, Dissolved oxygen, pH and Conductivity. These are the major influencers of the river ecosystem (Cude, 2007). The concentration of BOD values from 2006 to 2019, is almost above 2 mg/l annually, except in 2009 and Dissolved oxygen values are more than 7 mg/l. The longitudinal profile of pH values shows 7.75 to 8.05 from 2016 to 2019, associated with the increasing toxic waste in the river through anthropogenic activities along the river. The poor solid waste management practices and discharges

Table 3: Land use and land cover change during 2009 to 2019

S.No	Class (sq. km.)	2009	2019
1	Water body	0.9621	1.0152
2	Built up	25.9047	40.9518
3	Vegetation	7.5861	8.3916
4	Agriculture	17.1279	11.6712
5	Open Space	13.9248	3.4758
	Total	65.5056	65.5056

of domestic wastes on the river are observed during the field survey (Figure 5). There is an open drain which is the key contributor to polluting the Yamuna river. Other activities such as washing clothes and open dumping of waste decreased and degraded the river ecosystem and beautification. Open defecation and drainage systems are the key factor of water pollution in the study area (Figure 3). The conductivity is a measurement of the capability of water to transmit electric current in water bodies and it demarcates the total concentration of different types of salts in the water body and

its concentration plays a key role to make any water drinkable or not (Ruby and Divya, 2014). There is a sharp increase of conductivity from 2006 to 2012 but after 2016 there is a reduction in Conductivity till 2019.

solid waste is very high in the ghat. The dumping of sewerage waste along the river Yamuna and other human activities such as washing of clothes is shown in Figure 3.

The main sewage drain in the city drown very close to the Balua ghat which is well known as Chacha Nala, is the major source of water pollution in the area. There is high density of slum colonies along ghat (Allahabad slum development report) where no proper drainage system is available and people are openly dumping domestic waste into the river. The religious activities and unscientific ways of dumping waste materials also cause water pollution. Along the river open defecation is also noticed and humans and animals both use the river water for bathing. The city is famous for its ghats

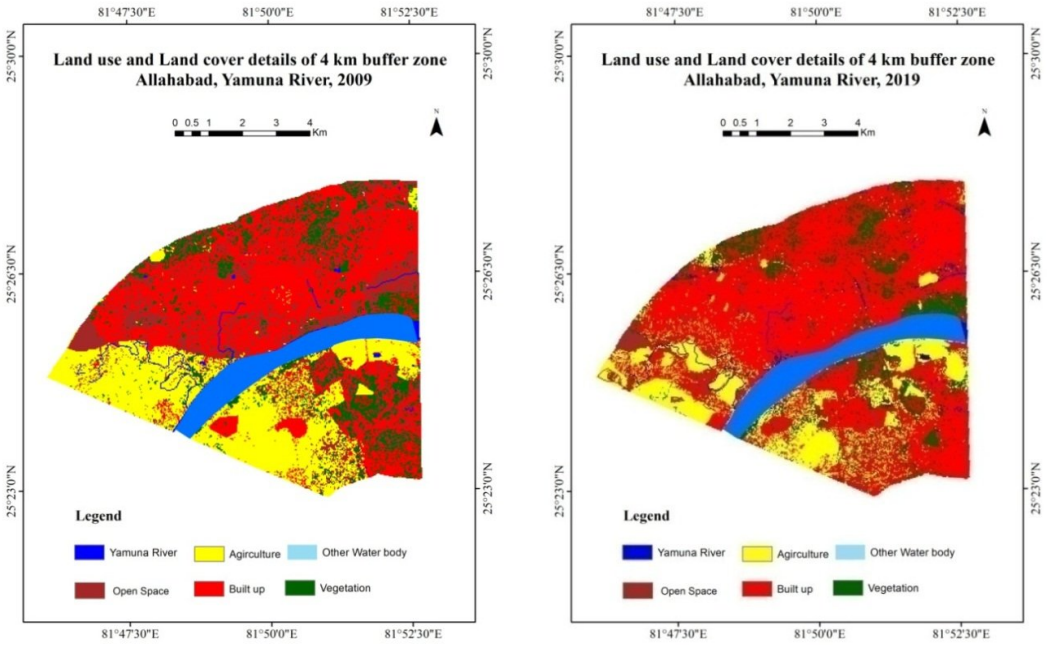

Fig. 1: Landuse and landcover of 4 km buffer of Allahabad
Source: Prepared by the Authors

4.3 Ground Analysis of study area:

During field survey of the city, most important finding is the poor condition of drains and the number of slums nearby Balua Ghat along the river Yamuna that has deteriorated water quality of the river. The area has unconstructed sewage drains, open dumping of solid waste and washing clothes with chemicals by using river water. The contamination of chemical and and Yamuna river banks. Field survey is carried out at the time of Magh Mela. The number of devotees has come every month in this city and city have a high footfall of tourist on different religious occasions. On the other hand, dumping of puja materials such as coconuts, flowers and other material are also noticed. There is less awareness about river health, people left the rest of the materials on ghats of the river and there is no provision to monitor these activities in the ghat(Mehta et al. 2014).

To understand the plight of the Yamuna river along

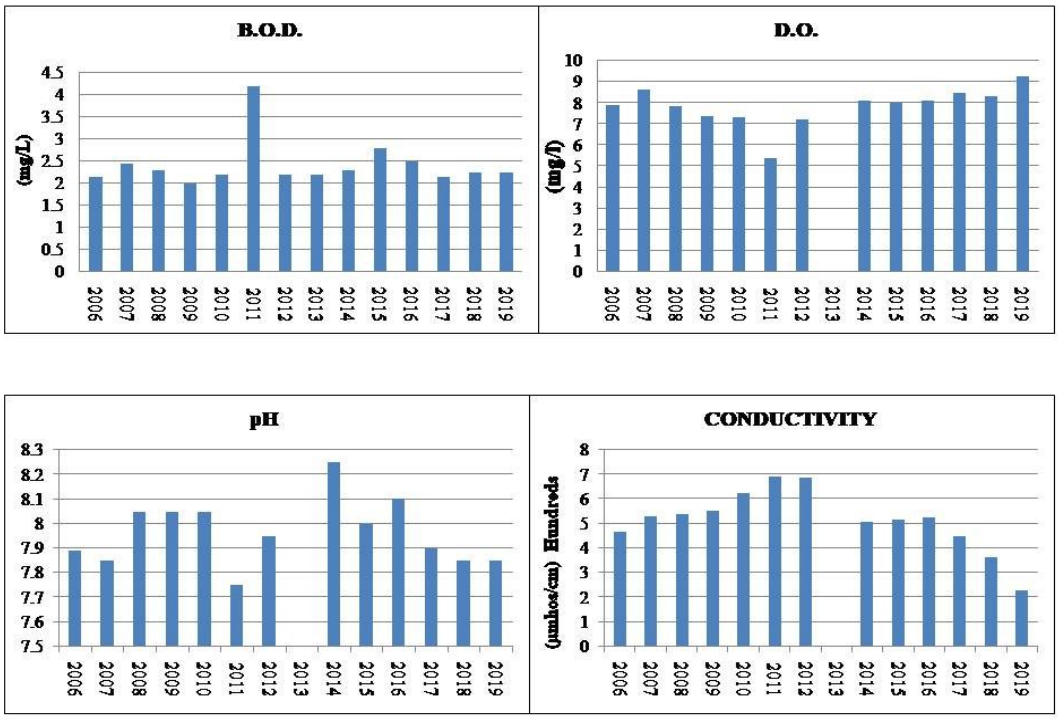

Fig. 2: Distribution of BOD, DO, pH and Conductivity in Yamuna river at Allahabad
Source: CPCB, 2019 (Prepared by the Authors, 2021)

Fig. 3: Dumping of sewerage waste and washing of cloths along River Yamuna
Source: Primary survey, 2021

with Allahabad city, we chose the five core environmental indicators such as Environmental Quality, Water Quality, Solid Waste Management, Green cover, Sewerage and Sanitation.

Table 4 shows the respondent's view about the core environmental indicators. About 65 per cent respondents replied that environmental quality in the study area is low. About 53percent respondents

suggested that situation of solid waste management is poor in the city. The development of dumping sites along the river is mainly due to the settlement of slum population. Green cover is comparatively less along the river due to unplanned and illegal construction of slums. Open sewage is also visible in Fig. 2 which directly join river Yamuna and make it further polluted. Respondents suggested that the state of sewerage and sanitation need to be improved.

with the cleanliness of river Yamuna. Tourists are also conceded in this survey because most of the ghats are well known for tourist attraction sites. Majority of tourists are also not satisfied with the cleanliness in the surrounding of Yamuna river. Water quality is comparatively better at Sangam where River Yamuna, Ganga and Saraswati meet.

Many respondent suggested that the poor

Table 4: Core Environmental Indicators of the River Yamuna

Indicators	Good	Average	Low	Very Low	Can't Say	Total (%)
Environmental Quality	31.7	3.3	65	--	--	100
Water Quality	--	--	96.7	3.3	--	100
Solid waste management	--	46.7	53.3	--	--	100
Green cover	--	--	96.7	3.3	--	100
Sewerage and Sanitation	--	--	100	--	--	100

Source: Primary survey, 2021

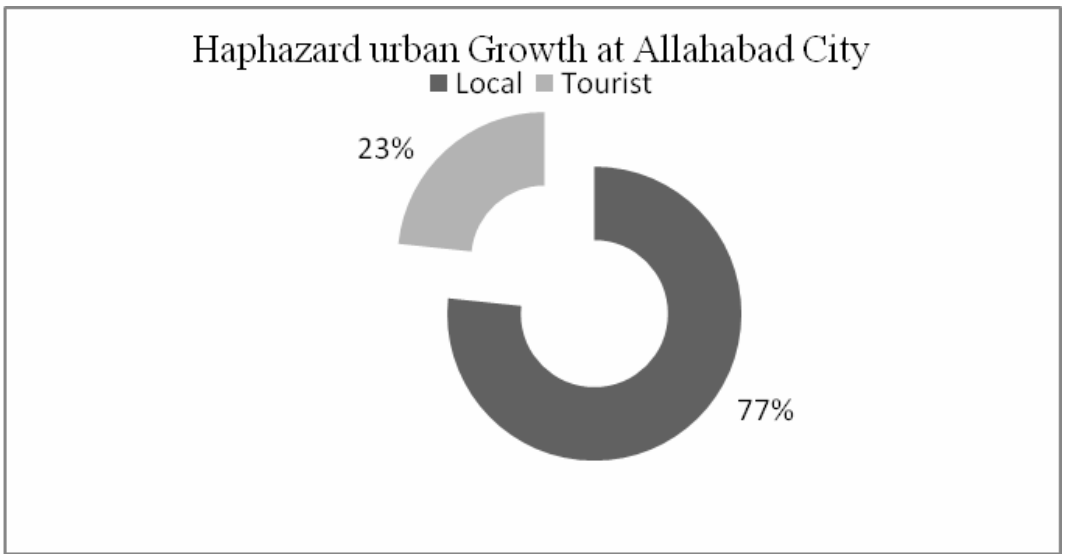

Fig. 4: Status of urban growth at Allahabad city
Source: Primary Survey, 2021

Explaining the haphazard urban growth at Allahabad city (Figure 4), nearly 77 per cent of local respondents suggested that the city has haphazard urban growth and about 23 per cent of tourists have the same concern which is directly related to poor management of waste generation.

To understand the satisfaction level of cleanliness in the Yamuna river (Figure 5) opinions of locals were considered and found that majority are not satisfied

infrastructure is the main issue regarding the cleanliness at Yamuna river, on the other hand most of the tourists suggested the there is a lack of awareness among the people about the cleanliness. Open defecation is the main issue which can be resolvedonly if there is a proper infrastructure such as barriers and toilets at ghat along the river. There is a need for awareness among the locals about cleanliness, hygiene and sanitation.

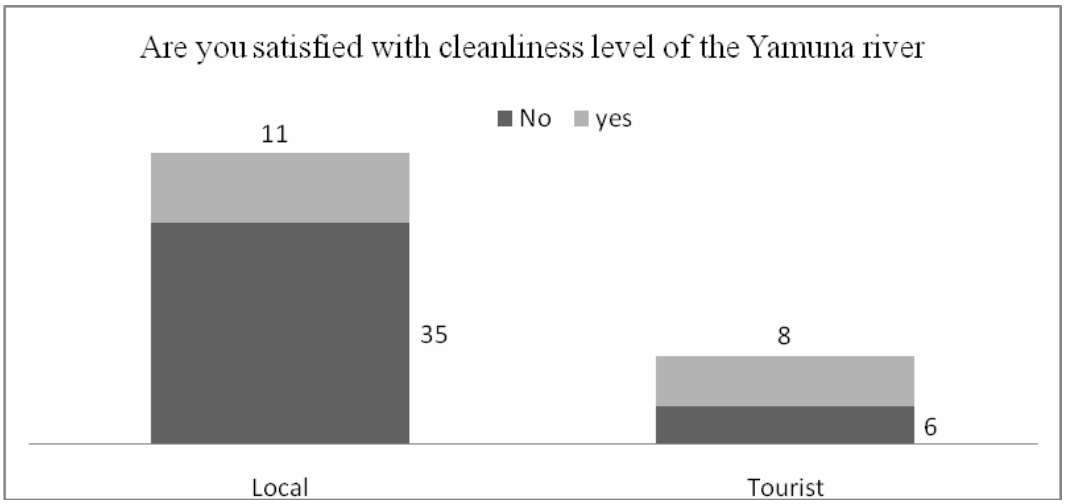

Fig. 5: Perception of local people about the cleanliness of river
Source: Primary Survey, 2021

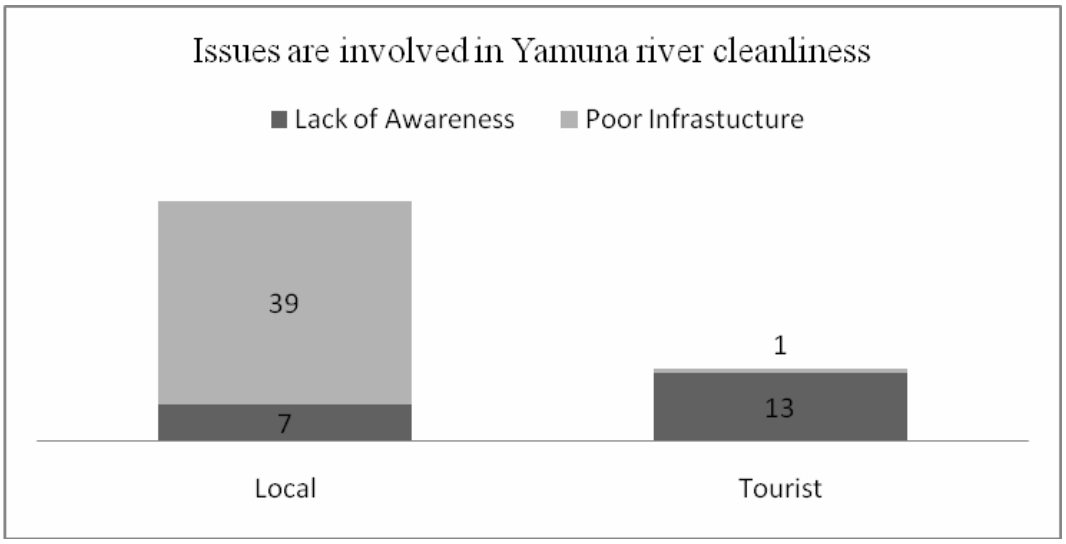

Fig. 6: Issues Associated to Yamuna river Cleanliness
Source: Primary Survey, 2021

5. Mitigation strategies for water pollution, Balua Ghat, Allahabad.:

From the lower segment of Yamuna river, Allahabad city is chosen as focus site. Land use change due to anthropogenic activities also affect Yamuna ecosystem. Slums along the river and open drains are connected with river aremain polluting factors. There is need to control slums along the river and to stop activities such as washing of clothes and open defecation. Open dumping of waste material in the banks of the river need to be restricted. There is need of public participation in creating awareness among the local people. There is a need for the establishment of a special task force or department to continuously monitor the sanitation along the river. There is need to use modern technology in sewarage treatment plants (STP) to treat polluted water and which can be used for other purposes. There is need of an integrated system of solid waste collection, disposal and management in the city. For instance, to clean the river, a Dutch organisation (The Ocean Cleanup) launched a system called Interceptor. It is a

self-directed system to collect floating plastic and pollutants from rivers. This machine consists of floating barriers attached to processing plants, which resemble barges and are anchored to the river bed. There is a conveyor belt that separates the waste from the river and moves it up to the shuttle, which automatically dumps the waste into containers on a separate barge docked. This machine can extract 50,000 kilograms of trash from a river each day and go up to 100,000 kilograms in optimized conditions (The Ocean Cleanup | Dezeen). Such interceptors can also be used for the removal of plastic or floating pollutants from the River Yamuna. There is need to reduce contamination of water and stop throwing solid waste material in the Yamuna river. Figure 7 shows very easy technique to reduce the merging of solid waste in the river from the nearby settlement area. The system consisting of a long plastic floating tube, which is approximately the length of a football pitch suspended at the water's surface. A nylon skirt extending below that guides

Fig. 7: Plastic waste in River Yamuna at Balua Ghat
Source: Primary Survey, 2021

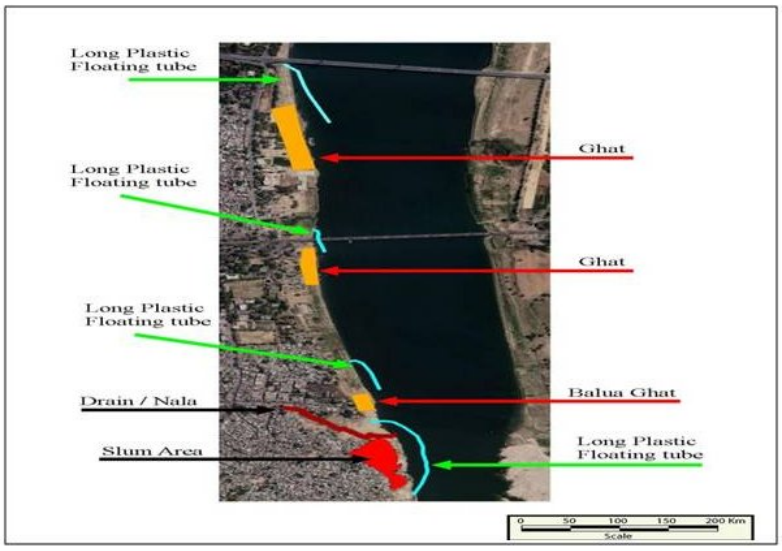

Fig. 8:

debris into a retention system that concentrates the plastic for collection. This technique is useful in the mitigation of water pollution in various segments of the river atBalua Ghatand cost effective too.

In Allahabad, some of the locations are identified to use these techniques to solve the problem of water pollution through contamination of solid waste material. The observation of the field suggested some of the locations or sites are identified for the deployment of this technique. By this technique, we can stop the contamination of solid waste in river water specially in highly polluted stretches. Furthermore, as the river system is facing a serious environmental threat thus solidarity approach is required for its management. Netherlands is such a country that has used a solidarity approach to improve water management (Deltacommissie, 2008) of the Rhine river basin with the help of the Rhine action plan on floods (Bernauer and Moser, 1996). It is important to share information, issues and mitigation plans between different government organizations (Baril et al. 2006). In India solidarity approach still has no real ground. The linkages between practical research and governmental application are still missing. There is a lack of awareness about the utilization and protection of natural resources including river water resources. There is a need for linkage between the top of the vertical point (Government Stakeholders) and the bottom point (local people) for improving the water quality of the river.

6. Conclusion:

Balua Ghat along the river Yamuna is one the famous ghat of Allahabad city, which attracts thousands of tourists and also is a center of attraction for settlement purpose due to availability of water, good sources of income, comparatively better air quality and scenic beauty of the river. Thus this interaction of human beings with their milieu particularly with the water of river Yamuna was a matter of concern and was analyzed on a temporal and spatial scale. The study reveals that the water quality of the river at Balua ghat is under stress, majorly heavy concentration of population and its unsustainable practices make the situation worse. The land use change from 2009 to 2019 shows the rapid urban growth along the river and unprecedented reduction in open space by 13.92 to 3.47 sq. km. within a decade. The population of the city is increasing at the decadal rate of 16.50 per cent. 65 per cent of the local population consider the overall environmental quality of the area is poor and majority of population consider sewage and sanitation in very poor condition and main determinant for the water quality of the area. Locals also consider haphazard population growth as a serious problem. There is a requirement for proper planning of city waste management. To protect and improve the water quality of the River Yamuna, R3 or Trio of R's (Revive, Regeneration and Recalculate) can be an effective way. Revive the river with the help of increasing its depth as well as water harvesting and management, which will help to enhance the water level of the river. For Regeneration of the river required to develop a green belt along the river bank that will help to reduce the dumping of solid waste, proper sustainable utilization of land and development of a healthy lifestyle, especially in the big cities like Allahabad. Recalculate the river strength for the development of a resilient and smart city by creating a new perspective of the river, such as development of environment friendly sustainable economic activities along the river by adding value and developing new opportunities for locals. Overall in the perspective of natives and analysis through the scientific methods, it can be summarized that the water quality of Balua Bhat is not satisfactory. Thus a collective solidarity approach based on individual, community and institution level needs to be formed with a proper plan of implementation. Ultimately locals are the key driver and utilizer of the resources of the Balua ghat so they have to be more cautious about the sustainable utilization of the water resource and its management. This can be done through extensive sensitization of the local population about the sustainable management of water resource and their environment.

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