RESEARCH PAPER

DYNAMICS OF URBAN GROWTH AND ENVIRONMENTAL CHALLENGES: A CASE OF KOLKATA, INDIA

Falguni Dey
Assistant Coordinator, Post Graduation Department of Geography, Women's College Calcutta, Affiliated to University of Calcutta, P-29, Kshirode Vidyavinode Avenue, Baghbazar, Kolkata, West Bengal, India, Pin Code – 700003
***Corresponding author:** falgunigeo@outlook.com
Received: October 30th, 2020 / Accepted: August 2nd, 2021 / Published: October 1st, 2021
https://DOI-10.24057/2071-9388-2020-194

ABSTRACT. The history of development of Kolkata as a megacity in India dates back to 300 years. The scenario changed when the administrative headquarter of the British East India Company was established in erstwhile Calcutta, located at the bank of the River Hugli in the lower Gangetic plain. Since its inception, Kolkata has undergone rapid formal and functional change. Both national and international migration has led to the demographic explosion, urban industrial development and an increase in economic opportunities which caused environmental degradation. Until 1793, the urban dynamics of Kolkata followed a linear pattern along the left bank of the Hugli River. A similar trend continued along the right bank from 1793 to 1947 and extended up to its periphery post-independence. In this paper, an attempt was made to explore the influence of river ghats on the urban environment along the selected stretch of the River Hugli. Human activities like garbage disposal (0.089), sewage disposal (0.088) and idol immersion (0.084) have a negative impact on the river water. Secondly, this paper attempts to study the vertical expansion of Kolkata. It has been observed that the average height of buildings in the CBD area is 84.6 meters while along the peri-urban area it is only 10.61 meters proving the distance decay effect (R^2 = 0.405 and R^2 = 0.314). Besides, the mean values of DO (5.179mg/l), BOD (8.5mg/l) and COD (34.5mg/l) in the river water reflect the degrading water quality for the aquatic environment. Geospatial assessment techniques were used to understand the research problems and combat the environmental challenges. Complex functional development and decaying urban quality of life along the Hugli River has led to critical environmental transformation.

KEYWORDS: Urban Morphology, Distance Decay Effect, Sustainable Development, River Water Pollution, River Ghats

CITATION: Falguni Dey (2021). Dynamics Of Urban Growth And Environmental Challenges: A Case Of Kolkata, India. Geography, Environment, Sustainability, Vol. 14, No 3, p. 24-31 https://DOI-10.24057/2071-9388-2020-194

Conflict of interests: The author reported no potential conflict of interest.

INTRODUCTION

Since its inception Kolkata, or erstwhile Calcutta, has undergone a rapid change in terms of its urban morphology, environmental interaction, ambient air and water quality management (Roy 1982; Kosambi and Brush 1988; Mahadevia 2001; Bardhan et al. 2011; Mukherjee 2012). Due to rapid industrial growth, expansion of trade routes, progress in communication and commerce as well as irrigation in the agricultural sector there has been a swift increase in the urbanization in Kolkata along the river Hugli (Ghosh 1950; Helmer and Hespanhol 1997; Singh et al. 2015). As a result, exodus number of people from the vast hinterland started settling within the urban centres in search of job. The banks of the river Hugli experienced an imbalance in the growth of population because the river acted as a natural barrier that hindered people from settling alongside equally (Dhar 2014). This phenomenon led to the foundation of the crisscross transport network to connect either side of the river by rail and roadways development (Mandal 2000; Chatterjee 2007). Besides, densely settled urban pockets along the river discharge toxic waste which contaminates the water and is then transported further down the stream to reach the Bay of Bengal (Mukherjee 2009; Cengiz 2013). The long stretch of the river Hugli on the western side of Kolkata is characterized by the presence of numerous ghats ('Ghat' means series of broad and flat steps leading down to a river or water body. The term is commonly used in many parts of South Asia), which sprung up during different periods of history. They served for embankment protection apart from the services they rendered for trading, loading of merchandise on barges, boarding passengers on vessels and other religious and household chores (Chakraborty and Nath 1995; Dey 2013). With increasing layers of complex functional attributes, urban centres started flourishing in both vertical and horizontal dimensions at the cost of the environment (Sarkar and Bandyopadhyay 2013; Mitra et al. 2012). Therefore, to answer the research questions raised in this paper, the following objectives are taken into consideration, a) explore the status of the Hugli river based urbanization and adjacent urban environment in terms of land use patterns; b) assess the quality of ferry services that connect Howrah and Kolkata; and c) examine the status of water pollution in the Hugli river and people's perception of the possible causes. The Hugli river as a part of the Ganga action plan (National Mission for Clean Ganga, Ministry of Water Resources, River Development & Ganga Rejuvenation 2018) requires thorough investigation regarding human interference in Kolkata through the assessment of municipal solid and liquid waste management, agricultural effluents, ferry transportation services, idol immersion etc[1].

[1]www.nmcg.nic.in 2018

The nineteenth century ushered in a new era of development in commerce, which made Kolkata a centre of trade and capital. However, it was in 1690 when Job Charnock realised the potential of this region and laid the foundation of British Calcutta[1] on the site of the *Sutanuti, Govindapur and Kalikata* villages on the eastern bank of the Hugli river (Murphey 1964; Mitra 1977). With the growth of trade, attention was given to the improvement of communication systems, and mercantile activities in Calcutta received a tremendous stimulus with the opening of railways and other new lines of communications (Ghosh 1991; Bhattacharyya 2018). Naturally, the port of Calcutta called for further improvements, which led to the construction of docks (Bhatta 2009). It must be noted that up until 1860 the port of Calcutta had a very small hinterland[2] comprising only Howrah, Hugli, 24 Parganas, and a small part of eastern Bengal (Fig. 1). But the establishment of jute and cotton factories in Calcutta and its suburbs and the opening of the new lines of communication expanded this hinterland (Table 1). With the development of heavy machinery and production units, manufactured goods were distributed to various parts of India from Calcutta. The major items of export from this region were indigo, jute, cotton etc. (Bhaskaran 2014; Mitra and Mitra 2015).

STUDY AREA

Kolkata Metropolitan Area (KMA) extends beyond Kolkata Municipal Corporation (KMC) area and stretches over the neighbouring districts like Howrah and Hugli along the right bank of the Hugli river, whereas, Nadia, North 24 Parganas and South 24 Parganas are located along the left bank. Since the Hugli river flows through the middle of the KMA area, it divides the area into western and eastern halves (Majumder 2020). The study area (Fig. 2) for the present paper stretches between Hugli bridge or *Vidyasagar Setu* in the south to Bally bridge or *Nivedita Setu* in the north, with Howrah bridge or *Rabindra Setu* in the centre. The total length of the right bank which is under the Howrah Municipal Corporation is 11.76 km. The left bank stretches about 12.42 km. Regarding the location of the linking bridges, Hugli and Howrah Bridge belong to the KMC area and Bally Bridge is located outside of KMC. The selected stretch of the river within the study area is meandering and concaving towards Kolkata.

MATERIALS AND METHODS

This paper is a blend of both quantitative and qualitative analysis based on both primary and secondary data. While studying the selected stretch, the area was divided into four zones. The criteria of classification of the zones are mainly based on administrative jurisdictions (KMC and KMA), distance from Central Business District (CBD) of Kolkata and orientation of the three main bridges passing through the river Hugli. With the help of GPS, ghats, bridges and riverside buildings were digitally observed to understand their geospatial pattern. A total of 11 ghats on the left bank (4 ghats in Zone I and 7 ghats in Zone II) and 3 ghats on the right bank (1 ghat in Zone III and 2 ghats in Zone IV) are taken into consideration in this study. The criteria of sub-grouping the ghats are mainly based on their accessibility in terms of taking bath, regular immersion of idols, sources of the toxic municipal outfall, religious site, burning ghats and availability of ferry service. Water samples were collected on a stratified random selection basis to measure the water quality and different water properties. The map of Land Use Land Cover (LULC) pattern showing its evolution from erstwhile Calcutta to contemporary Kolkata is referred from the National Atlas and Thematic Mapping Organization (NATMO) map which was prepared by P. Nag (1997)[3].

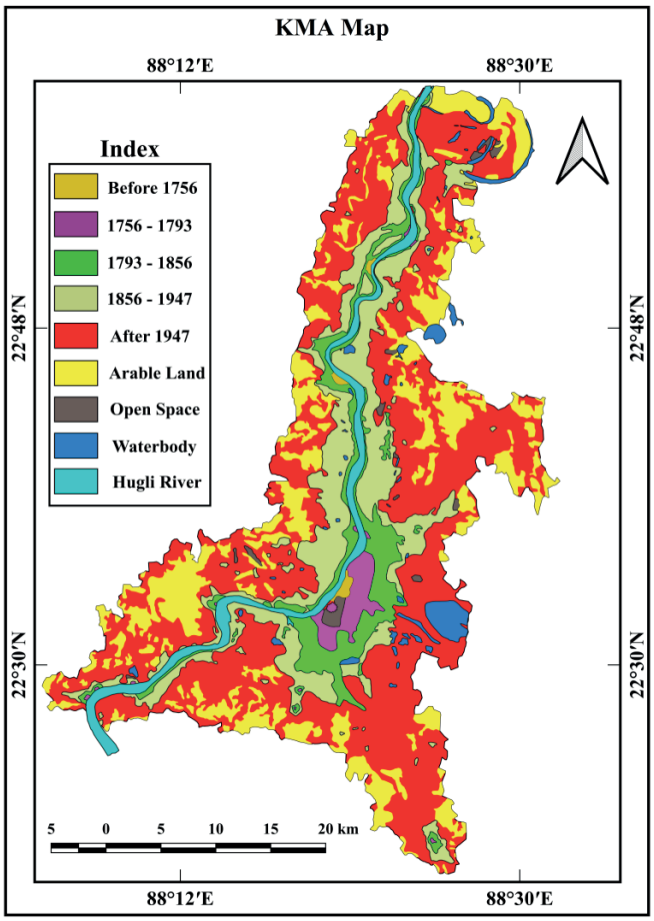


Fig. 1. Growth of Kolkata Metropolitan Area (KMA)

Table 1. Growth and Development of Kolkata Metropolitan Area along the Hugli River

TIMELINE	SPRAWL AND OUTGROWTH
Till 18th century	Mainly colonial Calcutta was developed during this era. Along with it other colonial towns like Sreerampore, Chandannagar and Chunchura also developed in different isolated pockets
Early 19th century	The outgrowth of urban areas in a linear pattern along both east and west bank of the Hugli river from Kalyani in the north to Uluberia in the south
Mid 19th to mid 20th century	Extensive urban development and spreading off to peri-urban areas of the adjacent districts away from the Hugli river
Late 20th century to early 21st century	Calcutta conurbation development because of increased linkage with neighboring towns along the Hugli river.

[1]Mitra 1952
[2]Kundu 2003
[3]NATMO 1997

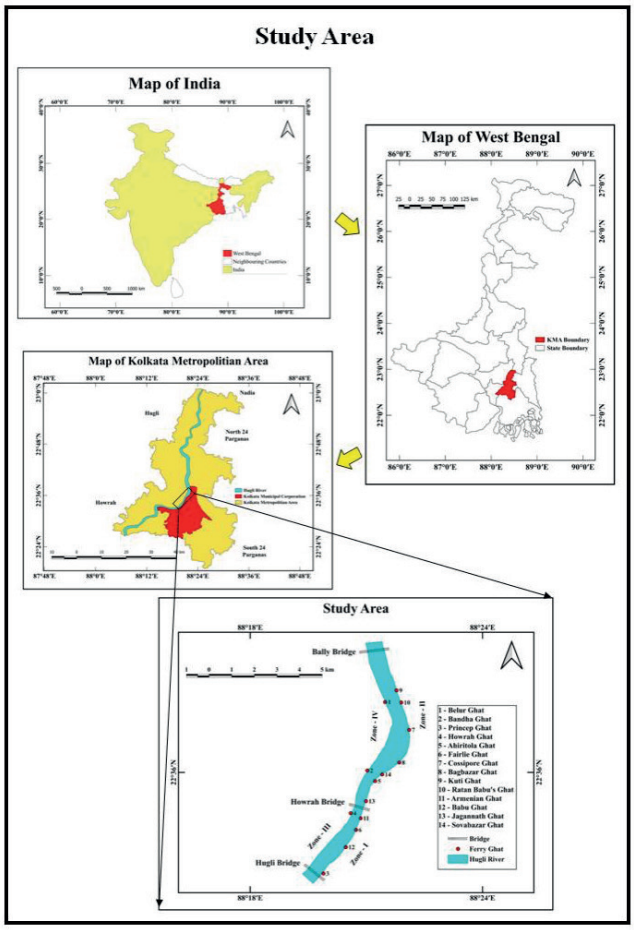


Fig. 2. Location of the Study Area in Kolkata, India

This land use land cover map comprises the historical evolution of Kolkata over the past 300 years. Location map is prepared and analysed using Q-GIS mapping software. Round-the-clock ferry service analysis was prepared based on the data collected from the West Bengal Transport Corporation Department (2016). A perception study on 488 respondents which is about 0.6 percent of the average daily number of passengers through a Ferry ghat was conducted to understand the ferry service quality. Another perception study on 209 respondents which is about 3.12 percent of the daily average number of visitors of a Ghat was conducted to understand water pollution in the Hugli River on a random sampling basis. The Average Weighted Index (AWI) technique was employed to verify the ground truth and correlate the opinions to combat the environmental challenges.

RESULTS AND DISCUSSION

Urban Morphology of Kolkata

Kolkata started developing around the Esplanade and BBD Bag area, which currently functions as the Central Business District (CBD) of the city. The area is occupied with the law and administrative offices, business and commercial centres, sports and entertainment venues, market and transport headquarters, which characterizes its land use pattern as that of a business district area. Over time, the urbanization process has achieved its highest rate and reached distant suburban places (Rajashekariah 2011), although the land value and demand decrease with increasing distance from the CBD area. The city has experienced rapid growth mainly in its south, east, south-east, and south-west direction (Fig. 1). Apart from horizontal expansion, the CBD area has experienced vertical extension with skyscrapers, high-rise administrative and residential buildings. Towards the north along the left bank of the Hugli river, Kolkata experiences a gradual and rapid transformation of land use from administrative to old and native residential type (Table 2). Jute, cotton, chemical industries etc. are found away from the CBD area and mostly along the river bank.

On the other hand, the scenario of urban development along the right bank of Hugli river under the Howrah Municipal Corporation area (HMC) is indeed different. The area is mainly covered by densely populated residential areas like Bally, Belur, Liluah, Salkia, Ghusuri etc. being the headquarter of the southeastern railway, Howrah station is located on the right bank of the Hugli river and extends over a vast area. Other than that, Avani riverside mall has come up as an alternate recreational destination. Peri-

Table 2. Zone-wise Land Use analysis along the Hugli River

ZONES	MAJOR LANDMARKS ALONG THE RIVER	MAJOR LAND USE TYPES
Zone – I (3.88 km)	Lord Princep memorial park, Victoria Memorial, Racecourse, Fort William, Esplanade, New Market, Shahid Minar, Eden Gardens, Netaji Indoor Stadium, Babu Ghat bus terminus, Ordinance factory headquarter, Calcutta high court, Calcutta swimming club, Raj Bhavan, St. Johns Church, New Secretariat building, GPO, Flotel, SBI headquarter, Millennium park, Laldighi, BBD Bag, Writers building, Lalbazar, Fairley place, Kolkata Port Trust headquarter, Bengal chamber of commerce, Armenian church, Barabazar, Mahatma Gandhi road, Mallick ghat flower market etc.	Law, Administrative and Defence, Business and Commercial, Sports and Games, Leisure and Entertainment, Market area and Transport
Zone – II (8.54 km)	Loha patti, Jorasanko, Jorabagan, Nimtala burning Ghat, Rambagan, Garanhatta, Ahiritola, Beniatola, Hatkhola, Rabindra Sarani, Kumartuli, Sovabazar, Hatibagan, Bagbazar, Canal and Lock gate, Circular railway, Chitpur, Ghoshbagan, Chunibabu Bazar, Cossipore, Paikpara, Tala, Swadagar Pally, Goshala Basti, Mitra Bagan, Satchasi Para, Ramlila Bagan, Sinthi, Sajye Bagan, Rabindra Bharati University, Baranagar, Baranagar Jute Mill, Bon-Hugli, Alambazar, Ashokegarh, U B colony, Dakshineswar Temple, etc.	Mainly pockets of old residential areas which are named after the occupation class of the natives. Mixed land use and partly Industrial
Zone – III (3.66 km)	Avani river side mall, Choura basti, Lichu bagan, Railway museum, Railway club, Howrah railway station, Howrah bus depot, Howrah taxi stand etc.	Rail transport and warehouses, partly residential
Zone – IV (8.10 km)	Gulmohar Railway Quarter, Pilkhana, Mali Panch Ghara, Salkia, Ghusuri, Bhotbagan, Vivekananda Pally, Liluah, Belur, Belur Bazaar, Belur Math, Barendra Para, BBD Nagar, Bally etc.	Mostly mixed residential and partly industrial

urban expansion along this bank has no limit as it has already reached the interior of the Howrah and Hugli districts. Apart from horizontal expansion, the vertical urban limit along this bank is inadequate, although newly built residential complexes are increasing the limit of the skyline.

It has been observed that the river Hugli which flows southward is gradually reaching sea level. The extension of the Hugli river towards its downstream between Bally bridge (MSL 14 meters) and Hugli bridge (MSL 05 meters) shows a trend of descending elevation. Contrary to it, from the CBD to the suburban areas, the vertical urban extension of Kolkata is gradually decreasing as we move upstream along the Hugli river. The majority of the high-rise buildings are located within the CBD area[1]. For example, Chatterjee International (91m, 24 floors), Tata Centre (79m, 18 floors), The 42 (245m, 62 floors), Everest House (84m, 21 floors), Birla House (60m, 16 floors), New Secretary Building (38m, 12 floors) etc. Peripheral areas do not only transform to residential land use, but the average height of buildings in areas like Shovabazar, Ahiritola, Cossipore, Baranagar, Bally, Belur etc. have shown gradual decrease (Fig. 3a and 3b).

Ferry Service over the Hugli River

Days before steamers and railways made their appearance in India, the principal means of transport in Bengal and the province of Hindustan was by boats, laboriously towed or sailed over the magnificent waterways of the Ganges and its affluent (Munsi 1980). The present study area is a part of the National Waterway – 1 (NW-1 runs 1620 km from Haldia in West Bengal to Allahabad in Uttar Pradesh) which passes through the Ganges, Bhagirathi and Hugli river systems[2]. A total of 28 ghats that are found within the study area are either used for ferry services and or for public bathing. Ferry service on the Hugli river is a transport breakpoint between Howrah and Kolkata. Compared to other modes of transport available in Kolkata, the ferry service is not the ultimate choice for passengers. Perhaps due to its nominal fare, it was initially used by industrial labourers to reach their workplaces which were situated along the bank of the river Hugli.

Perception study on the quality of the ferry service reveals that passengers are highly satisfied with low transport cost, level of comfort during journey and contribution of ferry service to mass transportation in Kolkata. They are also satisfied with the service frequency and connectivity of the ghats they commute through. On the other hand, the majority of people are partly satisfied with the surrounding environment of the Ghats, travel time and speed of the vessel. And lastly, people are not satisfied with the late-night security for both men and women due to increasing antisocial activities in the city (Table 3). Ferry service as a mode of transport is a dying sector in Kolkata. Since it connects the breakpoint of transport between Howrah and Kolkata, its significance cannot be denied.

Water Pollution in Hugli River

Wastewater discharges did not disturb the balance of the ecosystem since the nature has the capacity to degrade the wastes and restore. With the increasing pressure of

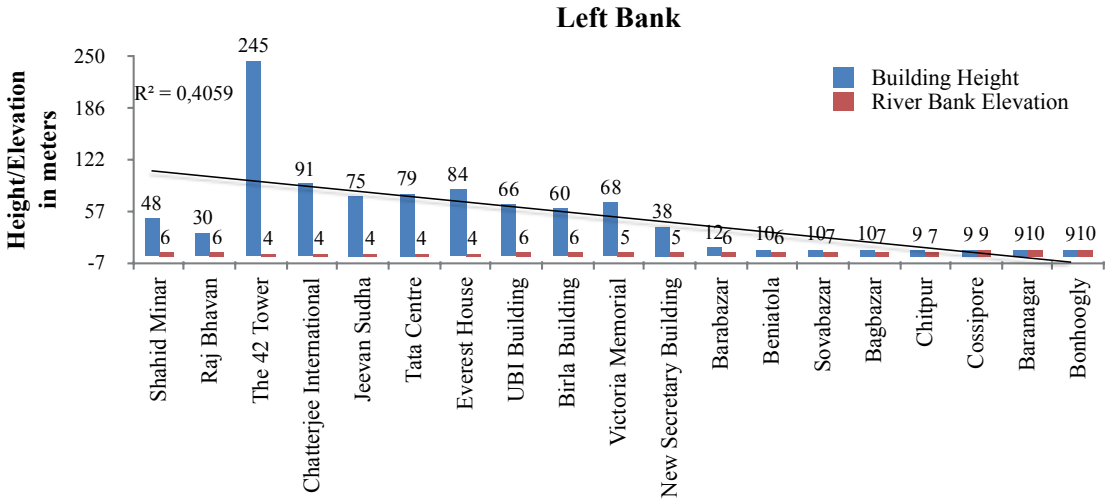


Fig. 3a. Comparing River Bank Elevation and Building Height in Kolkata along the Left Bank of the Hugli River

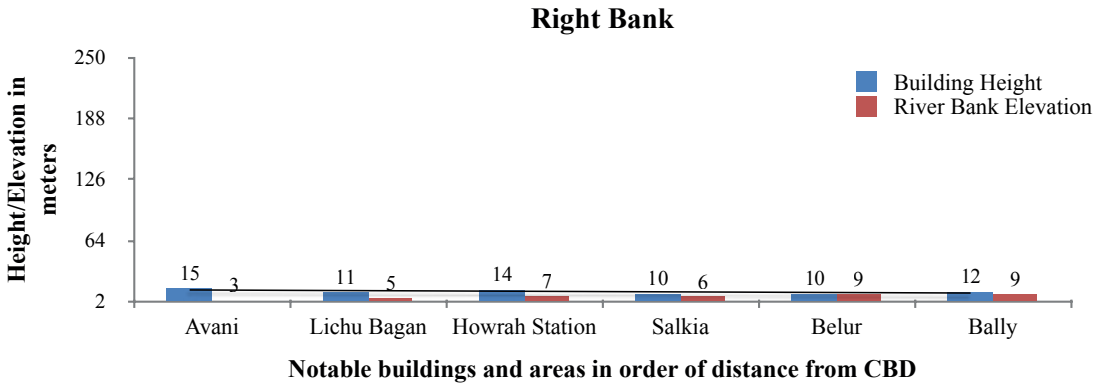


Fig. 3b. Comparing River Bank Elevation and Building Height in Howrah along the Right Bank of the Hugli River

[1]www.skyscrapercenter.com 2015
[2]www.iwai.nic.in 2021

Table 3. Passengers' Perception on the Quality of Ferry Service over the Hugli River

ISSUES	HIGHLY SATISFIED	SATISFIED	PARTLY SATISFIED	NOT SATISFIED	NOT AT ALL SATISFIED	AVERAGE WEIGHTED INDEX (AWI)
Service Frequency	124	182	125	49	8	0.069
Passenger Fare	252	101	75	46	14	0.077
Vessel Quality	127	113	162	80	6	0.064
Crowd and Queue	129	83	160	101	15	0.061
Travel time and Speed	92	110	189	81	16	0.060
Late night Security	53	74	129	162	70	0.044
Ghat Connectivity	141	147	110	90	0	0.067
Ghat Environment	49	109	243	70	17	0.055
Journey Comfortability	323	139	21	5	0	0.090
Contribution to Mass Transport	247	147	52	42	0	0.081
					Total Number of Respondents	N = 488

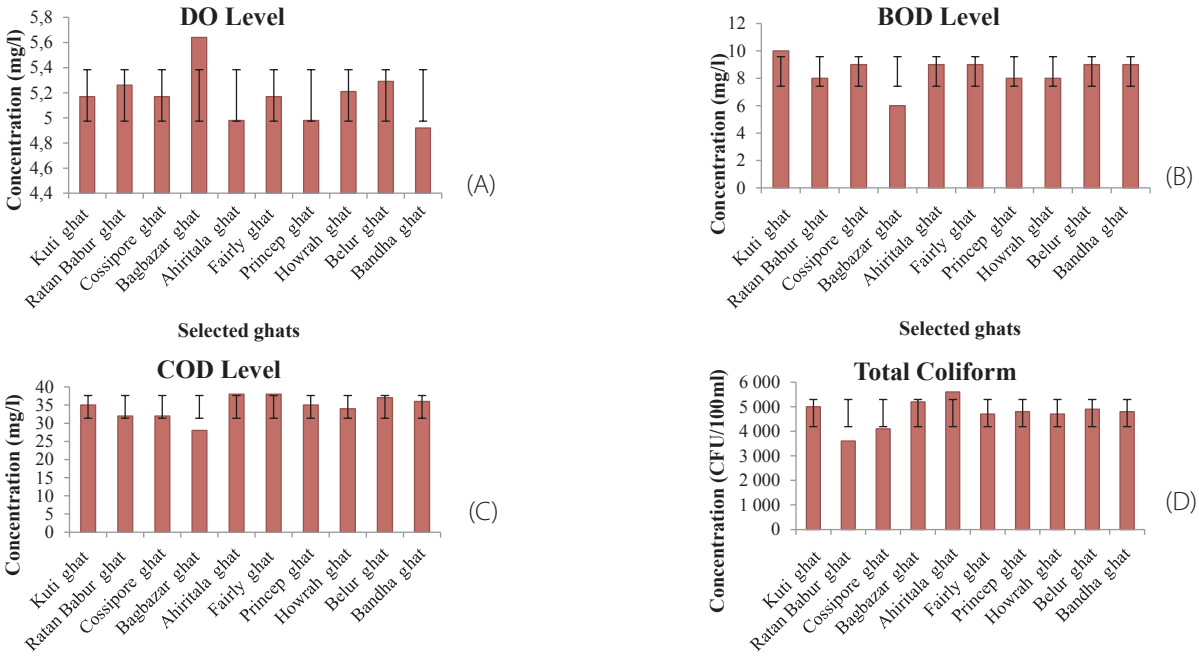
population and the shooting up level of pollution, the replenishing capacity of nature had gradually slowed down (Mohanta and Goel 2014). Municipal and industrial wastewaters are directly released into water bodies with or without treatment (Rudra 2015). In addition, other anthropogenic activities such as agriculture result in a non-point discharge of pollutants into rivers causing serious environmental problems and therefore posing a threat to human health (Table 4). This has led to deterioration in water quality rendering it unsuitable for human consumption and sustenance of aquatic life (Shaw 2005). Taking the selective parameters into consideration and their threshold limit, the Hugli river ghats exhibit an escalating pollution profile (Basu and Main 2001; Biswas 2003). Maximum and minimum values were recorded and the permissible limit was also noted to measure the vulnerability of ghats. These ghats are used by the local people for bathing, washing clothes and performing other daily rituals. Unlike Banaras ghats where people visit for religious ceremonies as well as for recreation, Kolkata ghats are not only devoid of such provision but are struggling for existence. (Bhaduri 2012). However, to commemorate the hundred years of Kolkata Port Trust (KPT), entire ghats, bridges and amusement parks were lit up for urban renewal and aesthetic beauty.

The Hugli river ghats are used for multiple purposes which has influenced the degree of association of people with it. Be it religious or domestic or transport, river ghats have turned into a dumping point. This has not only resulted in environmental imbalance but also negatively affected the levels of Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Coliform bacteria. Excessive growth of algae and eventually lowering level of dissolved oxygen in water poses a serious threat to aquatic life. This can result in insufficient amounts of dissolved oxygen available for fish and other organisms. At sea level, typical DO concentrations in 100-percent saturated fresh water will range from 7.56 mg/L at 30 degrees Celsius to 14.62 mg/L at zero degrees Celsius[1]. An inter-ghat analysis of DO level shows that the aquatic system of the Hugli river is under serious threat (Fig. 4A). BOD test was also performed to determine the effect of dirty water containing bacteria and organic materials on

Table 4. Details of Selection Criteria of Water Sample Collection from different Ghats

SELECTED GHATS	SOURCE OF OUTFALL	CRITERIA OF SELECTION
Kuti ghat	Outfall from burning ghat	Burning Ghat, idol immersion
Ratan babur ghat	Outfall from burning ghat and local drains	Burning Ghat, idol immersion
Cossipore ghat	Outfall from temples and factory areas	Temples, small factories, ferry service
Bagbazar ghat	Outfall from temples and burning ghat	Temples, ferry service and circular railway
Ahiritola ghat	Outfall from burning ghat and local drains	Nimtala burning ghat, temple and ferry service
Fairly ghat	Outfall from parks and stations	Ferry service, frequent movement of boats, circular railway station and Millennium Park
Princep ghat	Outfall from army campus	Military camp, Hugli Bridge and circular railway station
Howrah ghat	Outfall from Howrah railway station	Ferry service
Belur ghat	Outfall from Belur math and surrounding areas	Ferry service
Bandha ghat	Outfall from Salkia area	Bathing ghat, idol immersion

[1]Minnesota Pollution Control Agency 2009



Source: Envirocheck 2009

Fig. 4A to 4D. Level of different Chemical and Biological Parameters in the Water of the Hugli River

animal and plant life when released into a stream or lake (Fig. 4B). Chemical Oxygen Demand is another important water quality parameter because it provides an index to assess the effect of discharged wastewater on the receiving environment (Fig. 4C). Higher COD levels mean a greater amount of oxidizable organic material in the sample, which will reduce Dissolved Oxygen (DO) levels. Therefore, DO is inversely correlated with COD and BOD. The presence of Coliform bacteria in water on the other hand indicates faecal contamination and can cause diarrhoea and other dysenteric symptoms. A minimum of 3600 to maximum 5600 mg/l threshold of Coliform bacteria presence is safe but the results of ghat-wise analysis shows an alarming state of the Hugli Rriver water for human consumption (Fig. 4D).

Peoples' views and concerns regarding the emerging environmental problems were analysed through a perception study on 209 individual respondents, randomly selected from different ghats. People strongly agree upon the threats arising due to industrial waste, garbage disposal, sewage disposal and idol immersion. People are unsure about their opinion on bathing and washing in the Hugli river but they agree that dead bodies and animal waste play a significant role in the contamination of the river Hugli. Thus, people indirectly blame the municipal discharge of sewage water and industrial waste but are not ready to take any voluntary initiative at a micro level to keep the Hugli clean. Ever-increasing pressure of population on either side of the Hugli river and escalating index of urban growth act as a catalyst towards further environmental decay (Table 5).

CONCLUSION

The discussion in the preceding paragraphs has directed attention to the changing trend and pattern of urbanisation in the Kolkata Metropolitan Area along the river Hugli, which will be insightful in guiding the future planning and policy execution for the city. Fundamentally, it was observed that

Table 5. People's Perception on Causes of Water Pollution in the Hugli river

CAUSES	STRONGLY AGREE	AGREE	PARTLY AGREE	NOT AGREE	NOT AT ALL AGREE	AVERAGE WEIGHTED INDEX (AWI)
Idol Immersion	118	50	37	4	0	0.084
Bathing	19	92	75	14	9	0.062
Washing	31	45	60	55	18	0.052
Animal Waste	45	59	25	65	15	0.056
Agricultural Waste	96	51	38	6	18	0.074
Industrial Waste	138	45	18	8	0	0.087
Garbage Disposal	129	66	14	0	0	0.089
Sewage Disposal	135	51	23	0	0	0.088
Ferry Service	31	43	61	41	33	0.050
Dead Bodies	22	74	81	19	13	0.059
					Total Number of Respondents	N = 209

urban dynamics and river hydrodynamics are negatively correlated. Horizontal urban sprawling along with skyscrapers and high-rise projects in Kolkata have extended the vertical limit of the city challenging the environment and urbanization balance during the last three decades. The urban morphology of Kolkata is therefore changing into a complex functional landscape due to growing interaction and direct dependence of people on the river Hugli. Crisscrossing bridges and river transport connectivity between both banks of the Hugli have influenced the urban economic opportunities for both Howrah and Kolkata. Due to the continental drift of the Indian plate in the northeast direction against the Asian plate, the Meghna basin is getting deeper and the river Hugli is suffering from a lack of water flow. The Ganga action plan is therefore of much significance to increase the navigability of this river, sustain the water flow and reduce bacterial concentration with seasonal variation. Symbiotic consideration of issues like urban development, environmental protection, economic growth, morphometric dynamics of the river, socio-cultural interaction etc. can make the city environmentally sustainable and develop as a complex urban morphology.

REFERENCES

Bardhan R. et al. (2011). Linking Urban Form and Quality of Life in Kolkata, India. 47th ISOCARP Congress. Available at: http://www.isocarp.net/data/case_studies/1923.pdf [Accessed 17 Aug. 2019].

Basu S.R. and Main H.A.C. (2001). Calcutta's Water Supply: Demand, Governance and Environmental Change. Applied Geography, 21(1), 23-44, DOI: 10.1016/S0143-6228(00)00018-7.

Bhaduri S. (2012). Pollution at River Ghats of Kolkata: A Profile. Geographical Review of India, 74(4), 409-424.

Bhaskaran P.K., Mangalagiri S. and Bonthu S. (2014). Dredging Maintenance Plan for the Kolkata Port, India. Current Science, 107(7), 1125-1136. Available at: https://www.jstor.org/stable/24105626 [Accessed 14 Aug. 2018].

Bhatta B. (2009). Analysis of Urban Growth Pattern using Remote Sensing and GIS: A Case Study of Kolkata, India. International Journal of Remote Sensing, 30(18), 4733-4746, DOI: 10.1080/01431160802651967.

Bhattacharyya D. (2018). Empire and Ecology in the Bengal Delta: The making of Calcutta. Cambridge University Press, New Delhi, India, ISBN: 9781108425742.

Biswas S. (2003). Rapid Estimation of Major Wastewater Discharges to River Hooghly between the stretch of Palta to Dhankheti Khal. West Bengal Pollution Control Board, Kolkata, India DOI: 10.13140/RG.2.1.1796.4406.

Cengiz B. (2013). Urban River Landscapes. Advances in Landscape Architecture, 551-586, Available at: https://www.researchgate.net/publication/300453647_Urban_River_Landscapes [Accessed 4 Jan. 2016].

Chakrabarty P. and Nath S. (1995). Analyses of some Physicochemical Parameters of a Tributary of Ganga, West Bengal, India. Global Journal of Bio-science and Biotechnology, 4(1), 185-190.

Chatterjee S.P. (2007). The Partition of Bengal: A Geographical study with Maps and Diagrams. Geographical Society of India, Kolkata, India.

Dey F. and Majumdar K. (2015). Pavement Dwellers in Kolkata: Issues and Challenges. Researchers World, VI (2.2), 1-13. DOI: 10.13140/RG.2.2.11061.91368.

Dey T. (2013). Viability of Passenger Transport System through Hooghly River in Kolkata City. Hill Geographer, XXIX(2), ISSN 0970-5023.

Dhar S.B. (2014). Influence of the River Ganga on the Urban Process in Kolkata Metropolitan Area. IOSR Journal Of Humanities And Social Science (IOSR-JHSS), 19(9), 60-67.

Envirocheck.org, (2009). Envirocheck Official Website. [Online] Available at: www.envirocheck.org [Accessed 6 Aug. 2010].

Ghosh A.K. (1991). Ecology and Environment of Calcutta. In: Dasgupta B. et al. Eds.,Calcutta's Urban Future: Agonies from the Past and Prospects for the Future. Government of West Bengal, Calcutta, India.

Ghosh S. (1950). The Urban Pattern of Calcutta, India. Economic Geography, Clark University, 26(1), 51-58 Available at: http://www.jstor.org/stable/140968 [Accessed 4 Mar. 2018].

Helmer R. and Hespanhol I. (ed.). (1997). Water Pollution Control – A Guide to the Use of Water Quality Management Principles, Case Study I – The Ganga, India. United Nations Environment Programme, the Water Supply & Sanitation Collaborative Council and the World Health Organization by E. and F. Spon. ISBN 0 419229108.

Iwai.nic.in, (2021). National Waterways 1. [Online] Available at: http://iwai.nic.in/waterways/national-waterways/national-waterways-1 [Accessed 10 may 2021]

Kosambi M. and Brush J. E. (1988). Three Colonial Port Cities in India. Geographical Review, American Geographical Society, 78(1), 32-47, Available at: http://www.jstor.org/stable/214304 [Accessed 4. Mar.2018].

Kundu N. (2003). Urban Slums Reports: The case of Kolkata, India. Understanding Slums: Case studies for the Global Report on Human Settlements. Available at: https://www.ucl.ac.uk/dpu-projects/Global_Report/pdfs/Kolkata.pdf [Accessed 12 Jul. 2018].

Mahadevia D. (2001). Sustainable Urban Development in India: An Inclusive Perspective. Dev pract 11, 242-259, DOI: 10.1080/09614520120056388.

Majumder S. (2020). Assessment and Detection of Land cover Changes in the Southern Fringe of Kolkata using the Remotely Sensed Data. Geography Environment and Sustainability, Russian Geographical Society, DOI: 10.24057/2071-9388-2020-65.

Mandal R.B. (2000). Urban Geography: A Text Book, Concept Publishing Company, New Delhi, India.

Mitra A. (1977). Calcutta Diary. Frank Cass and Company Limited, London, ISBN 0714630829.

Mitra C., Shepherd M., and Jordan T. (2012). Assessment and Dynamics of Urban Growth in the City of Kolkata. In: Dutta A. et al. (Eds.). Facets of Social Geography: International and Indian Perspectives, 541–555, Foundation Books, DOI: 10.1017/UPO9788175969360.031.

Mitra R. (1952). Kalikata Darpan, Pratham Parba, Subarnarekha Publication, Kolkata.

Mitra T. and Mitra S. (2015). Region, Periphery and the City Core: Transformations in Morphology and Growth Symbiosis: A Case of Kolkata City and Region. RSA Conference, Kolkata.

Mohanta T. and Goel S. (2014). Assessment of Water Quality of Three Different Aquatic Environments Over Three Seasons. 1st International Congress on Environmental, Biotechnology, and Chemistry Engineering IPCBEE, IACSIT Press, Singapore, 64(10). Available at: https://www.academia.edu/6680146/Assessment_of_water_quality_of_three_different_aquatic_environments_over_three_seasons [Accessed 4 Mar. 2018].

Mukherjee J. (2009). Beyond the Urban: Rethinking Urban Ecology using Kolkata as a Case Study. International Journal of Urban Sustainable Development. February, 2015, DOI: 10.1080/19463138.2015.1011160.

Mukherjee M. (2012). Urban Growth and Spatial Transformation of Kolkata Metropolis: A Continuation of Colonial Legacy. ARPN Journal of Science and Technology, 2, Special Issue, 365-380, ICESR, ISSN 2225-7217.

Munsi S.K. (1980). Geography of Transportation in Eastern India under the British Raj. Calcutta: Published for Centre for studies in Social Sciences, Calcutta.

Murphey R. (1964). The City in the Swamp: Aspects of the Site and Early Growth of Calcutta. The Geographical Journal, 130(2), 241-256. Available at: http://www.jstor.org/stable/1794585 [Accessed 4 Mar. 2018].

National Atlas and Thematic Mapping Organization (1997). Growth of Kolkata Metropolitan Area. Govt. of India.

Nmcg.nic.in, (2018). National Mission for Clean Ganga Ministry of Water Resources. River Development and Ganga Rejuvenation. Govt. of India Official Website [Online] Available at: https://nmcg.nic.in/pdf/13_Guide%20Lines%20IAndD%20and%20STP%20-%20Final.pdf [Accessed 22 Jun. 2020].

Pca.state.mn.us (2009). Low Dissolved Oxygen in Water Causes, Impact on Aquatic Life – An Overview. Minnesota Pollution Control Agency [Online] Available at: https://www.pca.state.mn.us/sites/default/files/wq-iw3-24.pdf [Accessed 14 Jul. 2017].

Rajashekariah K. (2011). Kolkata: Urbanization and Impact on Ecological System. Impact of Urbanisation on Biodiversity Case studies from India, WWF-India, 27-37.

Richmond M. and Antiporda C. (2014). Hugli River Distributaries: A Study of Health, Water and Pollution. Research Project in theories of Landscape Architecture, GSD, fall 2012, Available at: http://www.michelerichmond.com/hugli-river-distributary [Accessed 11 Nov.2017].

Roy B. (1982). Marshes to Metropolis Calcutta (1481-1981). National Council of Education, Calcutta

Rudra K. (2015). Industrial Pollution Management in the River Ganga. State Workshop on Forestry Interventions for Clean Ganga, West Bengal Pollution Control Board Dept. of Environment, Govt. of West Bengal.

Sarkar S. and Bandyopadhyay S. (2013). Dynamics of Peri Urban Interface: Issues and Perspectives of Management. Transactions, 30(1), 49-62.

Shaw A. (2005). Peri-urban interface of Indian Cities: Growth, Governance and Local Initiatives. Economic and Political Weekly, 40, 129-136.

Singh R.B., Haque M.S., and Grover A. (2015). Drinking Water, Sanitation, and Health in Kolkata Metropolitan City: Contribution towards Urban Sustainability. Geography Environment and Sustainability, Russian Geographical Society, 8(4), 64-81, DOI: 10.24057/2071-9388-2015-8-4-64-81.

Skyscrapercenter.com (2012). Global Tall Building database of the CTBUH. [Online] Available at: http://www.skyscrapercenter.com/ [Accessed 19 Oct. 2015].

Wbtc.co.in, (2016). Ferry Service in Kolkata, Govt. of West Bengal. [Online] Available at: https://wbtc.co.in/ [Accessed 11 Mar. 2018].