6th International Symposium

on

Advances in Civil and Environmental Engineering Practices for Sustainable Development

(ACEPS-2018)

Faculty of Engineering, University of Ruhuna
Galle, Sri Lanka
15th March 2018

APN Special Session

on

"*Development of new water supply strategies in two major cities of India and Sri Lanka in the context of climate change, rapid urbanization and population growth : a vulnerability assessment approach*"

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APN Project reference: CRRP2O16-06MY-Kumar

Title: Development of new water supply strategies in two major cities of India and Sri Lanka in the context of climate change, rapid urbanization and population growth: a vulnerability assessment approach

Funded by: Asia-Pacific Network (APN) for Global Change Research

Abstract of the project:
This project aims to re-examine the current urban water use system and propose a new one to cope up with the future climate change, rapid urbanization and population growth in two South-Asian Cities. In the new system, each water resource will be properly allocated to each water use by considering the balance between water supply and demand. This requires information on available amount, and chemical and biological quality of various water resources, recharge zone identification for sustainable planning as well as people perception and willingness to pay. Two of main cities in South Asia; Guwahati (India) and Colombo (Sri Lanka), are selected as research fields. Both locations fall under Asian monsoon region but are on different phases in economic and demographic growths. Henceforth, suggested water supply strategies are going to be an integral part of infrastructure development of urban area especially in developing countries. Climate change and related uneven rainfall distribution cause water shortage. In such areas, safe water supply might become unsustainable, because water pollution becomes severer by decrease of water recharge and unintentional shift of water resources. We intend to evaluate urban water use strategies suitable for each city from various angles and develop Water Quality Information Platform (WQIP) and new strategies of sustainable water supply under climate change scenario. The research will have an impact not only on the critical scientific understanding of emerging chemical and biological pollutants issues posing threat on water potable use, but also on the development of a sustainable water management in urban and agriculture sectors.

COVER MESSAGE

It is a pleasure for us to welcome all the participants to the APN Special Session under the 6th International Symposium of "Advances in Civil and Environmental Engineering Practices for Sustainable Development (ACEPS-2018)", in Galle, Sri Lanka.

We organize this special session funded by APN to report the progress of research programs conducted by the member of on going APN project entitled "Development of new water supply strategies in two major cities of India and Sri Lanka in the context of climate change, rapid urbanization and population growth: a vulnerability assessment approach"

Our team would like to thank the APN for believing the India-Sri Lanka-Japan collaboration and funding the project. We offer our gratitude to all the organizing committee of ACEPS-2018 for giving us a special session under their symposium. We would also like to thank all administration, faculty, staff, research scholars and other members of three collaborative universities; Indian Institute of Technology (IIT), Gandhinagar, University of Ruhuna, Sri Lanka and Kanazawa University, Japan, without whose support whole event would not have been possible.

We are glad we managed to present eight papers in this conference. The main objectives of this special session are to understand the expert's view, and site-specific problems and solutions to support on going APN collaborative research among India, Sri Lanka and Japan.

We also express our sincere thanks to our guests, speakers, authors, members of the international advisory committee and many others who volunteered to assist to make this event a success.

Thanking you,

Principal Investigator:
Dr. Manish Kumar, Indian Institute of Technology Gandhinagar, Gujarat, India

Co-Investigators:

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CSIRO-Mk and MIROC5: A Case Study of Brahmaputra River Watershed

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Abstract: *The issue of Global climate change has recently gained momentum due to its impacts on the environment and its components. Anthropogenic activities like deforestation, agricultural practices, burning of fossil fuels etc. have contributed to the rapid change in the global climate. Disruption of river flows, mobility, dilution of contaminants, effect on chemical reaction kinetics, enhanced potential for toxic algal bloom, reduced dissolved oxygen level, extinction and migration of aquatic animals are some of the implications of climate change. So prediction of climate change for future is of utmost importance to take the necessary measures. Keeping this in view, here we document the future climate change for the Brahmaputra river basin by Global Climate Model (GCM). Temperature and precipitation over the Brahmaputra region was reproduced by two models, namely CSIRO-Mk3.6 and MIROC5. Spatial and temporal resolution of both the models is 4.5km and 1 hour respectively. Rainfall and temperature data for the years 1981-2000 (called the past data) were used as raw data, and used to predict the temperature and precipitation for the years 2046-2065(called the future data). Average yearly temperature for present and future came out to be 28^{0}C and 29.5^{0}C by CSIRO model and 26^{0}C and 27.2^{0}C by MIROC model, whereas average yearly precipitation was 1250 mm and 1260mm by CSIRO model and 1300mm and 1300mm by MIRCO model respectively.*

Keywords: *Global climate model, precipitation, CSIRO, MIROC.*

1. INTRODUCTION

Global climate change has always been a major concern, but now this has gained momentum as the climate change is happening at a rate that is unprecedented over decades to millennia. The concern is grave also because most of it (greater than 95% probability) is due to the human activities.

Planet's average temperature has risen about 1.1^{0}C since the late 19th century with most of the warming occurring in the past 35 years, largely due to carbon dioxide and man-made emissions. Much of this heat is being absorbed by the oceans which resulted in warming of the top 700 m of the ocean surface by 0.302 ^{0}F. Satellite observations show that the snow cover in the Northern Hemisphere has decreased in the past 50 years and the snow is melting at a faster rate. Global sea risen by 8 inches in the past 100 years, but the most striking fact is that in the past 20 years, it has risen to almost 16 inches.

Anthropogenic activities like deforestation, burning of fossil fuels has caused disruption of global carbon cycle which is one of the key issue for climate change. Atmospheric carbon dioxide concentration has been increasing causing global warming, changes in air temperature and rainfall patterns. Thing change could affect river flows, mobility, chemical reaction kinetics and hence dilution and transportation of the contaminants, combined with the deterioration in the quality of the water. Apart from these, other effects include low flows, reduced flow velocities, higher water residence times in rivers and lakes will enhance the potential for toxic algal blooms, reduced dissolved oxygen levels in the river water. This climate change is projected to affect individual organisms, the size and structure of their populations, structure and functioning of ecosystems. There have also been evidences of extinction and migration of aquatic animals towards the poles.

Change in climate at an alarming rate and its severe implications have led to the need for predicting the future climatic conditions based on the statistical and mathematical model so as to take necessary measures beforehand to minimize the effects of climate change. So here we document the probable temperature and precipitation for the years 2046-2065 (future data) by using the data from the years 1981-2000 (raw data). Raw data was fed into two models, namely CSIRO-Mk (Commonwealth Scientific and Industrial Research Organization) and MIROC5 (Model for Interdisciplinary Research On Climate-Phase 5). Then we present the relative variations in the predictions of temperature and precipitation by both of these models by comparing theircorrelation coefficientvalues on yearly as well as monthly basis.

2. SITE LOCATION AND METHODOLOGY

Region of interest is the Brahmaputra river basin. The river originates from Kailash ranges of Himalayas and flows for about 2900 km through China, India and Bangladesh and finally joins Ganga. The rives has number of tributaries at its north and south banks, some of them are Jiadhal, Subansiri, Dhansiri, Debang, Krishnai etc. in north-east part of the country, the river flows in a highly braided channel, with average width varying from 6 to 18 km with some exceptions. Since the river is highly braided, its water level changes greatly both spatially as well as temporally. The average annual runoff of the river is 537.2 km^3.

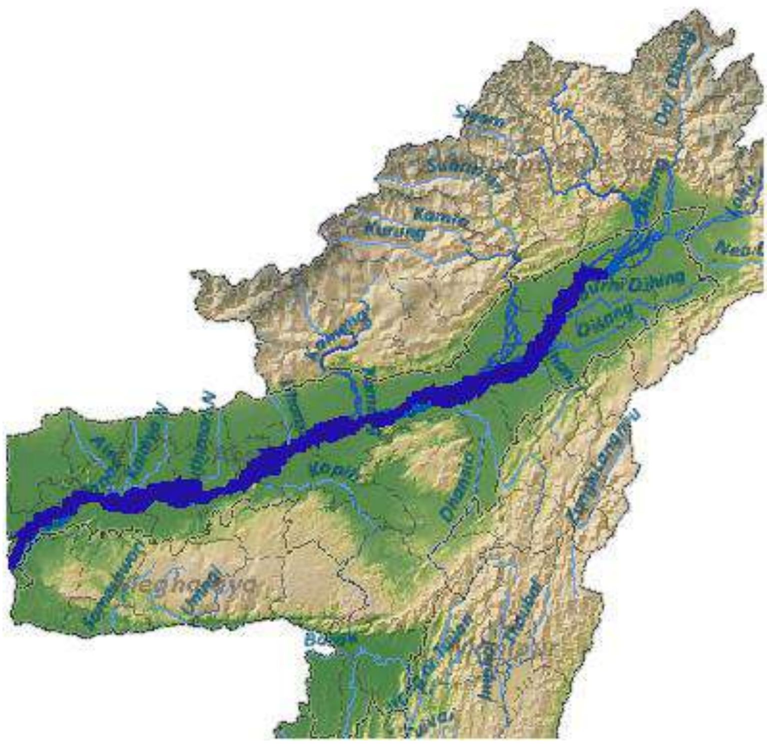

Figure1Brahmaputra River Basin Overview Map, Generated under India WRIS

The climate change prediction model can be predicted the climate characteristics of the region of interest. Two models were selected from the 61 climate change prediction models provided by Coupled Model Inter-comparison Project, Phase 5 (CMIP5) through Data Integration and Analysis System (DIAS). Specifically, the output data of the CMIP5 20th century reproduction test scenario (historical) and lattice data based on precipitation measurements created by the Global Precipitation Climatology Project (GPCP) are compared for the region of interest and a climate change prediction model with high reproducibility is selected.The reproducibility of each climate model is evaluated with regards to theaverage precipitation for 6 months from May to October of the wet weather season during 27 years from 1979 to 2005 (10N-30N, 70E-100E).Two proper models (CSIRO and MIROC5) are selected as the climate change prediction models with comprehensive comparing their correlation coefficient values with respect to the GPCP data.The entire methodology can be pictorially depicted by the following flowchart as shown in Fig. 1.The used output of the models are based on the representative concentration pathways' scenario as the radiative forcing of 6 W/m^2. This condition is considered as the global warmingeffect with atmospheric CO^2 increasing. The model output data were extracted from 1981 to 2000 during 20 years through the DIAS server. The 24*36 grids output of all precipitations in the target area (24N-30N, 88E-97E) were extracted with 0.25 degree resolution. Also the past reproduction data of air temperature (24*36 grids) was extracted with 0.25-degree resolution, but we could extract the air temperature (6*9 grids) for the future with coarse resolution of 1 degree.

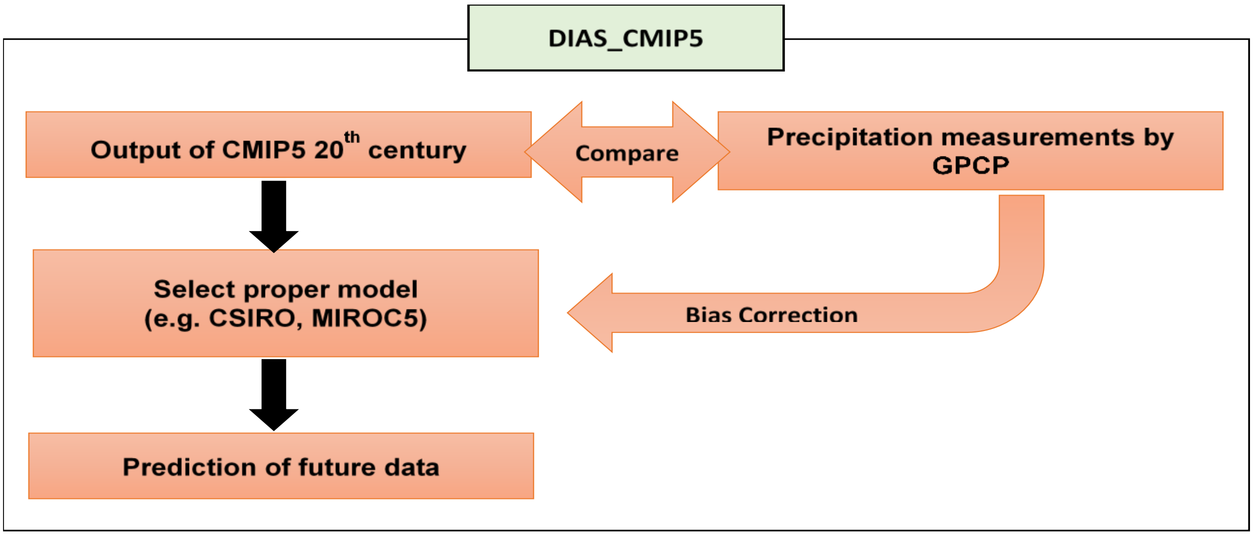

Figure 2Flowchart depicting the methodology of predicting the future temperature and precipitation

3. RESULTS AND DISCUSSION

3.1. Temperature prediction

Yearly temperature prediction by both the models showed increase in the temperature relative to the temperature of past years. However, prediction of the temperature by CSIRO model was comparatively higher than that predicted by MIROC model. Monthly temperature prediction also showed the same pattern for both the models. For CSIRO model, the temperature may rise as high as 38^0C (which month?) while for MIROC model it may reach to 32^0C.

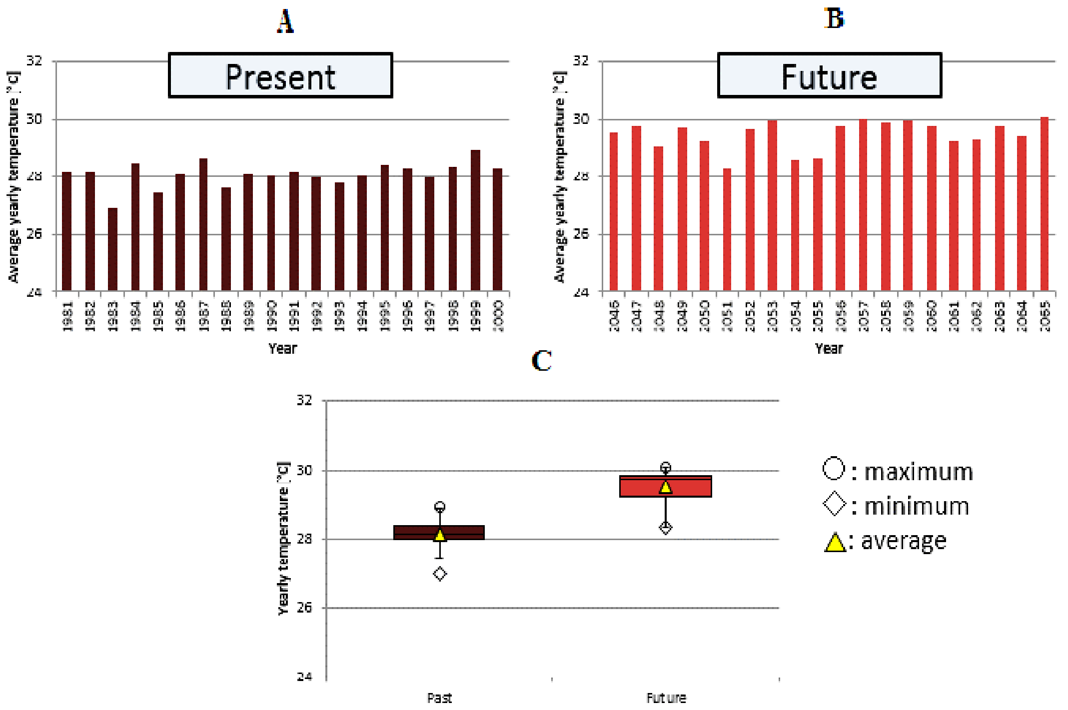

Figure 3: yearly temperature by CSIRO Model. A*)* **present yearly temperature** *(***1981-2000***)* **B***)* **future yearly temperature** *(***2046-2065***)* **C***)* **comparison of yearly data for present and future***.* **average temperature for the present case is 28^{0}C whereas for future it is 29.5^{0}C**

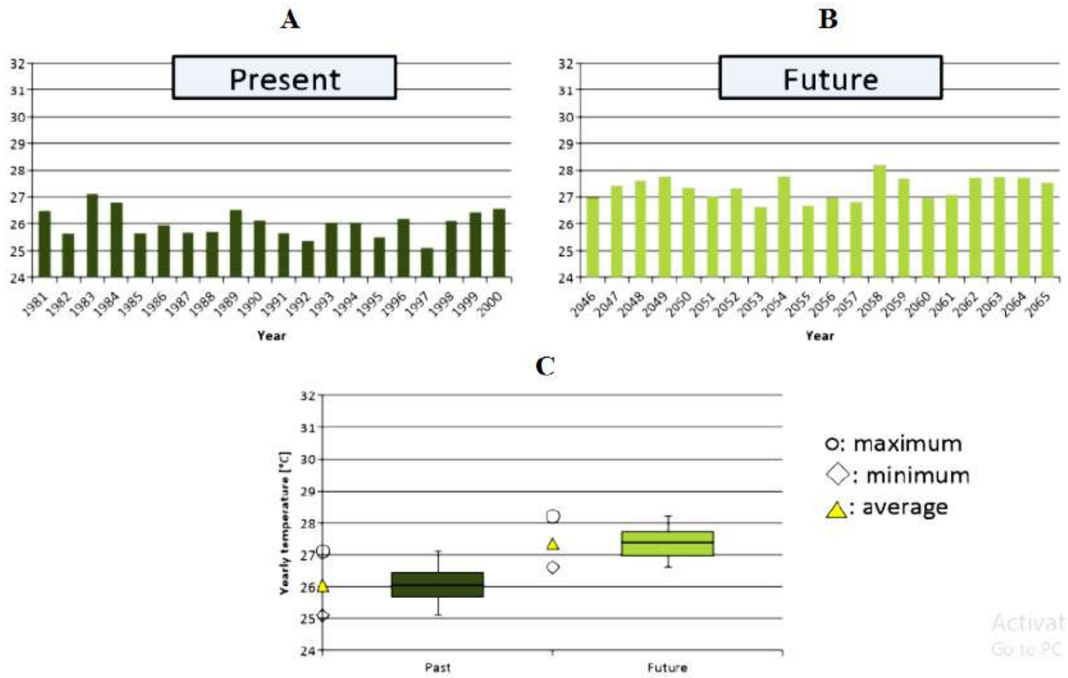

Figure 4: yearly temperature by MIROC Model*.* A*)* **present yearly temperature** *(***1981-2000***)* **B***)* **future yearly temperature** *(***2046-2065***)* **C***)* **comparison of yearly data for present and future***.* **average temperature for the present case is 26^{0}C whereas for future it is 27.4^{0}C***.* **temperature prediction by miroc model is lesser than that by CSIRO Model**

Fig. 2 (A) shows the temperature variation for the present years (1981-2000). It can be seen that except a few years, the yearly temperature is close to 28^{0}C. Minimum temperature recorded being 27^{0}C in the year 1983 and the maximum being around 29^{0}C in the year 1999. From fig 2 (B), it can be seen that

the temperature for the future years is predicted to increase, reaching a maximum of 30⁰C. For most of the years the annual temperature is close to 30⁰C. Fig 2(C) shows the comparison of both, the present year and the future year average, minimum and maximum yearly temperature. Maximum and minimum temperature for the present and future years are 29⁰c, 30⁰C and 27⁰C, 28.8⁰C respectively.
Fig.3 (A), (B), (C) show temperature variations for the years 1981-2000, 2046-2065, and comparison for both the set of years. In the years 1981-2000, the minimum and maximum temperature was 25⁰C and 27⁰C whereas for the years 2046-2065 these values were 26.5⁰C and 28.1⁰C. Clearly there has been an increase in temperature by approximately 1.5⁰C over 50-60 years of span. Temperature predicted by MIROC model is comparatively lesser than that predicted by CSIRO model.

3.2. Precipitation prediction

Precipitation prediction was carried out on yearly as well as monthly basis. Average precipitation by both the models for present and future cases was more or less same, being in the range 1200-1300 mm, but the magnitude of extreme events (floods and draughts) was different. Maximum and minimum precipitation by CSIRO model was 2000 mm and 800 mm (Fig.4), whereas by MIROC model, these values were 2000 mm and 750 mm (Fig.5). So yearly variation of precipitation is not much, but as far as monthly variation is concerned, there are quite a few variations (Fig.6). By CSIRO model, maximum monthly precipitation is decreased along with the number of rainfall months. The maximum precipitation for present years is 700 mm at September but for future years, its only 500 mm at June. MIROC model for monthly precipitation show somewhat different picture. According to this model, the maximum monthly precipitation for present as well as future years is more or less same, being equal to700 mm at July. Also the number of rainfall months remain the same.

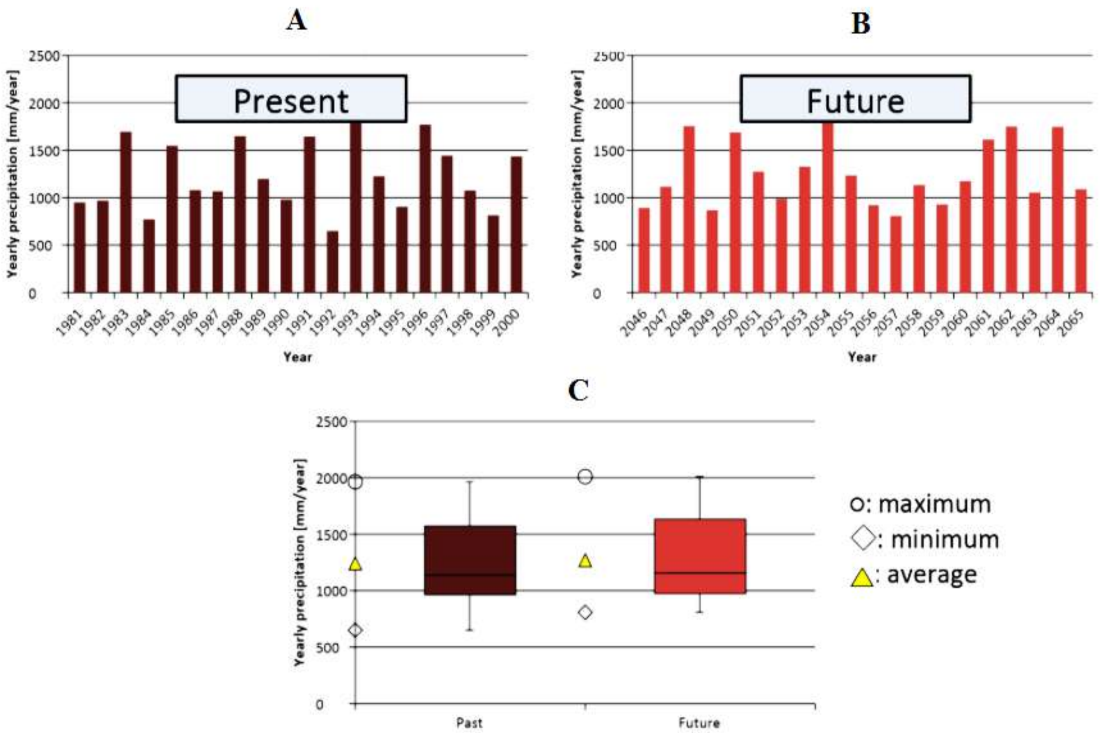

Figure5:Yearly Precipitation by CSIRO Model. A) Present Yearly Precipitation (1981-2000) B) Future Yearly Precipitation (2046-2065) C) Comparison of Yearly Data for Present and Future. Average Precipitation for the Present and Future Years is more or less same, 1200 mm.

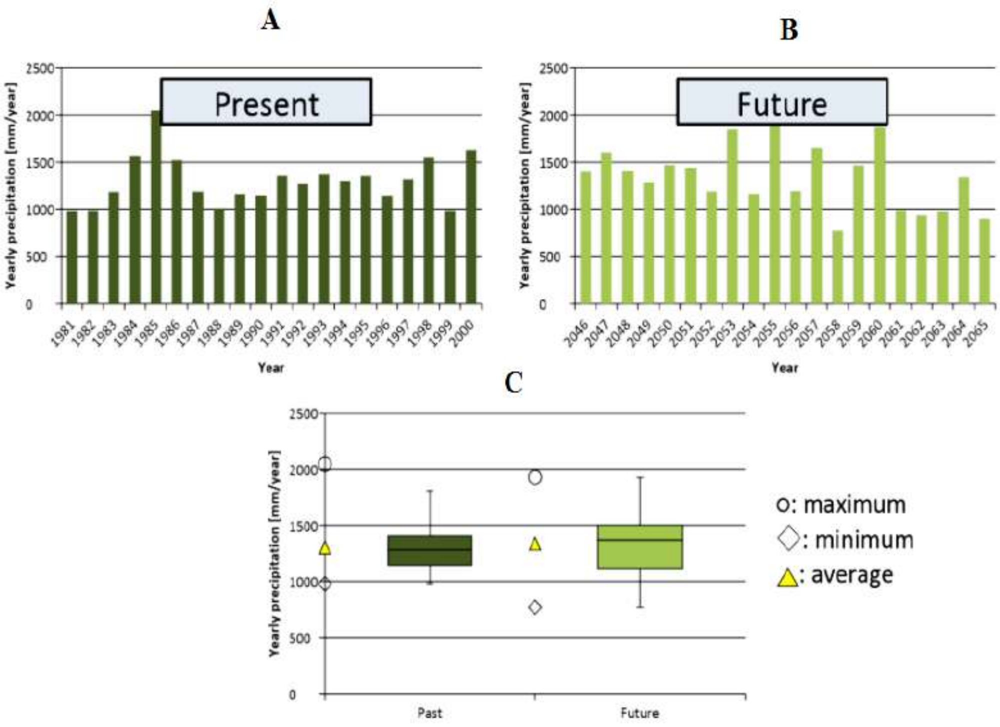

Figure6:Yearly Precipitation by MIROC Model. A) Present Yearly Precipitation (1981-2000) B) Future Yearly Precipitation (2046-2065) C) Comparison of Yearly Data for Present and Future. Average Precipitation for the Present and Future Years is more or less same, 1300 mm.

Table 1Table for comparison of predictions by different studies for the Brahmaputra basin

Paper	Data	Models	Predictions
Impact of climate change in floods in Brahmaputra basin using CMIP5 predictions (Present Study)	Observed daily rainfall data taken from APHRODITE website. GCM data obtained from CMIP5 data portal website.	BCC- CSM1-1 CanCM4 FGOALS-g2 IPSL-CM5a MRI-CGCM3	No significant changes in the total monsoon rainfall. Increase in the number of spells (storm events) with high intensity rainfall. Duration of very long flood waves will decrease in future.
Ghosh, S., Dutta,S., 2012. Impact of climate change on flord characteristics in Brahmaputra basin using a macro scale distributed hydrological model. J. Earth Syst. Sci. 121(3), 637-657.	RCM simulated rainfall	Macroscale distributed hydrologic model	The analysis predicted that although the number of flood events would decrease in future, the peak discharge and duration of flood would increase.

Gain, A.K, Immerzeel, W.W., Sperna Weiland, F.C., and Bierkens, M.F.P.: Impact of climate change on the stream flow of the lower Brahmaputra: trends in high and low flows based on discharge-weighted ensemble modelling, Hydrol. Earth Syst. Sci., 15, 1537-1545	Daily precipitation and data to calculate daily reference potential evaporation were collected from the data portal of the Program for Climate Model Diagnosis and Intercomparison (PCMDI)	Used discharge weighted ensemble model based on inputs from 12 GCMs. The output from these 12GCMs was forced into Global Hydrological Model PCR-GLOBWB	The study predicts a very strong increase in annual peak flow which may have severe impact on flood.
Mirza, M.M.Q., 2002, Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. Global Environ. Change 12,127-138.	Daily rainfall data was taken from APHRODITE website.	The output from 4 GCMs was forced into Global Hydrological Model.	The results predicted the substantial increase in mean peak discharge.
Climate change reproduction by Global Climate Model (Our study)	Global long term climate data of IPCC AR5	Output of IPCC AR5 is fed into two models namely, CSIRO-Mk and MIROC5	Predicted for the years 2046-2065. Both the models predicted increase in temperature for the above mentioned years. There is not much variation in the annual precipitation of the future years relative to present years.

Table 2 Table for specifications of the models

Model	Spatial Resolution	Temporal Resolution	Spatial correlation coefficient	Root Mean Square Error
CSIRO-Mk3.6	4.5 km mesh	1 hour	0.65	4
MIROC5	4.5 km mesh	1 hour	0.7	3.3

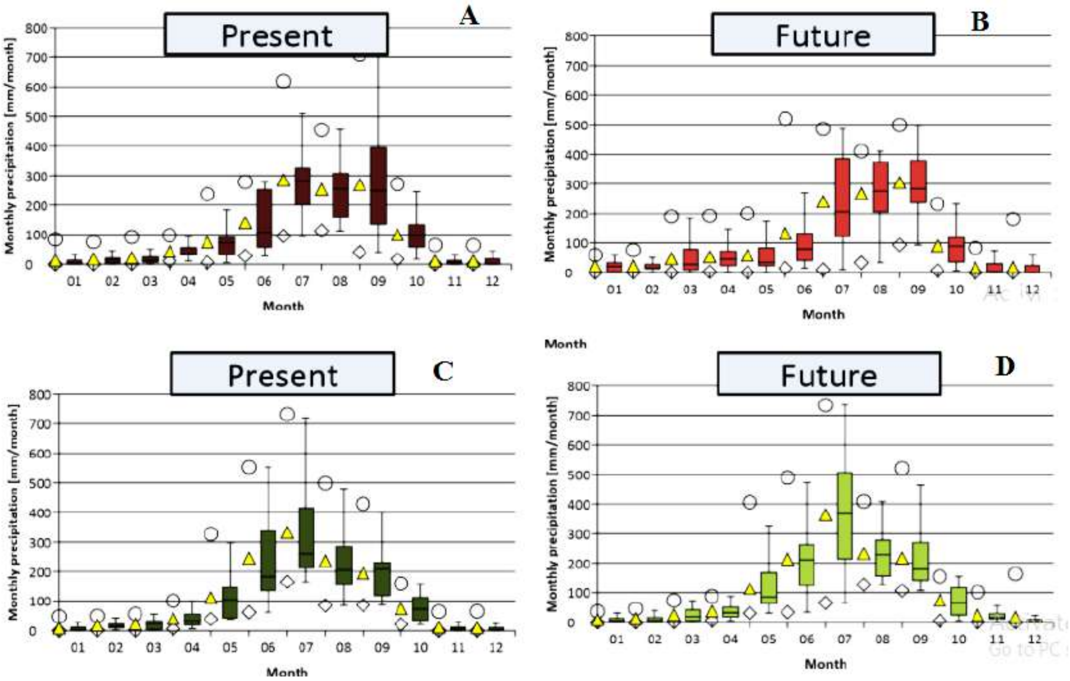

Figure 7: Monthly Precipitation by MIROC Model. A) & C) Present Monthly Precipitation (1981-2000) by CSIRO and MIROC model B) &D) Future Monthly Precipitation (2046-2065) by CSIRO and MIROC model. Precipitation Values by MIROC Model is more or less same but varies for CSIROModel.

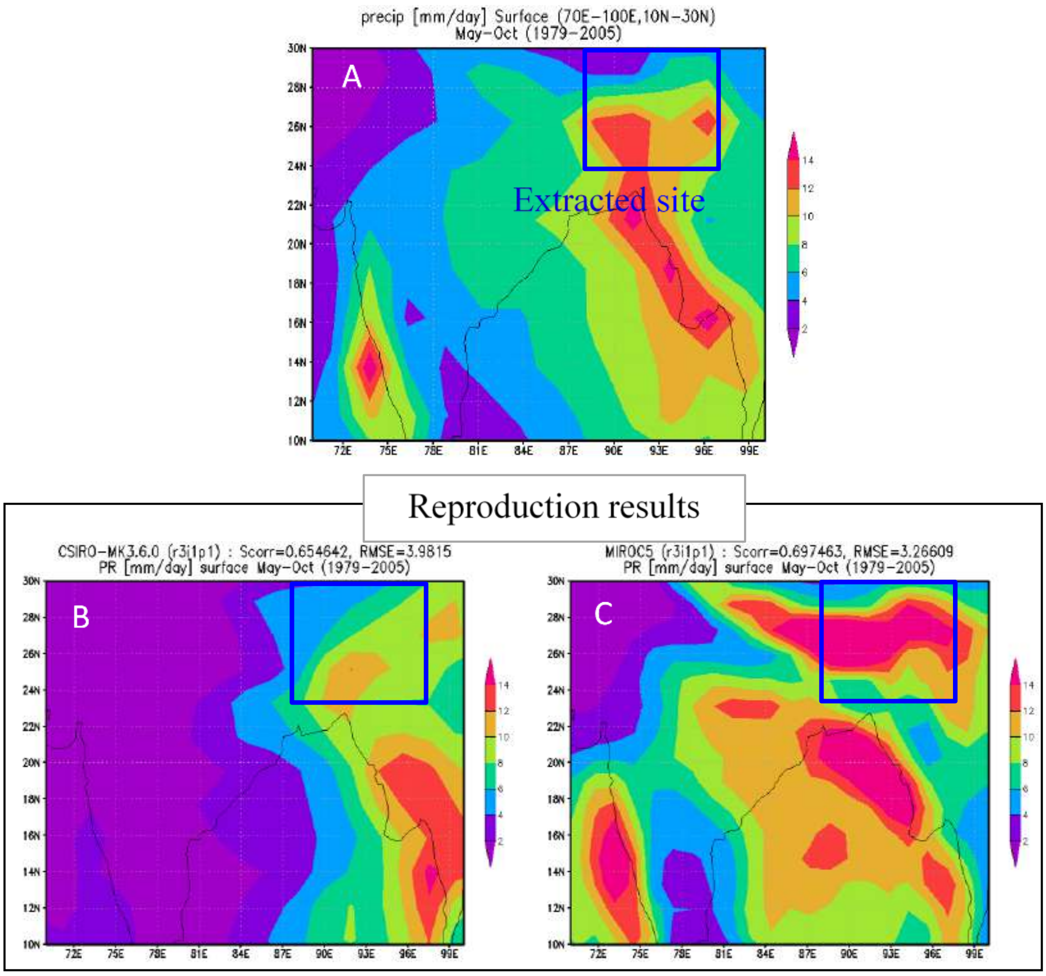

Figure 8: Pictorial Representation of Reproduction Data for the Brahmaputra Basin for the Years 1979-2005 by CSIRO and MIROC Models

4. CONCLUSION

Temperature and precipitation prediction for the future years (2046-2065) was carried out by using two mathematical models, namely CSIRO and MIROC. Results by CSIRO and MIROC5 differ. On determining their correlation coefficient, we find that MIROC5 have correlation coefficient higher (**0.7**) than CSIRO-Mk3.6 (**0.65**). The predicted values of temperature and precipitation by MIROC are comparatively more accurate than that by CSIRO. Also the Root Mean Square Errors of MIROC5 is **3.3** while for CSIRO, it is **4**. MIROC5 has significantly better reproducibility than CSIRO. The mean could property obtained from the sophisticated prognostic schemes in MIROC5 shows good agreement with satellite measurements. Climatological precipitation and SST have been improved in MIROC5 in several respects: more realistic zonal SST gradient on the equator, and topographically anchored precipitation associated with the Asian monsoon.

5. ACKNOWLEDGEMENT

This paper is funded by DST-JSPS Indo Japan project (2016-2018)

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Spatial Variability in Channel Processes and its Applications for River Management

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Abstract: *The sediment dynamics in a river channel is a fundamental process which governs the morphology and biodiversity of a river. The Narmada River, located in Central India is a tropical bedrock dominated river. It has been significantly affected by anthropogenic disturbances, which has resulted in flow reduction and silted channel reaches. A reach was defined as the channel stretch between two gauging stations. We carried out a systematic analysis of suspended sediment load data for the basin to identify the aggrading and degrading reaches along the main channel and assess the controlling factors. The erosion hotspots in the river basins were also mapped. The sediment yield of the main channel was the highest at the upstream-most station (25000 t/km^2/year) which decreased inversely with 0.48 power of the upstream area. The midstream reaches were characterized by spatial variability in processes with reaches showing significant degradation at aggradation along long profile. The aggradation pattern of these reaches will help to define policy framework for sandmining from the Narmada River. Spatial distribution of aggradation-degradation reaches is governed by geological and topographic variability in the river basin.*

Keywords: *Sediment yield, sediment budget, sediment mining, Narmada River, central India.*

1. INTRODUCTION

The study of sediment dynamics of a river system provides conceptual knowledge of downstream morphological changes in response to adischarge, sediment supply, grain size variations (Schumm, 1977). Sediment Yield (SY) is widely used to quantify the sediment flux in a river basin. The SY is a proxy for the amount of hillslope erosion within its upstream reaches, deposition in the flood plains and the transport capacity of the channel, and thus an indicator of theriver reach morphology and biodiversity (Mossa, 1996). Thus, an understanding of discharge and sediment dynamics is required to undertake river management and restoration measure to maintain the river health (Norris & Thoms, 1999).

This manuscript provides a systematic analysis of sediment dynamics in the Narmada River basin, Western India to identify the dominant processes at reach scale and to identify the hotspots of erosion processes. Further, a framework for sustainable river management along the river is determined. The Narmada river channel is highly affected by severe sand mining especially in the downstream of the various dams. Since the downstream reaches of dams are already sediment starved due to siltation in the upstream reservoir, further uncontrolled dredging of sediment may be unsustainable for the natural functioning river and for supporting ecosystem. Hence there is a need for understanding the sediment dynamics in terms of sediment budgeting for sustainable river management.

2. STUDY AREA

The Narmada River basin is a 1312 km long river draining a catchment of 98,987 km^2 (Fig. 1). It originates at an elevation of 1057 m and flows through a rift valley alternating between bedrock gorges and patches of alluvium (in its downstream reaches) (Kale et al., 1994, Maurya et al., 1995).There is marked seasonality in the river flow, with 50% to 80% of discharge occurring in the monsoon period(Gupta and Chakrapani, 2007).The average rainfall in the basin is 110 cm (Rajaguru et al., 1995); with an annual variability between 80 and 160 cm (Gupta & Chakrapani, 2007).

3. DATA AND METHODOLOGY

Flow data and suspended sediment concentration for 12 stations (eight along themain channel and four along tributaries) were obtained from the CWC archives (Fig. 1). Data was available for the period between years 1987 to 2015. The sediment concentration data was available only for the monsoon months. Stations along the trunk stream were indexed from upstream to downstream as N1 to N8, and tributary stations were marked as T1 to T4. Segments of the channel between two consecutive stations were defined as a reach.

The daily sediment load at a station was estimated as the product of daily discharge and sediment concentration data. Further, the total annual sediment load at a station was divided by the upstream area to obtain the sediment yield. The sediment storage within different reaches along long profile was estimated based on the mass conservation principle. Thus, the net storage at a reach was taken as the difference between total annual sediment load between its downstream and upstream station. Reaches with negative storage were considered as erosion dominated, while those having surplus storage of sediments were considered deposition dominated. The reaches with negligible net sediment accumulation were defined as transfer reaches. The deposition dominated reaches were considered suitable for sediment mining up to the limit of 50% of the excess sediment storage within that reach.

4. RESULTS AND DISCUSSION

4.1. Spatial variability in erosion processes at basin scale

The annual sediment flux of the Narmada River basin to the ocean for the study period (1987-2015) was 2900 t/km^2/yr. This value is twice the value of annual yield reported by Milliman & Syvitski (1992) (1400 t/km^2/yr).Milliman & Syvitski (1992) gave this estimate based on regression analysis of global dataset for basin area and maximum elevation, which is an indirect method of SY estimation and does not take into account other controlling factors like discharge and sediment concentration. Our SY estimates are based on daily observed discharge and sediment concentration data for a long-term (29 years) period, which represents the impact of basin characteristics on erosion processes.

The SY of the Narmada River decreases downstream by a factor of 0.48 with respect to the upstream basin area. A power law relationship between sediment yield (SY) and upstream drainage area with exponent explained 48% of the variability in SY. The sediment yield of Narmada River basin was highest at the upstream-most station (25,000 t/km^2/yr) and ranged between 15,000 to 20,000 t/km^2/yr for midstream stations and was lowest at the downstream-most station (~2,000 t/km^2/yr). Such high values of sediment yield in the upstream reaches could be attributed to the erodible basaltic lithology with hillslopes as steep as 0.06 m/m. Additionally, high discharge values during the monsoon season further provide high sediment erosion and transportation capacity to the river (Dendy & Bolton, 1976; Gupta and Chakrapani, 2007).The upstream reach and few midstream reachesare dominated by erosion processes (Fig. 1). These sites should be the focus of erosion control measures.

4.2. Aggradation-degradation reaches

We observed an increase in the sediment accumulation with respect to the increase in drainage area, except few reaches at upstream reaches. The dominance of erosion processes in the upstream reachesof the basin can be attributed to steep bedrock channels in the upstream part of the Narmada River basin. We mapped spatial variability in aggradation-degradation processes. Midstream reaches arecharacterized by negative value of sediment budget(Fig. 2).While the midstream appears to be the sediment transfer zones because of high sediment discharge from tributaries. The lower reaches had a depositional environment due to low slopes, resulting in lower transport capacity of the river.

5. CONCLUSION

The process-based understanding at high spatial resolution aids in determining the sources and sinks of sediments in a river system. The suspended sediment output from a basin represents a complex interaction of sediment supply, it'smobilizationand reworking within the river basin. Sediment budget analysis based on daily discharge and sediment concentration data for the Narmada River basin suggests that the upstream reaches are erosion dominated with high rate sediment erosion (~ 20,000 $t/km^2/yr$). These reaches had negative sediment storage by 300 Mt compared to upstream. The deposition dominated downstream reaches had a surplus supply of sediment by 350 Mt compared to upstream. These reaches could be planned for controlled sediment mining for urban growth. We recommend the limit to sediment mining as 50% of the surplus storage based on our analysis. Erosion hotspot areas should be planned with suitable remedial measured including soil stabilization and vegetation growth.

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Evaluation of Groundwater Quality with Emphasis on Arsenic and Fluoride Concentration in Guwahati: Economic Hub of Northeast India

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Abstract: *The present work focuses on the evaluation of groundwater for drinking purpose in relation to Arsenic (As) and Fluoride (F^-) contamination. 17 groundwater samples were collected and analysed for major ions, As, F^-, and Fe. Hierarchical cluster analysis (HCA) suggested reductive dissolution of Fe (hydr)oxides responsible for As release in the area. Association of Fluoride (F^-) with both phosphate as well as silicate minerals in the post-monsoon season revels that released of F^- from both phosphates as well silicate minerals like apatite and phyllosilicates respectively. Arsenic concentration appears to be dependent on depth in both the seasons. Non-cancer health risk from both As-F^- was highest in children, followed by adult males and females. Hazard indices (HI) revealed that children (3-8 years) were at greater health risk than adults. Thus, the new generation seems to be at higher risk.*

Keywords: *Arsenic, fluoride, groundwater, health risk assessment, Guwahati.*

1. INTRODUCTION

Groundwater is one of the most exploited natural resources on the planet because of its inherent advantages over surface water, which include comparatively higher purity, lesser evaporation losses and a wider distribution. Naturally it replaces by surface water from rivers seepage, surface infiltration due to precipitation, stream and lake. Groundwater in urban areas can suffer from many kinds of contamination from both natural and anthropogenic sources. The presence of contaminants in groundwater is an important issue because it affects possible uses of water. Among contaminants from natural sources, arsenic and fluoride are the most serious. Origin of Arsenic (As) and fluoride (F-) in groundwater are mainly of geogenic (Amini et al., 2008). Mineral, which has been the cause of As release into the groundwater, are arsenopyrite, scorodite, orpiment, and realgar(Kim et al., 2003; Smedley and Kinniburgh, 2002) where as fluorapatite, hydroxyapatite, fluorspar and cryolite are some of the mineral, which release F^- into the groundwater. Depending on the chemical composition of the groundwater and environmental condition of the aquifer, there are different process which governs the release of As and F^- into the groundwater. Health risk assessment due to the consumption of As contaminated groundwater has shown that the effects are mostly visible in younger age groups of the population like children (3-8 years old) (Kumar et al., 2017). Arsenic can lead to many complications apart from acute toxicity and cancer risk, while drinking F^- contaminated water leads to fluorosis, but in some cases, it can effect mental behaviour and brain growth in children (Wang et al., 2007).

In India, about 30 % of the urban population and 90 % of the rural population use groundwater for household purposes (Bhattacharyaet al. 2014). Deterioration of groundwater quality has been a major reason of concern in all the developing cities with Guwahati as no exclusion in this regard. Spite of being situated on the bank of the river Brahmaputra, it depends heavily on groundwater resource for its water requirements. 69.90% of the households in the city use groundwater, while 27% depend on municipality water supply and the rest on surface water obtained mostly from streams (Das and Goswami, 2013). Therefore, this study has been undertaken with the following objectives-assessment of water quality for drinking purpose, identification of hydrogeochemical process governing groundwater quality and primary Health Risk Assessment caused due to consumption of As and F- contaminated water.

2. Material and methods

Guwahati is located in the Kamrup (Municipal) district of Assam, latitude 26°10'45" N and 91°45'0" E longitudes on the southern bank of the river Brahmaputra with an area of about 216 sq. kms. A total of 17 groundwater samples were collected during pre-monsoon season, June 2014 and post-monsoon season, January 2015**.** The standard methods prescribed by the American public health association (APHA, 1998) were used for all the hydrochemical analyses. Fluoride was measured using Thermoscientific Orion STARA 214. Arsenic was analysed using Atomic Absorption Spectroscopy (AAS, Thermoscientific ICE 3000). Electrical conductivity (EC), pH, and total dissolved solids (TDS) were measured onsite using a multi-parameter probe (HANNA HI9828). A preliminary health risk analysis was conducted following USEPA 1989 guidelines to evaluate cancer and non-cancer health risks among inhabitants exposed to As and F^- contaminated drinking water. Non-cancer health hazards for As and F^- in groundwater were calculated from the CDI and reference dose (R_fD) (USEPA (United States Environmental Protection Agency), 2002). The population was categorized into three groups: children (3-8 years old) and adults male and female (>19 years old). Average body weights were 10, 70 and 58 kg for children, adult males and females, respectively (USEPA, 2002). Chronic daily intake (CDI, mg/kg weight/day) of As and F^- was determined assuming consumption of 1.7, 3.7 and 2.7 L of water per day by children, adult males and females, respectively(BOARD, 2005; Grandjean, 2004)

$$HI = CDI/R_f\ D$$

Reference dose for As and F^- is 3×10^{-4} and 0.06 mg/kg body weight/day (USEPA, 2012). The accuracy of the analytical methods was checked by calculating the inorganic chargebalance, which is:

$$\text{Inorganic charge balance} = \frac{Tz^{+} - Tz^{-}}{Tz^{+} + Tz^{-}}$$

Inorganic charge balance where $Tz+$ and $Tz-$are total cations and total anions respectively (Kumar et al., 2006). The charge balance of the data is within5%.

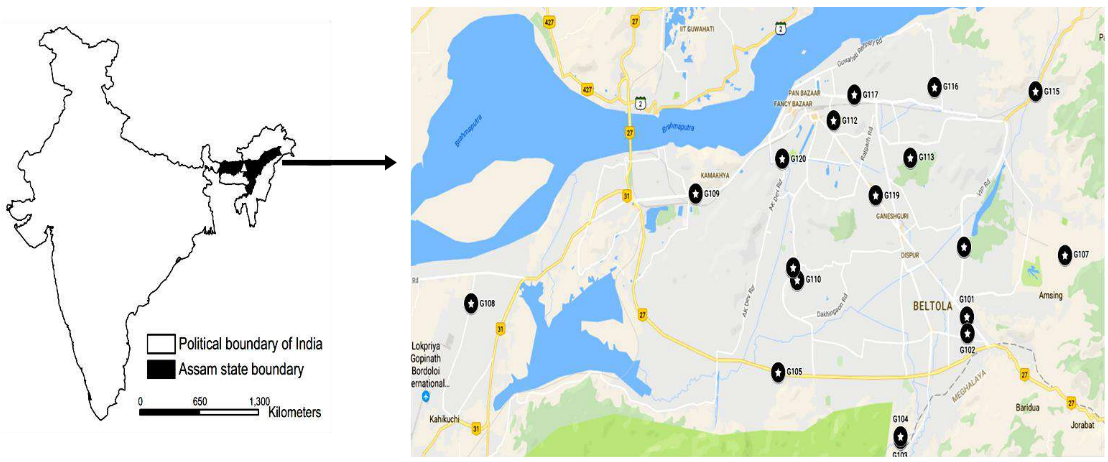

Figure 1:Map showing sampling locations of Guwahati

2.1. Results and discussion

The range average and standard deviationvalues for each water quality parameter analysed for both the pre and post-monsoon seasons is been presentedin **Table1**. The pH of the analysed sample varies from 6.88 to 8.09 with a mean value of 7.42 in pre-monsoon and in post-monsoon 7.48 to 8.22 with a mean value 7.88, pH of groundwater samples is alkaline in nature. Increasing value of pH in the post-monsoon indicates that dissolution has been enhanced due to thehigh interaction between soil and rainwater(Subramanian and Saxena, 1983). The EC value varies from 171 to 1078 µS/cm with a mean value of 472.71 in pre-monsoon and 148.70 to 819 µS/cm in post-monsoon with average value 220.65. The higher average value of EC in the pre-monsoon indicates that the enrichment of salt due to evaporation effect in the pre-monsoon followed by subsequent dilution through rainwater (Kumar et al., 2007). The total dissolved solids (TDS) varied from 84 to 487 mg/L with an average of 220 mg/L in pre-monsoon and 104.50 to 745 with an average value 220.65. HCO_3^- is slightly higher in the pre-monsoon period (400 mg/L) indicating the contribution from carbonate weathering process (Kumar et al., 2007). Low HCO_3^-concentration in the post-monsoon season may be due to the precipitation of HCO_3^-along with other cations (Kumar et al., 2010). Higher concentration of SO_4^{2-} was found in pre-monsoon indicates theaddition of sulphate by the breakdown of organic substances of weathered soils, sulphate leaching, from fertilizers and other human influences(Craig and Anderson, 1979; Miller, 1979; Singh, 2004). The concentration of chloride in the pre-monsoon is higher than that in post-monsoon, which is perhaps due to the rising water table in the pre-monsoon periods which dissolves more salts from the soils (Ballukraya, PN, 1999). PO_4^{3-} concentration is low in both the season with an average value 0.04 and 0.09 mg/l in pre and post-monsoon. Low concentration may be because of phosphate adsorption by soils as well as its limiting factor nature due to which whatever PO_4^{3-} is applied to the agricultural field is used up by the plants (Kumar et al., 2007). NO^{3-} in ground water generally originates from non-point sources such as leaching of chemical fertilizers & animal manure, ground water pollution from septic and sewage discharges etc. (Singh, 2010). In the study area NO^{3-} concentration is low in both the season. SiO_2concentration is higher in post-monsoon it may be due to silicate weathering in the area.

Table 1 Descriptive statistics for pre and post-monsoon season. All units are in mg L^{-1}, except EC Depth and As, which have been expressed in µScm^{-1}, feet and mg/L respectively. BDL stands for "Below Detection Limit"

Parameter	Pre-monsoon		Post-monsoon	
	Range	Avg±StdDev	Range	Avg±StdDev
Depth	24-900	161±219.43	24-900	161±219.43
pH	6.88-8.09	7.42±0.33	7.48-8.22	7.88±0.2
EC	171-1078	472.71±269.53	148.7-819	373.92±192.91
TDS	84-487	220.06±124.93	104.5-745	220.65±161.99
HCO_3^-	50-400	172.12±82.39	80-205	150.35±33.24
Na^+	0.50-42.57	15.38±13.32	50-112.45	82.78±16.77
K^+	0.32-16.38	2.42±3.82	0.36-3.15	1.47±0.78
Ca^{2+}	13.30-43	24.95±10.51	2.21-40	14.07±10.27
Mg^{2+}	0-57.54	19.41±15.17	0.35-4.65	4.1±0.98
Cl^-	42.60-319.5	136.57±89.05	42-153.36	83.84±30.27
PO_4^{3-}	0.01-0.08	0.04±0.02	0.03-0.3	0.09±0.06
SO_4^{2-}	4.78-80.22	23.99±26.58	8.64-53.36	18.85±13.34
NO_3^-	0.01-3.69	0.63±1.11	0.01-3.69	0.34±0.88
SiO_2	15.53-39.47	28.36±7.51	17.12-54.18	34.39±9.48
Fe	BDL-0.10	0.01±0.03	0.38-7.53	1.97±2.19
As	0.12-2.75	0.57±0.66	0.71-6.05	1.87±1.31
F	0.12-2.13	0.55±0.49	0.11-2.06	0.529±0.44

The existence of alkaline environment enhances the solubility of silica and it reveals thesecondary impact of silicate weathering (Kumar et al., 2007). The concentration of cations is in the order of Ca> Mg> Na>K in pre-monsoon and calcium concentration varies from 12.60 mg/l to 25.88 mg/l, magnesium from 0.01 mg/l to 24.66 mg/l, sodium from 0.50mg/l to 17.49 mg/l and potassium from 0.32mg/l to 2.71 mg/l in pre-monsoon season. For the post-monsoon season, the order is Na> Ca > Mg> K. In general weathering, dissolution and base-exchange processes control the levels of cationic concentrations in

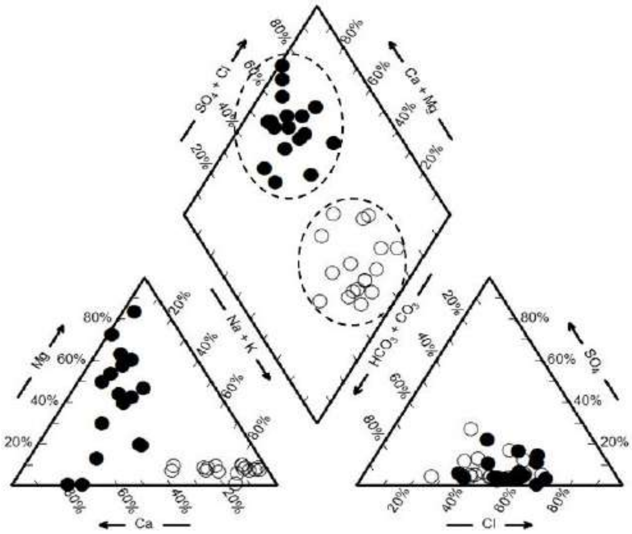

Figure 2:Piper Diagram for Pre (Black Dots) and Post-Monsoon (Blank Dots)

groundwater (Saikia et al., 2011). The variation in Ca^{2+} in pre and post-monsoon (i.e. 25.88 to 14.60 mg/l) may be due to the weathering of carbonates and plagioclase feldspar minerals (Bhattacharya et al., 1997). The concentration of As is in the range of 0.12-2.75 in pre and 0.71-6.05 in the post-monsoon season, which is below the permissible limit (<10 μgL^{-1}) of WHO 2008. However, the concentration of F^- is in the range of 0.12-2.13 in pre and 0.11 and 2.06 in post-monsoon, which is above the permissible limit (> 1.5 mgL^{-1}) of WHO in both the seasons. Looking into the individual samples for F^- concentration it has been found that only one sample exceeds the concentration of WHO whereas all other samples are within the range and fit for drinking and other activity purpose.

Piper diagram (Piper, 1944) can be utilized to determine the water types. It can be observed from (Fig: 2) that there is a clear indication of recharge during the post-monsoon season. In the pre-monsoon season, the water type is mainly Ca-Cl-SO_4 and Ca-Mg-Cl-SO_4. In post-monsoon season, silicate weathering becomes dominant as the water type becomes primarily Ca-Na-HCO_3 and Na-Cl-SO_4type.

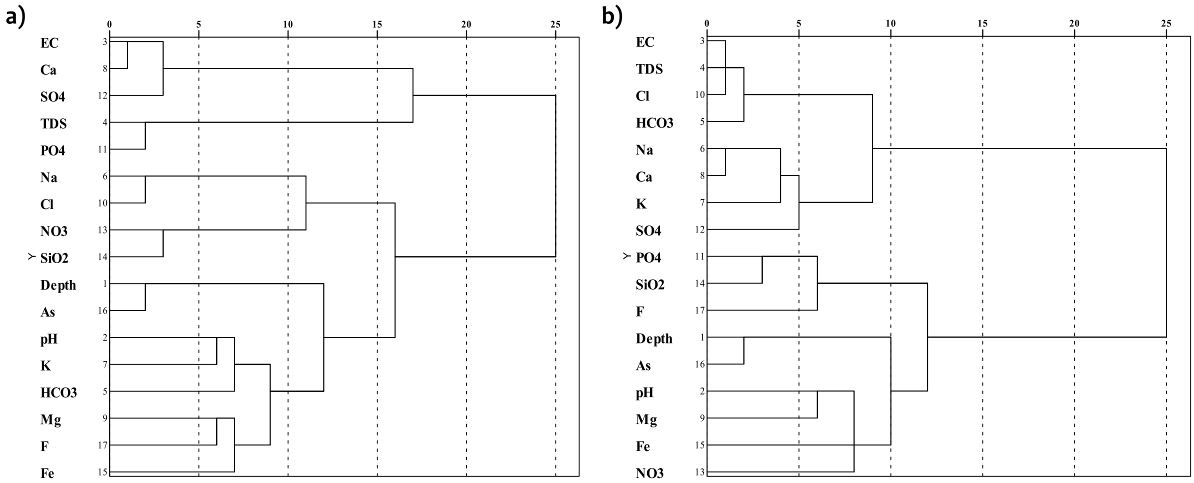

Figure 3: Dendrogram Showing the Clusters of Different Water Quality Parameters during a) Pre-monsoon and b) Post-monsoon of the Study Area

Bicarbonate ions may compete with F^- oxyanions sorbed on Fe (hydr)oxides (fig. 3a) under conditions of higher pH because of decrease in number of adsorption sites, as shown in the dendrogram. Arsenicmay also compete for the same adsorption sites on the Fe (hydr)oxides, while the entire process is governed to a large extend by pH. Release of As appears to be depth dependent in both the seasons. Fluoride appears to be released from both phosphates as well as silicate minerals like apatite and phyllosilicates respectively in the post-monsoon season. Fe and F^- are clustered close to each other during the post-monsoon which proves that F^- is released secondarily from Fe (hydr)oxides. During the pre-monsoon, PO_4^{3-} and TDS are clustered together because PO_4^{3-} from detergents etc. are mobilized during the pre-monsoon, while the influx of rainwater leads to an elevation in weathering and dissolution. In both the seasons reductive dissolution of Fe (hydr)oxides is the governing mechanism of As release

Table 2 Non-carcinogenic Hazard Index (HI) for children and adults in the Guwahati City

Percentage (%) of Non carcinogenic Hazard Index (HI) exceeding value 1			
HI	Children	Adult (F)	Adult (M)
Arsenic	Post-monsoon		
≥1	35	6	12
Fluoride			
≥1	71	24	35
	Pre-monsoon		
Arsenic			
≥1	18	0	0
Fluoride			
≥1	82	24	35

In our study, children are more susceptible to F^- 82% in pre and 71% in post-monsoon seasons. Because of their more water intake to body weight ratio, compared to adult male and female, which led to higher chances of dental fluorosis. In the case of As also children are in risk as compared to adults due to the same reason. Overall, health risk due to the consumption of F^- contaminated drinking water is more in Guwahati than As and children are at high risk.

3. CONCLUSIONS

- In some places, groundwater of Guwahati is not suitable for drinking which shows As is within the limit but F^- exceeds the limit of WHO for drinking water.
- The water type I mainly Ca-Mg-Cl-SO_4in pre-monsoon and Ca-Na-Cl-SO_4type in the post-monsoon season. Release of F^- is probably influence by increase in pH with increase in alkalinity and competes with HCO_3^- for adsorption sites. In both the seasons reductive dissolution of Fe (hydr)oxides is the governing mechanism of As release
- Non-cancer health risk from both As and F_was also highest in children, followed by adult males and females. Aquifer depth appeared to have an important influence on As and F_-related health risks in the BFP.

4. ACKNOWLEDGEMENTS

This work was funded by SERB- DST Govt. of India to Dr. Manish Kumar (SR/TP/ES-32/2012) under the Fast Track Young Scientist Scheme awarded.

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Microplastic and Heavy Evaluation in the Riverbed Sediment of the Sabarmati River Gujarat, India and the Kelani River Sri Lanka

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Abstract: *This study is about the microplastics under the field conditions at four locations along Sabarmati river in India and two locations along Kelani river in SriLanka. The experiments were performed to estimate the amount of microplastic pollution dynamics in the sediments and its relation with sediment texture, grain size, heavy metal, organic matter. Microplastic concentration of both the sizes (75-212µm& 212µm-4mm) is found higher at the downstream sites. The microplastics are higher in Sabarmati river than inKelani river.*

Keywords: *Microplastic, heavy metal, riverbed sediment, Sabarmati, Kelani.*

1. Introduction

Surface water is used for the drinking purpose all over the world but the recent studies show that contaminant concentration in the water has increased. There are various new contaminants introduced due to urbanisation, industrialisation like heavy metals, Biochemical oxygen demand nutrient. Also, some of emerging pollutants like pharmaceutical and personal care products. Recently microplastics are great concern for study because the use of plastics has increased in different sectors like in transportation, telecommunications, clothing, footwear etc. The production of plastics has increased to 260 Mt/year in the 21th Century (Europe, 2013). It's also bring attention for future application novel medical applications, in the generation of renewable energy and by reducing energy used in transport (Andrady & Neal 2009). The sources of microplastic in river water are improper waste disposal, insufficient waste management, and urban runoffs,(Barnes et al 2009) microplastics in washing machine effluent from synthetic textiles. These are not removed by treatment plant due to small size and buoyancy (Browne et al 2011).This study aims to estimate the amount of microplastics in the sediments. The relation with sediment texture/ grain size, heavy metal, organic matter. Sabarmati river in India and Kelani in SriLanka were chosen for sampling as both are tropical developing countries and the possibility of finding organic matter and microplastics is high because of improper waste dumping practices in both the countries.

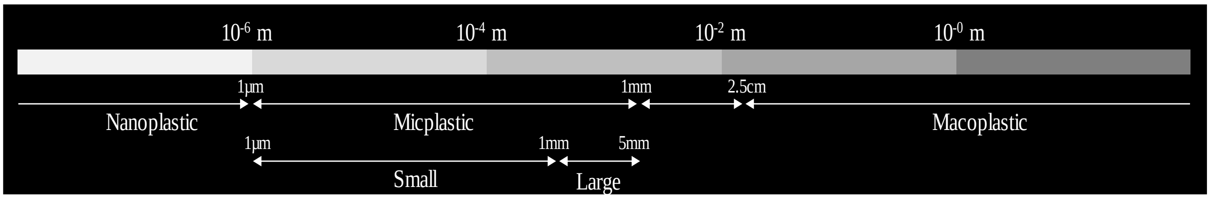

Figure 1Nomencluture of plastic debris based on size (**MSFD GES Technical Subgroup on Marine Litter, 2013**)

2. Study area

The study was conducted in the river of two different countries Kelani River, Colombo, Sri Lanka and Sabarmati, Gujarat, India in the month of June, 2017. Four river sites from Sabarmati and two river sites of Kelani were collected.

Figure 2: Map showing Sampling locations A) Kelani River, Colombo, Sri Lanka B) Sabarmati River, Gujarat, India

2. Methodology

River samples were collected and analysed for heavy metal by APHA 2005, microplastic by Nel et al 2018 and klein et al. 2016, grain size distribution by dry sieving and organic matter content by loss of ignition test according to Konare et.al 2010.

3. Results and discussion

3.1 Sediment grain size analysis of Sabarmati and Kelani river

The samples of Sabarmati River sediments were containing Sandy Gravel, Gravelly Sand and Slightly Gravelly Sand. Cations derived from mineral weathering and pollution sources are preferentially adsorbed onto clay (negatively charged surface), which has the highest surface area to volume ratio of any particle size class. This suggests that since there is least clay fraction, therefore the probability of finding the pollutants in labile forms is maximum thus posing higher risk of exposure.

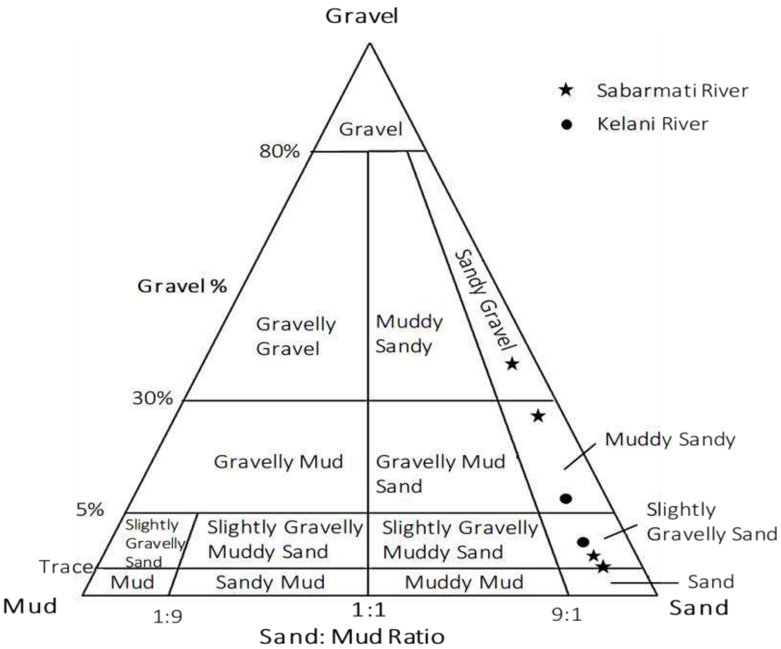

Figure 3:Composition of the two Riverbed sediment based on their grain size

3.2 Organic matter in rivers

Organic matter (Humus) has the ability to interact with metal ions, oxides, hydroxides, mineral and organic compounds, including toxic pollutants, to form water-soluble and water-insoluble complexes. Through the formation of these complexes, humic substances can dissolve, mobilize and transport metals and organics in soils and waters, or accumulate in certain soil horizons. Accumulation of such complexes can contribute to reduction in toxicity. The organic matter content is found more in Kelani river than in Sabarmati river.

3.3 Heavy metals

Higher metal concentration is seen at upstream site suggesting closer proximity to source. Copper and Iron concentration are higher as compared to Selenium and Nickel (more toxic). Metal distribution trends in both the river are same: **Fe>Cu>Ni>Se**. The Copper compounds are widely used in agriculture and are a possible source of drainage anomalies. Positive trend is seen in case of Se and Ni with Organic matter while negative trend with Cu and Fe in Sabarmati River. Since Cu and Fe are present in higher concentration therefore it suggests that these metals underwent desorption from the complexed surface. Organic matter is showing positive trend with Ni and negative trend with Fe, Cu and Se in Kelani River.

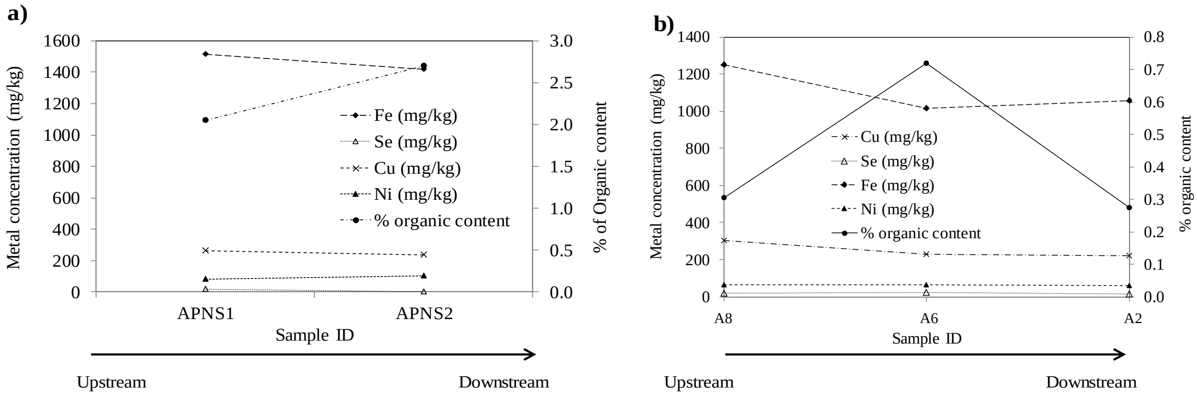

Figure 4: Scattered plot showing the heavy metal concentration in different sampling location

3.4 Microplastics

Microplastic concentration of both the sizes (75-212µm & 212µm-4mm) is found higher at the downstream site. The microplastic is higher in Sabarmati river than in of Kelani river.

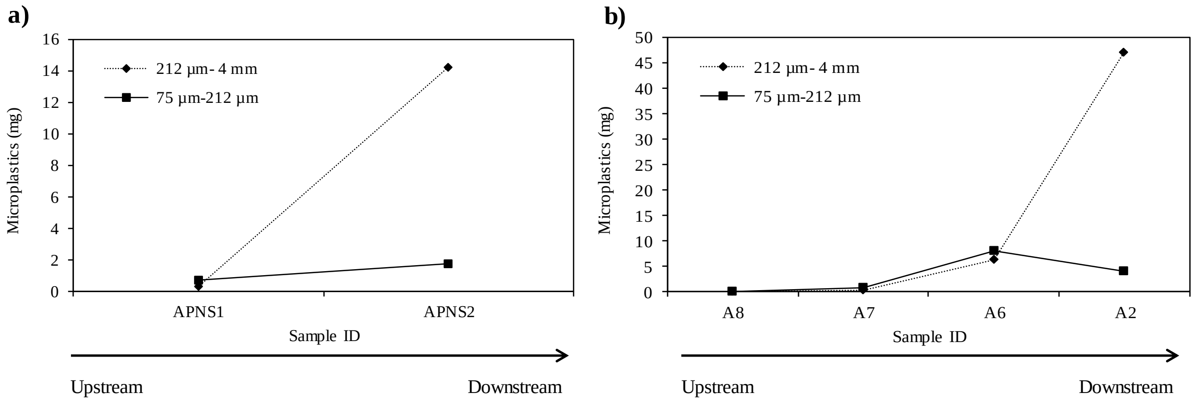

Figure 5: Scattered plot showing the microplastic concentration in different sampling location

6. 4. Conclusion

The Sediment grain size distribution of Sabarmati and Kelani River are Sandy Gravel, Gravelly Sand and Slightly Gravelly Sand suggesting least clay fraction and therefore the probability of finding the pollutants in labile forms is maximum thus posing higher risk of exposure.Metal distribution trends in both the rivers are same:

Fe>Cu>Ni>Se

Copper compounds are widely used in agriculture and are a possible source of drainage anomalies.Positive trend is seen in case of Se and Ni with Organic matter while negative trend with Cu and Fe in Sabarmati River. Since Cu and Fe are present in higher concentration therefore it suggests desorption of these metals from the complexed surface.Organic matter is showing positive trend with Ni and negative trend with Fe, Cu and Se in Kelani River.Microplastic concentration of both the size (75-212µm & 212µm-4mm) are found higher in downstream sites.

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Occurrence of Pharmaceuticals and Personal Care Products (PPCPs), Fecal Bacteria and Virusesin Surface Water in Guwahati City of Assam, India

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Abstract: *Water samples were collected in the populated city of Guwahati. The samples were measured for a wide range of pollutants including 5 compounds in the group of Pharmaceuticals and Personal Care Products (PPCPs), fecal bacteria and 5 viruses, including Hepatitis A, Norovirus GI and GII, Aichi and PMMoV. Extremely high concentrations were observed in samples from canals located in urban area. Caffeine was found to be the most abundant among PPCPs at highest concentration of 22,733 ng/L following by theophylline and acetaminophen. While, carbamazepine and crotamiton was found at incomparably low concentration. E. coli was also observed at concentration as high as 4.0 log(CFU/ml) in canal samples. Among viruses, PMMoV was found to be the most abundant at concentration up to 23,738 copies/mL in canal samples. Results indicated that high contamination of human sources pollution exists in the urban canals and at Guwahati city section of the Brahmaputra River.*

Keywords: *Viruses, Pharmaceutical and Personal Care Products (PPCPs), fecal bacteria, surface water, Brahmaputra River, Guwahati.*

1. ntroduction

Guwahati city is located in Assam, India. The city is known as the largest city of Assam with rapid urbanization which results in the production of large amount of pollutants daily. These pollutants from the urban area finally enter surface water system and flow into the Brahmaputra River along Guwahati city. Brahmaputra River so the water quality is in concerned.

Recently, chemical compounds in the group of Pharmaceuticals and Personal Care Products has gained more interest due to their specificity to human source pollution and their higher persistency to those of microbial indicators. *E. coli* and total coliform are important as traditional fecal indicator bacteria. They are regulated indicators and were normally included in the monitoring scheme. However, the presence of fecal bacteria does not always indicate the contamination from human sources pollution because of their presence in animal guts also. On the other hand, viruses are directly related to human health risk and should be considered. Each pollutant has different characteristics which beneficial when monitoring in combination. Integrated monitoring information is helpful in evaluation of the impact of contamination from urban area.

This study aims to investigate, for the first time, the contamination of PPCPs, viruses and fecal bacteria in a lake and canals in Guwahati city and in Brahmaputra River.

2. MATERIALS AND METHODOLOGY

2.1. Surface water sampling in Guwahati city

Water sampling event was conducted on 26th and 28th June 2017. Surface water was collected for 8 sampling points in Guwahati city of Assam, India. Sampling locations are indicated in **Figure 1.** Locations include points in Brahmaputra river (R1-R4), a lake (L1) and canal (C1-C3) in urbanized area of Guwahati city. Samples were analyzed for 5 PPCPs compounds including acetaminophen, theophylline, caffeine, carbamazepine and crotamiton. Samples were also measured for microbial parameters including 5 viruses (Hepatitis A, Norovirus GI and GII, Aichi and PMMoV) and fecal bacteria (*E. coli* and total coliform).

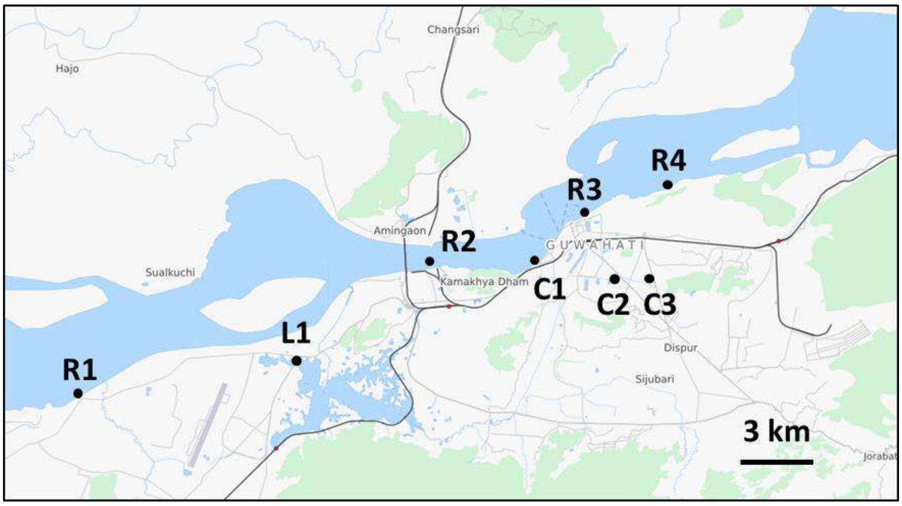

Figure 1: The map of sampling points in Guwahati city

2.2 PPCPs analysis by high resolution Fourier transform mass spectrometer

00-ml samples were collected in pre-combusted glass bottles added with 1g/L of ascorbic acid for sample preservation. Samples were then, transported to laboratory andwere filtered through glass fiber filter (GF/F, 0.7 □m). After that, samples were kept in a refrigerator at 4 °C.

Samples were injected with internal standard before applied to solid phase extraction procedure. Extraction procedure were done as follows. The Oasis HLB cartridge(6cc) were preconditioned with 5-ml Methanol and 5-ml MilliQ water (pH = 4). Samples were then passed through the cartridges at the flow rate of 10 ml/min followed by flowing air through for 30s.The cartridges were washed with 2 x 5 ml of MilliQ water (pH = 4) and analytes were eluted with 2 x 5 ml. of methanol at flow rate of 1 ml/min. The eluents were dried under a gentle stream of nitrogen gas at 40 °C until drynessand were reconstituted in 1-ml of methanol: water, 50:50 (v/v) then, stored at -20 °C until analysis.Recovery during extraction was different in each compound ranging from 55.8% to 101.9%.

A LC-MS system using Orbitrap Fourier transform mass spectrometry was used for the PPCPs detection and analysis. Analytes were separated in LC system equipped with Thermo hypersil gold column 150 × 2.1 mm with 5 μm particle size. Every compound was detected in positive ion mode. Mobile phase used includes: solvent A (water with 0.1% formic acid) and solvent B (methanol with 0.1% formic acid) at a flow rate of 0.2 ml/min according to program following: Initial conditions 100% A, decreased to 90% in 4.5 min, decreased to 60% in 22.5 min, then decreased to 0% in 15 min and finally returns to the initial conditions after 4.5 min with the re-equilibration of the column set at 7 min. Total acquisition time is 53.5 min. The MS instrumental setting and gradient elution program is set following the previous study (Kosma et al. 2014). Data were acquired in full-scan mode with two scan events simultaneously over a mass range of 150.0 – 300.0 for molecular ion and 50.0 – 200.0 for fragment ion. In-source collision-induced dissociation (CID) at 20 eV was performed to produce fragment ion from molecular ion.

The detection and confirmation of target compounds was based on mass-to-charge ratio (m/z) and retention time with criteria of 5 ppm mass tolerance and 0.3 min retention time window. For each target compound, one molecular ion $[M+H]^+$ and at least one fragment ion was acquired. Information on retention time and mass-to-charge of each compounds are shown in **Table 1** and **Table 2** for internal standards.

Table 1 Information of target PPCPs compounds with retention time and mass-to-charge.

Compounds	Abbre-viation	Elemental composition*	Retention time (min)	Mass-to-charge (m/z) Molecular ion [M+H]+→ Fragment ion
Acetaminophen	ACE	$C_8H_9NO_2$	9.05	152.0708→ 110.0600 → 65.0386
Theophylline**	THEO	$C_7H_8N_4O_2$	11.76	181.0720→ 124.0505 → 96.0559
Caffeine	CAF	$C_8H_{10}N_4O_2$	14.73	195.0877→ 138.0662 → 110.0713
Carbamazepine	CMZ	$C_{15}H_{12}N_2O$	33.34	237.1022→ 194.0964 → 192.0808
Crotamiton	CTMT	$C_{13}H_{17}NO$	36.94	204.1383→ 106.0651 →136.1121

*For uncharged analyte molecule.
**Caffeine-IS was used for quantification

Table 2 Information of internal standards

Compounds	Elemental composition*	Mass-to-charge (m/z) Molecular ion [M+H]+
Acetaminophen-IS	$^{13}C_2C_6H_9{}^{15}NO_2$	155.0744
Caffeine-IS	$^{13}C_3C_5H_{10}N_4O_2$	198.0977
Carbamazepine-IS	$C_{15}H_2N_2OD_{10}$	247.1650
Crotamiton-IS	$C_{13}H_{10}NOD_7$	211.1822

*For uncharged analyte molecule.

3. METHODOLOGY FOR VIRUS CONCENTRATION AND QUANTIFICATION

3.1 Virus concentration procedures

Water samples were concentrated as follows (**Figure 2**). In the first concentration step, 200 µL of 2.5 M $MgCl_2$ was added to 50 mL of water samples to obtain a final concentration of 25 mM and then passed a negatively charged membrane (HA, 0.45-µm pore size, 47 mm diameter, 9.6 cm2 area, Millipore, Japan). Next the membrane was rinsed with 200 mL H2SO4 (0.5 mM, pH 3.0) to elute the cations. Then 5.0 mL of 1 mM NaOH (pH 10.5) was passed through the membrane and collected in 5mL tube which contained 25µL of 100mM H2SO4 (pH 1.0) and 50µL of 100x TE Buffer beforehand, obtaining the 1st concentrated samples. After that, 5 mL of the 1st concentrated samples were further concentrated by using an ultrafiltration device (Ultracel YM-50, MWCO 50 kDa, Millipore) according to the manufacturer's instructions to obtain final volumes of approximately 600 µL. Next, the final concentrated samples were subjected to further steps, including viral RNA extraction, reverse transcription, and qPCR

3.2 Viral RNA extraction and reverse transcription

Viral RNA was extracted using a QIAamp viral RNA minikit (Qiagen) according to the manufacturer's protocol. Reverse transcription (RT) was carried out using a High Capacity cDNA reverse transcription kit (Applied Biosystems). The thermal conditions for RT were set as follows: 25°C for 10 min, 37°C for 120 min, and 85°C for 5 min. The cDNA was utilized for qPCR analysis.

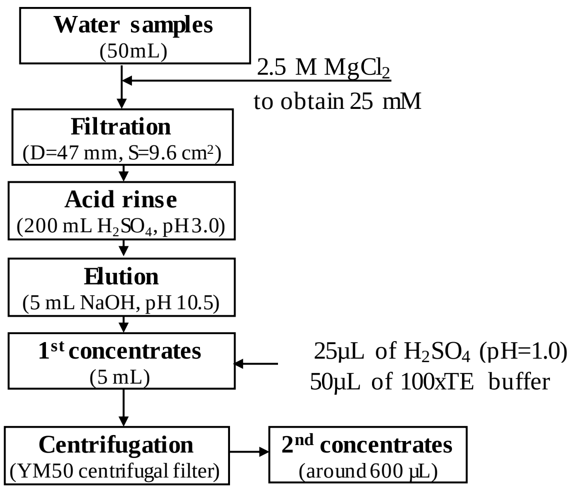

Figure 2 : SchematicDiagram of the Virus Concentration Processes

3.3 Virus quantification by qPCR

Real-time PCR (qPCR) was conducted using 20 µL of reaction mixture that contained 5 µL of cDNA, 10 µL of TaqMan Gene Expression Master Mix (Applied Biosystems), 1 µL each of 10 µM forward primer and reverse primer, 0.5 µL of 5 µM TaqMan probe, and 2.5 µL of nuclease-free water. The StepOnePlus real-time PCR system (Applied Biosystems, Tokyo, Japan) was used for real-time PCR analysis with cycling conditions of 95°C for 10 min, followed by 50 cycles at 95°C for 15 s and 60°C for 1 min. Ten-fold serial dilutions (1.0 x 100 to 1.0 x 104) of a plasmid DNA containing the target sequence were amplified to generate calibration curve for quantification of viral genomes.

4.RESULTS AND DICUSSION

4.1. Occurrence of Pharmaceutical and Personal Care Products (PPCPs)

Concentration of PPCPswere summarized in **Table 3**below with limit of quantification for each PPCPs compound included in the bottom of the table. It should be noted that concentration of crotamiton was not reported in exact values because the result was unreliable due to high contamination found in blank sample. However, rough concentration can be estimated. Crotamiton is presented at higher concentration at C1 and C3 than other locations but at concentration as low as 10-20 ng/L range.

Table 3 Concentration of PPCPs in each sampling location

Sample points	Location	PPCPs concentration (ng/L)				
		Acetamino-phen	**Theophyl-line**	**Caffeine**	**Carbama-zepine**	**Crotamiton***
L1	Lake	<LOQ	<LOQ	<LOQ	<LOQ	<20
R1	River	<LOQ	<LOQ	<LOQ	<LOQ	<20
R2	River	<LOQ	609	805	<LOQ	<20
R3	River	<LOQ	277	410	<LOQ	<20
R4	River	<LOQ	<LOQ	<LOQ	<LOQ	<20
C1	Canal	5,967	2,939	22,733	75	<20
C2	Canal	4,064	2,384	19,577	53	<20
C3	Canal	2,156	1,625	11,445	<LOQ	<20
LOQ		100	153	100	10	10

From **Table 3,** PPCPs were not detected in lake indicating no significant contamination from human source pollution in the lake. Focusing on samples from Brahmaputra river, samples were collected in line from R1 to R4. Theophylline and caffeine were found in higher concentration at R2 and R3 which are located near the urban area. This indicates the impact of contamination from the urban area in wide area of river along Guwahati city between locations of R2 and R3. However, the impact of contamination from urban area gradually recede by the dilution with river water and by natural attenuation processes with the longer distance from the urban area. R1 and R4, which refer to further upstream and downstream of the river, were found to be not affected by human source contamination from the urban area as PPCPs were not detected in these locations.

On the other hand, PPCPs were found in extremely high concentration in samples taken from canal in Guwahati city. This canal lies along the city and finally make a discharge into Brahmaputra river. The highest concentration of all 5 PPCPs compounds were observed at C1 locating nearest to the discharge point. Comparing to C2 and C3, C1 is the last point before water is discharged into the river thus, the contamination was accumulated in the water with the distance across Guwahati city. At C1, the highest concentrations among 5 PPCPs compound was caffeine at concentration as high as 22,733 ng/L. Acetaminophen were presented in second highest concentration at 5,967 ng/L followed by theophylline (2,939 ng/L) and carbamazepine (75 ng/L). Even though crotamiton was found at higher concentration at C1, it was presented in very low concentration. The abundance of PPCPs compound directly related to consumption behavior and very dependent in each countries and regions. It is possible that crotamiton is not widely used in Guwahati city or in India.

4.2. Concentration of fecal bacteria and viruses

Concentration of viruses and fecal bacteria were summarized in **Table 4** below with detection limit for each microbial parameter included in the bottom of the table

Table 4 Concentration of viruses and fecal bacteria in each sampling location

Sampling points	**Virus concentration (copies/mL)**					**Fecal bacteria concentration log(CFU\mL)**	
	Hepatitis A	**Norovirus GI**	**Norovirus GII**	**Aichi**	**PMMoV**	***E.coli***	**Total coliform**
L1	<DL	<DL	<DL	<DL	82.1	<DL	1.4
R1	<DL	<DL	<DL	<DL	15.7	1.7	2.4
R2	<DL	<DL	<DL	<DL	164.4	1.4	2.4
R3	<DL	<DL	<DL	<DL	136.9	1.3	2.1
R4	<DL	<DL	<DL	<DL	15.2	0.6	1.5
C1	52.5	0.2	5.8	567.1	23,738.4	4.0	4.6
C2	41.8	0.6	3.5	385.4	15,236.5	3.8	4.6
C3	10.6	0.2	2.6	170.0	14,557.5	3.9	4.7
Detection limit	10.0	10.0	10.0	10	10	1	1

Table 4shows concentration of microbial parameters including 5 viruses and,*E. coli* and total coliform as fecal bacteria. Similar to PPCPs, microbial parameters showed significantly lower contamination in lake sample and river samples with viruses not detected, except for PMMoV, and significantly lower concentration range of fecal bacteria compared to concentrations found in canal samples.

For river samples, *E. coli* was found higher at R1 and gradually decrease with distance to R4. Result suggest additional sources of *E. coli*near location of R1 which are not from human sources. In addition, high inactivation rate of *E. coli* by attenuation processes in river can be assumed.

Trend of concentrations in canal is similar to those of PPCPs in which the contamination from urban area gradually decreased with the distance and were maximized at C1 before flowed into river. At C1, highest concentrations were observed with PMMoV found in the highest abundant among viruses at concentration of 23,738 copies/mL. While, Aichi virus showed second abundant, followed by Hepatitis A and Norovirus. Similarly, *E. coli* was at highest concentration of at 4.0 log(CFU/mL) at C1. Result suggests canal inside Guwahati city was highly polluted and was responsible for contribution of great amount of pollutants which deteriorate the water quality in Brahmaputra river. High concentration of these pathogenic viruses that was detected canpossibly pose health risks to human.

PMMoV, which was found in the highest abundance, was proposed as a promising fecal indicator in previous studies (Kuroda *et al.,* 2015; Hamza *et al.,* 2011;Kitajima *et al.,* 2014). PMMoV is a plant pathogenic virus and they are not considered to present pathogenicity to human. The result in this study emphasize their suitability as an indicator due to their high abundance and easiness for detection.

4.3. Relationship between PPCPs and microbial parameters

As described in the previous section, PPCPs showed similar tendency with fecal bacteria and viruses comparing among samples. The concentration was high in canal samples and was very low in lake and river. Similar trend among them is clear in canal samples which showed C1 as the most contaminated location followed by C2 and C3.

In river samples, *E. coli* showed higher concentration in R1 samples whereas PPCPs showed higher concentration in R2 and R3. This indicates that PPCPs can have a different tendency from *E. coli* because of their different specificity to human sources pollution. PPCPs are more directly associated toraw sewage. On the other hand, *E. coli* are presented in both human and animal feces. Apart from raw sewage, they can also contaminate surface water through surface runoff and from agricultural area.

Focusing on locations of R2 and R3, theophylline and caffeine was detected even though viruses and fecal bacteria were not. This indicate their different persistency in environmental water system. Fecal bacteria tend to have high susceptibility to inactivation by natural attenuation processes while, viruses are more persistent but present in low number. The exception is for PMMoV virus which have high abundance.

5. CONCLUSION

Surface water sampling was conducted in Guwahati city in June, 2017. Samples were collected from 8 locations in total including from lake, Brahmaputra river and canals in the city.

Less contamination was found in lake. PPCPs were not detected indicating no contamination from human sources or wastewater.

In river samples, a slightly high concentration was found for theophylline and caffeine at 609 and 805 ng/L in the locations near to the urban area. PPCPs were not detected in the locations in far upstream and downstream of Brahmaputra river. Viruses were not detected in all river samples except for PMMoV.

Significantly high concentration of PPCPs, viruses and fecal bacteria were observed in the canals samples indicating they were highly polluted from human source contaminants. *E. coli*, which is traditional fecal indicator was observed at as high as 4.0 log(CFU/mL). Caffeine was found in highest abundance among 5 PPCPs at concentration of 22,733 ng/L. For viruses, PMMoV was found in highest concentration at 23,738 copies/mL.

Overall results showed caffeine as the highest abundance among 5 PPCPs. PMMoV was observed as the highest abundance among 5 viruses. The result suggests their usefulness as potential sewage markers because of their abundance which give rise to convenience in detection. Information is useful for determining water quality parameters in monitoring scheme in the future.

6. ACKNOWLEDGEMENT

This work was supported by the DST-JSPS Bilateral Exchange Project Collaborative Research (2016-2018). We thank laboratory members for their help in collecting samples and chemical analysis.

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A Water Quality Sustainability Strategy for Brahmaputra and Kelani Rivers through Health Risk Assessment and Identification of Spatial Distribution of Nutrient, Heavy Metal and Antibiotic Resistant Bacteria

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Abstract: *The contamination of water by hazardous and toxic metals is harmful for the human consumption but the effect is even more critical in presence of excessive nutrient (*NO_3^-*) and antibiotic resistant bacteria. Heavy metal pollution (HPI) is a powerful tool for ranking amalgamated influence of individual heavy metal on the overall water quality and a view of the suitability of surface water for human consumption.The HPI values of both the rivers are within the critical range of 100, thus suggesting no harmful impact of heavy metal contamination so far in the sampling sites. Health Risk Index (HRI) values of Fe, Cu, Ni and Se in the surface water are also ≥ 1 thus no critical hazard is observed. Two sites in Brahmaputra River were identified with resistant variety of E.coli, moreover, bacteria resisting to tetracycline is an indication of contamination through wastewater and environmental sources.*

Keywords: *Brahmaputra, Kelani, antibiotic resistant Bacteria, HPI, HRI.*

1. INTRODUCTION

Heavy metal contamination in water is recognized as a severe environmental problem and presence of antibiotic resistant bacteria makes the situation even more critical therefore the study related to water contamination has become important. Quality indices are useful in getting a composite influence of all parameters of overall pollution. It makes the assessments into a reproducible form and compiles all the pollution parameters into some easy approach. Numbers of methods have been applied to develop quality indices for estimation of water quality with respect to water quality parameters (Couillard & Lefebvre, 1985). In recent years much attention has been given to the evaluation of heavy metal pollution in surface water by using the HPI (Katyal, 2011). HPI is defined as a rating reflecting the composite influence of different dissolved heavy metals (Reza & Singh, 2010). The critical pollution index value for drinking water should be less than 100.*Nutrient pollution* and harmful algal blooms also *cause* major environmental damage as well as serious health issues in man and animals (Nieder et al. 2018). Antibiotic-resistant organisms get passage into water environments through human and animal sources. These bacteria contain resistant genes which alters the genes of indigenous microbes. Industries are also major source of liberating these antibiotics in the water bodies, potentially altering microbial ecosystems. Technology development for reduction of resistant bacterial loads in wastewaters, release of antimicrobial agents from biomedical and farm waste requires optimization of disinfection procedures and management of wastewater and manure. Thus an attempt of estimation of nutrient, heavy metal distribution pattern and heavy metal pollution index (HPI) in the Brahmaputra and Kelani River was made, along with estimation of health risk index (HRI) in the Brahmaputra and

Kelani River.Sensitivity analysis of the E.Coli isolates from the Brahmaputra River sample was also carried out.

2. STUDY AREA MAP

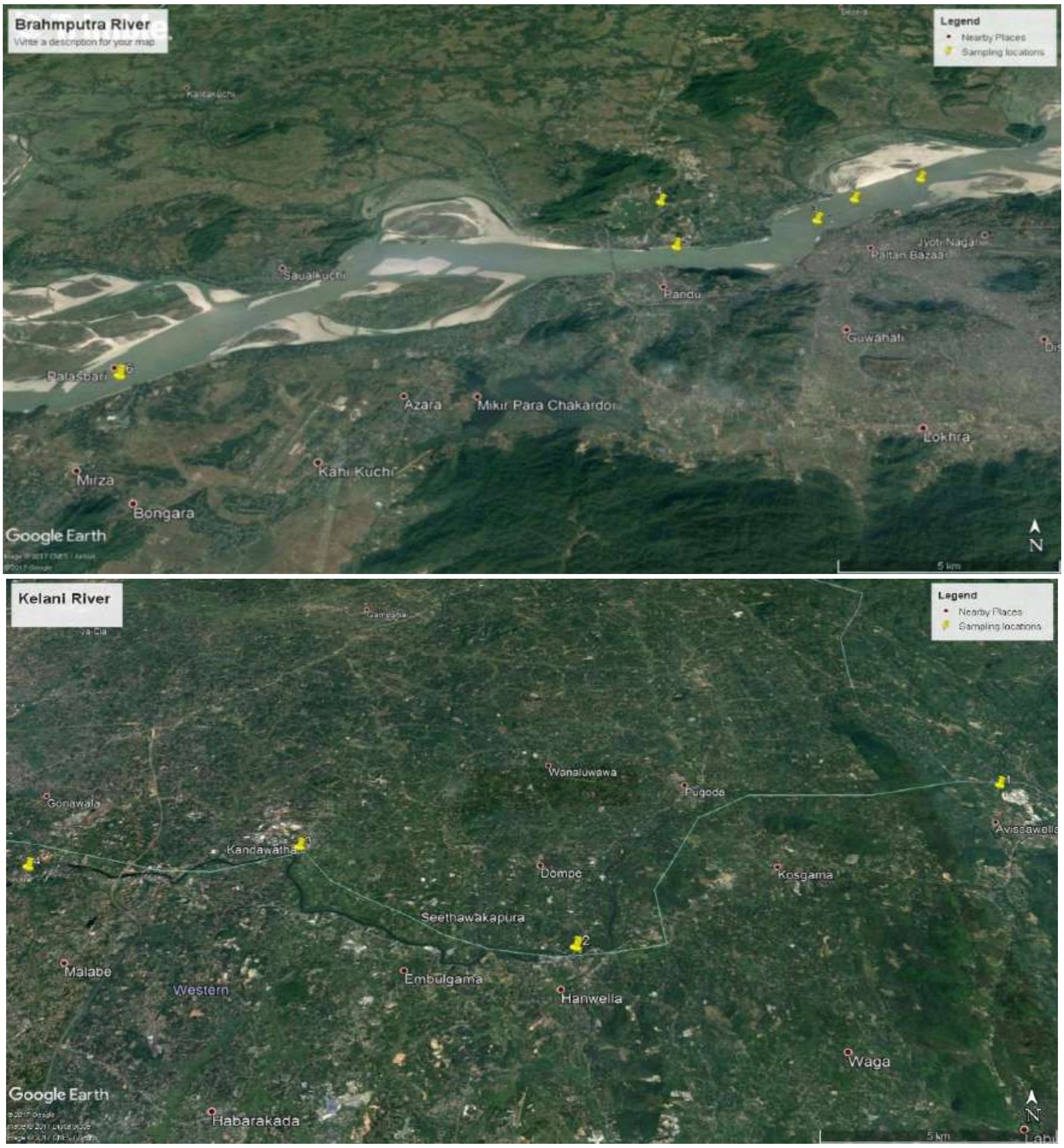

Figure 1:Map showing sampling sites in the Brahmaputra and Kelani River

3. METHODOLOGY

Sampling sites are shown in the **Figure 1**. 6 samples from different locations along the Brahmaputra and 4 samples from Kelani River were collected in prewashed 500ml polypropylene bottles. Samples were acidified with HNO_3^- and were kept at 4°C in the refrigerator for preservation till analysis. pH, EC(Electrical conductivity), DO(Dissolve Oxygen), TDS(Total Dissolve Solid), ORP(Oxidation Reduction Potential) using Multiparameter probe Ion selective electrode (HANNA HI9828**).** Heavy metals (Cu, Ni, Fe and Se) were analysed inAAS (Atomic Absorption Spectroscopy) Perkin Elmer Pinnacles 900Z. F^- was analysed using Thermo Scientific Orion fluoride meter.NO_3^- was analysed using Orion Star™ A214 pH/ISE Benchtop. $HCO_3^-$was analysed using Potentiometric Titration. Sensitivity analysis was done using Antibiotic Resistant Bacteria test Kit (ARB test Kit).

3.1. Estimation of heavy metal pollution Index

Heavy metal pollution Index (HPI) has been developed and formulated as,

$$HPI=\frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i}$$

$$Q_i=\sum_{i=1}^{n}\frac{|M_i-I_i|}{S_i-I_i}\times 100$$

Where, Q_i is the sub-index of the i^{th} parameter; W_i is the unit weightage of the i^{th} parameter; n is the number of parameter; M_i is the monitored value of heavy metal of i^{th} parameter; I_i is the ideal value of i^{th} parameter; S_i is the standard value of the i^{th} parameter.

3.2. Estimation of health risk Index

$$HI=CDI/R_fD$$

Where, R_fD is the reference dose and CDI is chronic daily intake. Reference dose for Fe is 8.25 mg/kg body weight/day, Cu is 1.15×10^{-3}mg/kg body weight/day, Ni is 2×10^{-2}mg/kg body weight/day and Se is 5×10^{-3}mg/kg body weight/day (USEPA, IRIS 2007).

4. RESULTSAND DISCUSSION

The pollution parameters are generally monitored for the assessment of quality of any system which gives an idea about the pollution with reference to particular water quality parameters. **Table 1** presents the statistical summary of the water quality parameters of the Kelani and Brahmaputra rivers.Higher concentration of Fe and Cu is observed in both Brahmaputra and Kelani Rivers (**Figure 2**).Anthropogenic sources of iron include the iron and steel industry, sewage and dust from iron mining.Iron sulphate is also used as fertilizer and Herbicide. Anthropogenic sources of copper include mining and smelting, electrical industry, agriculture, sewage sludge and steel works. Copper compounds are widely used in agriculture and are a possible source of drainage anomalies. Higher concentration of nutrient (NO_3^-) is observed in Brahmaputra River as compared to Kelani River
.

Table 1 Descriptive summary of the Kelani and Brahmaputra rivers

	Kelani River			Brahmaputra River		
Parameter	**Range**	**Average**	**Std. dev**	**Range**	**Average**	**Std. dev**
pH	6.4-6.9	6.62	0.17	6.2-8.0	6.96	0.46
EC(μScm^{-1})	40-210	105	79.7	98-648	224.4	179.2
ORP(mV)	27-78	55.5	17.44	-147-114	12	85.50
HCO_3^- (mgL^{-1})	75-175	110.8	44.43	65-170	108.6	27.94
F^-(mgL^{-1})	0.07-0.32	0.20	0.10	0.07-0.69	108.6	27.94

NO_3^-(mgL^{-1})	6.25-6.83	6.54	0.23	5.61-19.1	9.50	4.32
Cu(µgL^{-1})	381.8-609	457.6	95.49	405.4-538.4	467.8	39.30
Ni (µgL^{-1})	32.68-82.94	46.31	18.42	51.94-84.08	59.51	9.32
Fe(µgL^{-1})	1105-1700	1371.9	222.6	1142-1726	1446.7	188.5
Se (µgL^{-1})	1.34-54.16	22.83	20.25	9.78-93.76	43.56	29.95
HPI	13.38-21.26	12.15	2.26	8.73-20.97	15.28	4.45

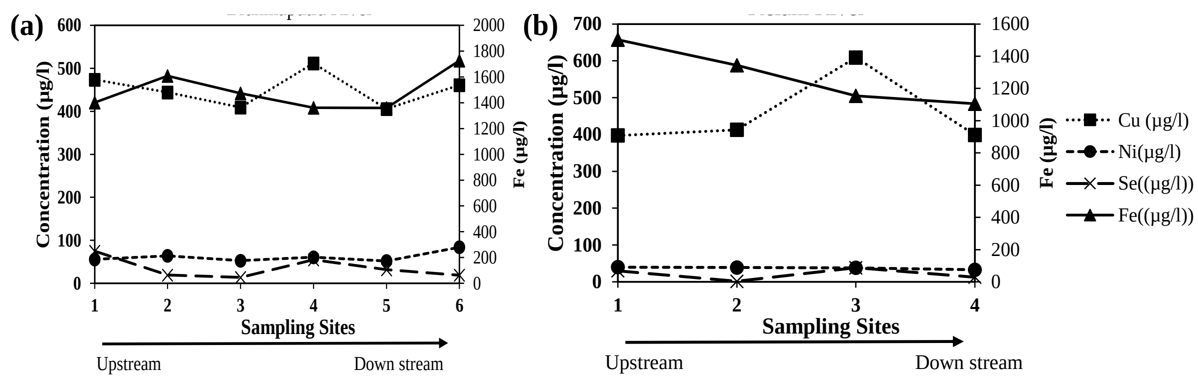

Figure 2:Metal distribution scenario in the Brahmaputra and Kelani River

Heavy metal pollution index (HPI) is a used to determine the aggregate influence of individual heavy metal on the overall quality of water whereas Health Hazard Index is calculated in order to evaluate any health implication caused by these metals when consumed over a period of time and with specific concentration as shown in **Table 2**. The HPI values of both the rivers are within the critical range of 100, thus suggesting no harmful impact of heavy metal contamination so far. The HRI values are also ≥ 1 thus no critical hazard is observed.

Table 2 Health risk Index and Heavy metal pollution Index

Sample ID	HRI Cu	HRI Ni	HRI Fe	HRI Se	HPI
		Brahmaputra River			
B-1	0.47	0.11	0.07	0.45	15.48
B-2	0.44	0.10	0.07	0.41	14.40
B-3	0.41	0.12	0.09	0.48	16.51
B-4	0.38	0.10	0.08	0.39	13.79
B-5	0.38	0.10	0.07	0.39	13.45
B-6	0.43	0.16	0.09	0.62	21.26
		Kelani River			
K-1	0.37	0.07	0.08	0.30	10.79
K-2	0.38	0.07	0.07	0.29	10.38
K-3	0.56	0.07	0.06	0.28	10.00
K-4	0.37	0.06	0.06	0.24	8.73

E. coli isolates were tested for its sensitivity and resistance to 4 groups of antibiotics namely Quinolones, Aminoglycosides, Sulfonamide and Tetracycline. The sensitivity percentageindicates the effectiveness ofthe antibiotics in treatment of infection caused by the E. coli isolates. It is observed that sample L-4 and L-6 were 100% resistant to Levofloxacin, Ciprofloxacin, Norfloxacin and Kanamycin suggesting 0% sensitivity to these antibiotics. Only sample L-6 has 30% sensitivity to Tetracycline. Sample L-3 is most resistant to Tetracycline (60%) which is in agreement to the finding of Kim et al., 2007 and Threedeach et al. 2012 suggesting bacteria resisting to tetracycline were most frequently detected in wastewater and environmental sources, therefore in other words it suggests maximum contamination of river water in this site with wastewater, while sample L-5 was resistant to Ciprofloxacin (90%) and Norfloxacin (80%) respectively. Sample L-3 is found to be more sensitive to Quinolones and Aminoglycosides as compared to Sulfonamide and Tetracycline respectively. While sample L-5 has maximum sensitivity to Kanamycin which is an Aminoglycoside.

5. CONCLUDING REMARKS

Higher concentration of Fe and Cu is observed in both Brahmaputra and Kelani Rivers but nutrient concentration is higher in Brahmaputra River. Thus aantibiotic resistant bacteria were analysed and were detected in two sites of Brahmaputra River. Thus risk assessment protocols for antibiotics and resistant bacteria in water, and their prevention from mixing through source tracking must be prioritized. A policy for segregation of human-originated and animal-originated bacteria with environmental organisms is advisable.

6. ACKNOWLEDGEMENT

We would like to acknowledge Asia Pacific Network (Reference Number: CRRP2016-06MY-Kumar) for providing the funding to carry out the research. We would like to acknowledge Dr. G.G Tushara Chaminda and Dr. Ryo Honda for the sensitivity analysis tests.

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Climate Governance and Sustainability, Climate Proofing and water Resilience of Guwahati City

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Abstract*:* *Due to increasing population, Industrialization and urbanization Guwahati city is facing change in weather as well as environmental problem which will lead to climate change. If this rapid change will continue, in few decades it will result into several disasters for human lives. As the migrating population and encroachment of lands are growing every day, human settlement needs planning for its sustainable growth. The countryside growth of housing and slum formation inside town needs evaluation by examining the data from the government ministries, academic institutions, and case studies. The resilience planning of a city is the backbone of resistance for disaster management. The government policy and stakeholder's participation are the major keys for urbanization development. Water resilience technique needs to be quite efficient and reliable for citizens particularly in the flood prone area during rainy season and also in dry season, as the river is originated from glacier the uncertainty of flooding can be extreme. The Guwahati city is the most important and densely populated city of North-Eastern part of India, where the natural hazards are common like the flooding and sand slide on the foothills.*

Keywords: *Population growth, migration, natural disaster, resilience plan, stakeholders, sustainability.*

1. INTRODUCTION

Environmental planners are nowadays concerned with understanding the phenomenology of persuasion to instill a sense of sustainability in the society. As natural resources getting extinct every second, critical period on the planet has come bringing with it plethora of questions, which needs pragmatic space in current debates. In this research paper, I will examine the Guwahati city's resilience strategy in the times of natural disasters and through this data, I will conceptualize the unapproached factor which is local participation in mitigation efforts for saving biodiversity, biosafety, climate change and governance.

From the year of 1712, the invention of the first widely used steam engine by Thomas Newcomen to the year of the first description of greenhouse warming by Swedish Knut Angstrom in 1900[3], the use of available minerals and ecological resources has been the main course to take for economic development. The domination of scientificsolution for every problem has created a lack of civic consciousness and moreover, scientific way of finding the solution for the sustainable environment seems to be inappropriate. This prompts an important question which is how to find the balance between specialized expert knowledge and public participation in sustainability?

The repeated failure of climate summits to produce a global treaty over the past decades, the un-efficient and less explicit decision of bureaucracy and the poor record of climate diplomacy were the centre of attention among academicians in the past to try and understand the problem of depleting environmental resources. Many scholars are now turning away from this theoretical informative research to more value integrated and their expectation from people, needs and demands of an urban population, people's perception of government planning and its impact on the sustainability of the environment. From the case study of Guwahati on quality of life by Daisy Das, analysis of planning by The Energy and Research Institute (TERI) (with respect to the government ideas of Master Planning of 2025) and the researches by Guwahati University and various useful interconnections can find the complexity between resilience strategy and present condition of the environment, where the role of civic consciousness must play when it comes to sustainability, which is the focus of the paper.

1.1. The collaboration in making of Planned Region and Guwahati city

The gulf between diplomacy of science and policy for implementation in scientific assessment is in nature lacking the proper way of finding solutions to environmental balance. The present systematic theoretical study focuses on how science can assist global environmental risks. The use of scientific knowledge is shared among specialized experts. The actual solution lies in linking experts from every discipline, and this solitary should transmit to policy making. The scientist and engineers need to reach out to the public and seek collaboration for effective policy making. Deliberation between experts and citizens is the need of the day. A collaboration between scientific and non-scientific community is needed to understand the local needs of society. The issue of lack of local participation gets complex when local people calculate technology as a risk and don't trust the scientific experts. The research on sustainability for environment generally focuses on laboratory experiments and data interpretation, but the needs of solution lies in making it more interdisciplinary with multinational collaboration. From the account of Global Political Environmentalist, the solution of every environment problem needs to be done in the spherical collaboration of citizens and experts. Their policy making terminology should be discussed in the public sphere where everyone should get their own space. Interdisciplinary review plays vital role, where the diverse ideas can be discussed making dialogue between stakeholders such as NGOs, industry, public and the media. This will extend the peer communities, bringing to focus multiple viewpoints. This wide participation beyond the narrow group of science experts, in collaboration for developing scientific ideas is called as "democratization of science". Due to the prevalent stereotype that the scientific knowledge and assessment does not come under environmental politics, the bridge between institutions of scientific elites and policymakers seems blurred for sharing worldviews. The deeper intervention of science with political process can revitalise its social process for constructing sustainable knowledge.

Regional planning has many aspirations which involve broader citizens to favour strong democracy which should not only become representative but also a participatory approach. There is a notion among stakeholders that scientific planning is not something the common citizen can grasp. The wide gap between specialist and people should be narrowed, once this is done people can directly approach them for the factors affecting their lives and this is a participatory scientific assessment. Citizen juries having public speakers to speak in science and technology affairs can attempt to incorporate citizens in environmental sustainability management. The representation of people in scientific decision making will greatly increase the quality and legitimacy of scientific assessment. The participation of citizens do not necessarily transform the scientific norms, it could be challenging but this can be done for better quality understanding at ground level assessment. The accountability of science is beyond peer review process at present but this should not be the case, scientific ideas should include a variety of actors participating in the assessment process and needs more communication with the public regarding the value assessed in scientific result. The model of sustainability in environment grants authorial power to scientists, bureaucrats, and specialists. Critics points into the negative side of scientific goals which needs to acknowledge the demands, agendas, and concerns of indigenous knowledge with the involvement of "glocal" level of "place-based" cognition in planning and environmental risk management [9]. The poor representation of scientist from developing and underdeveloped countries is another highly problematic issue pertaining to having proper scientific knowledge available for all citizens. The fatal destruction of environment needs more practical and open-ended discussion, where policy, politics, and process should be transparent. The engagement and exchange of dialogues between multiple stakeholder NGOs, media, public, industry and peer communities in planning is a pragmatic way to incorporate in environmental sustainability.

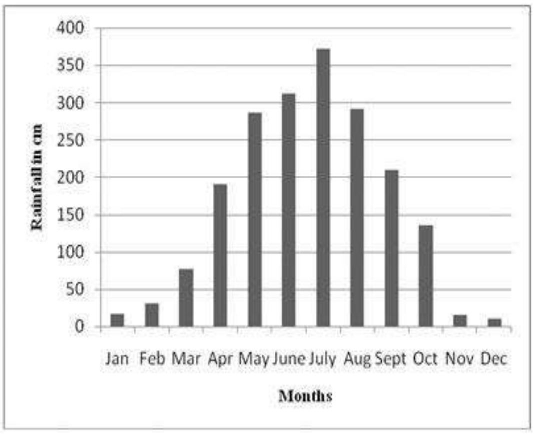
A report by The Energy and Resources Institute (TERI) on 2013, for Climate proofing Guwahati, Assam has evaluated the resilience plan in synthesis way. The population of Guwahati is 968,549 as per the CENSUS 2011[4] by Government of India. The report focuses on hazardous and vulnerable components for urban risk, where they had extracted local information as secondary data. They have tried to analyze the risk and vulnerability, which includes the climatic research, informed public, stakeholders engagement, sector coordination, land use planning, service provision, urban environmental management, ecosystem, resource efficiency, resilient infrastructure and system capacity. The function of land is limited as the geographical features generally don't get changed, but the risk vulnerability can be assessed by physical landmass study. Their goal was to assess the risk of the city to climate change impacts, regulatory environment, and resilience measurement. They are interested in ways to integrate them into planning and city resilience strategy. Guwahati is the major city of north-east, which has undulating topography with 13th highest population concentration in India, which is facing several hurdles like drainage issue, degradation and encroachment of wetland and water bodies, lack of sewage system, unplanned and unregulated growth of the city, lack of waste disposal, slum formation, landslide, urban flooding and public health and sanitation issues. TERI's approaches to resilience strategies are through critical assets, sector imparted by the future and current risks, and government parameters for building water resilience through the identification of sectors and strategies for intervention. The climate trend in Guwahati has observed an overall decrease in seasonal rainfall but there is also extreme increase in rainfall during monsoon season, this is one of the factors in attributing urban flooding. Bharalu River (Tributary of Brahmaputra), is experiencing a major flood prone area of the region, which is caused by manmade hazard owning to a number of issues like lack of drainage system, unmanaged solid waste, hill cutting and unplanned city growth etc. The city is experiencing about 1.2°C average maximum and, 1.3°C average minimum temperature [4]. landslide is a very frequent phenomenon in Guwahati, the increase in encroachment in hill area due to population growth is causing people dying in low lying hills.

The urbanization trend is a major problem for the city, as the population increased 84.69% from 1991 to 2011 and as the unplanned density mushrooming is still going on as small pockets, the encroachment of significant natural features like a natural wetland, watershed areas, and hills. These things are causing non-climatic stress for a city, like the inadequate capacity of existing drainage system, the problem of an improper sewage system and solid waste, marginalisation of slum while planning and service provision, inadequate public health management, lack of resources and infrastructure and low emergency response capacity. The Masterplan of Guwahati CMP-2025 considered housing as their first priority which needs 67687 houses till 2025 which is thrice the need for 2005. The increase in population is a reason behind the conversion of sparse vegetation which is not only causing soil erosion but also flooding. The Brahmaputra is the major natural resource of the city and its one of the tributary Bharalu river, which is the important channel for drainage of the city carries the major chunk of waste discharged from the city and its industries. This causing degradation of river water. The destruction of wetland is quite common in the region, as from the data it has been seen a drastic reduction of 14.1% between 1990-2002. The illegal construction of demilitarized zone is going on by the dumping of garbage and filling of the lakebed, and further, the decrease in vegetation and wetland is causing bareness of the city.

A project worth 2.8 billion (90% funded from central government) was sanctioned for proper water supply in the city. The master plan of 2025 estimated the generation of 225 MLD from Guwahati and 107.2 MLD in new towns which requires 3.0098 billion for sewage and sanitation system. There is no other planned drainage system working other the 17 km of drainage made by Town and Country planning organization in 1970, which now after the reports needs the proposed amount of 7.5 billion. Guwahati is receiving 80% of rainwater in 90-120 days in the rainy season, leading to waterlogging and flash flooding in the city. The Masterplan reveals the 90% of waste generated is organic in nature and the land require for dumping is 91 hectares by 2025. The migration into the city in the search of the job is quite often, the number of pockets in 2012 survey was 217.

The city resilience strategy of Guwahati consists of four major components like housing, ecologically sensitive planning, urban infrastructure and services, which is trying to cover questions related to critical assets, sector impacted by the current and future risks, vulnerable classes and government parameters, the goal of each of the three is to reduce the risk of disaster. The residents of all type are covered in the planning and also has some strategies for preventing disasters like no construction should be allowed on slopes more than 20%, minimizing the amount of vegetation cutting and proper storm water drainage management. As per the data on soil erosion on 20th Dec 2013, an estimated 5-10 ton/ha/year was lost in erosion, and hence basement should not be allowed in the flood-prone area, it was also suggested to make 'improvised septic tank' for new construction. There should be the mandatory provision of adoption of Sustainable Urban Drainage System for all housing projects. The energy efficiency for 2025 is estimated to be increased to 2,78,965 dwelling units. The government of Assam made strategies for housing construction, where they have given guidelines for construction building on slopes, technical details for use of septic tanks, soil erosion control, rainwater harvesting for storage and its mandatory provision for the adoption of sustainable urban drainage for all group of housing. There is a strategy for no build up area in the Eco-sensitive region, and the implementation of climate resilience urban development based on the environmental parameter and ward level resilience planning. For balancing the negative impact, there is a need to increase awareness among citizens, with the help of policymakers and communities. As per the conservation of wetland, the wetland rules 2010 has managed to prepare the wetland. Urban infrastructure and services are the backbones of urban civilization, it needs efficient and good quality of water supply, proper metering system, and bill collecting system at place. The Jal board plans and design the system, where the future project is to provide 425 MLD in the year 2025, TERI has suggested to storing rainwater, it has also suggested to the city government to ban on unauthorized extraction of groundwater in the city. The quality of water should be monitored by Jal board. The transmission loss in the city is high as 40%. TERI has recommended reducing water loss, making use of efficient meters, asset management and controlling leakage to reduce water dropping. The sewage system of Guwahati needs to developed and monitored water quality at disposal point. The natural drainage system needs more study on its paths and flows. This will require in-depth study of topographical features of the city and hydrological pattern. The resilience strategy strongly recommends making storm water management plan with the integration of all departments as well as private industries. Solid waste management needs proper planning of collection of waste with proper treatment and disposal system. The undulating topography and location own multiple disasters in the Guwahati cities. The challenges are increasing as the unplanned settlement is on the lap of disaster, this needs extensive prevention planning. There are several studies going on in the planning and the Disaster Management for Kamrup District. This has facilitated the emergency services during disaster [8].

The area on flat alluvial plains are having less depth of water in comparison to the area beside residual hills, however the deeper water level is also seen in some of the area of alluvial plain like Paltan Bazar, Nepali Mandir and Rehabari, the incepted reason behind is this could be the withdrawal of water for domestic or commercial use [12]. Encroachment in the land of watershed is common but there is broadening in formation of watershed found in Guwahati in the terms of geographical fault, lying beside the corridor of Fatasil and Narakasur hills. The area of Birkuchi, Garchuk, Fatasil Ambari, Silsako belongs to the zone of weathered rocks, which is having 50-60 meters of thickness of sandy layers resulting in the natural convenient filtered water. The level of dug walls in pre-monsoon period varies from 2-4 meter in plain land and in foothills zone it varies from 5-10 meters. The good quality of water can be found from 15 meters of depth. The depth of tube well by Public Health Engineering Department has 30 meters of depth which yields 2000-3000 litres of water in an hour. In the western side of the city the tube walls of 200 meters is showing good discharge of 70-100 cu.m/hr. The central part of the city has maximum depth of 100 meters which yields up to 80 cu.m/hr. The hard rocks present in the sediment areas are found to be good for ground water cycle. The pH level of Greater Guwahati is found in between 6.5-8 units which are considered in safe zone [8].



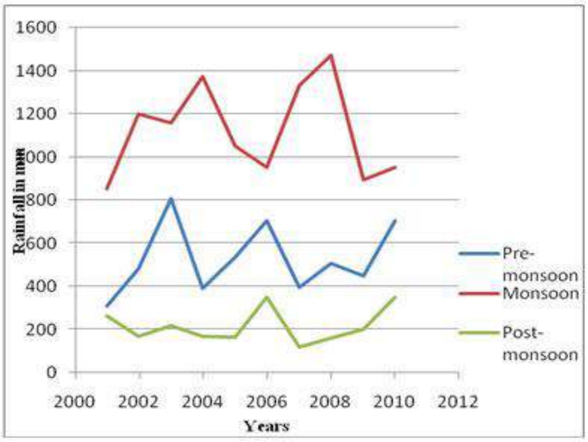


Figure 1:Mean monthly rainfall in Guwahati City   Figure 2:Seasonal Variation of rainfall (Das et al 2013)

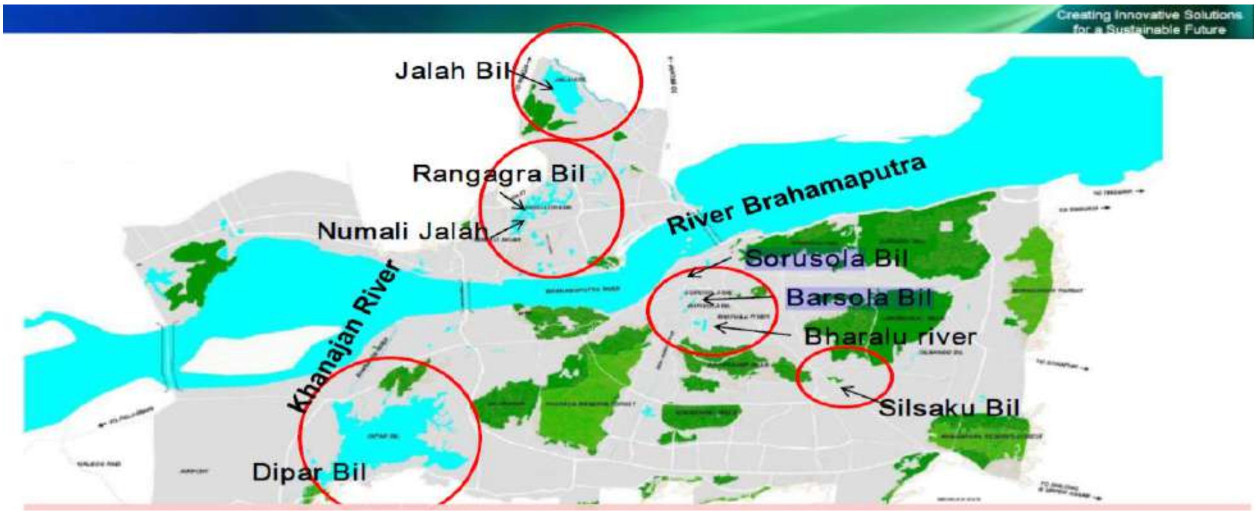


Figure 3: Major watershed area of GuwahatiSource: [7]

In the present time Municipal Corporation of Guwahati, Engineering Department, Assam Water Supply Board and Sewage Board is providing water to the city for their domestic use. The demand of 425MLD estimated in Master Plan of 2025 can be fulfilled by Brahmaputra river, but the un organised and inadequate water planning system is unable to meet the public needs which made a majority to the population to depend on groundwater. The major watershed in Guwahati is the Brahmaputra and its tributaries like Bharalu, Khanajan, Bondajan and Basistha, and some lakes like Jalah, Rangagra, Numali, Dipar, Silsaku, Solusora, Barsola etc.

The approximately consumption of water in Delhi by The Centre Groundwater Board (CGB) is 272410000 m^3 against the actual recharge of 171860000 m^3, where the aquifers exist in 30m to 60m down to floodplain of Yamuna river and the depth of water level varies in Delhi from 1.20m to 67.73m, the Groundwater level in Mumbai seems better than other metropolitan cities, here water level varies from 1.80m to 10m, in an estimation by the scientists of National Geophysical Research Institute (NGRI), in ten years most of the megacities of India will be almost dry[2]. In the case of Colombo (Sri Lanka) the Water Resource Board (WRB) and National Water Supply and Drainage Board (NWS & DB) which is involved in groundwater studies played an excellent role in water management throughout the city, the total supply of water in Colombo is 561889.0 m^3 /day, where 100% of the water is supplied from surface water, Tokyo (Japan) has the largest underground water tank in the world and from the data of Tokyo Metropolitan Government 80% of water resource of Tokyo city comes from Tonegawa and Arakawa River and around 20% of water comes from the Tama river.

From the data of Rural Water Supply and Sanitation Project for the Low Income States(RWSSP-LIS), April 2013 (Ministry of Drinking Water and Sanitation, Government of India, New Delhi, India) of Assam state, people are sceptical about service delivery, and they don't want to share their capital for piped water supply. It is also found that they are not aware of scheme details and not paying attention in training organized by the government. The Employment data showed Self-employed population as 47.5% where the male population is 50.1% and female population is 34.4% (Source: Desai et al, 2012) which is indicative of major population in the city which lives with the sentiments of uncertainty of livelihood. The 30% of water supply in cities are from agencies and rest of the households manage to get it from their own efforts, some conflicts appear which indicate towards the lack of state presence in public welfare. Guwahati city has nearly 30,000 street vendors according to the NGOs STEP, where the maximum of invaders are not legal, which lives in constant fear of the municipal officials, police and local goons (The Assam Tribune 2012a, 2012b). A case study of Guwahati is discussed by Daisy Das is based on her research on quality of life in urban region of Guwahati, where she tried to explore life assessment through her major criteria of evaluation which constitute Physical, Economic and Social Environment, constitute Provision of necessary environmental condition and Satisfaction from the condition of environment. Through this research, she found that the quality of life comprises physical, economic and social environment, where people are unsatisfied with every aspect of their life. The most unsatisfactory things were caused by the government officials and authorities like the cleanness of water to insecurity at home, which showed some change in the second survey where the satisfaction level showed more decrement and the most unsatisfactory thing was the condition of traffic and from the Master Plan data, the density of road was found comparatively very low from another cities of India.

The above assessment and discussion of climate proofing Guwahati by TERI pretends to take care of every group of people, where the data of public involvement and satisfaction forced us to think about the uncertainty of planning and implementation. The master plan of 2025 must be planned in the presence of experts but TERI still suggested to make it with the coordination of academic institutions, various level of authorities and organizations. The less involvement of people in the city development shows the downside of the planning. The population increase in the hilly area directly indicates the ignorance of the authorities of the area. Until the striking of disaster, there is not much planning, this apathy takes away a lot of life in Guwahati. The assessment by Daisy Das on the life of people clearly indicates the level of dissatisfaction among people. The less study on watershed of the region indicate towards the less awareness among the citizens and also less involvement of institutions in the study of the factors affecting a city. The involvement of every citizen makes planning rich and effective, in the case of Guwahati city the involvement is abysmal. There is no disaster resilience strategy which is functioning right now in Guwahati. In case of any disaster, they have emergency services which are quite inefficient in the case of flood in the recent years. Studies are going on with the collaboration of various international management projects and institutions, which is a good approach. From an article by Richard C. Smardon, India has good history of ground level participation in natural resources management, despite of high density of population growth as compared to European and North American countries. Community based participation has played a major role in management of waste[12]. The working class classification in India is quite diverge and complicated, hence expecting everyone in waste management participation seems uncertain, which also needs to be studied by Indian scholar.

The apparent environmental achievement for climate sustainability is a problematic idea which needs serious contemplation. Sustainability leads to better quality of life which directly leads to development. Sustainability affects us in more than one way which include our cultural interdependence, music, ideological value, technology, arts, civics, politics, economics and ecological entity, which further take a shape in form of development and globalisation The multi-disciplined aspect needs different kind of approaches coming from different perceptions arising from scientific experts, architects, designers , planners, teachers and social scientists. Urban planning and environmental sustainability require intervention from experts of all fields. Open discussion in a multidisciplinary platform where every individual would be able to share their idea. The case of Guwahati city needs to be studied from various aspects because the reason behind the inappropriate sanitation and waste management cannot be put entirely on the authorities. The long history of migration in the city has strengthened the ethnic identity of the state, the main reason behind conflict of thoughts between government and citizen is the forest land earlier inhabited by the tribal and marginalized society. The mushrooming of the countryside and periphery areas are the most hostile regions.

The better connection between scientist and public can improve the knowledge in the scientific literature which can further contribute in remedies for hazards. “Let’s not give any historian a reason to write that we ruined the global response to climate change”-Radoslav S. Dimitrov in his article on the Paris agreement states the present situation and governance on climate change. The present assessment of physical landscape, climatic condition, andeconomic status need to be studied in the micro level because the implementation of planning seeks the minute information of the area. The ignorance of planning for unauthorized and illegal housing is quite common in planning statement but the planning should be done before the expansion of the city, and the city always needs an extra capacity of livelihood for future purpose of expansion. The lack of sewage and solid waste management in the city can further cause hurdles in any kind of technology to perform in the region and it can affect as fatal consequences for the living population. The perfect architecture and civil technology could resist the hazards for several times but this is not what a sustainability seeks. The excellent planning and management of water supply in Tokyo and Colombo inspires to plan with a better understanding of geographical region. Urban Planning is a long-term goal and it counts on each individual to get access to their sources in a systematic way to get utilization of resources with the consideration of vegetation as a challenging and most useful resource.
“Construction leads to destruction, so think minutely before planning”-(Personal Note).

2. ACKNOWLEDGEMENT

The author would like to thank Miss Isai Amudhu S.S of the Humanities and Social Science, Indian Institute of Technology, Gandhinagar for her valuable discussion and initial review of the manuscript.

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Antibiotic Resistant Escherichia coli in Kelani River, Sri Lanka

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Abstract*: Occurrence of antibiotic resistant bacteria (ARB) and antibiotic resistant genes (ARG) in Kelani River, Sri Lanka was evaluated as a pre-emptive effort to control antibiotic resistant gene ARB/ARG contamination in Kelani River. Four sampling points were selected from a 40 km stretch of Kelani River starting from downstream of Seethawaka EPZ (Awissawella) to Ambathale. E. coli colonies were isolated from the surface river water, and resistance to quinolones (i.e. norfloxacin, NFX, ciprofloxacin, CIP, levofloxacin, LVX), aminoglycosides (i.e.kanamycin monosulphate (KM), tetracyclines (tetracycline, TC), and sulfonamides (i.e. sulfamethoxazole (ST) was evaluated. We found resistant E. coli strains at all sampling points, almost all resistant E. coli demonstrated resistance to more than one antibiotic, and the resistance ratio for TC and ST were higher (≥0.9) than for other antibiotics. Contrasting patterns were observed between resistance to quinolone and non-quinolone antibiotics; a decrease downstream for quinolones and an increase in resistance for non-quinolone antibiotics, suggesting different factors governed the pattern of resistance in quinolones. Generally, ARG screening was in agreement with the antibiotic resistance test. However for quinolone resistance, further screening of other types of quinolone resistance determinants is needed.*

Keywords: *Antibiotic resistant bacteria, antibiotic resistant genes, occurrence, wastewater, rivers, resistant ratio.*

1. INTRODUCTION

Bacterial resistance to antibiotics occur when an antibiotic, is no longer capable of controlling or preventing the bacterial growth (Alam and Deng, 2015). Resistance occurs naturally through mutation over a long period. However, an overuse of antibiotics may accelerate the occurrence of resistance and select for resistant strains over susceptible strains. (Coutinho et al. 2013). Antibiotic Resistant Bacteria (ARB) spreads vertically and horizontally which implies passing Antibiotic Resistant Genes (ARG) to new generations (Judaibi, 2014) and exchanging resistant genes between different bacterial species (Judaibi, 2014 and Poria, 2016).

Contamination of the aquatic environment with ARB is an issue which needs immediate attention. The urban water treatment cycle consists of water abstraction, disinfection, consumption, collection, treatment and delivery to the environment (Mania et al. 2015). However the treatment process employed before delivering the water to the environment is conducive for the development of antibiotic resistant genes (Threedeach et al. 2012) owing to the presence of antibiotic molecules in wastewater. This imposes a selective pressure on ARB of human and animal origins which potentially promotes horizontal gene transfer (Mania et al. 2015). A recent study has revealed ARB discharged with the treated wastewater interacts with biofilms, the layer of slime composed of microorganisms, contributing to gene transferal among existing bacteria. ARB have been discovered up to 1km downstream of a discharge location in Tordera River Basin, Nothern Spain (Proia et al. 2016) and in some cases the distance was 4km (Alam and Deng, 2015). E. coli isolated from the Chaopharya Delta, a dense canal network in Thailand, has increased resistivity to antibiotics near urban lands (Honda et al. 2016).

As in most developing countries, the practice of over the counter antibiotics sales (Honda et al. 2016) also happens in Sri Lanka Antibiotic resistance is a major consequence of these improper consumption practices. E.coli in urine samples taken from the Out Patients Departments (OPD) of two teaching hospitals in Colombo, Sri Lanka has demonstrated resistance patterns to commonly used antibacterial agents including, ampicillin (85%), followed by nalidixic acid (58.5%), trimethoprim/sulphamethoxazole (47.1%), ciprofloxacin (46.2%), norfloxacin (43.7%) amoxicillin/clavulanic acid (36.3%) and nitrofurantoin (15%) and multi-drug resistance was seen in 44% of samples (Senadheera et al. 2016).

Since rivers receive the treated effluent of wastewater treatment plants (Goni-Urrriza et al. n.d) and hospital wastewater effluents (Devarajan et al. 2016), river water becomes the main receptacle for the pollutants resulting in freshwater resource pollution by microbial contaminants. .Even though studies have revealed that hospital effluents contain a higher prevalence of antibiotic resistant genes with higher concentrations of antibiotic residues, it is still classified as a domestic effluent which is not subject to any legal restriction for reducing microbial loads before discharge into municipal sewers (Mania et al. 2015) most of which connect to rivers and streams. In this study, we evaluated the occurrence of ARB and ARG in the Kelani River, Sri Lanka from samples taken at four locations along a gradient of potential ABR/ARG sources as part of a pre-emptive effort to control antibiotic resistant gene (ARG)/ARB contamination in this regionally important river in terms of both economic and political concerns.

2. MATERIALS AND METHODS

2.1. Sampling

Surface water samples were collected at four locations in the Kelani River (Figure 1). For antibiotic resistance tests, 50mL of river water was stored in sterile 50mL centrifuge tubes and kept on ice during transfer to the lab to help preserve the microbiological conditions. For the screening of the ARG, 2L of surface water was collected and stored in a sterile polyethylene bag. All samples were chilled with ice during transport to the laboratory. Filtrates of the water samples were prepared by filtering two aliquots of 400 mL of each sample through 0.2µm polycarbonate membrane filters. The membrane filters were then frozen at -20 C and sent to Japan for DNA extraction. The FastDNA spin kit was used for DNA extraction of the filtrate following the manufacturer's protocols.

Figure 1: Sampling Points

First sampling point is downstream to Seethawaka Export Processing Zone (EPZ), an industrial zone located near Kelani River. The zone consists of a 180 acres industrial area that accommodates mainly food processing and apparel industries with a worker population of 21500. An Industrial WWTP with a capacity of 9900m3/d and a sewerage treatment facility are is available inside the zone. Treated effluents are released to Kelani River upstream to the sampling location (BOI Sri Lanka, 2016). Hanwella Bridge was selected as the second sampling point. Third point is downstream to Biyagama EPZ in which apparel, food and beverage processing, latex and chemical manufacturing industries are located. A common WWTP is available for industrial and municipal wastewater treatment within the EPZ. However, the treated effluents are used for gardening purposes as per recent renovations (BOI Sri Lanka, 2016). Sampling stretch ends at Ambathale water intake which is the pumping location of Kelani River water. After treatment the water is supplied for the drinking and domestic purposes of nearly 80% (Chaminda et.al) of Colombo municipals.

2.2. E.coli concentration

Water samples were diluted by appropriate 10-fold dilution steps considering the anticipated E.coli concentration. The samples were diluted in triplicate using a phosphate buffered MgCL or 0.8 – 0.85% NaCl solution. Each diluted (or undiluted) water sample was then filtered through a sterile 0.45 µm membrane (47-mm diameter, ADVANTEC®). Each filter was then placed on solidified Chromocult® Coliform Agar ES, (Merck Microbiology, Darmstadt, Germany) in a 47 mm petri dish prepared following the manufacturer's instructions. .Some samples were processed using 37mm monitor kits (Advance Toyo, Tokyo Japan) which contain a gridded 0.2 µm membrane-filter inside with a pad underneath the membrane to absorb the culture media. The dishes were then incubated for 22 – 24 hours at 35.5 °C. The number of E.coli colonies per mL of water sample filtered (CFU/mL) was obtained by counting the dark blue/violet colonies, other coliforms by counting the pink colonies; the total coliform count is the sum of E. coli and other coliforms.

2.3. Antibiotic resistance ratio

E. coli for the antibiotic resistance test was cultured in sterile PERLCORE® Trypto-Soy Broth (EIKEN Chemical Co., Ltd). E.coli colonies were picked from the previously incubated samples and suspended in 4-5 mL broth in sterile tubes. Twenty individual colonies with similar shape were cultured from each sampling point. The tubes were then incubated at 35.5°C for 18 hours.

Agar medium for the antibiotic resistance test was prepared using PERLCORE® Sensitivity Test (ST) Agar (EIKEN Chemical Co., Ltd) following the manufacturers protocol. The media solution was autoclaved at 121 C for 20 minutes, cooled to 55 C, and then 20 – 25 ml of the agar solution was set into 90 mm petri dishes. After the agar was set, the prepared E.coli culture was smeared on the ST agar with a sterile cotton swab. After 3 – 5 minutes, antibiotic discs (KB Disk®, EIKEN Chemical Co., Ltd.,) were placed on the ST agar with a distance between disks of at least 24mm. The dishes were placed in a preheated incubator (37 °C) within 15 minutes of placing the discs. After incubation for 16 – 18 hours, the diameter of growth inhibition of the E.coli was measured. The resistance level of colonies can be assessed using the criteria provided in Table 1 (Standard Operating Procedure for Antibiotic Resistance Test for E.Coli in Water Samples, Water Intro, 2016)

Table 1 Criteria for determining antibiotic resistance of E.coli

Antibiotic category	Antibiotic disk	Diameter of inhibition circle (mm)		
		Resistant	Intermediate	Sensitive
Aminoglycoside	Kanamycin Monosulphate (KM)	≤13	14-17	≥18
Tetracycline	Tetracycline (TC)	≤11	12-14	≥15

Quinolone	Norfloxacin (NFX)	≤12	13-16	≥17
	Ciprofloxacin (CIP)	≤15	16-20	≥21
	Levofloxacin (LVX)	≤13	14-16	≥17
Sulfonamides	Sulfamethoxazole (ST)	≤10	11-15	≥16

The Resistance Ratio, the ratio between the number of resistant E. coli colonies and the total number of cultivated E. coli colonies (i.e. the twenty colonies) was calculated for each antibiotic at each sampling point.

2.4. Screening for antibiotic resistance genes

Antibiotic resistance genes were amplified by polymerase chain reaction (PCR). The PCR was performed in a thermal cycler (BioRad 2720) with reaction conditions as in Table 2 for thirty cycles. Six different classes of antibiotic-resistant gene based on antibiotic mechanisms were chosen. The primers used for the amplification of ARG are listed in Table 3.

Table 2 PCR conditions used for the amplification of ABR genes

PCR conditions	Temp (°C)	Time (min)
initial denaturation	95	3
denaturation	95	0.5
annealing temp.*	xx	0.5
extension	72	0.5
final extension	72	7

** depends on the annealing temperature of each primer.*

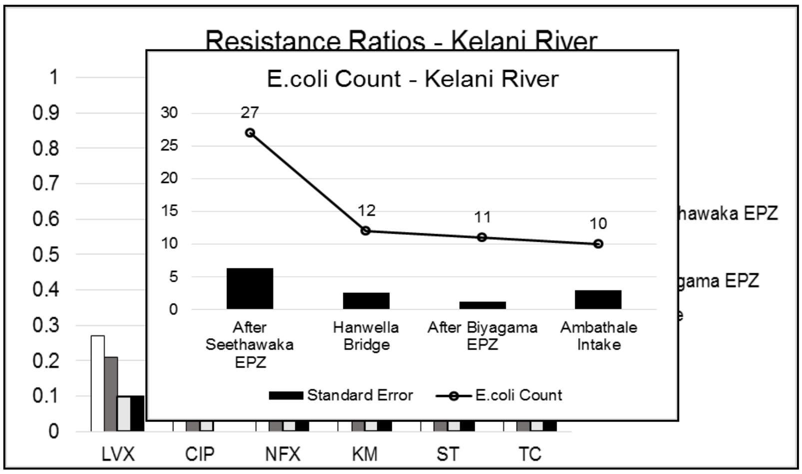
Table 3 Primers sequences used to target different mechanisms and classes of antibiotic resistance genes

Antibiotic Mechanism	Antibiotic Class	Target	Forward	Reverse	Reference
DNA gyrase:	fluoroquinolones	qnrS	GCAAGTTCATTGAACAGGGT	TCTAAACCGTCGAGTTCGGCG	Kim et al. 2009
		gyrA	AAATCTGCCCGTGTCGTTGGT	GCCATACCTACGGCGATACC	Kim et al. 2009
30S subunit	tetracyclines	tetW	GAGAGCCTGCTATATGCCACG	GGGCGTATCCACAATGTTAAC	Ma et al. 2011
Folate synthesis	sulphonamides	sulI	CGCACCGGAAACATCGCTGCAC	TGAAGTTCCGCCGCAAGGCTCG	Pei et al. 2006
	trimethoprim	dfrI	ACGGATCCTGGTGTTTGGTTGGACGC	CGGAATTCACCTTCCGGCTCGATGTC	Gibreel and Skold, 1998
Cell wall synthesis	vancomycin	vanA	TCTGCAATAGAGATAGCCGC	GGAGTAGCTATCCCAGCATT	Volkmann et al. 2004
	beta lactams	ampC	CCTCTTGCTCCACATTTGCT	ACAACGTTTGCTGTGTGACG	Ma et al. 2011
		CTX	ACGCTGTTGTTAGGAAGTG	TTGAGGCTGGGTGAAGT	Seyedjavadi et al. 2016
		TEM	GCGGAACCCCTATTTG	ACCAATGCTTAATCAGTGAG	Olesen 2004

3. RESULTS AND DISCUSSION

3.1. E.coli concentration

A reduced E.coli concentration (CFU/mL) was observed from upstream (after Seethawaka EPZ) to downstream (Ambathale intake) as shown in Figure 2. After the Seethawaka EPZ sampling point a considerably higher E.coli concentration was measured compared to downstream sampling points



which may suggest a poor quality of the Seethawaka EPZ discharges.

Figure 2:E.coli Concentration

3.2. Resistance ratio

Overall, the resistance ratio of the quinolone antibiotics, LVX, CIP and NFX decreased from upstream to downstream (Figure 3). This could be due to the deposition of antibiotics in the river bed or degradation of available antibiotics. Table 4 shows the number of resistant colonies for each antibiotic and colonies resistant to more than one antibiotic.

Compared to the Chaophraya River, Thailand, which was subjected to a similar type of study in 2016 (Honda et.al, 2016), quinolones (LVX, CIP and NFX) demonstrated a higher resistance ratio in the more urbanized area downstream than in upstream areas. Contrary to findings from the Chaophraya River, the resistance ratio for quinolones gradually decreased downstream in the Kelani River. For the Chaophraya River, resistance to quinolones was more likely affected by land use patterns rather than upstream conditions, while from the sampling locations in Kelani River, the resistance to quinolones might be affected by the presence of the wastewater treatment plant located upstream of the first (after Seethawala EPZ) and third sampling points (After biyagama EPZ), For non-quinolone antibiotics, KM, ST and TC,, higher resistance was observed at downstream locations compared to upstream locations which may indicate that resistance to these antibiotics was affected by land-use patterns, similar to the results observed in Chaophraya River (Honda et al. 2016). A more thorough investigation is needed to clarify these results by addition of sampling locations before the Seethawaka WWTP and further downstream in more urbanized areas.

Table 4 Resistant colonies

Sampling point	No. of resistant colonies						No. of colonies resistant to more than one antibiotic
	LVX	CIP	NFX	KM	ST	TC	
After Seethawaka EPZ	4	9	3	8	16	16	17
Hanwella Bridge	4	7	5	11	11	16	15
After Biyagama EPZ	2	2	3	4	14	18	17
Ambathale	3	0	4	4	17	18	16

3.3. Antibiotic resistance genes

Table 5 shows the ARG screening results for the samples.

Table 5 ARG screening results

Samples	qnrSm	gyrA	tetW	sulI	vanA	ampC	dfr1	blaCTX	blaTEM
After Seethawaka EPZ	-	+	+	+	-	+	-	-	-
Hanwella Bridge	-	+	+	+	-	+	-	-	-
Raksapanna	-	+	**+	+	-	+	-	-	-
Ambathale intake	-	+	**+	+	-	+	-	-	-

Note:

+ Detected

- Not Detected

** Very weak

Of the tested genes, ampC, tetW and sul1, were detected in all samples but. blaCTX, blaTEM, vanA and dfr1 were not detected. These results are in accordance with the antibiotic resistant test above where resistance to sulfamethoxazole, tetracyclines were observed. Although the qnrS gene that confers resistance to quinolone (e.g. levoloxacin, ciprofloxacin, norfloxacin) was not detected, our antibiotic resistance test showed resistance to the quinolone drugs we tested.A mutation in gyrA gene may cause low-level of quinolone resistance (Hooper et al. 1999), and further sequencing of the PCR products of the gyrA gene is needed to determine if the quinolone resistance determining (QRDR) region of gyrA gene detected was mutated or not. Furthermore, Yang et al. (2012) found genes conferring resistance to quinolones (qnrS, aac(6′)-Ib-cr) were more likely to co-occur with ampC in plasmid of S. marcescens. We detected ampC gene which confers resistance to β-lactam antibiotics (eg ampicillin). It could be that the resistance to quinolones that we observed was dictated by other types of quinolone resistance determinant genes which we did not test.

4. CONCLUSION

Resistant E. coli strains were detected at all sampling points, and all sampling points contained E.coli strains that showed resistance to more than one antibiotic. The Resistance Ratio for TC and ST were comparatively higher (≥0.9) than for other antibiotics Contrasting patterns were observed between resistance to quinolone and non-quinolone antibiotics; a decrease downstream for quinolones and an increase in resistance for non-quinolone antibiotics, suggesting different factors/mechanisms governed the pattern of resistance in quinolones compared to non-quinolone antibiotics. Both LVX and CIP resistance reduced downstream. However the non-quinolone antibiotic (i.e. KM, ST and TC) Resistance Ratio, tended to increase downstream. ARG screening test results are in agreement with the antibiotic resistance test. However, for the quinolone resistance, further screening of other types of quinolone resistance determinants is needed.

5. ACKNOWLEDGEMENT

This research was supported by Asia Pacific Network (APN) under Collaborative Regional Research Program (CRRP2016-06MY-Kumar). We express our thanks to University of Ruhuna, Sri Lanka and Kanazawa University, Japan for facilitating the laboratory experiments. We would also like to thank National Water Supply and Drainage Board, Sri Lanka for cooperating in sampling.

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Water Quality Modelling in Kelani River Downstream

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Abstract: *This study is aimed to investigate the water quality condition in Kelani River downstream. The secondary data collected from the 'Pavithra Ganga Program' was used to evaluate the existing water quality condition in Kelani River and QUAL2k modelling software was used to predict the water quality within the selected upstream and the downstream. The model was calibrated and validated by inputting kinetic parameters, point source data, non-point source data and geometrical data. The main concern was given to water quality parameters like dissolved oxygen (DO), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total Nitrate (TN) and total phosphate (TP).After the validation, calibrated model was used to predict the water quality along the Kelani River. It was revealed that BOD_5/COD ratio increased from upstream to downstream indicating that the biodegradable waste is more prominent in downstream. Even though the quality of water at Ambatale intake is currently within the proposed inland water quality standards for drinking and conventional treatment, the situation may rapidly vary due to emission of pollutants by non-point sources resulting in the increased population along the river and expansion of the residential area. The calibrated QUAL2k model for Kelani River can be used for planning and managing the Kelani River downstream.*

Keywords:*Water quality, modeling, Kelani River, downstream, QUAL2K.*

1. INTRODUCTION

Rivers play an important role in providing many of the needs of living beings. Agriculture, industry, and domestic are concentrated along the rivers because the rivers provide transportation facilities and an easy way of discharging waste. Agricultural activities have leant towards rivers as the flood plains are exceptionally fertile due to the nutrients that are deposited in the soil when the rivers overflow. In Sri Lanka, Kelani River is the most economically important river which originates from the central highlands and flows through the most densely populated districts Colombo (2.3 million) and Gampaha (2.3 million). 25% of the total population of Sri Lanka is accounted by these two districts (DCS, 2012). It is the primary source of providing drinking water for the Colombo Metropolitan Region as well as the Sabaragamuwa and Central Provinces and it provides 80% of drinking water to the Colombo city (Mallawatantri *et al.* 2016). The River and its tributaries are intensively consumed for various basic needs such as washing, bathing and homestead agriculture.

At present, the river water is getting deteriorated due to industrial, domestic and agricultural activities. Most of the industries are concentrated along the Kelani River. Urbanization also has imposed considerable strain on the quality of Kelani River water, and the authorized authorities find it extremely difficult to control the contamination of river water. Kelani River is the most polluted river in Sri Lanka (Illeperuma, 2000). Two major industrial zones; Biyagama and Seethawaka are located near the Kelani River. In addition, enormous number of individual industries are located outside the industrial zones along the river. The river drains across the most populated province in the country thus, there are many industries releasing treated and untreated industrial wastes into the river. Industrial parks which are also known as export processing zones are the areas mainly planned for establishment of manufacturing industries with related facilities. Biyagama is the largest industrial zone in Sri Lanka, located in the area of 180 hectares, including 65 firms. Biyagama industrial zone discharges its wastewater into Rakgahawatte Ela which is situated approximately 3km upstream from Ambatale intake. Seethawaka industrial park comprises of 30 firms and it is situated in Awissawella and it drains its wastewater directly into the Kelani River.

Water quality modelling is considered as one of the best option of mitigating river water pollution. Water quality models are of vital importance to gain the best economic and social solutions for water problems.

Among the water quality models, QUAL2E was the widely used mathematical model for river and stream water quality to evaluate the conventional pollutant impact and predict the water quality along the streams. However, due to some limitations it was modified by Park and Lee, and they developed QUAL2K, 2000, which included the addition of new water quality interactions. It was further developed by Chapra and Pelletier with the name of QUAL2K, 2003. By modifying the QUAL2K, 2003, Pelletier *et al* developed QUAL2Kw, which is the modernized version of QUAL2E (Kannel *et al*. 2007). The aim of the study is to evaluate the existing water quality condition of Kelani River downstream and to model the water quality of Kelani River downstream.

2. MATERIALS AND METHODS

A water quality monitoring program called 'Pavithra Ganga' have been conducted for the last 55 km by Central Environment Authority (CEA) and National Water Supply and Drainage Board (NWS&DB) for the Kelani River and the secondary water quality data needed for the analysis were obtained from this program. When considering about the upstream of Kelani River, it is extremely good in condition because it flows through central highlands and river gets runoff mainly from agricultural lands.

So, the last 55 km were highly affected by industrial pollution, domestic pollution and urban runoff. From these 55 km, last 10 km which was situated near the sea were heavily influenced by tides and during dry season this area was influenced by sea water intrusion. Therefore last 45 km were taken into account for the modelling work; considering Awissawella as the upstream boundary Ambatale as the downstream boundary.

The overview of the research methodology is displayed in the following Figure 1.

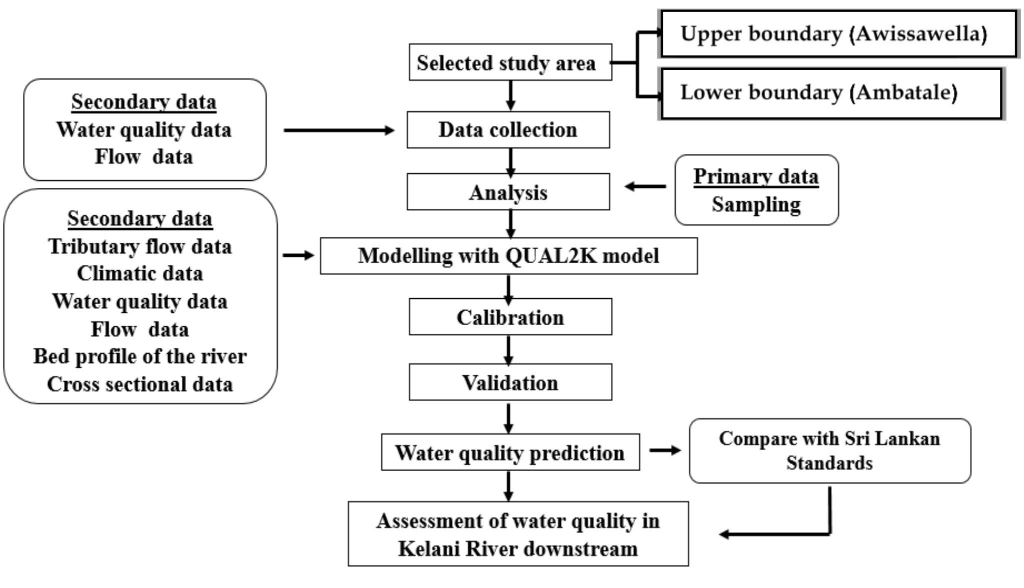

Figure 1: Overview of the Research Methodology

2.1. Data Requirement for the QUAL2K Model

There were several input parameters need to feed the model to take required outputs. Some of them were water quality data (two different data set in two different times), hydraulic data (slope, width, depth and etc.), hydrological data (flow, velocity and etc.), climate data, point and non-point source data, kinetic parameters and etc. Due to the time limitation and practical difficulties most of the data has to be collected as the secondary data and from the literature values. Table 1 shows the data collected locations to input into the qual2K model.

Table 1 Data requirement and relevant sources

Data Requirement	Source
Water Quality Data 1. Main Stream 2. Point Sources	Field Measurements (NWS&DB)
Flow Data	Irrigation Department
Industrial Pollution Load Data	Central Environmental Authority
Climate Data	Metrological department
Cross Sectional Data, Bed profile	Irrigation Department
Model Parameters	Literature

Figure 2: Study Area

The sampling locations used for the calibration and validation processes has shown in the above Figure 2 which was generated on the Google Earth map.

Water quality data of following locations were obtained.

(i) Ambatale intake
(ii) Hanwella Bridge
(iii) Weliwita Bridge
(iv) Pugoda Ferry
(v) Kaduwela Bridge
(vi) Sithawaka Ferry

Water quality data of tributaries namely, Raggahawatte Ela, Maha Ela, Pusseli Oya, Wak Oya and Pugoda Ela were taken to input as point sources to the model.

2.1.1. River segmentation

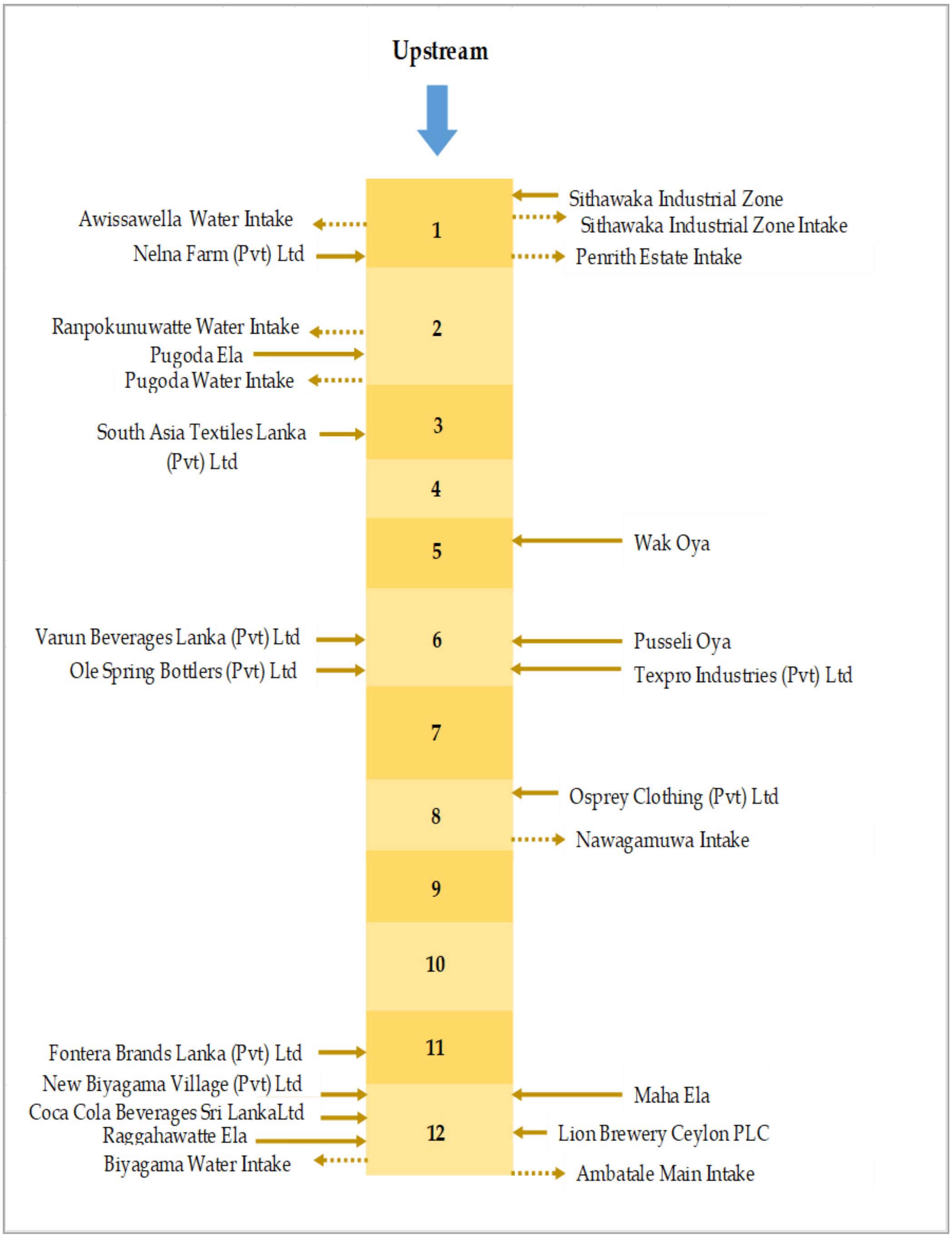

Figure 3: Segmentation Diagram of the Study Area of the Kelani River for the QUAL2K Application

According to the model, the river has to be divided into number of reaches because the model denotes a river as a series of reaches. A reach is defined that have constant hydraulic characteristics such as slope and bottom width. To divide the Kelani River into reaches the bed profile of the river is needed. From the department of Irrigation, Colombo, the bed profile along the Kelani River was taken. Figure 3 shows the segmentation of the river and it consists of twelve reaches, five tributaries, individual firms and nine abstraction points.

2.1.1. Kinetic rate parameters

In the calibration process simulated water quality values were fine tuned in to the observed water quality values by adjusting the kinetic rate parameters within the acceptable limitation. The main kinetic parameters and the used values have shown in the following Table 2.

Table 2 Kinetic rate parameters used for the calibration

Parameter	Used Value	Range in literature
Re aeration rate, k_a	0-5 /day	0-100/day
BOD oxidation rate, k_{dc}	3.5/day	0-5/day
Sed denitrification transfer coefficient, v_{di}	0 m/d	0-1 m/d
Pathogens, decay rate, k_{dx}	0.5/day	0-20/day

3. RESULTS AND DISCUSSIONS

Water quality data of past six years were analyzed and it was revealed in both the low flows and high flows BOD/COD ratio increases from upstream to downstream (Figure 4). This implies biodegradable waste is more prominent in the dowstream.

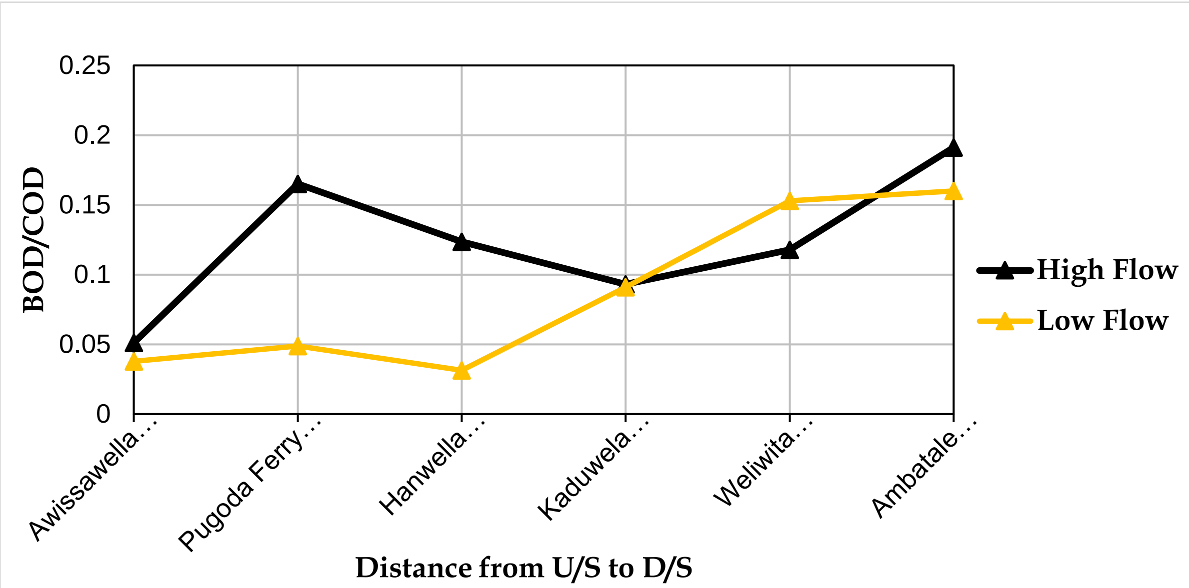

Figure 4: Average BOD/COD variation along the river downstream

This implies that relevant authorities have taken steps to control COD input to the river from individual industries by implementing of pollution control abatement practices but they do not concern about BOD, this is mainly due to the non-point sources like illegal septic tank disposal, solid waste and agricultural wastewater.

Then water quality of Kelani River was modelled by using QUAL2K model. The calibrated and validated water quality prediction results are shown in the Figure 5 and Figure 6 respectively. QUAL2K model was simulated for DO, BOD_5, TN, pH and Pathogens. At the model calibration DO and BOD_5 were focused as they are the critical water quality parameters.

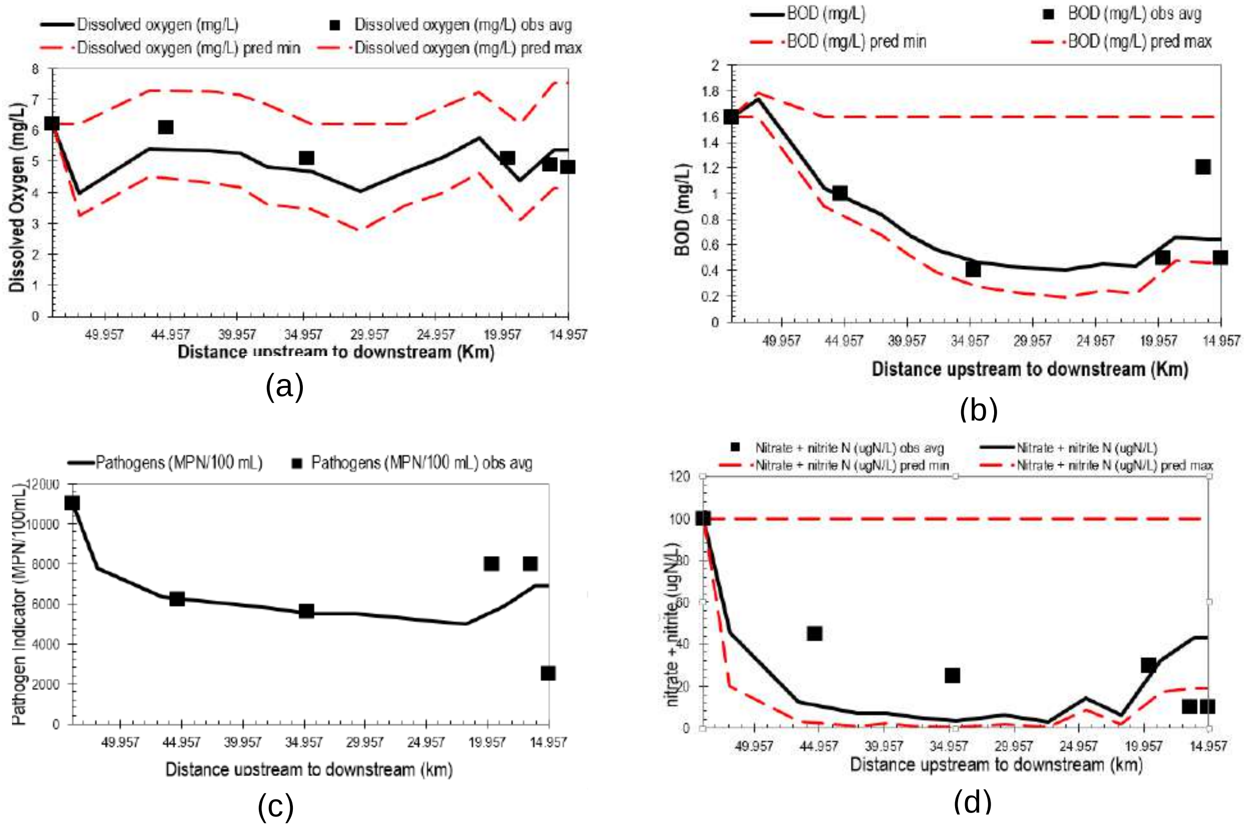

Figure 5: QUAL2K Model Calibration

Figures 5(a) and 6(a) show the Dissolve Oxygen (DO) profile along the modeled reach for the calibration and validation phases respectively. It was obvious fro the Calibrated graph of DO that the lowest DO level is in 29 th km, this may due to the pollution load from Pusseli Oya. And also the nature of the river affects for this DO drop.

The model predicted BOD values are shown in the Figure 5(b) and 6(b) .There are some variations with the predicted values and the observed values. Even if it is so both values are shown a same behaviour along the river. And also observed values are limited to minimum and maximum boundary of the model predicted values

The Figure 5(c) and 6(c) shows the calibration and validation results for Nitrate. It was difficult to match all the measured values and simulated values in each point. Because, there is a possibility for experimental errors in measured values. Nitrate concentration decreases from upstream to downstream.

Total Coliform concentration also does not exactly comply with the observed value. (Figure 5(d)). QUAL2K only considers the pathogen die off rate and settling only. It does not consider the dynamics of the bacteria. This may be a reason for the difference between observed and simulated values. Due to the dense urbanization downstream of the river occupied the maximum amount of pathogens.

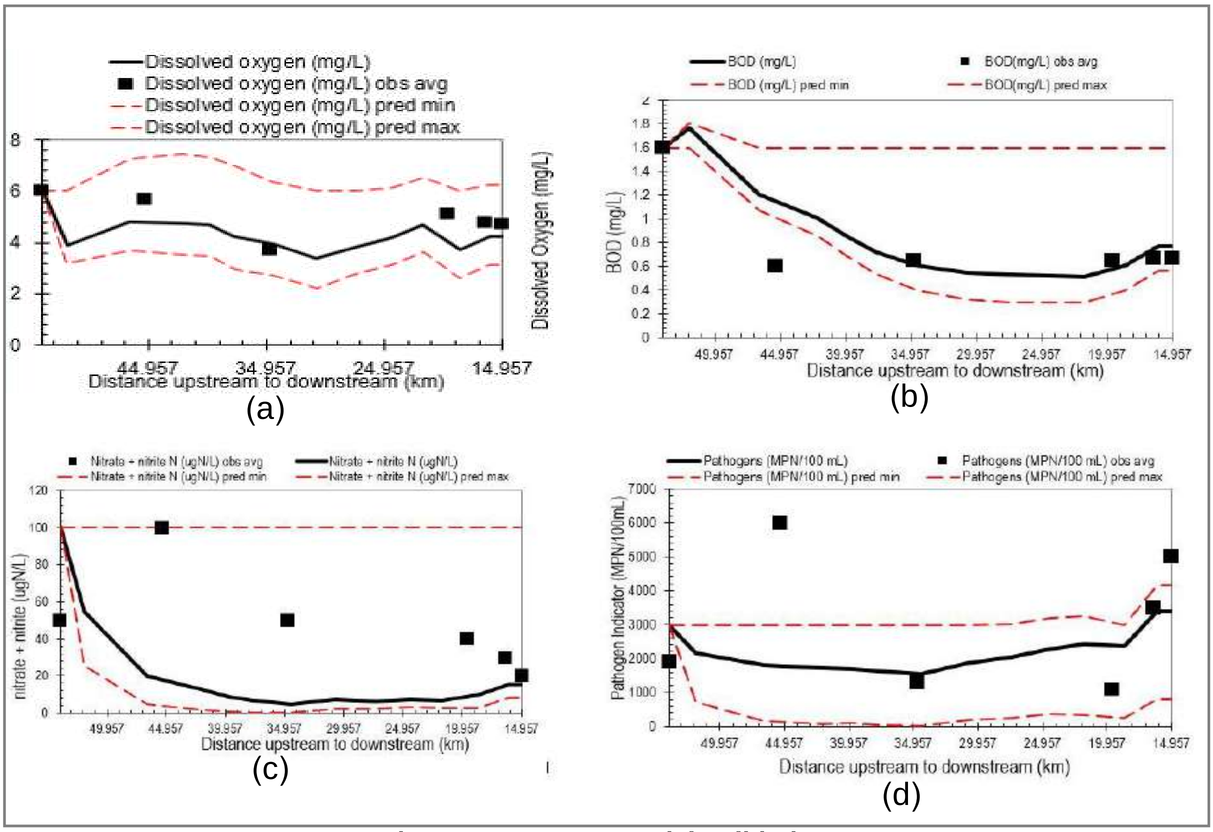

Figure 6: QUAL2K Model Validation

Then by using this calibrated model water quality was predicted for the lowest flow of the last six years. By applying this critical condition, it was checked whether the water quality is complied with the Inland water quality standards of Sri Lanka.

According to te Figure 7, in all the reaches BOD levels are lower than the proposed Inland water quality standards of drinking and bathing in the dry season. However, there is a slight increase of BOD level in 18 th km because of the effluents from individual industries.

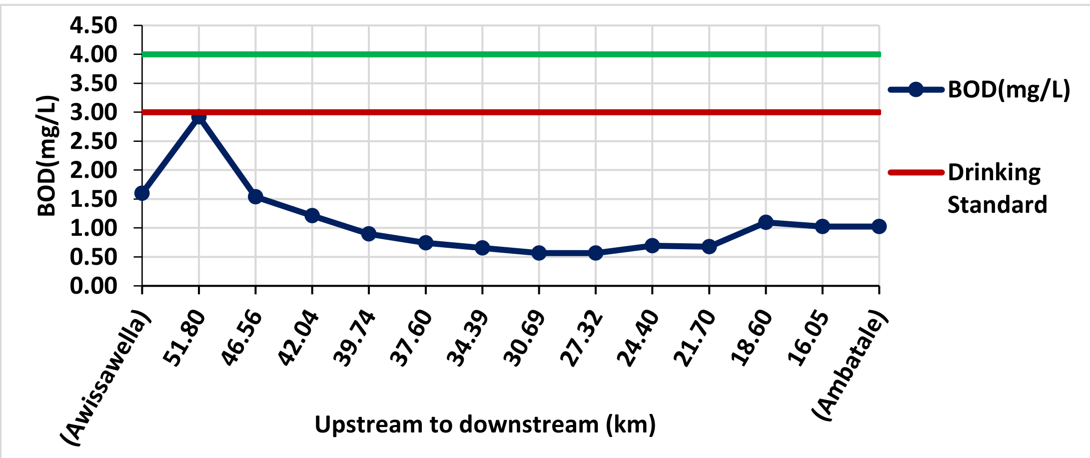

Figure 7: BOD Variation along the River in the Lowest Flow

4 CONCLUSION AND FUTURE DIRECTIONS

Initially last six years water quality data were collected from NWSDB and analysis was done. It was revealed that BOD_5/COD ratio increases from the upstream to downstream indicating that the biodegradable waste is more prominent in the downstream. It was also noted that the authorities have taken measures to reduce only the COD level and no attention has been paid for the increased (BOD_5), which is mainly due to non-point source pollutants. The QUAL2k model both calibrated and validated was used to predict the water quality (DO, BOD_5, TN, TP, pH, pathogens and temperature) of the Kelani River downstream. Finally, the calibrated and validated models were used to predict the water quality along the river for the lowest flow. From that results, it can be concluded that it is satisfied with the proposed Inland water quality standards of Sri Lanka except few places.

As for the future directions, calibrated model can be used to analyze the condition when it needs to have a new water intake, it can provide recommendations to new implementation such as new industrial zones which are going to implement within the catchment area and it can recommend them which kind of treatment has to be done for their effluents before emitting to the environment.

5 ACKNOWLEDGEMENT

The authors would like to express their thank to the Sri Lankan institutions namely National Water Supply & Drainage Board (NWS&DB), Central Environmental Authority (CEA), Irrigation Department and Meteorological Department for their help in providing necessary data used in this study. They also would like to acknowledge the support of Department of Civil and Environmental Engineering, University of Ruhuna.

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