Climate change versus urban drinking water supply and management: a case analysis on the coastal towns of Bangladesh

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Abstract

Clean urban drinking water supply is now a crucial problem; about 8.2 million people live in the coastal urban areas in Bangladesh. The global warming and climate change is a new threat for the urban secure drinking water supply. Sea Level Rise and vulnerability of drinking water in the coastal areas is getting degrade due to high salinity intrusion and arsenic contamination in 102 towns, that have been affected by various degrees of salinity intrusion. Salinity and arsenic contamination in surface and ground water in the coastal region has created severe negative impacts and degraded drinking water quality. Global climate change impact is a new threat for the coastal urban inhabitants. The impacts with 1.5 m SLR about 15% of the population will be affected and displaced. Therefore climate awareness and applied research should be initiated to change the attitude of the people. The objective of this paper is to understand the impacts of climate change on urban drinking water management in small towns. GIS application would be the appropriate tool for decision making and comprehensive management plan for coastal region.

Keywords

Global climate; urban drinking water; salinity; coastal towns; management.

INTRODUCTION

Clean urban drinking water supply is now a global problem, and most of the countries are suffering in urban drinking water supply and management (Gleick, 1998 ; Biswas, 2000). The most basic human needs is safe water in supporting of life through drinking (Biswas, 2000). Coastal urban water pollution is a serious problem in the ganges delta region. The urban effluents contain different types of contamination like salinity (NaCl) intrusion and Arsenic (AS) contamination, chemical and metal contamination by industrial effluents that include Cd, Cu, Pb and Zink etc (Anu, 2007).The urban water management is critical for the proper operation within the natural environmental system and critical to support of the human society. The climatic change and scarcity of upstream fresh water supply and increasing of salinity is one of the significant and widespread forms of surface and groundwater pollution (Wescoat, 2003). It is caused by the effects of irrigated agriculture, upstream water withdrawal and salt intrusion is common in coastal region of the Ganges delta in Bangladesh. The coastal region and the towns are very important for Bangladesh. About 34.8 million people live in the coastal zone and 8.2 million people live in coastal urban areas (UN-ESCAP, 1988 ; Islam, 2001). The urban population in Bangladesh grew annually by 6.2% of total coastal population this has been much higher than the national population growth. In 8 coastal districts less than 5% urban people use tap water for drinking other sources of drinking water are 2% from well, 61% from tube well and 33 % from pond. The global warming and climate change is a new threat for the urban secure drinking water supply and management in the coastal towns of Bangladesh (Islam, 2007 ;

Islam, 2001). Global warming and sea level rise and vulnerability of quality of drinking water in the coastal areas is getting degrade due to high salinity intrusion and water pollution. The preliminary results of the study shows that water quality has degraded in dry season (February-June) in the coastal rivers where 60% water is poor quality where EC dS/m is 55 and 40% is good quality and EC dS/m is 27. It is also threat for coastal ecosystems which is a new additional factor determines the long term management strategy for urban water management in the coastal region of Bangladesh. Coastal urban area both surface and groundwater have become unfit for human consumption. In the consequences about 0.170 million hectares (20.4%) of new land, and almost 17 small towns out of 102 have been affected severely by various degrees of salinity during the last three decades. The saline front defined by 6 ds/m isohaline has penetrated up to 220 km north from the coast. The salinity has exceeded the recommended level 2 dS/m for potable water; it is a critical time to supply fresh drinking water to the coastal urban towns in Bangladesh. On the other hand a predicted sea level rise (SLR), accelerated by global warming will cause a further 'Squeezing' of the natural tidal land. In Bangladesh case it has been projected by IPCC and MoEF that 3 mm/ year sea level rise which will occurs before 2030 and 2,500 km²coastal land (2%) will be inundated and affected by coastal salie water.

Besides these more urban environnemental problems will arise in the coastal region such as; water pollution and scarcity, soil degradation, urban solid and hazardous wastes, loss of urban bio-diversity which will create food insecurity and would harmful for urban human habitation. In such situation it will further create an unstable urban ecology in the coastal region. The lack of knowledge, awareness and seriousness of the immense problems that are facing the country in the immediate future of coastal urban towns is most striking. Therefore climate awareness education and applied training and research should be initiated in order to change the attitude of the people and the government. It is necessary and emergence to develop technically feasible, low cost, locally available affordable and appropriate devices to live with saline water related costal urban extremes. The paper has been prepared based on primary and secondary data sources. The findings are the preliminary results of the study. The objective of this paper is to understand the global climate change impacts on environment of coastal towns, urban water supply and human habitation. GIS application to visualize and analyze of environmental data that could be the appropriate tool for making a long-term planning for the urban drinking water supply to the coastal towns and the management of urban ecology in Bangladesh.

GOGRAPHICAL LOCATION AND PHYSICAL CHARACTERISTICS

Bangladesh is situated in the Ganges-Brahmaputra-Meghna River catchments. The coastal region of Bangladesh is located in the south of the country. The coastal length is 710 km and the coastal area comprises 36,500 km² with a population of 35 million and coastal urban population is 8.2 million (BBS, 1999). There are 3 metropolitan cities, 11 medium size district towns and 88 small coastal towns are located in the coastal region (Figure 1). The small towns are located under the administrative zone of the following district territory such as Satkhira, Khulna, Bagerhat, Pirojpur, Jhalokati, Barguna, Patuakhali, Barisal, Bhola, Lakshmipur, Noakhali, Feni, Chittagong and Cox's Bazar (Figure 1). The coastline of the Ganges delta extends from the month of mouth of Hoogly-Bhagirathi River in the west to the mouth of the Padma-Meghna River in the east (Figure 1) (Islam, 2008). The coastal area of the delta is confined roughly in an area between longitudes 80° 0´ E to 91° 0´E and 21° 30´N to 22° 30´N latitude. The coastal area of Bangladesh is deltaic active and hydrologically dynamics. The coastal areas of Bangladesh have been defined and categorized by Coastal Area Resource Development and Management Association (CARDMA) in three different types of coastal regions on the basis of physiographic characteristics. These three divisions are: The Eastern Region, The Central Region and The Western Region. The eastern coastline extending from the Big Feni River to Badar Makam along Chittagong is regular and unbroken and protected along the sea by mud flats and submerged sands. The Cox's Bazar sand beach about 145 km long is part of this coastline.

The central region runs east from the Tetulia River to the big Feni River estuary and including the mouth of the combind flows of the Ganges-Brahmaputra-Meghna Rivers. This is why this region is characterized by heavy sediment input, formation of new chars and river bank erosion and accretion. The western region covers the coastline westward from the Tetulia River to the international boundary located at the Hariabhanga River (Figure 1). This region is mostly covered with dense mangrove forests with reduce the River bank erosion. The rivers of the region are mostly stable; land accretion does not occur massively (Jalal, 1992).

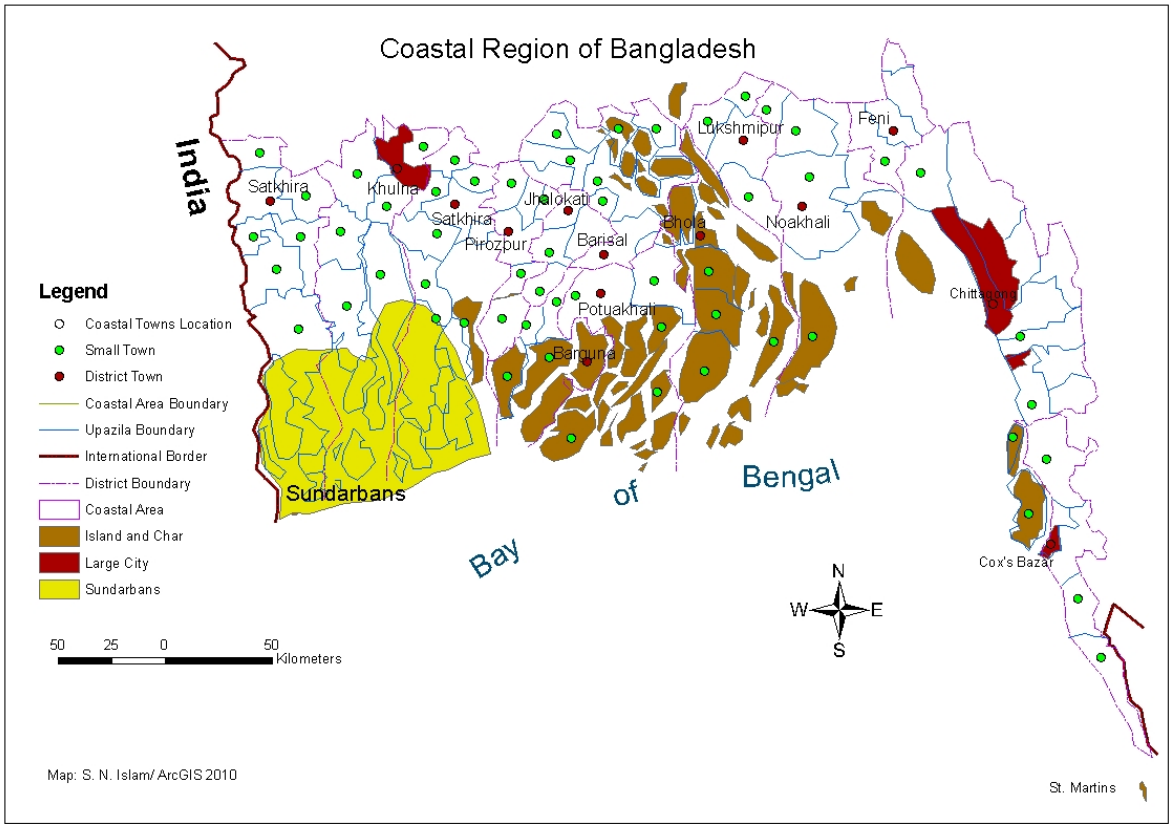

Figure 1 The costal area and small towns location in the coastal area of Bangladesh

These three categories are defined three types of divisions based on the physiographic and ecological characteristics such as;

Pacific Type: The eastern region of Chittagong specially a narrow strip with a long sandy beach in Cox's Bazar, known as Eastern Region. This eastern region has Pacific characteristics (Figure 1).

Atlantic Type: The western region is known as Atlantic type coastal region in Bangladesh. The Sundarbans is largely covered by mangrove forests. This coast is more stable than other part of the coastal region; its character is like the Atlantic characteristics (Figure 1).

Central Region: The Ganges-Brahmaputra-Meghna (GBM) River systems fall into the Bay of Bengal through the Meghna estuary. The Meghna estuary is located in the central region of the coastal Bangladesh. The central region is more unstable and most vulnerable. Coastal char formation, river erosion and accretions are the regular activities and character of region (Figure 1). The GBM system is discharged through the low-lying area of the central coastline, heavy sediment at inputs from the rivers result in a morphologically dynamics coastal zone. The central region has deltaic characteristics.

MATERIAL & METHODS

This interdisciplinary study has been carried out based on primary and secondary data sources. Data was collected from 17 small coastal towns (Matbaria, Patharghata, Kalapara, Galachipa, Munchiganj, Kaliganj, Ashasuni, Koyra, Paikghacha, Botiaghata, Dumuria, Rupsha, Morelganj, Mongla port, Satkhira, Khulna and Bagerhat) and 3 medium sized towns (Satkhira and Bagerhat and Barguna district Towns) in the coastal region of southern Bangladesh in 2003 and 2008 and the samples were collected from the Soil Resource Development Institute (SRDI, 2000) laboratory in Dhaka. In addition to a time series data on surface water were collected from two Sundarbans rivers (Munchiganj–River and Passur-Mongla River). All data has been reconstructed and developed for computer base analysis and visualization. Data were collected during the dry month and wet month when the salinity rate is increased in the high rate. The missing data were manipulated within the EXCEL interpretation. The preliminary study results have been showed in this paper. It has planned to continue this research as Post Doctoral research project. The next step of research will carry out on primary data sources. The following data collection methods will be followed; data collection from all the coastal secondary towns will be collected from town surveys. Present tidal inundation and floods measurement will be done on satellite imagery analysis. 6 workshops will be arranged at the coastal towns in 6 location for shareholders opinion and participation where approximately (1500 people) will participate. A summer school will be arrange where young scholars, PhD and master students will participate those are working on urban water related issues. A social vulnerability survey will be arranged on coastal urban towns (50 towns) in Bangladesh. Some special software will be used for this research such as ArcGIS 9.2, SPSS, EVIEW, VENSIM, and MATLAB software for data analysis, visualization and modelling purpose.

RESULTS AND DISCUSSION

The impacts of climate change in any given region depend on the specific climatic changes that occur in that region. This is because local climatic changes can differ substantially from the global average climatic change (Harvey, 2000). A consideration of climatic change at the regional level would therefore appear to be mandatory in the development of both national-scale and global-scale policy responses to the prospect of global warming. Indeed, this imperative has been driving the effort to develop better predictions of climatic change at the regional level (Harvey, 2000). The theory behind climate change impacts are illustrated in figure 2 below. Anthropogenic factors impact the environment and influenced on urban water (Harvey, 2000). There is scientific consensus that natural and human activities are beyond reasonable doubt the main explanation for the current rapid changes in the world's climate (Harvey, 2000; Drake, 2000). The concentration of atmospheric Co_2 in 1750 was 280 ppm, and increased to 379 ppm in 2005, representing a whopping increase of 100 ppm in 250 years (IPCC, 2007). The IPCC projected that the estimate of total SLR of 49cm, with a possible range of 20 cm for 21st century (IPCC, 2007). This poses problems especially for people and infrastructure on coasal areas and low lying areas of the world. For example, the cyclone-vulnerable and tidal wave attacts on offshore of coastal Bangladesh could be devastated with terrible consequences for all people of the urban towns of the country (IPCC, 2007; Thomas, 2006). The ratio of soil and organic matter production to decomposition is lost through water and wind erosion (IPCC, 2007), which is one of the main factors that adversely affect on ecology and it is the root cause of urban water damage, and urban health risk which is reducing of social welfare of urban population (Figure 2) (Harvey, 2000). Climate change leads to floods, salinity intrusion and erosion. These three factors may cause damage to urban surface and ground water quality and urban ecology (Figure 2) (Hidayati, 2000). Climate change results in fluctuation of temperatures, which may affect the ecology and urban agro production. Besides SLR and temperature change, there are some other

factors that influence surface water and urban ecology (Figure 2). Owing to lack of these opportunities, the urban drinking water quality is falling in developing countries specially, the low lying countries like Bangladesh (IPCC, 2007) resulting in urban health insecurity (Figure 2).

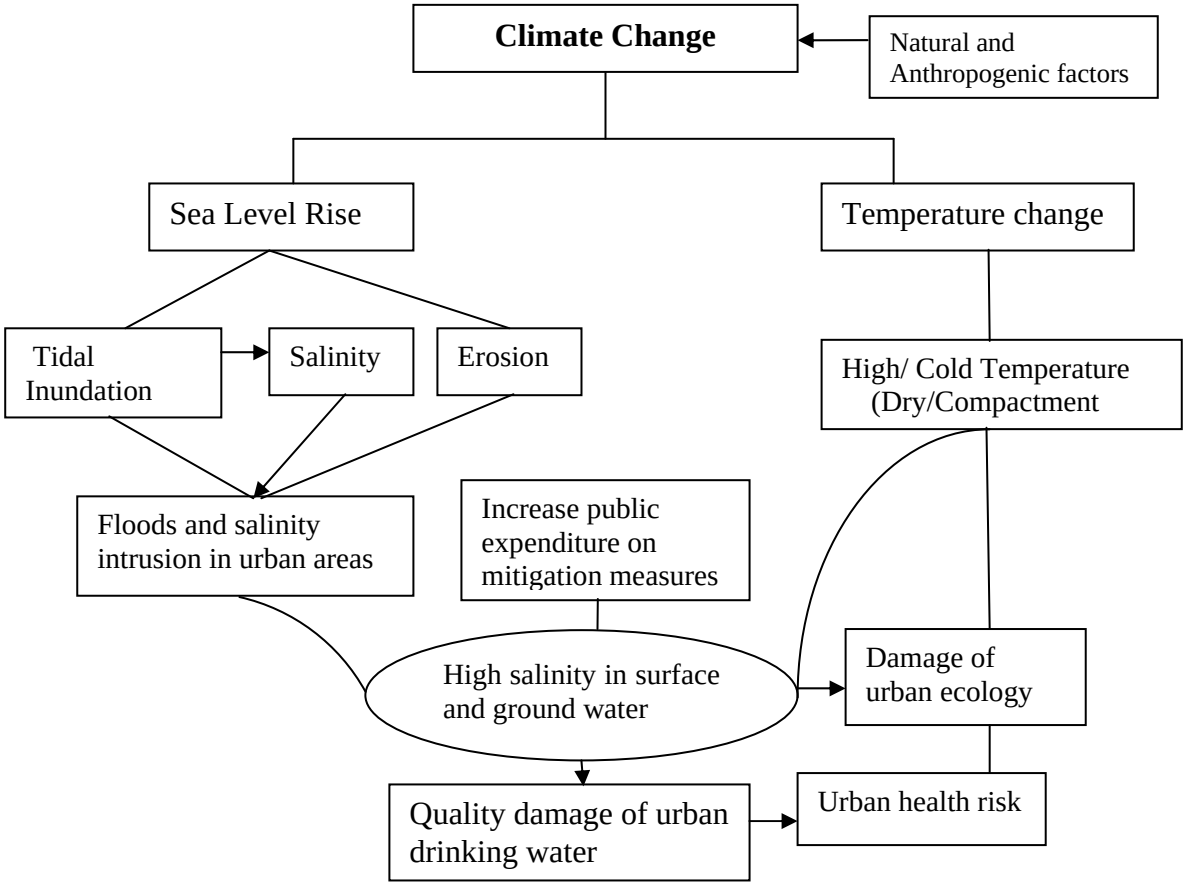

Figure 2 Flow chart of climate change impacts and urban water quality damage

The poorest countries are those with predominantly agricultural based economies with the poorest people living mainly in the rural areas and small towns (Ahmed, 2001; Ahmed, 1999), as evident in Bangladesh. Food security and drinking water appears to be of primary concern and threatened by thermal and water stresses, SLR, increased flooding, and strong winds (Naylor et al., 1997). Health vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (Mohan et al., 2005). Figure 2 (above) illustrates the theory behind this study and is within the theoretical concept of climate change and its impacts that is creating urban social vulnerability and health risk and threats to urban ecology.

The table 1 shows the severely affected coastal towns in southern Bangladesh. There are 17 relatively in high risk towns are located in the coastal region and the surface and ground water is affected due to high salinity penetration in the upstream area and arsenic contamination in ground water. The Farakka Barrage construction in India on the Ganges river in 1975 is one of the obstrucle of fresh water supply to the coastal region in Bangladesh. On the other hand global climate change impacts as results sea saline water penetrating due to capillary upward movement. The sea water increased upto 240 km from the coast. The river water salinity 6 dS/m has penetrated upto 171 km north from the coast. It is also affecting the urban drinking water.The recommended measures of salinity for potable water is 2 dS/m (Islam, 2007).

Table 1. The coastal town's area affected by salinity and the population size

Name of towns	City area km²	Salinity affected area %	Population
1. Barguna *	15.57	46	26,484
2. Mathbaria	15.92	65	16,573
3. Patharhgata	18.31	68	13,060
4. Galachipa	9.60	72	17,547
5. Kalapara	19.49	74	16,330
6. Munchiganj	2.10	88	5,225
7. Kaliganj	7.96	77	13,518
8. Ashasuni	6.81	85	7,611
9. Sathkhira *	27.84	45	86,372
10. Koyra	10.06	81	8,636
11. Paikgacha	2.12	81	13,656
12. Botiaghata	8.30	69	6,224
13. Dumuria	6.93	68	14,189
14. Rupsha	2.30	45	5,600
15. Morelganj	15.36	65	22,136
16. Mongla-Port	17.79	78	60,561
17. Bagerhat *	7.53	56	51,504

(* Medium size towns according to administration and population)

Table 2. Surface water salinity in ECW (dS/m) in 17 coastal towns in Bangladesh

Name of Towns	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Barguna *	3.1	4.2	21.1	20.1	22.3	5.8	3.1	1.9	1.5	1.1	0.7	0.6
Mathbaria	4.3	4.6	21.3	21.4	23.2	7.1	3.1	2.0	1.8	1.2	0.9	0.8
Patharghata	5.1	4.1	22.3	26.6	22.4	6.7	3.1	2.1	2.0	1.0	1.0	0.6
Kalapara	5.2	4.6	20.2	23.2	21.2	7.1	3.1	2.1	2.0	1.2	1.0	0.8
Galachipa	5.5	4.3	24.3	25.2	20.3	6.2	3.2	2.1	2.0	1.6	1.2	1.0
Munchiganj	5	17	28	52	50	29	12	10	9	6	4	2
Kaliganj	5.9	9.3	14.9	22.1	28.2	12.3	1.6	2.2	3.6	3	5.5	6.4
Ashasuni	1.8	7.8	18.6	17	31.6	8.6	1.5	2.2	5.2	4.9	6.1	1.2
Sathkhira *	1.6	5.8	10	17	29.8	1.2	0.5	0.5	0.4	0.5	1.1	3.2
Koyra	1	1.3	6.4	18.5	18.8	3.3	0.6	0.4	0.5	0.5	0.4	0.5
Paikgacha	2.7	7.3	26.3	27.8	45.7	14	11.7	2.2	1.4	3.8	3.5	3.1
Botiaghata	4.1	6.6	16.3	16.6	29	0.5	0.5	0.3	0.3	0.4	0.4	0.5
Dumuria	1.2	4.2	8.6	18.2	27	1.4	0.6	0.5	0.4	0.9	0.9	1
Rupsha	1.6	3.6	13.7	18.1	20.3	3.8	0.3	0.2	0.3	0.3	0.3	1
Morelganj	4.5	3.3	11.1	9	18.3	4.3	1.8	1.1	0.8	1	0.9	1.3
Mongla-Port	7.6	9.4	19.1	19.5	24.9	11.2	6.3	2.8	0.5	0.5	0.5	1.7
Bagerhat *	1.9	5.4	10.2	17.7	17	4.2	2	1.1	0.8	1.5	1.3	1.7

In table 2 shows the urban surface water salinity trends in 17 coastal towns in the coastal Bangladesh. The study found that surface and gound water water salinity is raised higher than 20 dS/m in 2009 in 17 coastal towns in the dry season (March - May). This rate is a strong threat for human health and risk for normal agricultural production. The figure 3 shows the monthly water salinity intrusion in the coastal towns in Bangladesh. Almost 50 coastal towns out of 102 are severely affected by high salinity intrusion due to shrimp cultivation, upstream fresh water shortage and climate change impacts. Urban drinking water supply is a challenging issue for the 3 metropolitan cities are located in the coastal region such as Chittagong, Barisal and Khulna (Figure 1). Figure 3 shows that the salinity intrusion trend is higher in the dry season (March – June).

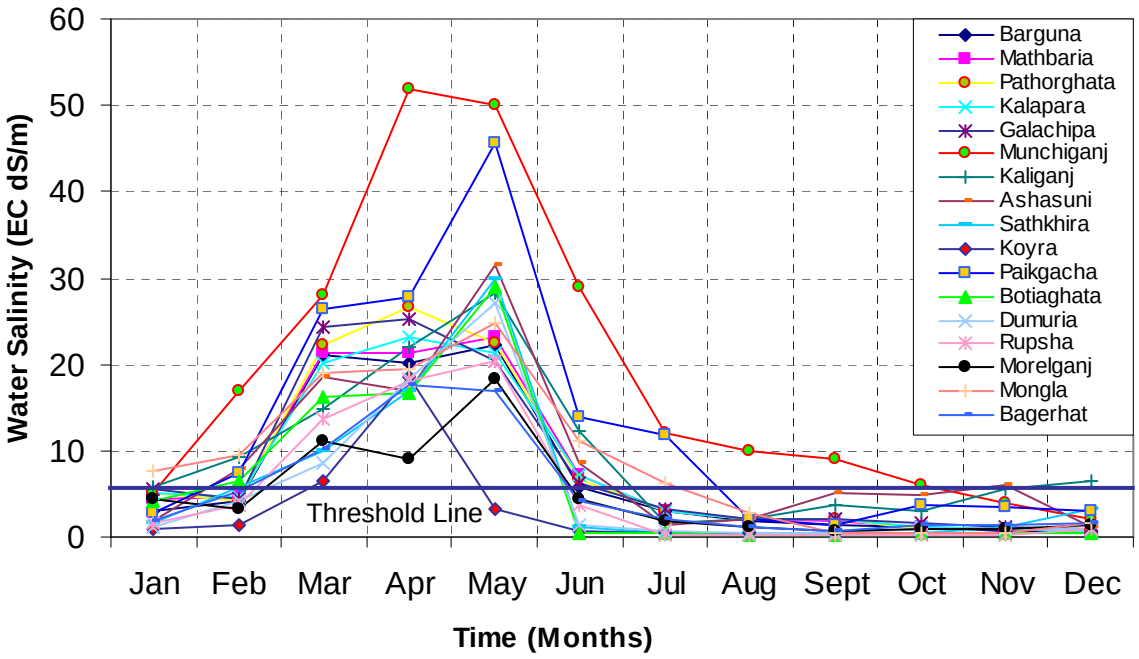

Figure 3 Monthly salinity intrusions in potential towns in the coastal region

The most portion of the land area of these 17 towns are affected by salinity intrusion (table 1) including Barguna (46%), Mathbaria (65%), Pathorghata (68%), Galachipa (72%), Kalapara (74%), Munchiganj (88%), Kaliganj (77%), Ashasuni (85%), Sathkhira (45%), Paikgacha (81%), Botiaghata (69%),Dumuria (68%), Rupsha (45%) and Mongla-port towns (78 % land area is affected). Accordingly 75% land area of Sathkhira district, 66 % land area of Bagerhat district, 32 % land area of Khulna district and 72% of land area of Barguna disctrict are affected by salinity intrusion which is threat for drinking water supply to the urban citizen (Islam, 2007).

CLIMATE CHANGE IMPACTS AND FUTURE OF COASTAL TOWNS

In world, most of the coastal towns are vulnerable and threatened by sea level rise and are densely populated areas. Bangladesh is one of the most vulnerable to sea level rise, as nearly 80% of its area consists of low-lying delta (Whyte, 1995). The Ganges delta in Bangladesh (80,000 km²) is one the vulnerable deltas in the world and having more than 1,000 people per km², with settlements occupying above 40 % of the landscape (Brammer, 1996). It is important to appreciate that the main threat from rising sea levels in such areas is not the direct effects of gradual upward creeping of the sea level, but the livelihood of the urban coastal people is more frequently and possibly the most severe problem (Doody, 2000). This is because of flooding episodes associated with storm surges on top of higher sea levels. Storm surges in the Bay of Bengal can rise 9 m above the normal level (Figure 4). During one storm surge in 1970 over 300,000 people died in the coastal towns and rural areas (Ali, 1999). There have already been several disastrous floods with massive losses of life in recent years, associated with storm surges cased by tropical cyclones; in 1985, 1987, 1988 and 1991 (Whyte, 1995). The 1991 cyclone killed at 125,000 people (Whyte, 1995), and the 2007 CIDR destroyed mangrove resources and almost 20,000 people were killed in the coastal zone of Bangladesh. Therefore climate change and sea level rise are expected to change the flooding and drought patterns in the Bangladesh coastal zone. This increased intrusion of saltwater can probably have a strong effect on the availability of usable urban drinking water and soil for all kind of human activities (Farouq, 1996). A predicted sea level rise, accelerated by global warming will cause a further 'Squeezing' of the natural tidal land (IPCC, 2007). In Bangladesh case it has been projected by IPCC (2007)

and MoEF that 3 mm / year sea level rise will occurs before the year 2030 and 2,500 km² land (2 %) will be inundated (Figure 4). About 20% of the net cultivable area of Bangladesh is located in the coastal zones and offshore island (Rahman, 2001). In these areas soils are affected by different degrees of salinity. For instance, about 203,000 hectare very slightly, 492,000 hectare slightly, 461,000 hectare moderately and 490,200 hectare strongly salt affected soils are assessed in southwestern part of the coastal area (Figure 4).

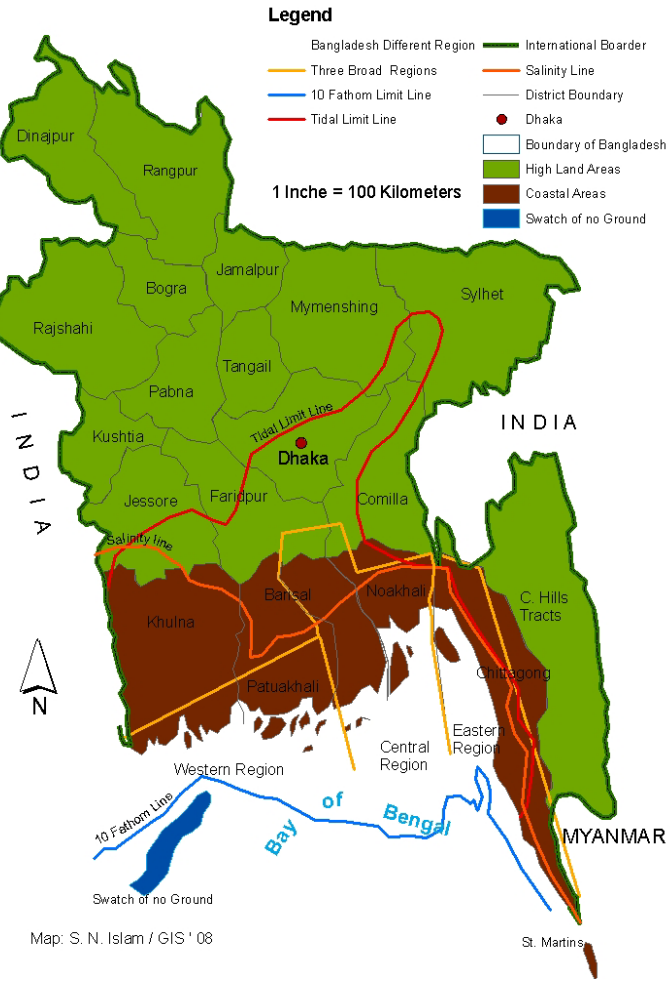

Figure 4 Climate change impacts and estimated affected coastal zone in Bangladesh

It has been predicted that with about 1.5 meter SLR, about 17 million (15 %) of the population will be affected. This mean that the urban and rural coastal people will have be displaced or go homeless, whereas 22,000 km² (16 %) land will permanently be inundated (IPCC, 2007). In addition, other problems will arise in the coastal belt, which are mainly environmental problems (such as water pollution and scarcity, soil degradation, deforestation, urban solid and hazardous waste discharge and loss of urban bio-diversity) and low coastal crop production. These problems could be detrimental to human livelihood and could be severe health risk (Mohan et al., 2005). The map (Figure 4) shows the location of coastal zones in Bangladesh that are affected by climate change and SLR impacts. Also, it shows areas of future environmental impact that have been projected by IPCC (2007). Figure 4 shows the three broad regions of Bangladesh with different potential geographical boundaries with colors such as: 10 Fathom offshore limit line, the tidal limit line, salinity line, high land area, coastal areas, swatch of no ground and location of case areas. The coastal region in Bangladesh is more vulnerable area where 102 coastal towns are located and more than 35 million people are settled down and all are facing problem to receive safe drinking water. The reduction of upstream fresh water in the Ganges river basin has

created environmental problem in the downstream and coastal urban areas of southern Bangladesh. In the coastal region 17 small towns are severely affected by high salinity intrusion in drinking water. Beside this the climate change impact has added as additional negative impact for the urban stakeholders.

CONCLUSIONS

The global climate change and environmental problems are both local and global in nature and have to be tackled collectively by the community participation within the intergovernmental framework and cordial cooperation. As a difficult to segregate ecological sensitive areas such as the southern coastal region of Bangladesh where 8.2 million coastal people are living and they will have to face at least 10 natural calamities every year, in addition climate change impact has added as additional threat to the coastal urban communities. The study finding shows the urban water salinity has crossed the potable drinking water threshold line (2 dS/m) in 17 cosatal towns. Some towns such as Satkhira Khulna and Bagerhat are affected by arsenic (AS) contamination in ground water. In such situation upstream fresh water supply and coastal urban drinking water quality improvement and management to protective measures have to be undertaken within the framework of national urban water supply and management planning. The community participation, awareness eduation, applied research and training programme should be included in the national urban water development programme.
The following points are strongly recommended for implementation in the coastal urban region in Bangladesh for better management ;

- Increase public awareness concerning environmental training and education, particularly related to the importance of the sustainable use of coastal urban drinking water and other natural resources.
- Provide information to the coastal communities concerning potable drinking water and natural resources collection, properly uses for long-term protection measures.
- Ensure community involvement in maintaining and protecting of coastal urban drinking water quality and other coastal resource development and management.
- Technology transfer to the local community for sustainable use of urban drinking water resources and desalination measures.
- Mangrove wetlands biodiversity maintenance in the coastal region; mangrove ecosystems functions and services should maintenance and reduce the high salinity intrusion from the coastal region for the better interest of coastal communities.
- It is important to identify and describe the good practices in coastal drinking water resources management within the local government, communities and stakeholders partnership.
- Needs to continue environmental discourse and dialogues for understanding the importance and inevitability of coastal urban drinking water resources and its appropriate use in sustainable manner. Different professionals and users participation is prospective for making integration for management.
- To develop and trained up capacity building of the local community groups, local government, stakeholders, NGOs and national policy makers and planners those are involved in coastal urban drinking water resource management activities.
- Maintain upstream fresh water supply and mitigate the affects of tidal inundation and high salinity intrusion in the urban areas which is degrading the drinking water quality.
- Policy, principles, plans, programme for sustainable coastal urban water resource

management should be more concreted and specific guideline direction (Islam, 2009).

- The national water policy (GoB,1999) should be implemented properly, in addition a policy guideline of coastal urban drinking water supply issue should be incorporated in national water policy in Bangladesh and it is necessary.
- In light of the drinking water crisis in the coastal region, this study is suggested that rain water haevesting (Mezgebu, 2007) and surface water reuse would find an alternative solution that could mitigate urban drinking water supply and management problem in the coastal towns (FAO, 2004). Through the introduction of water harvesting programme that could intend alleviate recurrent safe drinking water crisis and could ensure food security in the coastal region.

Therefore an integrated coastal urban water resource management policies and guideline framework is necessary and it is emergency. The finding of this study could help to the policy makers to prepare a guideline framework for coastal urban drinking water quality maintenance, protection and proper management in Bangladesh.

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