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# Identification and Classification of Urban Water Bodies in Chittagong Metropolitan City, Bangladesh: A Geographic Inventory

Morshed Hossan Molla[1*], Mohammad Abu Taiyeb Chowdhury[2]

[1]PhD Fellow, Department of Geography and Environmental Studies, Faculty of Biological Sciences, University of Chittagong, Chittagong-4331, Bangladesh.
[2]Professor, Department of Geography and Environmental Studies, Faculty of Biological Sciences, University of Chittagong, Chittagong-4331, Bangladesh.

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**Abstract**
Urban Water Bodies (UWBs)- micro-morphological features in the urban environment- are often used as alternate sources of water for the city dwellers as well as raw materials for industrial and other uses. The major thrust of this research is to identify the location of existing UWBs on Chittagong Metropolitan City (CMC) map. The underlying objective is to classify those on various attributes as an exploratory device. In doing so, this study depicts their spatial distribution patterns on map, using Geographical Information Systems (GIS) as a means to an end. A number of quantitative and qualitative data collection techniques have also been utilized to aid the interpretation. The study reveals that some 1198 lentic and 51 lotic types of water bodies are observed in the city. Besides, lentic or static water bodies are found in different shapes and sizes as per their area or volume while lotic are slight straight channel or meander. Nearly 60 percent of the stagnant water bodies are occupying 10 to 30 hectares of area; almost 40 percent are showing water depth 5 to 10 feet. Moreover, of the total UWBs (1249), around 50 percent water bodies are closely associated with settlement. The water of these water bodies is used for different purposes: drinking, cooking, bathing, washing, fishing, sewerage. They are also used for fire distinguisher of Fire Bridget battalion, holding liquid pollutants and dumping development wastes. Since most urban water bodies (UWBs) are polluted and filled by sediments, hence, their water retention ability and various uses are gradually reduced. Therefore, public awareness for their protection and conservation together with systematic planning is strongly advocated.

**Keywords:** Urban Water Bodies, Wetlands, Ponds, Chittagong Metropolitan City.

## Introduction

Fresh water is the most productive life support systems of immense socioeconomic and ecological importance to mankind (Sugunan, 2007). Albeit, it constitutes only 0.01% of the total hydrosphere and water stored in wetlands including ponds and lakes are a small fraction of it. Historically, urban centers were typically located close to water bodies due to the ecosystem services that they provided to society, including water, food, power and transport (Everard and Moggridge, 2012; Chester and Robson, 2013). They also support vast numbers of fishes and other aquatic wildlife as well as used for alternate water sources for household consumption purposes. As well as, numerous people depend on them for their livelihood (Bashar, 2003). In addition, urban aquatic environments can provide psychological benefits, promoting reflection, relaxation, the feeling of freedom and even

*Corresponding Author (morshedgeo@yahoo.com)

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playing a spiritual role (Karmanov and Hamel, 2008; Voelker and Kistemann, 2013; Molla, 2016b), in a comparable manner to green spaces (White et al., 2010). In contemporary towns and cities, waterfronts remain the focus for many economic and recreational activities and have been the focal points for regeneration and restoration (Francis, 2012). Since the role of urban water bodies is multidimensional and diversified, urban flocks receive various sorts of benefits from this water bodies. Despite the enormous benefits of UWBs, industrialization has had a profound impact on the natural environment (Pickett et al., 2001 and Grimm et al., 2008).

The Chittagong Metropolitan City (CMC) is a commercial and industrial hub in Bangladesh. Nevertheless, the city has undergone radical changes in its physical form, not only in its vast expansion, but also through internal physical transformations over the last decades (Ahmed and Alam, 2008) in relation to the territorial expansion at different phases such as 1948, 1975 and 1992 respectively (Hashemi, 2006). In this respect, multi-sectoral economic activities have been accelerating the port facilities, large-scale industries and entrepreneurs in this area. It may be stressed here that of the total land cove, the UWBs covers only 12.74 percent land in city areas (CCC, 2007). Nowadays, UWBs in CMC are not only disappearing and are under constant threats but also changing in their shape, size, depths etc. mainly due to a number of natural process and manmade factors i.e. pollution of the water bodies (Rahman et al., 2011; Hossain *et al*., 2009; Alamgir, 2010; Rahman et al., 2010; Rashid, 2010; Molla, 2016a and Molla et al., 2020). Besides, rampant urbanization and unplanned infrastructural development, functional activities, economic events and territorial expansion have been accelerated the filled-up of Urban Water Bodies (UWBs) in the CMC (Bashar, 2003; Molla, 2016a; Karim, 2021 and Pathom Alo., 2021). It is striking to note that the total number of UWBs in CMC is declining gradually at a rate of 10 percent per year (Molla et al., 2020). On the other hand, CWASA is the sole organization that supplies water to the city dwellers through its limited distribution networks, but capable of supplying only 30 percent of the total demand (585 million litters, but fulfil 175 million litters waters per day- MLD in 2016) generated by over 4 million city dwellers (CWASA, 2010 and MPWS, 2009), although the capacity of supplying has been increased 40 percent in 2020 (CWASA, 2020). Under these circumstances, citizens have been suffering from irregular, inadequate and an unsafe water supply mainly because of inefficient management practices and this situation is worse in low-income residential areas (Molla et al., 2014). In this situation, these water bodies are considered as an alternative water sources for household uses for the city dwellers (Molla, 2016a).

Literature review suggests that a considerable number of studies/ surveys were conducted in the past that are found relevant to the research topic. To name a few, the Chittagong City Generalised Land use Map, 1989 identified nearly 145 well-recognised ponds, lake and small water bodies and 11 marshy areas. Besides, District Fisheries Department, 1991 noted almost 19,250 water bodies in the city. In an independent study, the Chittagong Development Authority (CDA), 2006-2007, recognized approximately 4,523 water bodies. Furthermore, Hossain et al., 2009 has found about 487 water bodies; Chittagong City Corporation Google Map, 2015 has figured out around 765 water bodies in CMC. However, no consensus exists among the studies concerning the proper theoretical approach to the issue. Therefore, this study addressed two comprehensive objectives (i) to identify the location of existing Urban Water Bodies (UWBs) in CMC and plot those on map and (ii) to characterize the nature of UWBs in the study area (as an exploratory device) and depict their

variable patterns over geographic space in tabular and graphic formats for informed decision making purposes.

## Materials and Methods

### Operational definition of Urban Water Bodies (UWBs)

In order to avoid the conceptual 'Jargon' of Urban Water Bodies (UWBs), it is better to begin with an operational definition for this study. Urban Water Bodies (UWBs) are the collective and operational terms for lotic and lentic water environment in urban area. The lentic or stagnant water bodies which are a body of standing water, ranging from ponds, seasonal pools, doba, dighi, and lakes. Besides, *lotic* or running water bodies which are a body of moving water, such as a tidal creek, river, spring, channel or stream, demarcation less fallow land, swamp and wetland. Nonetheless, literature reviews recommend that these water bodies are called Urban Water Bodies (Huda, 2004; Karabin and Kippen, 2001; Shah, 2005; Bansal and Bharti, 2012; Hughes et al., 2014; Harada et al., 2012) in Bangladesh in a wider research arena.

### *Study Area*

The study area of Chittagong Metropolitan City (CMC) is shown in Figure 1. It is located between $22^0$15 and $22^0$25 North latitudes and between $91^0$45 and $91^0$55 East longitudes along the southeast coast of Bangladesh. Chittagong is known as the premier port-city- one of the leading inland seaports of the South Asia, and widely regarded as the commercial capital of Bangladesh.

### *Analytic Procedures*

This is an empirical study of CMC which began with the Google City map at the initial stage. To achieve the main objective of the study: (i) Identification of existing UWBs in CMC, a time-series of Landsat data (Landsat TM images 30 m spatial resolution) were collected from the Space Research and Remote Sensing Organization (SPARRSO) of Bangladesh. Two types of data sets i.e. raster satellite data and vector data have been used for detecting the UWBs in the study area. As a follow up, the 'Ground Truthing Method'[1] has also been utilized to help detect the distribution of UWBs in CMC. Moreover, to calculate the number of water bodies, a checklist survey technique has been performed as a means to an end. Finally, the collected field data and images have been analyzed in an integrated manner to identify the distribution of UWBs in CMC. Geographic Information Systems (ArcGIS Version 9.3) software has been used to carry out operation in the study area. Besides, IBM SPSS Statistics V-2-64bit software (version: 20) and narrative analysis techniques have also been applied, respectively. Qualitative data have been examined with the help of two theories such as 'Grounded theory' and 'Narrative Analysis'. Quantitative data are interpreted with the help of 'Statistical analytic techniques including tools such as tables, charts, graphs, diagrams, figures and photographs.

In order to achieve the underlying objective: (ii) Exploration of characteristics or existing scenario of UWBs in CMC a combination of quantitative and qualitative social survey techniques have been

1 Ground Truthing is a term used to refer the absolute truth of something. Ground Truth = Estimated Accuracy (Go to 100 sites, right 90 times, 90% accuracy). Ground truth is an integral part of the use of remotely sensed data for land use change prediction.

utilized. Some eighteen (18) Key Informant Interviews (KIIs) were conducted for this purpose including relevant experts, professionals, policymakers and public representatives.

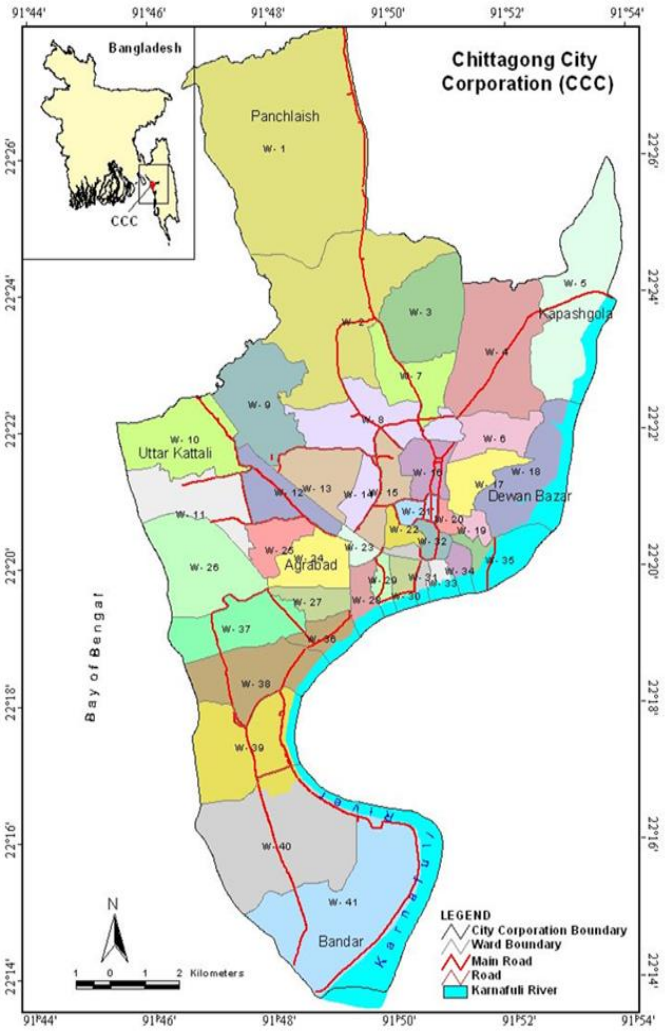



**Figure 1:** Geographical Location of Chittagong Metropolitan City.

Furthermore, transect walk (physical mapping) has been operated through covert observation of entire metropolitan city. In addition, to identify the various features of water bodies, a total 400 questionnaire has been conducted at household level who are regular users of the UWBs. A semi-structured questionnaire has also been employed for quantitative data collection at the household level of water body users. A sampling frame has been developed after estimation of the water body users. The sample size has been chosen in line with a statistical formula presented by Islam, 2014.

*Formula,* $n_0 = (\frac{z^2 pq}{d^2})$

Where, $\mathbf{n_0}$ denoted the desired sample size; **z** = standard normal deviate usually set at 1.96, which

corresponds to the 95% confidence level (1.96); **p =** assumes proportion in the target population estimated to have a particular characteristic (0.50); **q** = proportion of the estimation of population (1-p = 0.50); **d** = allowable maximum error in estimating a population proportion (0.05) respectively. Besides, the simple random sampling technique has been adapted for successfully operating of 410 questionnaires at a household's level. The representative sample size has been distributed on the statistical way with the help of following formula;

$$\text{Random sampling, } \mathrm{Nj} = (\frac{\mathrm{n}}{\mathrm{N}})Ni$$

Where, Nj = represents the sample size; N = total population size, (N = ni + nii + niii +…+ nn); Ni = population size of the study area and n= desired sample size separately.

## Results and Discussion

The characteristics of urban water bodies are considered as descriptive indicators to explore the existing conditions, management, and conservation of water bodies in CMC. Because of rampant urbanization, unplanned infrastructural development and changing land use pattern as well as natural processes, the shape, size, area, depth, seasonal variation of the water bodies are gradually changing. For instance, changes in shape, size, depth and seasonal variation are accelerated to filling procedure of water bodies in CMC. Firstly, the people of the city started the filling activities to be in the irregular places of the water bodies. This process is accelerated depending on the size of the water bodies. If the sizes of water bodies are small then the water bodies filled up rapidly. Besides, the filling activities are faster because of depth and seasonal variation. Owing to natural process and dumping of development and household wastes on water bodies, the depth of water bodies are reduced. These water bodies are quickly filled up and disappearing easily. Besides, year of creation and ownership pattern are essential elements for manage and conserve these water bodies in CMC.

## Detecting existing distribution of Lentic water bodies in CMC

From the collected satellite images, some 1352 water bodies have been detected in CMC (Figure 2). The findings have been confirmed by a Ward to Ward checklist survey as a follow up of the Landsat data Ground Truthing method. The method helped to identify UWBs more preciously; in total, some 1249 UWBs have been identified in 41 Wards of the study area (Table 1). Therefore, we will stick to the results of Ward to Ward checklist survey (1249) for further reference. This figure matches closely with the findings (1352) of satellite images.

As per digitalization of supplied satellite map, it was found that water bodies are concentrated in the western and north-eastern sites although the central area is hilly and western and eastern site have huge humid or fallow lands of Chittagong city. It is evident that although each and every ward is recorded as having water bodies, they mostly concentrated along the coastal belt. After construction of the coastal embankment from north to south alongside the Bay of Bengal's eastern coast, a port connecting road has been installed from outside from Chittagong city gate to Chittagong port (Chittagong, EPZ). In this context, new settlement has been built near the dam and created digging big holes (i.e., soil collection for building road and dam inside of city area) for road purposes. Thus, built a new small pond, especially called Doba in this area. Water bodies' availability has been proved that,

urbanization has been accelerated the disappearing of filled-up water bodies in everywhere in except the western side in the Chittagong Metropolitan City.

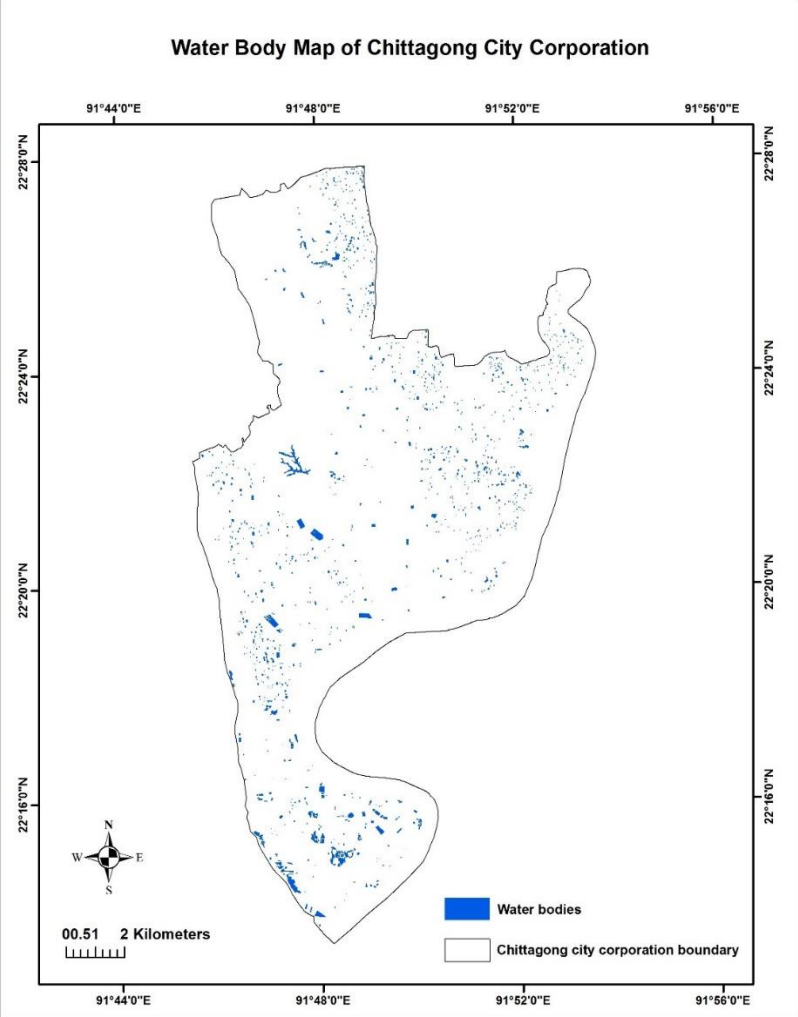



**Figure 2:** Spatial distribution of small water bodies in CMC.

**Table 1:** Urban Water Bodies (UWBs) in CMC: A Comparative List

| W. N | Ward Name | Water Bodies | |
|---|---|---|---|
| | | Google map, 2015* | Ward to Ward Survey |
| 1 | South Pahartali | 113 | 95 |
| 2 | Jalalabad | 45 | 51 |
| 3 | Panchlaish | 5 | 54 |
| 4 | Chandgaon | 45 | 85 |
| 5 | Mohra | 15 | 46 |

| W. N | Ward Name | Water Bodies | |
|---|---|---|---|
| | | Google map, 2015* | Ward to Ward Survey |
| 6 | East Sholashahar | 20 | 17 |
| 7 | West Sholashahar | 11 | 12 |
| 8 | Sulakbahar | 11 | 17 |
| 9 | North Pahartali | 10 | 9 |
| 10 | North Kattali | 71 | 82 |
| 11 | South Kattali | 13 | 40 |
| 12 | Saraipara | 24 | 28 |
| 13 | Pahartali | 10 | 11 |
| 14 | Lal Khan Bazar | 0 | 2 |
| 15 | Bagmoniram | 6 | 17 |
| 16 | Chawk Bazar | 15 | 16 |
| 17 | West Bakalia | 11 | 19 |
| 18 | East Bakalia | 13 | 52 |
| 19 | South Bakalia | 10 | 14 |
| 20 | Dewan Bazar | 2 | 4 |
| 21 | Jamal Khan | 5 | 3 |
| 22 | Enayet Bazar | 1 | 2 |
| 23 | North Pathantooli | 6 | 8 |
| 24 | North Agrabad | 26 | 34 |
| 25 | Rampur | 10 | 9 |
| 26 | North Halishahar | 23 | 141 |
| 27 | South Agrabad | 1 | 15 |
| 28 | Pathantooli | 4 | 5 |
| 29 | West Madarbari | 1 | 2 |
| 30 | East Madarbari | 1 | 4 |
| 31 | Alkaran | 2 | 3 |
| 32 | Anderkilla | 2 | 2 |
| 33 | Firingee Bazar | 4 | 6 |
| 34 | Patharghata | 11 | 6 |
| 35 | Boxir Hat | 10 | 20 |
| 36 | Gosaildanga | 9 | 12 |
| 37 | North Middle Halishahar | 41 | 57 |
| 38 | South Middle Halishahar | 91 | 115 |
| 39 | South Halishahar | 25 | 44 |
| 40 | North Pothenga | 30 | 44 |
| 41 | South Pothenga | 12 | 46 |
| **Total** | | **765** | **1249** |

***** *Counting of Chittagong City Corporation Google Map, 2015 (visited on 9 February, 2015: 8.30 pm to 5.00 am). The Google map has produced by satellite. Therefore, this map has detected the big size of water bodies, like Digi and Pond while small water bodies cannot detected. As, the statement has been verified after applied the Ground Truthing method. Hence, the methods, like counting the water bodies on google map and ward to ward checklist survey findings are dissimilar and detected different numbers of water bodies in Chittagong Metropolitan City.*

**Types of Urban Water Bodies (UWBs) in the CMC**

To classify the UWBs in CMC, Topo sheet maps have been used with supplementary information obtained from Key Informant Interviews checklist and Transect work survey. The summary of the results of classification of UWBs by types is shown in Table 2.

**Table 2:** Types of Urban Water Bodies (UWBs) in the CMC

| | Types of UWBs | Frequency | Percent |
|---|---|---|---|
| **Stagnant Water Bodies** | Pond | 980 | 78.5 |
| | River | 2 | 0.2 |
| | Lake | 1 | 0.1 |
| | Doba | 148 | 11.8 |
| | Dighi | 43 | 3.4 |
| ***Total stagnant (lentic) water bodies*** | | ***1198*** | ***93.9*** |
| **Running Water Bodies** | Khal* | 32* | 2.6 |
| | Tidal Creeks or Chara | 17 | 1.4 |
| | Fallow Land, Swamp and Wetland | 26 | 2.1 |
| ***Total running (lotic) water bodies*** | | ***51*** | ***6.1*** |
| **Total water bodies in CMC** | | **1249** | **100.0** |

* Appendix I.

Approximately eight categories and total one thousand two hundred forty-nine (1249) urban water bodies are detected in Chittagong Metropolitan City (Table 2). These water bodies have been classified into two broad and eight sub-categories based on their physical characteristics: such as *lentic* or stagnant and *lotic* or running. As the table indicates, about 93.9 percent UWBs are found static compared to only 6.1 running. Of the total UWBs, ponds and *doba* represents 78.5 percent and 11.8 percent, respectively. Besides, table 2 depicts that out of 51 *lotic* UWBs in CMC about 62.7 percent are *khal* and 33.3 percent are belong tidal creek or *chara* category.

## Shape of Urban Water Bodies (UWBs)

The types of the UWBs in CMC by geometric shapes are depicted in Figure 3. Seven broad types can be easily recognized: triangular, rectangular, parabolic, irregular, linear, round and square. Of the different categories shown, square (22.2 percent), rectangular (21.3) and round (20.3 percent) shapes are found as the most dominant, common and popular one because of the local custom. As an explanatory note, shape of UWBs depends on different factors, especially ownership, digging workers, bank erosion and area of water bodies of the owner and so on. The element of shape describes the external form or configuration of a landscape object (Avery and Berlin, 1985; Campbell, 2002; Jensen, 2000). Generally, cultural phenomena have geometrical shapes and precise boundaries. On the other hand, natural features tend toward irregular shapes with irregular boundaries.

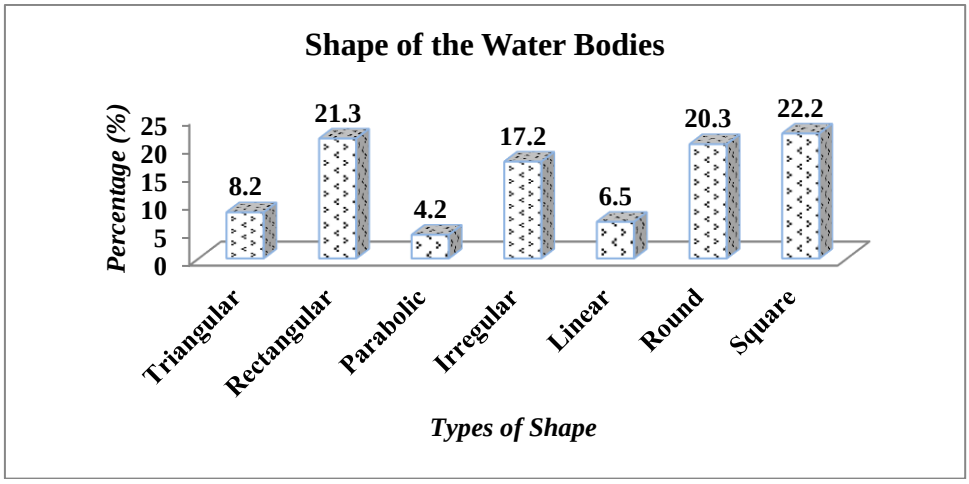



**Figure 3:** Shape of Urban Water Bodies in CMC.

**Area of Urban Water Bodies**

An area of UWBs means the amount of space occupied by the water bodies in the study area. However, the area of UWBs is relative because it depends on time and functional activities of the city.

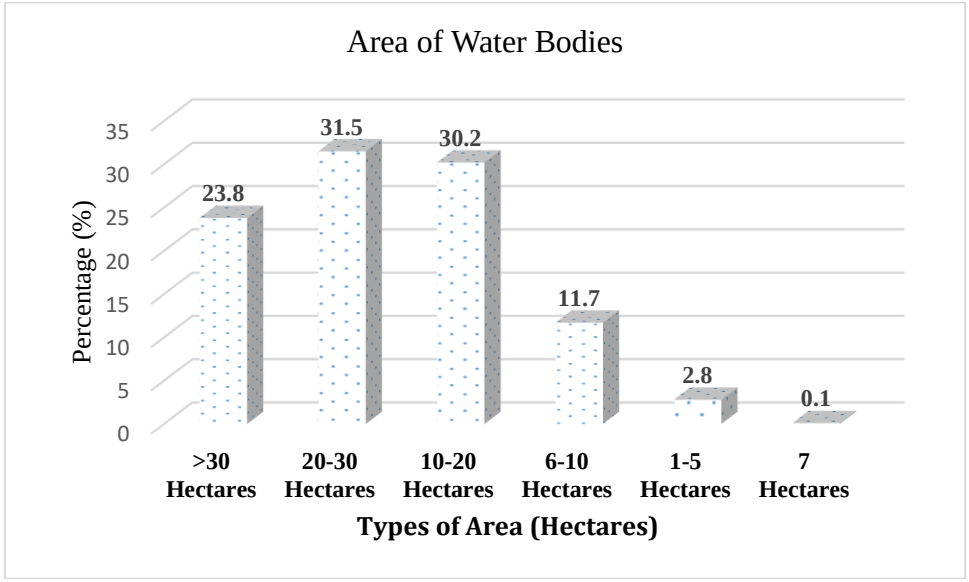



**Figure 4:** Area of Urban Water Bodies.

As Figure 4 depicts, six broad groups of UWBs can be conveniently identified in CMC. Nearly, two-thirds of the UWBs are found relatively large in size, ranging between 10 to 30 hectares. Besides, about 24 percent water bodies are quite big in size, occupying 30 hectares and above land area in CMC.

***Depth of Urban Water Bodies***

In Chittagong Metropolitan City, as Figure 5 indicates, the average depths of most UWBs in CMC are found relatively shallow. The average depth of nearly 30 percent UWBs is in between 1 to 5 feet; about 40 percent water bodies is in between 5-10 feet. Roughly 10 percent water bodies are showing average depth 15 feet and above.

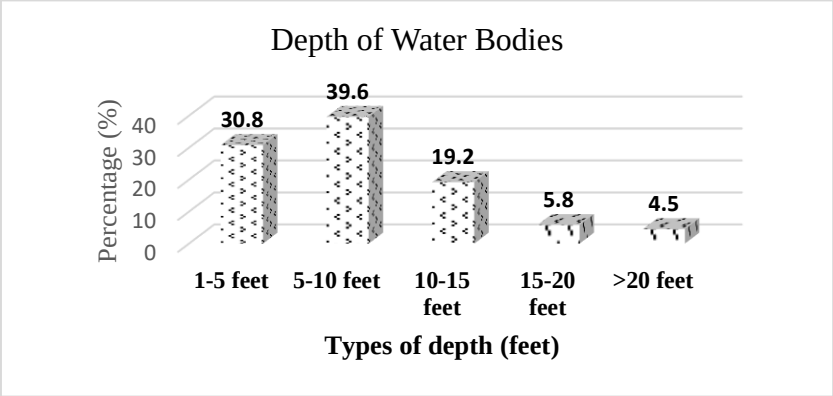



**Figure 5:** Depth of Urban Water Bodies.

Depth is a seasonal feature, being affected by many factors: monsoon rains, tidal and urban floods, and surface runoff during the rainy season and the evaporation during winter. All of the UWBs vary in depth, and therefore usefulness. Depth of water bodies and depth of water are relative conditions of UWBs in CMC. In rainy and winter season, water is available due to the increased depth of the length of water bodies. In late winter and summer season, water is reduced as a result depth of the length of water bodies in CMC

***Seasonal Variation or retention ability of water in Urban Water Bodies***

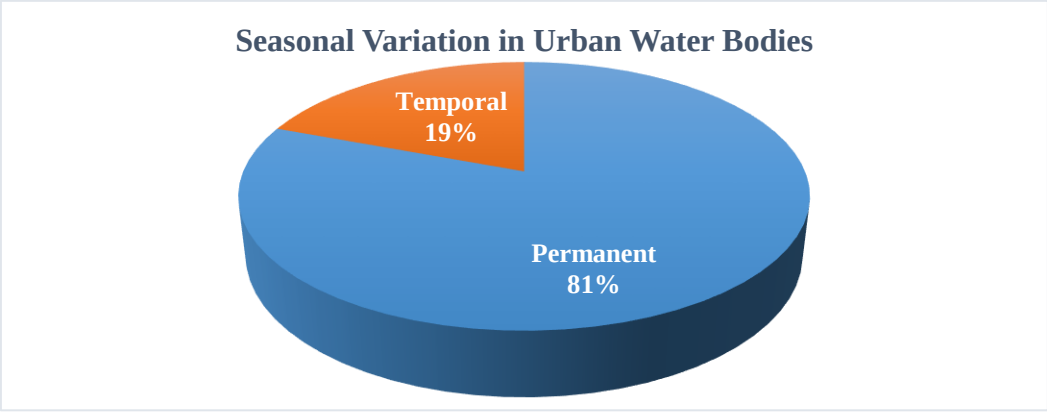



**Figure 6:** Seasonal Variation or retention ability of water in Urban Water Bodies.

As Figure 6 shows, about 81 percent water bodies in CMC are permanent and their water retention ability is whole year. In contrast, only 19 percent water bodies are found temporal and their water

retention ability are seasonal. In the rainy season and early summer season, water is available in every type of water bodies but on other seasons especially late winter and dry season, small types of water bodies' especially small ponds, dobas, tidal creeks and fellow lands water are disappeared in CMC. Seasonal variation of these water bodies is essential feature for urban citizen, because it is showing the water holding capacity of the water bodies in a year.

***Year of Origin of Urban Water Bodies (UWBs) in CMC***

This characteristic represents the creation of water bodies in CMC, as well as denotes the number of water bodies created in a particular decades.

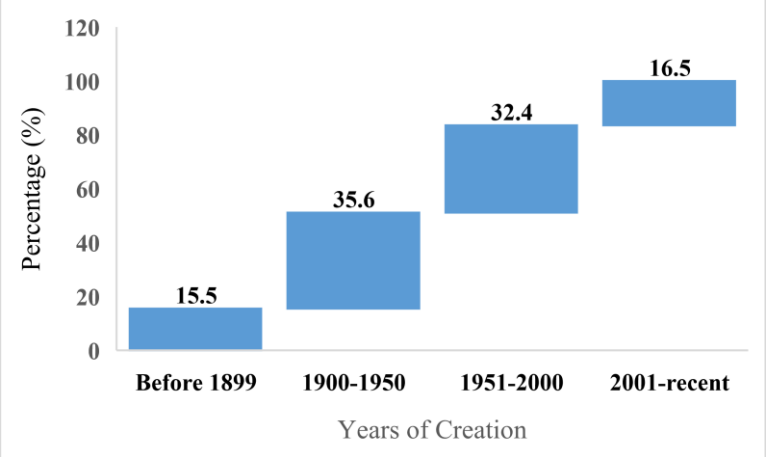



**Figure 7:** Year of origin of Urban Water Bodies.

As Figure 7 indicates, roughly 50 percent of the UWBs in CMC were created before 1950. About 32 percent UWBs were created between 1951 and 2000. Only 16.5 percent is of recent origin- after 2001. It is remarkable that, four major and well-known water bodies namely Agrabad Deva, Valuar dighi and Jora dighi were created during the establishment of the Bangladesh Railway in 1853. In recent time, a port-connected road is built along the beach from Chittagong port to Salimpur in Sitakunda. During building this road, a number of small water bodies were created for collection of soil for road building purposes. It has increased the total number of water bodies in Chittagong Metropolitan City. Urban territorial expansion is directly correlated with creating water bodies in Chittagong Metropolitan city. Population agglomeration, place for commercial, industrial, residential purposes, the Ground Level changes of Chittagong city starting from 1948 through 1975 and finally in 1992. As a result, the City Corporation, community and personal land owner are digging a lot of water bodies for urban household's purposes sometime industrial entrepreneurs digging ponds for emitting industrial waste and wastewater in CMC. Although, two forces created water bodies, for example natural or geological depression and another is anthropogenic causes. Therefore, a creation of urban water bodies is contentious processes from pre-history to present. Sometime filled-up and emerged, it is like looking a playing of natural and manmade events.

***Ownership Pattern of Urban Water Bodies (UWBs)***

Various types of ownership pattern are appeared in urban areas of Bangladesh for instance, urban

development authority and autonomous bodies, religious groups, personal, community, cantonment board, railway, private company, local government, engineering department and fire services etc.

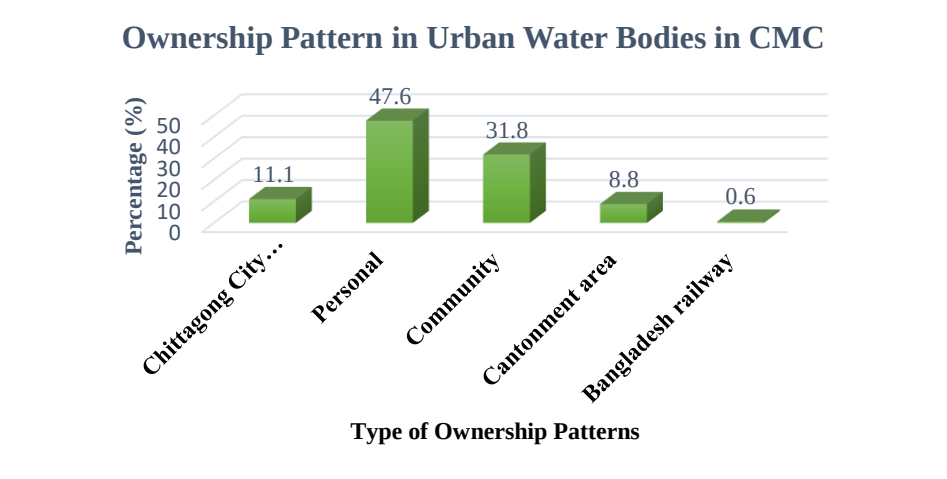



**Figure 8:** Ownership Pattern in Urban Water Bodies.

The ownership pattern of UWBs in CMC is depicted in Figure 8. About 47.6 percent of water bodies are represented by ownership of personal category, followed by 31.8 percent community-mostly dighi and big ponds. The Chittagong City Corporation owns roughly 11 percent of UWBs in CMC.

***Prime Uses and role of Urban Water Bodies***

For functional activities, water bodies are used in multi-dimensional purposes in urban areas of Bangladesh as Table 3 shows, some 16 categories of urban water bodies (UWBs) by prime use have been identified in the Chittagong Metropolitan City. About 63 percent water bodies are being used for household purposes, especially bathing, clothing and all types of household washing purposes. Fishing also occupies a remarkable share in the prime uses (Plate 1).

**Table 3:** Prime Uses of Urban Water Bodies

| Prime Uses | Frequency | Percent |
|---|---|---|
| Fishing | 130 | 10.4 |
| Shrimp culture | 11 | 0.9 |
| Households Purposes (drinking, cooking, bathing and washing) | 785 | 62.9 |
| Recreational Use | 6 | 0.5 |
| Purification of drinking water | 6 | 0.5 |
| Sewerage | 76 | 6.1 |
| Aesthetic | 24 | 1.9 |
| Fire brigade water | 3 | 0.2 |
| Irrigation | 20 | 1.6 |

| Prime Uses | Frequency | Percent |
|---|---|---|
| Fishing and households purposes (cooking, bathing and washing) | 88 | 7.0 |
| Fishing, households purposes and purification of drinking water | 2 | 0.2 |
| Fishing fire Bridget | 60 | 4.8 |
| Fishing and households purification of drinking water | 16 | 1.3 |
| Fishing and households | 16 | 1.3 |
| Fishing and households purposes and recreational use | 3 | 0.2 |
| Fishing and irrigation | 1 | 0.1 |
| Not use | 2 | 0.2 |
| **Total** | **1249** | **100.0** |

**Plate 1:** Uses of water bodies in urban area

**Holy purposes (Baizid Bostami pond)**

**Commercial fishing in Agrabad deba**

**Washing cooking items in Hindu Para near south Patenga**

**Bathing Purposes in Raja Pond in South Halishar**

**Washing cooking pots with rice at Jora dighi in Sharaipara**

**Washing clothes on pond water in Voluar dighi**

Typically, the role of UWBs is multidimensional and diversified, urban flocks receive various sorts of benefits, for instance water resource, environment, economy, social, culture, safety and religious purposes from this water bodies (Table 5, Appendix II).

**Citizen perception of the water quality status of Urban Water Bodies**

The Chittagong Metropolitan City is the commercial and industrial hub and port city in Bangladesh. Heterogeneous types of industry set up in this city, especially, garment, cotton, cement, jute, chemical, etc. is prime in six industrial zones around the city territory. For mismanagement of the industrial and municipal waste, surface water and water bodies are being easily polluted.

**Table 4:** Citizen perception of the water quality status of Urban Water Bodies

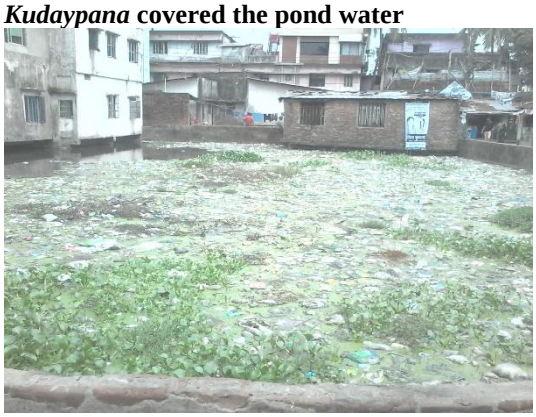
| Source of pollution | Type of wastes | Frequency | Percent |
|---|---|---|---|
| | Solid waste | 429 | 34.3 |
| Industrial source | Liquid waste | 27 | 2.2 |
| | Solid and liquid | 8 | 0.6 |
| Municipal source | Solid waste | 169 | 13.5 |
| | Liquid waste | 18 | 1.4 |
| Both (industrial and municipal) source | Solid & liquid | 61 | 4.9 |
| Commercial source | Solid & liquid | 44 | 3.5 |
| Non-polluted (aesthetically good) | | 493 | 39.5 |
| Total | | **1249** | **100.0** |

Table 4 shows the frequency distribution of UWBs in CMC by perception of water quality status (Plate 2). Four types of pollution sources can be conveniently recognized. Industrial source – mainly solid- waste has been found to the largest (34.3 percent) contributor followed by Municipal garbage (13.5 percent). However, a remarkable proportion (39.5%) of UWBs are not reported as polluted in the Chittagong Metropolitan City.

**Plate 2:** ways of Pollution of pond water

***Kudaypana* covered the pond water**

**Solid waste disposal by surface runoff**



**Solid waste floating on pond water**

***Algae blooming* on pond water**

## Conclusion

Urban water bodies (UWBs) are neglected micro-geomorphic features, degrading and disappearing day by day. Of the different pollution sources, anthropogenic activities such as industrial and municipal garbage, commercial to some degree and land development are found to be contributing factors. Any rehabilitation process of an urban water body requires significant cleanup efforts, a major overhaul of the humid land, and also the cleaning of the inflowing water. Particularly the purification of the currently untreated sewage is a major concern and requires an urgent attention. The rehabilitation of small urban water courses has not been a major topic until now. Interest in this topic has increased only recently and resulted in the establishment of various working groups, research collaborations and in the implementation of various projects in Southeast Asia.

## Appendix I

The research found that 32 khal or lotic water bodies in CMC, such as Chaktiai Khal, Chaktiai Diversion Khal, Dhomkkhal Khal, Noa Khal, Mirza Khal, Mahesh khali Khal, Nasir Khal (Agrabad R/A and Sheikh Mujib Road), Boro Khal, Kell Khal, Sadarghat Khal, Namuna Bazar Khal (Agrabad C/A), Chatteswari Khal (Chittagong Teachers Training College and Sports Ground), Jamal Khan Khal (Jamal khan), Hizra Khal, Sital Jharna, Murari Khal, Boalkhali Khal, Kattali Khal (Pahartali thana), Bakalia Khal, Rajakhali Khal, Rampura Khal, Pakija khal, Gainachara Khal, Badarpatti Khal, Zelepara khal, Dakshin Halishahar/ Naval colony Khal,

Munshi khal, Gupta Khal, Uttara Khal, Avay Mitra Khal, Deputy Khal, Halda River and Karnaphuli River respectively.

## Appendix II

**Table 5:** Role of Water Bodies in Urban Area

| Urban Environmental Variables | Actions | Description |
|---|---|---|
| Water Resource | Bathing | A large number of people from lower economic background use them for bathing. |
| | Washing | Washing of clothes, utensils and other domestic requirements. |
| | Cooking | Cooking rice, vegetable and consumptions purpose. |
| | Drinking | A large number of slum and lower income people used water for drinking purpose after treatment, like boiling and filtering. |
| | Retention of storm water | A huge volume of water is holding on this water bodies during rainy season or heavy precipitation. |
| | Custody of industrial discharged water | Solid and liquid pollutants, sludge released from industry to water bodies. |
| | Rainwater Harvesting | Acts as rainwater storage. |
| | Uplift of ground water level | Recharge water to ground water level. |
| Environment | Control micro climate | Waterbodies affect local micro-climate, making it cooler and soothing |
| | Open space | Waterbodies provide an open space, Providing room for air movement, Space for recreational use. |
| | Trees | Generally the waterbodies banks have tree plantations, preserving urban nature |
| | Birds | Create unique ecosystem and sanctuary of migratory, wild and native birds. |
| | Mammals and reptiles | Small herbs, small trees, leaf vegetables and fruits are built a community in surrounding sites of water bodes which created habitat of different sorts of animals and reptiles. |
| | Aquatic ecology | Waterbodies support many aquatic and other species, a receptacle of biodiversity in urban context |
| Economy | Fish Cultivation | Source for local employment and good protein |
| | Crab Cultivation | Commercially cultivated crab and shrimp along site of Bay of Beagle. |
| | Shrimp Cultivation | |
| | Recreational Site | Amusement center, like Agrabad Shishu Park, Fay's Lake & LAL Dighi |
| | Irrigation | Watering for agriculture purpose, like paddy cultivation, seasonal vegetable and food. |
| | Industrial raw material | A large number of industries in the port and EPZ areas are used water for cooling purposes. |

| Urban Environmental Variables | Actions | Description |
|---|---|---|
| | Constructional wastes ground | Constructional and development wastes dumped on unused water bodies. |
| | Soil collection for brickfield & road construction | Digging existing and creation new water bodies for soil collection purposes for brickfield & road construction. |
| | Navigation route | Chakktai Khal Khatungong retail hub |
| Social | Community Gathering | People spend time sitting around these waterbodies. Many waterbodies have seats around them and are an important place for local community gathering. |
| | Clubs | Because of open space, there often exist many clubs by the waterbody side. |
| Culture | Fair | Fairs are organized in the open spaces in front of waterbodies |
| | Heritage site | Nearly 2% water bodies have been considered the heritage site in CMC like LAL Dighi, Balua Dighi, Agrabad Deva. |
| Safety | Fire Extinguishing | In congested urban areas, Waterbodies are very useful as a source of water supply for extinguishing fire. |
| | Strategic Point for soldier | Every water bodies has been considered as a strategic point for solder in cantonment area. |
| Religious Purposes | Mosque | Source of water for ablution, clean of temple and soil for rising plinth. |
| | Temple | Source of water for sanctified of believers, clean of temple and soil for rising plinth. |
| | Scarify of Idolatry | Immersion of sculpture of Hindus religious community |

Source: Prepared by authors

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