Environmental Impact Study of Two Tannery Estates on the Buriganga and the Dhaleshwari Rivers

Final Report

June 2018

Department of Environment
Ministry of Environment, Forest and Climate Change
Government of the People's Republic of Bangladesh

Department of Environment

Final Report

on

Environmental Impact Study of Two Tannery Estates on the Buriganga and the Dhaleshwari Rivers

Acknowledgements

The Center for Environmental and Geographic Information Services (CEGIS), a Public Trust under the Ministry of Water Resources (MoWR) is greatly indebted to the Department of Environment (DoE) for awarding the study of 'Environmental Impact Study of Two Tannery Estates on the Buriganga and the Dhaleshwari River'.

Firstly, CEGIS would like to show the utmost gratitude to Dr. Sultan Ahmed, Director General, Department of Environment (DoE) for his confidence in CEGIS for the accomplishment of the assignment. We also express sincere gratitude to Mr. A. K. M. Rafiqul Islam, Deputy Director, Natural Resources Management (NRM), DoE for his valuable directions and advices on various aspects of the study from the beginning of the study.

CEGIS also expresses its gratitude to Dr. Md. Sohrab Ali, Director, Dhaka Laboratory, DoE, for his continued support and guidance in achieving various tasks of the impact evaluation and solution recommendation study in an efficient way. We are very thankful with such distinction to have a provocative Director from DoE who made such an environment to complete the whole work very smoothly.

Last but not the least; CEGIS is appreciating the support of Mr. Shariful Islam, Chemist, Dhaka Laboratory Office, DoE for his enormous support during reconnaissance visit and the detail field visit during the study.

Table of Content

Acknowledgements i
List of Tables vii
List of Figures ix
Acronyms and Abbreviations xiii
Unit of Measurement xvii
Executive Summary xix
1. Introduction 1
1.1 Background 1
1.2 Objectives 2
1.3 Scope of Works 3
1.4 Study Areas 3
1.5 Approach and Methodology 6
1.5.1 Approach 6
1.5.2 Methodology 6
1.6 Limitation of the Study 17
2. Environmental and Social Status of Hazaribagh Tannery Area 19
2.1 Introduction 19
2.2 Physical Environment 19
2.2.1 Water quality 19
2.2.2 Land resources 27
2.2.3 Soil quality 29
2.3 Biological Environment 31
2.3.1 Plankton Status 31
2.3.2 Fisheries Resources 31
2.3.3 Ecological Resources 36
2.3.4 Agricultural resources 38
2.4 Socio-economic Condition 39
2.4.1 Socio-economic Resources 39
2.4.2 Population, Demographic Profile and Ethnic Composition 40
2.4.3 Settlement and Housing 40
2.4.4 Public Utilities 42
2.4.5 Economy and Employment 42
3. Environmental and Social Status of Hemayetpur Tannery Area 45

3.1 Introduction 45
3.2 Physical Environment.. 45
3.2.1 Water Availability of Dhaleshwari River 45
3.2.2 Quality of Savar Tannery Effluents 46
3.2.3 Water Quality of Dhaleshwari River 49
3.2.4 Odor of Savar Tannery Estate... 56
3.2.5 Land Resources 63
3.2.6 Soil Quality 65
3.3 Biological Environment.. 65
3.3.1 Plankton Status 65
3.3.2 Fisheries Resources.. 66
3.3.3 Ecological resources 69
3.3.4 Agricultural resources... 73
3.4 Socio-economic Condition 74
3.4.1 Socio-economic Resources 74
3.4.2 Population, demographic profile and ethnic composition......................... 74
3.4.3 Settlement and Housing 75
3.4.4 Public utilities.. 77
3.4.5 Economy and employment 78
4. Existing Wastes Management Facility at STE..81
4.1 Introduction 81
4.2 Waste Generation Status.. 81
4.2.1 Liquid waste.. 81
4.2.2 Solid waste 81
4.3 Management Plans/Facility 83
4.3.1 Common Effluent Treatment Plant (CETP) 83
4.3.2 Solid Waste Disposal Yard.. 84
4.3.3 5.0 MW Sludge Power Generation System (SPGS)................................. 85
4.3.4 Systematic drainage system... 86
4.3.5 Internal road network development... 86
4.4 Status of waste management facilities of STE 87
5. Impact Prediction for Hemayetpur Tannery Estate....................................89
5.1 Impact on Water Quality 89
5.1.1 Changes in physical quality of the water 89
5.1.2 Changes in chemical status of the water 89

5.1.3 Changes in metal status of the water 90
5.1.4 Changes in WQI 90
5.2 Impact on Planktons 91
5.3 Impact of Odor 91
5.4 Impact on Soil Quality 92
5.5 Impact on Fisheries Resources 92
5.5.1 State and pressure for Chromium (Cr) 92
5.5.2 Impact Assessment 93
5.5.3 Sensitivity of fish to heavy metal 93
5.6 Impact on Ecological Resources 94
5.6.1 Impact on Flora 94
5.6.2 Impact on Fauna 95
5.6.3 Landscape capacities to supply Ecosystem Services in and around the Hemayetpur tannery area 96
5.7 Impact on Agricultural Resources 99
5.7.1 Bio-accumulation 99
5.7.2 Irrigation 99
5.7.3 Crop loss 99
5.8 Impact on Socio-economic Condition 100
5.8.1 Human health 100
5.8.2 Labor and working condition 100
5.8.3 Standard of living 100
5.8.4 Force changes of livelihood 101
5.8.5 Waste management due to increase population 101
5.9 Impact Evaluation of Savar Tannery Estate 101
6. State of Environment of Two Sites Tannery Estate 111
7. Future Management Suggestions 117
7.1 Performance Improvement of the CETP 117
7.2 Managing Odor Problem 117
7.3 Managing Soild Wastes 117
7.4 Enhancing Ecological Resources 118
7.5 Improving Socio-economic condition 118
7.6 Resources Monitoring 118
7.7 Institutional Framework 119
8. Conclusions 121

8.1 Conclusions 121
References 123
Appendix A: Reconnaissance Field Visit 129
Appendix B: Matrix-Evaluation of Socio-Economic Status.............................. 135
Appendix C: Available fish species in the Buriganga River 137
Appendix D: Major fish species in the Dhaleshawari river system 139
Appendix E: Chemicals Used in Leather Processing 141
Appendix F: ES scoring matrix of Hemayetpur Tannery area 145
Appendix G: Environmental and Social Monitoring Plan 147

List of Tables

Table 1.1: Aspects of Literature Review and list of Organizations Visited to Collect Information 8
Table 1.2: Water Quality Parameters and Testing Laboratories........ 9
Table 1.3: Water Quality Sampling Sites and their Characteristics 10
Table 1.4: The Weighted Values of Water Quality Parameters in Water Quality Index System – NSF........ 13
Table 1.5: Water Quality Rating as per NSFWQI........ 13
Table 1.6: Soil, river bed and plant sampling locations and its characteristics 14
Table 1.7: Parameters observed and sampling frequency 15
Table 2.1: Physical water quality status of the Buriganga River 20
Table 2.2: TDS and salinity status of the water quality of Buriganga River........ 22
Table 2.3: Status of organic pollution in the Buriganga River 23
Table 2.4: Status of chemicals in Buriganga River 23
Table 2.5: Status of metals in Buriganga River........ 24
Table 2.6: Classes of water in respect to Water Quality Index (WQI) 27
Table 2.7: Land Use of Hazaribagh Tannery Estate 27
Table 2.8: Presence of Chromium (Cr) in soil, sediment and plant in Hazaribagh Tannery Estate........ 29
Table 2.9: Composition of Zooplankton in Buriganga River 31
Table 2.10: Breakdown of fish habitats in the HzTC 33
Table 2.11: Seasonal Variation in Heavy Metal Bioaccumulation in to Fish 36
Table 2.12: Breakdown of Fish Production from Different Habitats in the HzTA........ 36
Table 2.13: Locations of the study area along with coverage of Upazilas 40
Table 2.14: Demographic Scenario of the Study Area 40
Table 3.1: Physical characteristics of the effluent quality of Savar Tannery Estate 47
Table 3.2: TDS Concentrations of the Effluent of Savar Tannery Estate 48
Table 3.3: Status of Organic Pollutants in the Effluent Quality of Savar Tannery Estate 48
Table 3.4: Status of metal pollutants in the effluent of Savar Tannery Estate........ 49
Table 3.5: Physical Characteristics of the Water Quality of the Dhaleshwari River........ 49
Table 3.6: TDS and Salinity status of the Water Quality of the Dhaleshwari River........ 51
Table 3.7: Status of organic pollution of the Dhaleshwari River 52
Table 3.8: Status of Chemicals in the Dhaleshwari River 53
Table 3.9: Status of Metals of the Dhaleshwari River 54
Table 3.10: Water Quality Index Calculation 55
Table 3.11: Classes of Water in Respect to Water Quality Index (WQI) 55

Table 3.12: Standard for Odor of ECR, 1997, SCHEDULE – 8 57
Table 3.13: Rate of emission of the Odorant from tannery industry 60
Table 3.14: Maximum concentration of the Odorant pollutants disperse from Savar Tannery Estate 60
Table 3.15: Land Use of Hemayetpur/Savar Tannery Estate 63
Table 3.16: Presence of Chromium (Cr) in soil, sediment and plant in Hemayetpur Tannery Estate 65
Table 3.17: Composition of Zooplankton in Dhaleshwari River.................................. 66
Table 3.18: Hazards of Trace Elements or Ions 67
Table 3.19: Breakdown of fish habitats in HmTC 68
Table 3.20: Breakdown of fish production in HmTA.. 69
Table 3.21: Chromium concentration of plant bodies along the study area.................. 73
Table 3.22: Locations of the study area along with coverage of upazilas 74
Table 3.23: Demographic scenario of the study area 74
Table 3.24: Demography of ethnic groups 75
Table 3.25: Household monthly income and expenditure in the study area 78
Table 4.1: The proportion of the types of tannery solid wastes generated from processing of 1 ton of raw hides... 83
Table 4.2: Solid waste generation scenario 83
Table 4.3: Status of the existing waste management facilities in Savar Tannery Estate 87
Table 5.1: Order of heavy metal accumulation and sensitivity of different fish species . 94
Table 5.2: Area of landuses in three different time period 96
Table 5.3: Impact evaluation of Savar Tannery Estate 102

List of Figures

Figure 1.1: Hazaribagh Tannery Cluster and its Drainage System, which is Directly Linked to the Buriganga 4

Figure 1.2: Savar Tannery Cluster, which is situated on the Bank of Dhaleshwari River. 5

Figure 1.3: Flowchart of the Study Methodology 7

Figure 1.4: Sampling Locations of Hazaribagh Tannery Estate 11

Figure 1.5: Sampling Locations of Savar Tannery Estate 12

Figure 2.1: Trend of temperature, pH, DO and TSS in Buriganga River 20

Figure 2.2: Trend of TDS in Buriganga River 22

Figure 2.3: Trend of organic indicators of water quality in Buriganga River 23

Figure 2.4: Trend of NO_3^- and PO_4^{3-} quality in the Buriganga River 24

Figure 2.5: Trend of Metals (Cr, Al, Pb, Zn) Concentrations in the Buriganga River ... 25

Figure 2.6: Status of fecal coliforms in Buriganga River 26

Figure 2.7: Land use map of Hazaribagh Tannery Estate 28

Figure 2.8: Time series data of Cr concentration in Hazaribagh soil 30

Figure 2.9: Time series data of mean Cr concentration in the Buriganga River sediment 30

Figure 2.10: Exponential smoothing series with linear trend of habitat suitability scores for the Buriganga River 32

Figure 2.11: Fish Composition of the Buriganga River at Baschila Bridge Point 34

Figure 2.12: Historical Trend of Heavy Metal Bio-accumulation to Fish based on Literature Review 35

Figure 2.13: Existing vegetation pattern of Hazaribagh Area 37

Figure 2.14: Chromium (Cr) Bioaccumulation at Hazaribagh Area main Channel 39

Figure 2.15: Housing Tenancy in the Study Area 41

Figure 2.16: Distribution of Households by Type 41

Figure 2.17: Households by Drinking Water Facilities 42

Figure 2.18: Employment Status among the Male-Female 43

Figure 2.19: Occupation Status among the Studied Population 44

Figure 3.1: Historical Maximum Discharge of the Dhaleshwari River (1991-2013) 45

Figure 3.2: Monthly Variation of Average Discharge of the Dhaleshwari River (1991-2013) 46

Figure 3.3: Dependable Average flow analysis of Dhaleshwari River (1991-2013) 46

Figure 3.4: Trend of Physical (pH, DO and TSS) Characteristics of Water Quality of the Dhaleshwari River 50
Figure 3.5: Trend of TDS in Dhaleshwari River 52
Figure 3.6: Characteristics of BOD in Dhaleshwari River 53
Figure 3.7: Status of Phosphate and Nitrate Concentrations in Dhaleshwari River 54
Figure 3.8: Status of Fecal Coliforms in Dhaleshwari River 55
Figure 3.9: Wind Histogram and WindRose diagram at Savar Tannery Estate 59
Figure 3.10: Maximum Concentration of VOC after Dispersion from Savar Tannery Estate 61
Figure 3.11: Maximum Concentration of H_2S after Dispersion from Savar Tannery Estate 62
Figure 3.12: Maximum Concentration of NH_3 after Dispersion from Savar Tannery Estate 63
Figure 3.13: Land Use Map of Hemayetpur/Savar Tannery Estate 64
Figure 3.14: Discharge of Industrial Effluent into the Dhaleshwari River 66
Figure 3.15: Exponential Smoothing Series with Linear Trend of Habitat Suitability Scores for the Dhaleshwari River 67
Figure 3.16: Fish species composition of the Dhaleshwari at Singair Bridge Point 69
Figure 3.17: Existing vegetation pattern of the Haringdhara Site 70
Figure 3.18: Egrets observed at solid waste dumping site at Harindhara Tannery Estate 71
Figure 3.19: Wildlife distribution within the Harindhara Tannery Estate 72
Figure 3.20: Bioaccumulation of heavy metals from tannery waste 73
Figure 3.21: Percentage of population by age group 75
Figure 3.22: Housing tenancy in the study area (%) 76
Figure 3.23: Distribution of households by Type 76
Figure 3.24: Households by drinking water facilities 78
Figure 3.25: Employment status among the Male-Female 79
Figure 3.26: Occupation status among the studied population 79
Figure 4.1: General flow diagram for leather tanning and finishing process 82
Figure 4.2: Design View of Common Effluent Treatment Plant (CETP) and Dumping (Disposal) Yard 84
Figure 4.3: Solid waste disposal yard 85
Figure 4.4: Layout Plan of SPGS (replacing Dumping Yard) building integrally with CETP 85
Figure 4.5: Internal road network system 86
Figure 4.6: Real picture of internal roads of Savar Tannery Estate 87

Figure 5.1: Comparison of WQI among Buriganga, Dhaleshwari and predicted Dhaleshwari River condition 91
Figure 5.2: Comparative scenario of Cr concentration in Hemayetpur and early stage of Hazaribagh 92
Figure. 5.3: Landuse maps of the study area in three different time periods 97
Figure 5.4: Ecosystem service capacity of different landuses of the study area 98

Acronyms and Abbreviations

%	Percent
µg/L	Microgram per liter
3R	Reduce, Reuse and Recycle
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AEZ	Agro Ecological Zone
Al	Aluminum
APHA	American Public Health Association
As	Arsenic
BADC	Bangladesh Agricultural Development Corporation
BBS	Bangladesh Bureau of Statistics
BSCIC	Bangladesh Small and Cottage Industries Corporation
BCSIR	Bangladesh Council of Scientific and Industrial Research
BDT	Bangladesh Taka
BFLLFEA	Bangladesh Finished Leather, Leather goods and Footwear Exporters Association
BIWTA	Bangladesh Inland Water Transport Authority
BLRI	Bangladesh Livestock Research Institute
BMP	Best management practices
BOD	Biochemical Oxygen Demand
BTA	Bangladesh Tanners' Association
BWDB	Bangladesh Water Development Board
Cd	Cadmium
CEGIS	Center for Environmental and Geographic Information Services
cell/ml	Cell per milliliter
CETP	Central Effluent Treatment Plant
CFU	Colony Forming Units
CH4	Methane
CNG	Compressed Natural Gas
CNRS	Center for Natural Resource Studies
COD	Chemical Oxygen Demand
CPCB	Center Pollution Control Board
CPD	Centre for Policy Dialogue
CPUE	Catch per Unit Effort

Cr	Chromium
Cr^{+6}	Hexavalent Chromium
Cu	Copper
D/T	Dilution Threshold
DCC	Dhaka City Corporation
DNA	Deoxyribonucleic Acid
DO	Dissolved Oxygen
DoE	Department of Environment
DPHE	Department of Public Health Engineering
ds/m	deciSiemens per metre
EC	Electrical conductivity
ECR 1997	The Environment Conservation Rules, 1997
EIA	Environmental Impacts Assessment
EPA	Environmental Protection Agency of USA
EPB	Export Processing Bureau
EQS	Environmental Quality Standard
ES	Ecosystem Services
ETPs	Effluent Treatment Plants
EU	European Union
FAO	Food and Agricultural Organization
Fe	Iron
FGD	Focus Group Discussion
FWIP	Future With Project
FWOP	Future Without Project
GBM	Ganges-Brahmaputra-Meghna
GC	Gas Chromatography
GC-MS	Gas Chromatography-Mass Spectrometry
GoB	Government of Bangladesh
H_2S	Hydrogen Sulphide
ha	Hactare
HCHO	Formaldehyde
Hg	Mercury
HH	HouseHold
HmTC	Hemayetpur Tannery City
HRs	Hours
HTE	Hazaribagh Tannery Estate
HU	Hazen Units

HYV	High Yield Variety
HzTA	Hazaribagh Tannery Area
IECs	Important Environmental Components
ILET	Institute of Leather Engineering and Technology
ILO	International Labour Organization
KII	Key Informant Interviews
LDC	Least Developed Country
LLWA	Leather Labors Welfare Association
LRI	Leather Research Institute
LWU	Leather Workers Union
m	Meter
m^3/day	Cubic meter per day
m^3/s	Cubic meter per second
MAC	Maximum Allowable Concentration
Mg	Magnesium
Mg/Kg	Miligram/Kilogram
mg/L	Milligram per liter
Mg/L	Miligram/Liter
Mg/m3	Miligram per Cubic Meter
MoU	Memorandum of Understanding
MoWR	Ministry of Water Resources
MT	Metric Ton
NCA	Net Cultivable Area
NGO	Non-governmental organizations
NH_3-N	Ammonium Nitrogen
NO_3-N	Nitrate Nitrogen
NRM	Natural Resources Management
NSF	National Sanitation Foundation
NSFWQI	National Sanitation Foundation Water Quality Index
NTU	Nephelometric Turbidity Unit
^oC	Degree Celsius
OU/m^3	Odor unit per cubic meter
OU_E	European Odor Unit
OUM^3	Odor units per unit volume
PAN	Peroxyacetyl Nitrate
Pb	Lead
p^H	Potential of Hydrogen

PO_4^{3-}	Orhto-phosphate
PPE	Personal Protective Equipment
ppm	Parts per million
Pt-Co	Platinum-Cobalt
RDPP	Revised Development of Sludge Project Proposal
RMG	Ready-Made Garments
ROS	Reactive Oxygen Species
RRA	Rapid Rural Appraisal
RTO	Regenerative Thermal Oxidation
SEHD	Society Environment and Human Development
SIS	Small Indigenous Species
SO_4^{2-}	Sulphate
SPGS	Sludge Power Generation System
SRDI	Soil Resource Development Institute
SRDI	Soil Resource Development Institute
SRTM	Shuttle Radar Topography Missio
STE	Savar Tannery Estate
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UNIDO	United Nations Industrial Development Organization
US EPA	United States Environmental Protection Agency
US$	United States Dollar
USGS	U.S. Geological Survey
UV	Ultraviolet
VOCs	Volatile Organic Compounds
WQI	Water Quality Index
Zn	Zinc

Unit of Measurement

1 m^2	= 10.77 ft^2
1 Decimal	= 435.60 ft^2
1 Decimal	= 40.47 m^2
1 Katha	= 1.653 Decimal
1 Bigha	= 33 Decimal
1 Bigha	= 20 Katha
1 Acre	= 3 Bigha
1 Acre	= 60 Katha
1 Acre	= 100 Decimal
1 Hector	= 247 Decimal
1 Hector	= 7.5 Bigha
1 Hector	= 2.47 Acre
1 Anna	= 0.0625 Decimal
1 Ganda	= 0.0031 Decimal
1 Kara	= 0.00078125 Decimal
1 Kranti	= 0.00026 Decimal
1 Til	= 0.000013 Decimal
1 feet	= 0.3048 meter
1 yards	= 0.9144 meter
1 cubic feet	= 0.0283168 cubic meters
1 cubic feet	= 28.316847 liter
1 mg/l	= 1 ppm
1 gm	= 1000 mg
1 km	= 1000 m

Executive Summary

From the very beginning of industrialization in Bangladesh, tanning industries have been playing a significant role in the country's economy. Due to its importance as a labor based export oriented industry, the full flourish of this industrial sector is essential. In accordance with this endavour, Government of Bangladesh (GoB) has shifted Hazaribagh Tannery Industries from Hazaibagh, Dhaka to Savar Tannery Estate at Harindhara, Savar, Dhaka for organizing and managing these industries with a target of sustaninable environmental management and ensuring regulatory requirements in regard to environmental and social standards. But, environmental pollution problems in Harindhara, Savar, have been aggravating day by day. Therefore, Department of Environment (DoE) has engaged Center for Environmental and Geographic Information Services (CEGIS) to conduct an environmental impact study of these tannery industries on both the Buriganga and Dhaleshwari River. The main purpose of this study is to assess the environmental impacts of Savar Tannery Estate on the adjacent environment especially on aquatic ecosystems. In this case, lessons those were learnt at Hazaribagh disaster, have been applied in assessing and identifying the sectors/issues to be managed more effectively in Savar Tannery Estate.

In the entire study, a comprehensive methodology has been followed. Desk work and literature reviews were conducted to understand the current situation of the industries and the extent of activities to be performed. After realizing the facts and scope of works, the study team performed a reconnaissance field visit to figure out the significant issues to be addressed along with the best applicable methods for assessing those issues scientifically.

During the study, surface water availability and water quality were examined in the physical environment while fish community and all the floral and faunal composition were assessed for biological environment. To understand the socio-economic statuses properly, human health, employment opportunity and standard of living were studied. In addition, agricultural resources were studied to have a complete picture of the study areas. Water quality were tested following in-situ and ex-situ methods whilst all other baseline information were collected through field visits (checklists, observation, interviews etc.) supplemented by secondary information from related organizations (BSCIC, BTA, LRI and DoE) and published papers. This study also includes odor dispersion modeling for Savar Tannery Estate and capacity assessment to support ecosystem services to the communities. AERMOD was used to observe the odor dispersion in the study area while score based matrix was performed to evaluate the ecosystem service capapcity.

Water quality has been chosen priority component in this study as tannery wastes impacted this resource rapidly. Numerous indicators were used to assess the current water quality status. Out of these, physical water quality parameters especially DO and TSS indicated negative impacts of tannery wastes on water body. The DO level of Buriganga River was about less than 2.5 mg/L while it was found in the range of 4.0-6.0 mg/L in the Dhaleshwari River. DO status is still in good condiction in Dhaleshwari River than the Buriganga River. TDS and salinity is not an issue at this moment in Buriganga and the Dhaleshwari River as these two parameters complied with the national standards for both the cases. Simialrity was also found in terms of Cr and other heavy metals such as Pb, Al and Zn as present conditions are not harmfull for both the riverine ecosystems. In the evaluation of water quality of Dhaleshwari River, there is an alarming issue of discharging high concentrations of

organic, chemicals and metal pllutants directly into Dhaleshwari River which could have adverse impacts on this aqutic ecosystem.

Polluted water affects fish community in many ways. Bio-accumulation of Cr was found high in the fish body in Buriganga River due to high Cr disposal for a longer period in the river which will ultimately affect the human who are consuming those fish. In the Dhaleshwari, no such issues were found yet regarding Cr in fish body. Breeding zone and fish eggs were damaged due to excessive pollutants and lack of light availability in the water column. The same reasons afflict the floral and faunal composition in both the rivers. Buriganga River lost its diversity since long while Dhaleshwari River started to face this problem since last year (2017, starting of Savar Tannery Estate). For instance, water loving snakes and Indian bullfrogs are already rare in Dhaleshwari River. Degrading of the riverine environment will ultimately destroy all the habitats of faunal biodiversity and lastly the ecosystem services.

Agriculture is facing the same Cr bioaccumulation issue through 'irrigation' and 'soil pollution'. There is a chance of Cr bioaccumulation in food crops in both the areas of HTE and STE. Beside the above stated scenarios, other frightening issues are the occupational health and safety (OHS) and human health impacts on the surrounding communities due to chemiclas used in rawhide and skin processing in the tanneries and by hazardous by-products disposing into surrounding environment. Labors and staffs of tannery industries and the neighboring living communities are facing chronic Odor issue along with skin diseases and respiratory problems. In addition, unsafe working environment and lack of Personal Protective Equipment (PPEs) puts tannery workers life in great danger.

Lastly, lack of cooperation among BSCIC, CETP Contractor, Tannery owners and surveillance department e.g. DoE, is a barrier to manage this tannery sectors more efficiently.

Suitable measures and its effective implementation could be the best solution in managing Savar Tannery Estate efficiently.

1. Introduction

1.1 Background

Since independence of Bangladesh, the country is slowly and steadily turning its attention to develop its economy, through industrial development, moving away from the agricultural sector (Sarkar, M. A. R., 2013). And in line with that plan, the Government of Bangladesh (GoB) has identified the leather sector as one of the promising sectors of the country with considerable growth and investment potential ranked 5th in the export-earning sector. Currently, Bangladesh produces and exports quality bovine and ovine, caprine (buffalo and cow; sheep and goat) leathers that have a good international reputation for fine textured skins. However, until now, the entire leather sector meets only 2.0% of the world's leather trade (US$75 billion). Leather industry contributes only 3.4% of total country's export (EPB, 2016).

Leather industry plays an important role in Bangladesh Economy due to its large potential for employment, growth and export. At the same time, it poses serious environmental threats by discharging liquid effluents and solid wastes directly into surrounding low lying areas without proper treatment (Tinni et al., 2014). Industrial wastes are major sources of pollution in all environments which require onsite treatment before discharge into sewage system (Emongor et al., 2005). In Bangladesh, there is a progressive increase in industrial wastes and due to rapid industrialization such waste products have been causing severe contamination to the air, water and soils thus pollutes the environment (Islam et al., 2000). The DoE identified 900 large polluting industries, which have no treatment facilities for effluent and wastes (DoE, 2001). These heavily toxic effluents were discharging directly to adjacent soils and rivers (Khan, 2006). Among all the industrial wastes tannery effluents are ranked as the highest pollutants (Azom et al., 2012).

The glaring evidence of industrial pollution could be noticed from the status of Buriganga River and other adjacent rivers in Dhaka City such as Balu and Turag. Since 1970, the wastes of Hazaribagh Tannery Estate (HTE), Dhaka are being discharged to the Buriganga indiscriminately. Any of the tannery of HTE, didn't have Effluent Treatment Plant (ETP) for treating chemical and metal pollutants coming from various rawhide and skin processing units and finished leather production. Among all the industrial wastes, tannery effluents have been ranked as the highest pollutants (Azom et al., 2012). About 40 heavy metals and acids are used for processing rawhides using traditional approach (UNIDO, 2005). Around 220 tanneries were found in HTE and of them 113 were in functional mode before shifting of HTE to Savar Tannery Estate (STE). It was found that 20,000 m3 of tannery effluents and 232 tons of solid waste were released per day during the operation period (1960-2012) of HTE, (Paul et al., 2013).

The tannery industries at Hazaribagh made the most damaging effect on the environment of Buriganga Watershed, which has caused serious impacts on human health, aquatic life, river ecology, society and environment. Working in a congested and unhygienic environment together with no safety protocols, the workers faced both health risks of exposure to many hazardous chemicals especially Chromium (Cr). The most inacceptable condition is the odor from leather industry, made the neighboring residents dissatisfied. Moreover, pollutants of Buriganga River, at the very first, destroyed the habitat of aquatic organisms like pelagic insects, benthos community and the fishes of the river, which disrupted the normal ecosystem functions at the foremost and later shattered the ecosystem functions completely. Water pollution tipped the degradation of soil quality over the last few decades as well. In the end, water pollution of Buriganga River has created artificial crisis of the availability of irrigation and recreational water use. Above all, loss of complete ecosystem services, has become now one of the major concerns of the surrounding community.

At Hazaribagh, lack of development and effective implementation design of policies for the maintenance and regeneration of the environment were the main lackings. In addition, inadequate sewerage and infrastructure facilities were found to be the secondary reasons of the Hazaribagh Disaster. These reasons made the situation worse (Banani, 2013) in the last decade. Adding to this, in a growing city like Dhaka, it was difficult for the government to shift human settlements who were residing near HTE. Unplanned tannery industry establishment and lack of proper urban planning was the main reason behind the nuisance situation. Having all those issues at once, the chance of restoring Buriganga River was becoming narrower day by day. Nevertheless, western companies showed more reluctance in purchasing leather and leather made finished products from the countries those are listed in the least environmental management activities.

The Hazaribagh Tannery Industry, has been shifted to the new location at Horindhara, called Savar Tannery Estate. A total of 200 acres of land were developed for 195 industrial plots in four categories of A-D considering the plot size. STE includes industrial plots, Central Effluent Treatment Plant (CETP), disposal yard, administrative building, drainage facility and sub-station for electricity supply to the industrial units. European Union (EU), obliged to install CETP by June 2014 in a functional mode, which was found incomplete with its poor construction materials, and faulty design in respect to treat all the pollutants coming from effluents especially salinity of the water (Speaker of the Parliament, December 2017).

A total of 154 tannery industries have been shifted to this new tannery estate out of 155. Of them, 111 industries have started productions partially with lots of difficulties. GoB, therefore, has become more concerned about the management of the newly established tannery industry more effectively.

Therefore, this study evaluated the likelihood of future impacts of Savar Tannery Estate on the adjacent Dhaleshwari River and its surrounding environment having the management approach as business as usual. This study also revealed environmental solutions to save the surrounding environment from any further degradation.

1.2 Objectives

The overall objective is to compare state of environment of two sites Tannery Estates and future projection of environmental impacts of STE if not managed properly.

However, this study has the specific objectives for:

- Evaluation of present tannery management activities, pollution abatement measures and performance of CETP;
- Assessment of likely future impacts of newly established tannery industry on Dhaleshwari River;
- Identification of best management aspects/practices for saving the adjacent environment from degradation;

- Identification of future research studies and/or projects in favor of sustainable management of tannery industries;

1.3 Scope of Works

This study is basically is a scoping study for finding out appropriate aspects of future environmental management of Savar Tannery Industry and its wastes. The scope of works is listed below.

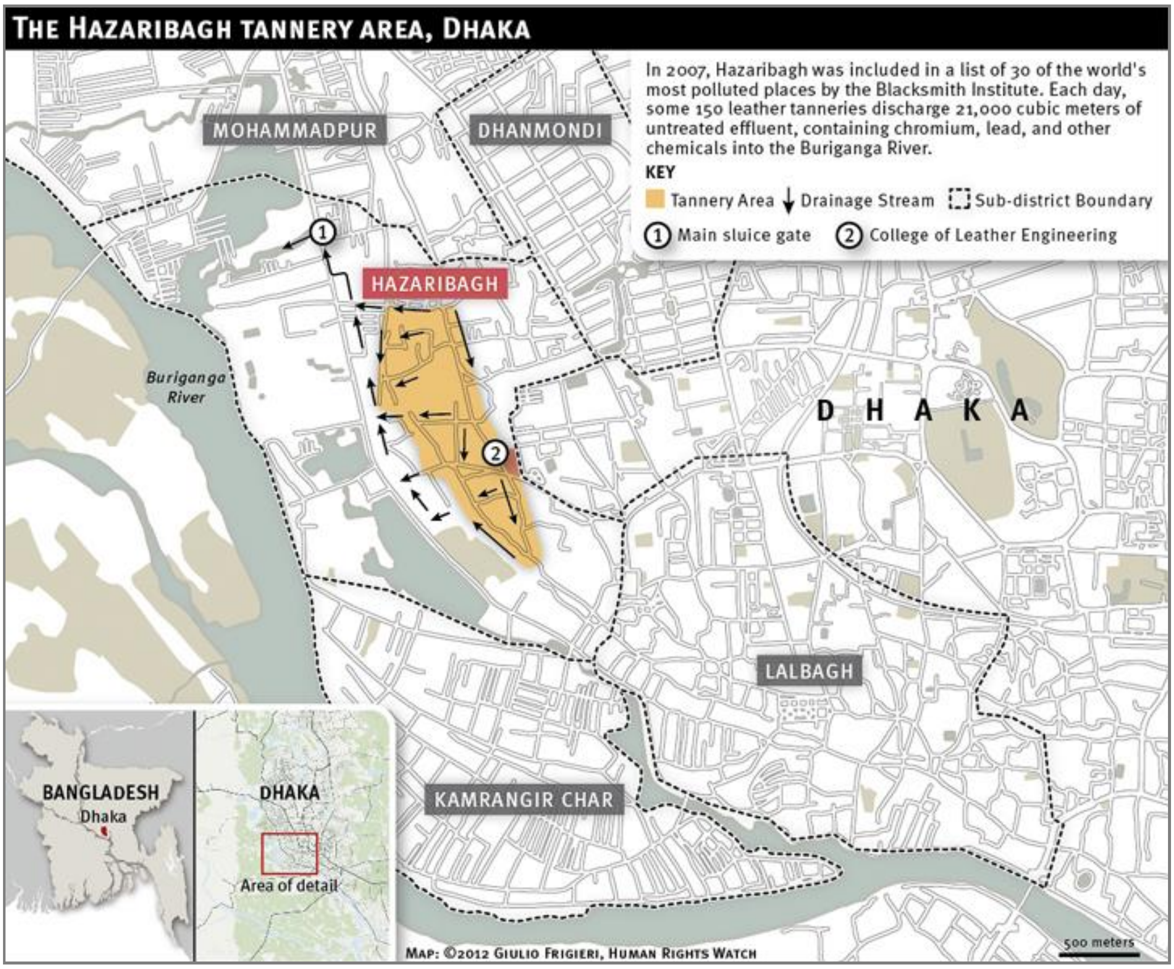
- Ongoing tannery wastes management practices observation and information/documents collection being used in handling this matter;
- Strategy and methods of pollution reductions measures; and
- Performance evaluation of CETP especially its water treatment capacity;
- Assessment of water availability, water quality and soil quality of the two rivers;
- Assessment of pelagic and benthos community together with floral and faunal diversity of the two rivers;
- Assessment of human health risk, employment opportunity and standard of living of the residents neighboring in both of the study area (Hazaribagh, Dhaka and Horindhara, Savar);
- Identification of important environmental components (IESCs) to measure the qualitative and quantitative impacts of tannery industry on environmental and socio-economic resources;
- Sorting of major issues and problems behind improper operations and management of tannery industry in the current management practices;
- Application of focus group discussion (FGD), key informant interviews (KII) and stakeholder consultation with relevant stakeholders, both in governmental and non-governmental sectors, to find out the best tannery management approaches/aspects /practices;
- Finding out the issues to be researched for the sustainable management of leather industry at STE;

1.4 Study Areas

Study area consisted of two different locations named Site1 and Site 2 inside Dhaka District. Site 1 was Hazaribagh Tannery Estate (HTE), its adjacent Buriganga River, and Site 2 was the shifted tannery estate of Horindhara, called Savar Tannery Estate (STE) on the bank of Dhaleshwari River. Around 8 km length and 2 km buffer zone for both the Buriganga and Dhaleshwari rivers were considered as study areas. The main reason of this areas was to see the direct impact of tannery industries along the rivers with tentative impacted zones. To understand the study areas properly, a brief description is given below to address the geographic locations and major features related to this study.

Hazaribagh Tannery Estate

Hazaribagh Tannery Estate is located very close to the bank of the Buriganga River. It was established in 1960s on 62 acres of land. More than 220 registered tanneries, 90% Bangladeshi, were located in Hazaribagh. Hazaribagh, once a peasant, semi-rural place in Dhaka, is now a wasteland of toxic swamps, garbage landfills and mountains of decomposing leather scraps. There was lack of planned infrastructure facilities at HTE. Most of the tanneries were not properly modernized and were using non-or semi-mechanized systems and antiquated processing methods. No tannery in Hazaribagh had effluent treatment facilities, posed a grave threat to environment. The industries disposed their untreated liquid wastes directly to the open drains, which was finally connected to the Buriganga. Industries also threw their solid wastes on the road like dumping station. Dhaka City Corporation (DCC) collected around 3,500 tons of solid wastes from this area every day during the operation time, but they were not able to collect highly hazardous tannery wastes properly. The Hazaribagh Tannery cluster is represented in **Figure 1.1**.



Source: Banani, 2013.

Figure 1.1: Hazaribagh Tannery Cluster and its Drainage System, which is Directly Linked to the Buriganga

Buriganga is a tide-influenced river, passing through the west and South of Dhaka. Some upstream rivers namely; Jamuna, Turag, Karnatali, Dhaleshwari and Tongikhal influence the flow of this river. The Buriganga originated from the Dhaleshwari River near Karnatali. The

Turag has joined the Buriganga at Kamrangirchar of Dhaka. In fact, the main flow of the Buriganga comes from the Turag. The present head of the Buriganga near Chhaglakandi has silted up and opens only during floods but the lower part is still open throughout the year.

The Buriganga is a single channel river whose upstream part is meandering in nature and the downstream part is more or less straight. Flow and sediment supply from the upstream to the Buriganga River is very low. It has been found that the bank line of the river is almost fixed for the last 60 years except changing of the off-take.

The length of the Buriganga River is about 29 kilometres. The maximum width of the River is 480m and the minimum 80m with an average width of 270m. The width of the river is almost same over the years.

Savar Tannery Estate (STE)

Savar Tannery Estate is situated at Horindhara on the bank of the Dhaleshwari River. A total of 200 acres of land has been developed for 195 industrial plots in 4 different categories (category A-D) considering the plot size. STE includes industrial plots, CETP, disposal yard, administrative building, drainage facility and sub-station for electricity supply to the industrial units. European Union (EU), obliged to install CETP by June 2014 in a functional mode, which was found incomplete with its poor construction materials, and faulty design in respect of treating all the pollutants coming from tannery effluents (Speaker of the parliament, December 2017).

Figure 1.2: Savar Tannery Cluster, which is situated on the Bank of Dhaleshwari River

Dhaleshwari River is a left bank distributary of the Jamuna River and after flowing for about 160km, the river finally ends its journey at the Upper Meghna River. Average depth of Dhaleshwari River is 122 feet (37m) and maximum depth is 265 feet (81m). Before entering into Manikganj District, the River splits into several courses such as the Pungli, Louhajang and Alongjani Rivers. The present course of the Dhaleshwari River is divided into two courses, the Northern course goes through Dhaka District as the Bangshi River and the Southern course as the Dhaleshwari River, enters into Manikganj. After flowing a few kilometers, the river is further divided into two courses; the Northern course assumes the name Dhaleshwari and merges with the Bangshi River, and the Southern branch taking the name as Kaliganga River flows in the Manikganj District, which carries most of the flow of the Dhaleshwari. The flow of the Ichamati and Buriganga merges with the Dhaleshwari River. Finally, falling in the Lakhya River near Narayanganj District, the combined course flows southwards to join with the Meghna River.

1.5 Approach and Methodology

1.5.1 Approach

This study followed a comprehensive approach in evaluating all the objectives properly. At first, a reconnaissance field was (**Appendix-A**) conducted to finalize the effective approaches and methods of the study. Then, this study evaluated impacts of Hazaribagh Tannery activities on Buriganga River together with a trend analysis. In addition, status of Dhaleshwari River and its adjacent areas were also assessed in terms of all environmental and social components. The lessons those were learnt at Hazaribagh Tannery Estate and its impacts on surrounding environment, was used to predict the impacts of Savar Tanneries on Dhaleshwari River and its adjacent areas. At the end, realizing the situations and the likelihood of future impacts of Savar Tanneries, environmental solutions were drawn for each of the sectors supposed to be managed more effectively and efficiently.

1.5.2 Methodology

This study used both qualitative and quantitative methods to evaluate the objectives of the study properly. The overall study procedure and the methods are presented in the following flowchart (**Figure 1.3**).

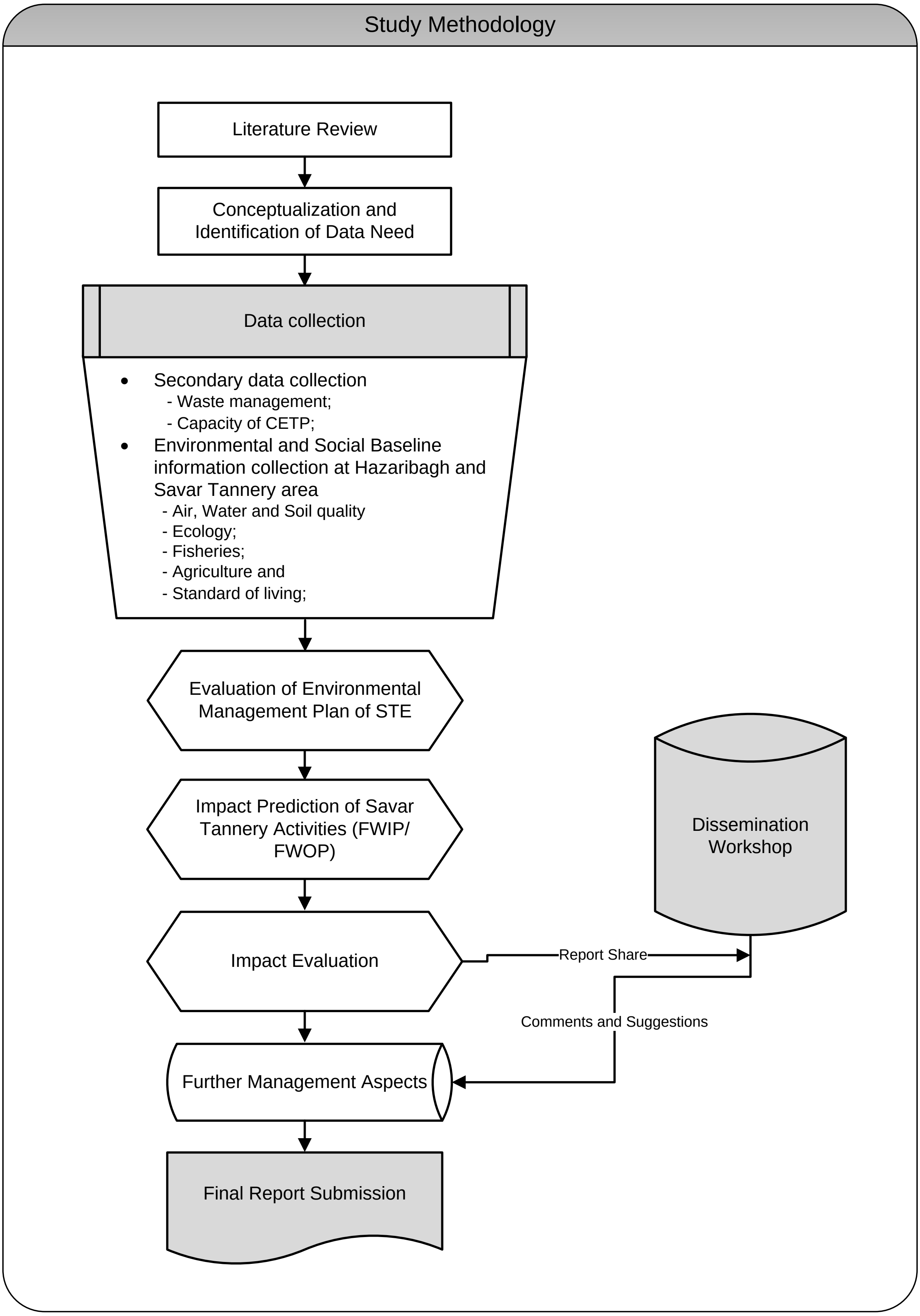


Figure 1.3: Flowchart of the Study Methodology

Secondary Information Collection

Academicians, individual researchers and related stakeholders conducted studies on leather processing system, leather products and potentiality in world market, pollution of leather industry, tanneries effects and possible solutions for sustainable management of leather sectors. Studies on the socio-economic consequences of leather industries are available in different journals. Therefore, this study, reviewed all the above-mentioned issues from published documents for gathering sufficient knowledge in relation to the study objectives. A table containing aspects of literature review and secondary information collection organizations is provided in **Table 1.1.**

Table 1.1: Aspects of Literature Review and list of Organizations Visited to Collect Information

Secondary Information	Data and knowledge gathering aspects/organizations
Literature review	• Leather Industry Development and Export: Bangladesh • Leather industry-environmental pollution and mitigation measures • Environmental effect of leather industry in Bangladesh • Environmental impacts assessment (EIA) of Tanneries • Treatment of wastewater of tanneries in Bangladesh • Environmentally sustainable leather industry in Bangladesh
Information from Government/ non-government organizations	• Major governmental and non-governmental organization acts for saving natural resources; ✓ Department of Environment (DoE) ✓ Bangladesh Water Development Board (BWDB) ✓ Ministry of Water Resources (MoWR) ✓ Center for Environmental and Geographic Information Services (CEGIS) ✓ Center for Natural Resource Studies (CNRS) ✓ Bangladesh Small and Cottage Industries Corporation (BSCIC) • Professional associations; ✓ Bangladesh Finished Leather, Leather Goods and Footwear Exporters Association (BFLLFEA) ✓ Bangladesh Tanners Association (BTA) ✓ Institute of Leather Engineering and Technology (ILET) ✓ Leather Labors Welfare Association (LLWA) ✓ Leather Workers Union (LWU)

Having a information and knowledge on Hazaribagh and Savar Tannery activities, an extensive field visit was conducted in both the tannery estates for the detailed primary data collection to construct a good baseline of both the study areas. The details of data collection comprised of six different resources (Air, Water and Soil quality, Fisheries, Agriculture, human health & standard quality of life) of three different types viz. Physical Environment, Biological Environment and Socio-economic statuses of the study area.

Environmental and Social Baseline Information Collection

Physical Environment

Water availability: Mainly water availability, water quality, odor status and soil quality of both the study areas were studied. Water availability of Dhaleshwari River at upstream of the Savar Tannery was collected from North-Central hydrological region model predicted by CEGIS.

Water Quality: A range of water quality parameters were selected in this study. Water quality parameters were selected considering the type of tannery wastes (solids and liquids) and its capacity in degrading water quality. Therefore, this study found numerous water quality parameters those were assessed are listed in the **Table 1.2**.

Table 1.2: Water Quality Parameters and Testing Laboratories

Type	Water Quality Parameters	Testing Laboratory
Physical	Odor Color Temperature Turbidity Total Dissolved Solids (TDS) Total Suspended Solids (TSS)	On site measurement by U-50 Multiparameter Water Quality Meter (HORIBA), device from CEGIS laboratory
Organic	Dissolved Oxygen (DO) Biochemical Oxygen Demand (BOD) Chemical Oxygen Demand (COD)	DPHE Central Laboratory, Mohakhali, Dhaka
Chemical	Nitrate nitrogen (NO_3-N) Ortho-Phosphate (PO_4^{3-}) Sulphate (SO_4^{2-}) Ammonium nitrogen (NH_3-N)	DPHE Central Laboratory, Mohakhali, Dhaka
Metal	Chromium (Cr) Aliminum (Al) Lead (Pb) Zinc (Zn)	DPHE Central Laboratory, Mohakhali, Dhaka
Microbiological	Fecal coliforms	DPHE Central Laboratory, Mohakhali, Dhaka

Surface water samples were collected in sterilized sampling bottles. Two sets of acidified and non-acidified samples were collected from each sampling point. All the samples for ‘Metal’ assessment were gone under acidification to stabilize the sedimentation of dissolved metals concentration inside the bottles. During transportation, samples were stored in the ice box which contain temperature <10ºC. E. coli sampling was carried out using EPA standard method and submitted to DPHE Central Laboratory within 6 hours of sampling time.

A total of 7 sampling points was considered in this study to assess the surface water quality. Two from Buriganga, two from Dhaleshwari River and three sampling sites from CETP and solid waste dumping yard. The details of the sampling locations have been presented in **Table 1.3**. The sampling locations of Hazaribag and Savar Tannery Estates are displayed in **Figure 1.4** and **Figure 1.5** respectively.

Table 1.3: Water Quality Sampling Sites and their Characteristics

SL	Sampling point	Study Area	Site Description and rationales	*Remarks*
1	Baschila bridge	Buriganga	This site is a little bit upstream of the previously disposed liquid waste from Hazaribagh tanneries in Buriganga. This data showed the tannery effect on upstream water quality.	
2	Showari ghat	Buriganga	A bit downstream of Hazaribagh waste disposal point. Showari ghat was selected to see the overall water quality status of Buriganga river at the downstream site.	Zooplankton sampling point
3	Singai bridge	Dhaleshwari	This site will provide the upstream water quality of Dhaleshwari River considering the new tannery estate.	
4	Milkyhata	Dhaleshwari	A bit downstream of Savar effluent disposal point. Milkyhata was selected to see the overall water quality status of Buriganga river at the downstream site.	Zooplankton sampling point
5	Effluent disposal point	Dhaleshwari	This site describes the effluent water quality being discharged after treatment by CETP.	
6	Dometic water disposal point	Dhaleshwari	To ascertain the domestic water quality status being discharged into Dhaleshwari from Savar tannery estate.	
7	Soild mixed liquid at soild waste dumping yard	Dhaleshwari	To understand the umexpected effluent quality directly coming from tannery.	

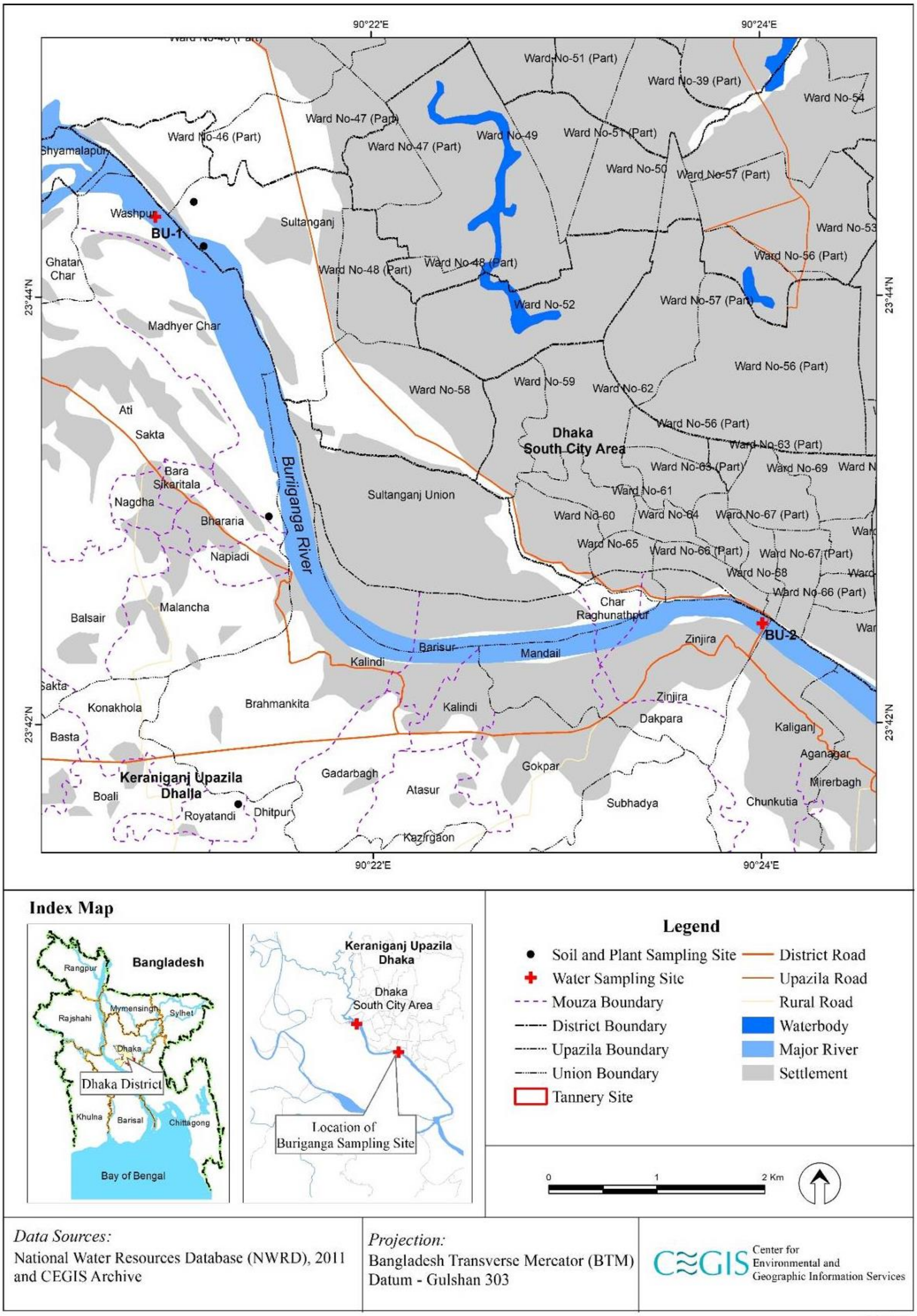


Figure 1.4: Sampling Locations of Hazaribagh Tannery Estate

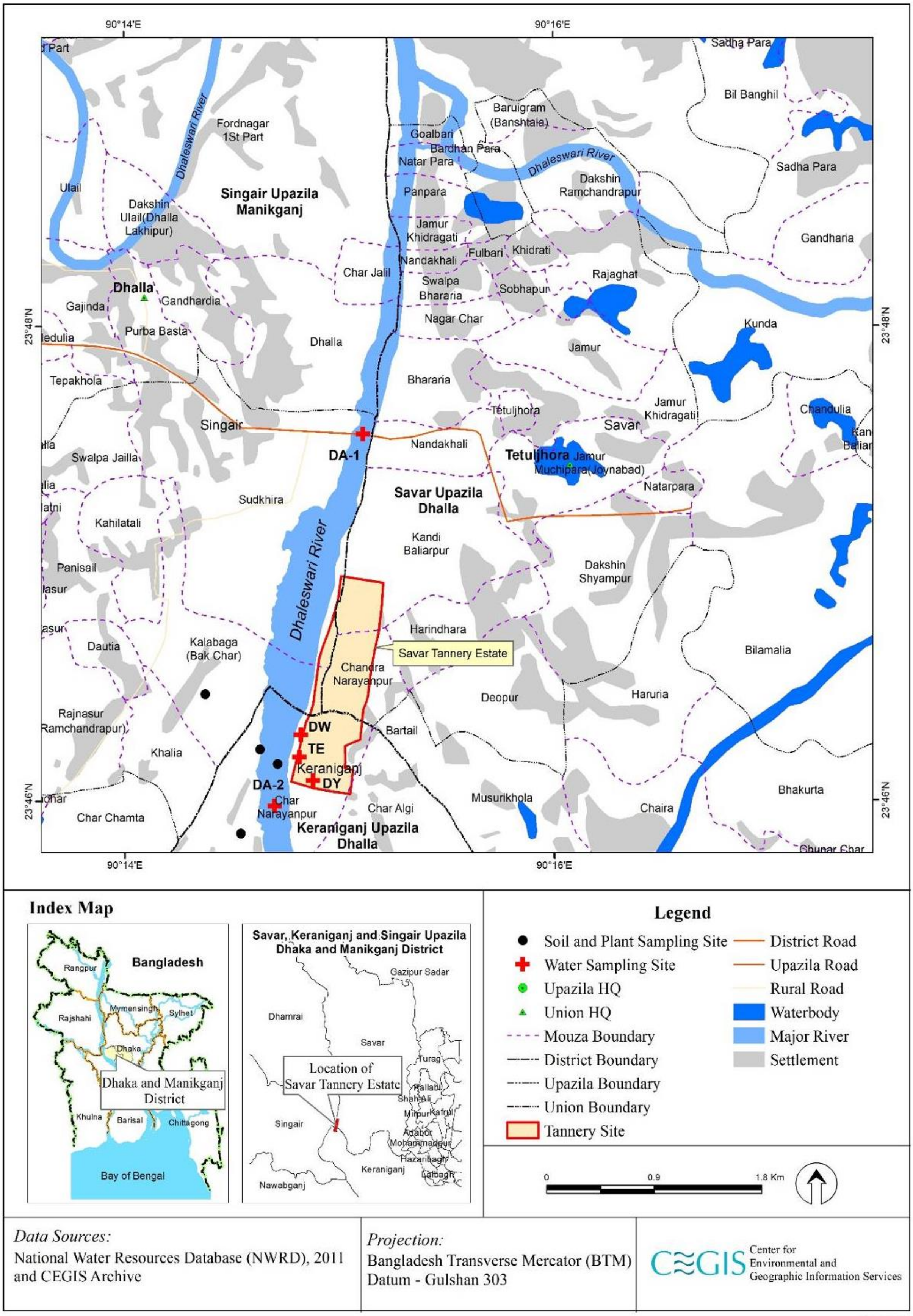


Figure 1.5: Sampling Locations of Savar Tannery Estate

Water Quality Index (WQI) Assessment: The water quality index formulated by National Sanitation Foundation (NSF), known as NSFWQI, was followed to calculate WQI of both the water bodies (Buriganga and Dhaleshwari Rivers). The WQI was based upon nine water quality parameters such as (i) Temperature, (ii) pH, (iii) Turbidity, (iv) Fecal Coliform, (v) Dissolved Oxygen, (vi) Biochemical Oxygen Demand, (vii) Total Phosphates, (viii) Nitrates and (ix) Total Solids. The recorded water quality data was transferred to a weighting curve chart (), wherefrom a numerical value of Qi was obtained. The mathematical expression for NSF WQI is given by-

$$WQI = \sum_{i=1}^{n} QiWi$$

Where,

Qi = sub-index for i^{th} water quality parameter;

Wi = weight associated with i^{th} water quality parameter;

n = number of water quality parameters

The weighted values of water quality parameters on water quality index system is presented in **Table 1.4**. For this NSFWQI method, the ratings of water quality were defined by using **Table 1.5**. For calculating sub-index, Water Research Centre calculator was used[1].

Table 1.4: The Weighted Values of Water Quality Parameters in Water Quality Index System – NSF

um.	Parameters	Weight
1.	Dissolved oxygen (DO)	0,17
2.	Fecal coli	0,15
3.	PH	0,12
4.	BOD	0,10
5.	NO_3	0,10
6.	PO_4	0,10
7.	Temperature	0,10
8.	Turbidity	0,08
9.	Dissolved solids	0,08
	$\sum_{i=1}^{n} wi$	1,00

Table 1.5: Water Quality Rating as per NSFWQI

National Sanitation Foundation Water Quality Index (NSFWQI)	
WQI Value	**Rating of Water Quality**
91-100	Excellent water quality
71-90	Good water quality
51-70	Medium water quality
26-50	Bad water quality
0-25	Very bad water quality

[1] https://www.water-research.net/index.php/watertreatment/watermonitoring/monitoring-the-quality-of-surfacewaters

Soil, River Bed and Plant Quality: In the physical environment, river bed sediment quality, soil quality and concentration of pollutants in plant body were also assessed from five different sampling sites. The quality was assessed in term of Cr concentration as Cr was the only pollutant coming from tannery wastes exclusively and possesses serious threats to human health. The soil quality was tested from *Soil Resource Development Institute* (SRDI), Farmgate, Dhaka. The site selection criteria are presented in **Table 1.6**. The sampling locations of soil, river bed and plants quality of Buriganga and Dhaleshwari Rivers are also presented in **Figure 1.4** and **Figure 1.5** respectively.

Table 1.6: Soil, river bed and plant sampling locations and its characteristics

SL	Sampling point	Site Characteristics
1	Main Channel	This was the major outlet of tannery wastes. Soil and plant sample was collected to have chromium contamination in soil and plant.
2	River bed/ Sediment	River bed sample was collected from Showari subsequent floating plant (water hyacinths) was also collected.
3	River Levee	River levee soil and plant sample was collected form in between main channel and river bed sample collecting point.
4	Agricultural Field	This site is situated in the opposite bank of the Buriganga River which is single cropped land. Soil and plant sample was collected to have chromium contamination in soil and plant.

Odor Modeling: The latest version of the USEPA regulatory model AERMOD has been used to predict and simulate the effects of Odous pollutants from the sources. However, AERMOD 8.9.0 air dispersion model has been used for predicting the dispersion of VOC, NH_3 and H_2S around the Savar Tannery Estate.

Biological Environment

In this study, zooplankton, fisheries resources and flora and fauna were assessed to see the status of biological environment of Buriganga and Dhaleshwari River.

Zooplankton Assessment: This study considers the method involved in microscopic examination of preserved zooplankton samples collected with a conical net towed horizontally from surface water. In assessing zooplanktons, single horizontal sample was collected from each of the river. A standard net size (56 micron) was used to collect the samples. Lugol’s solution was used to preserve the samples. In the laboratory, random counting method was used to count the planktons properly. The zooplankton sampling sites were the same sites of water quality sites of Showari Ghat for Buriganga and Milkyhata for Dhaleshwari River.

Fisheries Resources Assessment: In this study, fisheries resources were evaluated intensively as water pollution at first affects fish resources. In addition, it is basically very sensitive to the integrity of the aquatic ecosystem which can be at high risk by tannery activities. At first, a number of available published national and international literatures were reviewed comprehensively to understand the bioaccumulation process of heavy metals into fish body and their impact on fish morphology, physiological changes and behavioural pattern. Furthermore, different international standard for the prevalence of heavy metals in fishes were collected. Fish community was surveyed through conducting Focus Group Discussion (FGDs) and Key Informant Interviews (KIIs) by using checklist. A significant number of respondents were taken for understanding the fish community of the Buriganga and the Dhaleshwari River around the tannery industry.

Ecological Resources Assessment: Total 4 parameters were observed to assess the condition of flora and fauna. Species composition is essential to know the inhabitants of an area those are habituated within a particular environment. Species composition of flora was acquired from physical observations at the study area.

Wildlife abundance and their attitude can be changed for habitat degradation due to change of environmental quality. Disturbance to wildlife due to chemical pollution is another concern for this study that indicate the habitat suitability of an area.

Heavy metals accumulation, which may have effect on plant physiological activities as well as may enter in food chain of an animal. Chromium is a common chemical pollutant that is used in leather processing and contaminate water and soil is transferred to plant and animal body through bioaccumulation. This study observed the existence of chromium in plant body to ensure the bioaccumulation.

The parameters of flora and fauna and its collection frequencies are mentioned in **Table 1.7**.

Table 1.7: Parameters observed and sampling frequency

SL	Parameters	Bounding
1	Plant Species composition	Within and 100m surround of the tannery estate
2	Faunal species composition	Within and 100m surround of the tannery estate
3	Wildlife disturbance	Within and 500m surround of the tannery estate
4	Existence of Heavy metal (Chromium only) in plant body	Collected plant samples from waste dumping site, river, river levees and surround homestead area

Information on existing floral composition was collected through visual observations. Common faunal composition was also collected through visual observations and public discussions and disturbance to faunal communities ensured by discussion with local knowledgeable people residing nearby the study area.

Sample of plant body was collected for laboratory test to ensure the existence of heavy metal. In this regard, a total of 4 targeted site (i.e. waste dumping site, river water, river levees and surrounding homestead area) was sampled. In this regard, a total of 4 sample from each targeted site (i.e. waste dumping site, river water, river levees and surrounding homestead area) was collected (Table 1.6). The samples became a composite of 5 common species of each site and the species composition was same for both of the tannery estates (i.e. *Cyperus rotundus, Cynodon dactylon, Eichhornia crassipes Polygonum* sp. and *Oryza sativa*). Collected plant samples were sent to testing Laboratory of Dhaka University. Test results were compared with the standard values to ensure that whether the amount of the heavy metal is within or beyond the normal level.

Ecosystem Services (ES) Capacity Assessment: To investigate tannery effect on ES, 7 individual ES components modified after Sohel et al. (2015) under three main ES categories were considered. ES components that were highly relevant to the studied landuse classes available in and around tannery areas were considered. The three main ES categories used were: a) supporting services, those necessary for the production of other remaining ES (e.g. biodiversity, habitat quality); b) provisioning services, the products (e.g. fish production, agricultural crop production, freshwater supply) obtained from a particular landuse; c) regulating services, derived from a particular landuse (e.g. water purification and air quality regulation).

ES supply is strongly dependent on landscape structures and ecosystem functions (Burkhard et al., 2012). Ecosystem functions change with varying degrees of landscape naturalness or intactness. Therefore, potential ES hotspot areas were given priority during the assessment. To begin the ES scoring exercise, landuse classes (see Figure 5.3) were identified from an existing geo-referenced landuse map of the study area. An ES matrix was then developed linking a set of 7 ES indicators (on the x-axis) to landuse types (on the y-axis) (Appendix-F). The landscape's capacities to supply the individual ES were assessed and ranked on a scale ranging from 0 to 5, where 0 = no relevant capacity; 1 = low relevant capacity; 2 = relevant capacity; 3 = medium relevant capacity; 4 = high relevant capacity; and 5 = very high relevant capacity (Burkhard et al., 2009). The scoring of the individual ecological components and the respective ES was based on participatory scoring exercises. Comparison of ES change assessment of the study area was conducted by comparing three different time period (Year- 2000, 2015 and 2018) landuse practices. Landuses of 2000 was used as baseline condition of ecosystem services. Later tannery industry pollutant effects on ES of other landuses were assessed. The scoring matrix was than linked with landuse shapefiles using ArcGIS 10.3.1 to visualize the ES components at landscape scale.

Social Environment

In the evaluation of socio-economic status of the study, total 3 different aspects were observed viz. human health, employment opportunity, and standard of living. These three aspects have direct link to the tannery activities such as leather processing, finished leather production and exporting leather and leather goods. All these three aspects were evaluated following the Matrix provided in **Appendix-B**.

Existing waste management facility of STE

Major environmental management facilities of STE was central effluent treatment plant (CETP), soild waste dumping yard along with drainage systems to manage domestic wastewaters. Moreover, drainage networks were also established to carry out the effluents to CETP. In this section, major environmental management facilities were evaluated following the basic criteria of (i) Waste generation status (ii) Performance testing and (ii) Effectiveness of the management approach. These criteria were applied for both the liquid and solid waste management approaches.

Impact prediction for savar tannery estate (FWOP/FWIP)

This study predicted the likelihood of impacts of Savar Tannery Industry on Dhaleshwari River and its adjacent areas. To do so, experts of different sectors (Water and Air quality experts, Ecologists, Fisheries experts, Agriculturists and Sociologists) used the knowledge of Hazaribagh's present and past situation. Both primary and secondary information were used in this regard. In this study, scenario analysis of future with project (FWIP) and future without project (FWOP) was the main concept in evaluating savar tannery impacts on the relevant resources.

State of environment of two sites tannery estate

This chapter deals with the state of environmental and social conditions of two sites tannery estate. The present management approaches of the Savar tannery estate were evaluated in this section of the report. This was done through comparing the impacted situation of Hazaribagh Tannery Area and the predicted situation of Dhaleshwari Tannery Area in the aspects of water quality, aquatic production, fisheries resources, ecological resources (flora and fauna), agriculture resources and the socio-economic condition.

Further management suggestions

Observing the predicted situation of STE and identifying the major environmental and social issues, this study tried to find some suggestions to be adopted positively. In addition, this section also sorted the solutions/options of improving overall tannery environment and its adjacent environmental and socio-economic conditions. The solutions are suggested in seven different thematic areas of:

- Improving the performance of CETP;
- Managing odor problem;
- Managing solid wastes;
- Enhancing ecological resources;
- Improving socio-economic condition;
- Monitoring framework;
- Institutional framework;

1.6 Limitation of the Study

Current study found some limitations, which are listed below.

- The study duration was only 6 months. Therefore, it was difficult to see the variations of dry and wet seasons of the resources (water, air, soil, fisheries and ecological resources);
- Insufficient financial budget to conduct the study in a more demanding way;
- Lack of baseline data regarding environmental and social resources before establishing Savar Tannery Estate;
- Lack of organized secondary information regarding Hazaribagh Tannery Estate;
- It is very difficult to separate the impacts of tannery activities exclusively on rivers as there were other industries in the same study area;
- The study was a scoping study, where the main task was to identify the further management sectors of STE instead of identifying the solutions;

2. Environmental and Social Status of Hazaribagh Tannery Area

2.1 Introduction

Environmental and social situation of Hazaribagh Tannery Area was evaluated in terms of three different environmental settings viz. physical environment, biological environment and socio-economic conditions. The data collection of the study was conducted in June 2018.

2.2 Physical Environment

2.2.1 Water quality

To understand the physical characteristics of the water, total 7 parameters were observed in the study. The parameters were color, odor, temperature, pH, dissolved oxygen (DO), turbidity and total suspended solids (TSS). The status of physical characteristics of Buriganga River is presented in **Table 2.1.**

Color of the water becomes visible at the very beginning of any water body. In term of tannery industry, it is even more important as tannery effluent changes the water color vigorously with its huge organic parts. The color of river also depends on its tidal influence as mixing is the main driving force of spreading color in water. This study found that water color of Buriganga River had spatial variations. Near the Baschila Bridge, color formed as 9 Hazen unit while at the Showari Ghat it reduced to around 4 Hazen (**Table 2.1: Color**). In spite of spatial variations, water color of Buriganga River complied with the Bangladesh Standards for Drinking Water Quality (15 Hazen, ECR' 1997). On the other hand, odor also complied with the ECR' 1997 as Buriganga River gave no odor on the date of June 2018 (**Table 2.1: Odor**). The improvement of the quality of water color and odor of Buriganga River was because of a bit increase of freshwater availability during the survey time (Summer, 2018).

Temperature is another indicator to observe the overall river health status. Any surface water body contain temperature 30^{o}C at its best in tropical environment, is an indication of good environment for aquatic organisms. In Buriganga River, temperature was recorded little bit higher (32^{o}C) at the Showari Ghat than the upstream (30^{o}C) of the river, Baschila Bridge (**Table 2.1: Temperature**). It seemed like, at the downstream of the river, lots of commercial (transportation of goods and services etc.) activities on the both bank of the river, which make the water temperature comparatively higher than the other portion of the river including the time duration of the measurements in a day. Ahammed, drew the same picture in 2016 where he found 30^{o}C at Baschila Bridge and around 32^{o}C at the downstream points of Hazaribagh, Pagla and Fardiabad. Trend analysis showed that, even after shifting tanneries from the Hazaribagh area, temperature was recorded similar to the temperature recorded in 2009 by Hasan et al (**Figure 2.1: Temperature**). It indicated that, river Buriganga was not affecting the tannery activities only, other pressures were also present since long. Above all, temperature range was found within the ECR, recommended 20-30^{o}C most of the time.

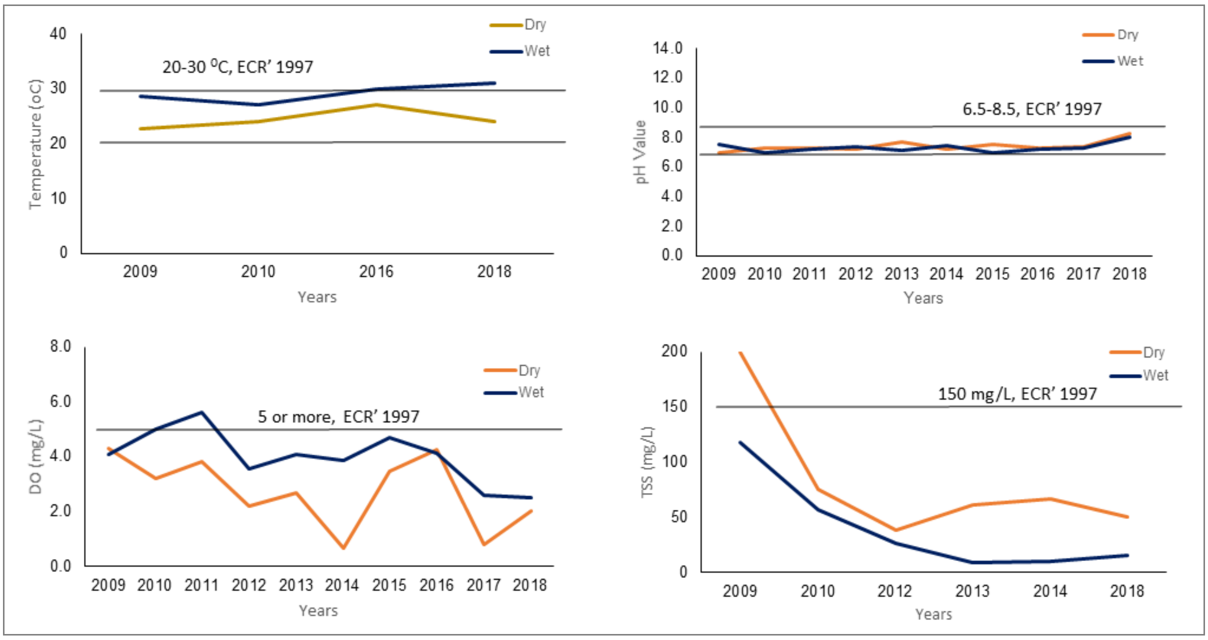
Surface water DO lower than 5.0 mg/L is a critical environment for most of the planktons and fish communities (ECR' 1997). Unfortunately, DO of Buriganga River was found lower than 3.0 mg/L at all locations (Baschila Bridge: 2.4 mg/L and Showari Ghat: 2.0 mg/L) (**Table 2.1: DO**). This scenario was developed since long as tannery effluents of Hazaribagh Tannery

Estate and other solids (domestic and municipal) mix with textiles effluents were dumped for more than several decades. In 2016, DO concentration of the river was found even lower (0.85 mg/L, Ahammed, 2016). Seasonal variations were also observed in this study (**Figure 2.1: DO)**. It was evident that DO level of Burigang River varied too much following dry and wet seasons. In all the observed years, Dry season DO were found lower than the 5.0 mg/L while it was sometimes higher than that in summer seasons. However, there was no improvement of DO status in Buriganga River until now. Organic and chemicals loads together with direct solid wastes dumping from other industries, community and commercial activities, polluting this river enormously.

Table 2.1: Physical water quality status of the Buriganga River

Site	Color	Odor	Temperature	DO	pH	Turbidity	TSS
Standards for Inland Surface Water Quality	15	Odorless	20-30	5 or more	6.5-8.5	15	150
Unit of measurement	Hazen		^{0}C	mg/L	Value	NTU	mg/L
Baschila bridge	9	0	30	2.6	8.4	57	13
Showari ghat	4	0	32	2.0	7.6	47	16

Source: CEGIS Survey, June 2018



Source
CEGIS Survey, 2018
Department of Environment, 2010-2017
Miti et al., 2009
Hasan et al., 2009
Begum and Tanvir, 2010
Ahman et al., 2010
Kibria and Kadir, 2015
Ahammed et al.,2016
Mottalib et al., 2017

Figure 2.1: Trend of temperature, pH, DO and TSS in Buriganga River

Buriganga River water was found slightly alkaline in nature. pH value ranged 7.6-8.4 (**Table 2.1: pH**). Instead of having spatial variation, all the observed points showed alkaline nature. At the upstream of Buriganga River (near Baschila Bridge, 8.4 pH value), alkalinity was almost 10 times higher than the downstream of the river (Showari Ghat, 7.6 pH value). However, pH value complied with all the standards of ECR' 1997 of 6.5-8.5 value (drinking standard, inland surface water quality standard, waste discharge standard). A trend analysis was performed from 2009 to 2018 where pH ranged in between 6.5-8.5 over both the Dry and Wet seasons (**Figure 2.1: pH**).

High turbidity restricts light penetration in the water body which reduces photosynthesis rate. Therefore, decline of food availability and DO level in the water body for the aquatic life forms. Buriganga River water turbidity was found low in concentration. Almost in every case, turbidity was found lower than 60 NTU (**Table 2.1: Turbidity**). Ahammed et al., 2016, also support this finding as they found the turbidity of 41 NTU at the same Baschila Bridge. However, the transparency of the water body was found less than 0.25 meter. This low depth profile of transparency was because of color of the water.

Amounts of suspended solids in Buriganga River were quite low in concentration, which ranged 13-16 mg/L while the EQS is 150 mg/L for inland surface water. This amount of solid is almost same as the recommended concentration for drinking water in Bangladesh (10 mg/L, ECR’ 1997). Trend analysis showed a declining tendency of TSS in Buriganga River. In 2009, TSS was found 200 mg/L at Dry seasosn and 118 mg/L at Wet season, which was reduced to 50 mg/L and 15 mg/L respectively in 2018 (**Figure 2.1: TSS**). This improvement might be the reason of shifting of Hazaribagh tanneries and stopping disposal of 20,000 m^3 untreated effluents daily into Buriganga.

Chemical characteristics of water quality

Chemical characteristics of the water quality were observed in terms of inorganic and organic indicators, inorganic minerals, dissolved metals and microbiological characteristics. Each of the characteristics is explained elaborately in this section.

<u>*Inorganic indicators of water quality*</u>

Two indicators of TDS and salinity were observed to understand the inorganic chemical state of Buriganga River.

TDS comprises inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water. Following the **Table 2.2** it is obvious that dissolved solids concentration was not high enough in the Buriganga River during the study. TDS concentration, which was less than 200 mg/L, indicated kind of good quality of water in terms of dissolved nutrients status.

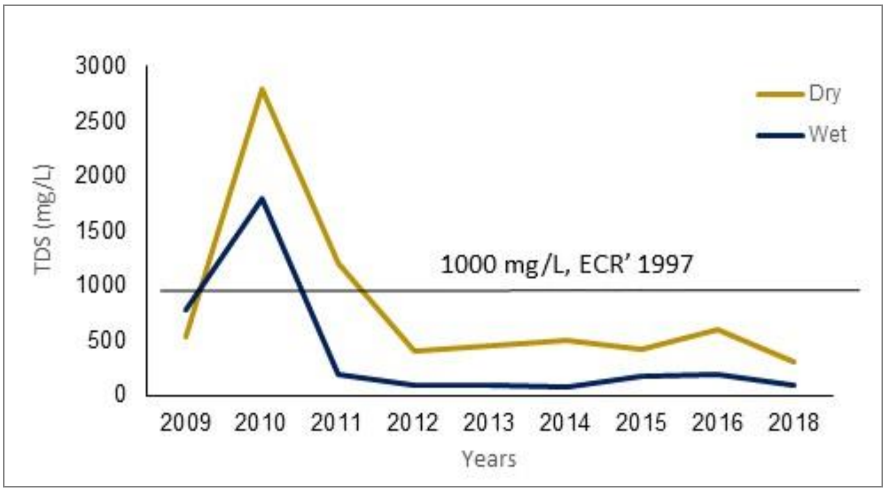
In the past years, TDS was even higher than the ECR stabdard (1000 mg/L) in Buriganga River at some points **(Figure 2.2**). However, at the recent time TDS concentration was found below the standard limit which indicates tiny improvement in term of dissolved nutrients availability.

This study also looked over the salinity status of water body. At the upstream point of Baschila Bridge, river water salinity was 0.1ppt while at the downstream of the river did not have any salinity issue (**Table 2.2)**.

Table 2.2: TDS and salinity status of the water quality of Buriganga River

Site	TDS	Salinity
Standards for Inland Surface Water Quality	1000 mg/L	0.0 ppt
Baschila bridge	161	0.1
Showari ghat	23	0.0

Source: CEGIS Survey, June 2018



Source: CEGIS Survey, 2018

Department of Environment, 2010-2017

Figure 2.1: Trend of TDS in Buriganga River

Organic indicators of water quality

According to the inland surface water quality (ECR' 1997), the BOD concentration should not exceed 10.0 mg/L. Beyond this concentration, fish community suffers for the required DO concentration as high BOD reduces dissolved oxygen. The average BOD concentration of Buriganga River was found around 10.0 mg/L at Summer, 2018. In contrary, the same river showed the BOD concentration of around 70.0 mg/L at Summer, 2015 (Ahammed, 2016).

Trend analysis indicated that biochemical oxygen demand of the river decreased over the years (**Figure 2.3**). In the recent years, it was observed that temporal variations in the BOD of the river exists. BOD of dry season was found unsuitable for the fishes where it becomes life supporting condition at wet season. Shifting of tanneries and freshwater availability during rainy season may be the main reasons behind this change.

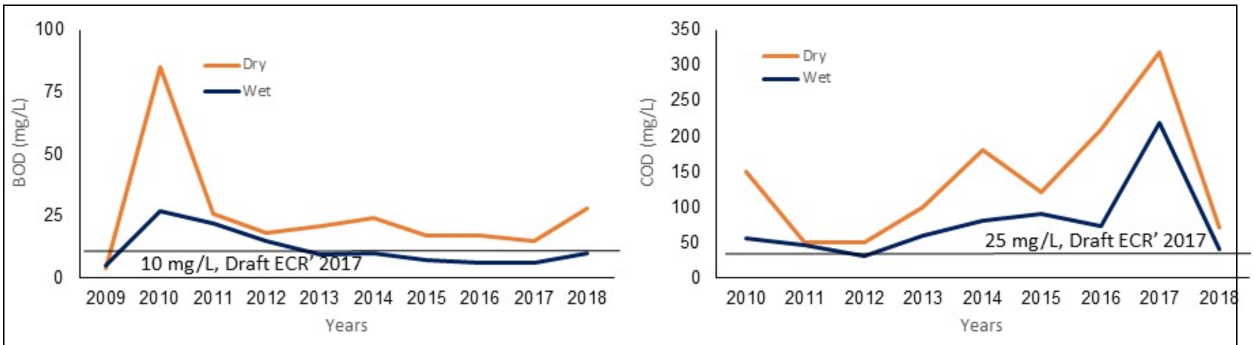
COD was slightly higher in the Buriganga River than the recommended value. During the study period, it was found that both organic and inorganic loads were comparatively lower than the previous studies. For instance, Ahammed et al., found the COD concentration range of 60-300 mg/L at 2016. Hazaribagh tanneries are not the only factor for high COD in Buriganga, there were other industrial activities that hinder the improvement of organic pollution.

The BOD and COD concentrations of the present study are presented in **Table 2.3**.

Table 2.3: Status of organic pollution in the Buriganga River

Site	BOD	COD
Standards for Inland Surface Water Quality	10 mg/L	25 mg/L
Baschila bridge	9	32
Showari ghat	11	48

Source: CEGIS Survey, June 2018



Source: CEGIS Survey, 2018

Department of Environment, 2010-2017

Figure 2.2: Trend of organic indicators of water quality in Buriganga River

Inorganic minerals of water quality

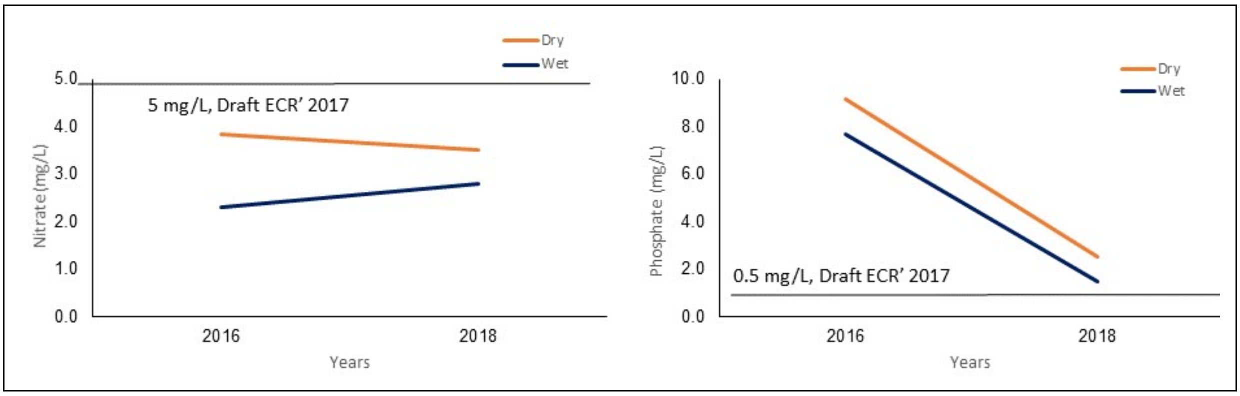
High NO_3^- and PO_4^{3-} concentrations are usually indicative of sewage/agricultural runoff pollution in a water body. The standard value of PO_4^{3-} concentration in natural water is 0.5 mg/L while it varies from 2.5-5.0 mg/L for NO_3^- concentration. In Buriganga River, the PO_4^{3-} concentration ranged three times higher (1.3-1.8 mg/L) than standard value while NO_3^- ranged within the standard limit (Draft ECR' 2017) (**Table 2.4:** PO_4^{3-} and NO_3^-). Even the industries were relocated, the NO_3^- and PO_4^{3-} levels in the river would not be improved too much in the short run. Other sources of pollution such as surface runoff, agricultural run-off and more importantly tanneries are not the main sources of NO_3^- and PO_4^{3-} in the Buriganga River. The status of NO_3^-, PO_4^{3-}, sulphate and ammonium as N are presented in Table 2.4.

Table 2.4: Status of chemicals in Buriganga River

Sampling locations	PO_4^{3-}	SO_4^{2-}	NO_3^-	NH_4-N
Standard for Inland Surface Water Quality	0.5 mg/L	400 mg/L	5 mg/L	1.5 mg/L
Baschila bridge	1.3	29	4.2	0.60
Showari ghat	1.8	33	2.8	0.80

Source: CEGIS Survey, June 2018

NO_3^- and PO_4^{3-} status of 2016 and 2018 were observed in the Buriganga River only due to the unavailability of data. However, this study found that NO_3^- concentration of the river was not a problem for the aquatic lifeforms so far in both dry and wet season. In contrary, PO_4^{3-} showed a different pattern. In 2016, PO_4^{3-} was too high (8-9 mg/L) in both wet and dry season. But, in 2018 it was reduced to near about 1.5 mg/L. Still, PO_4^{3-} of the river is high enough to affect the plankton community structure at a certain level.



Source: CEGIS Survey, 2018 and Ahammed, 2016.

Figure 2.4: Trend of NO_3^- and PO_4^{3-} quality in the Buriganga River

Dissolved metals concentration in water

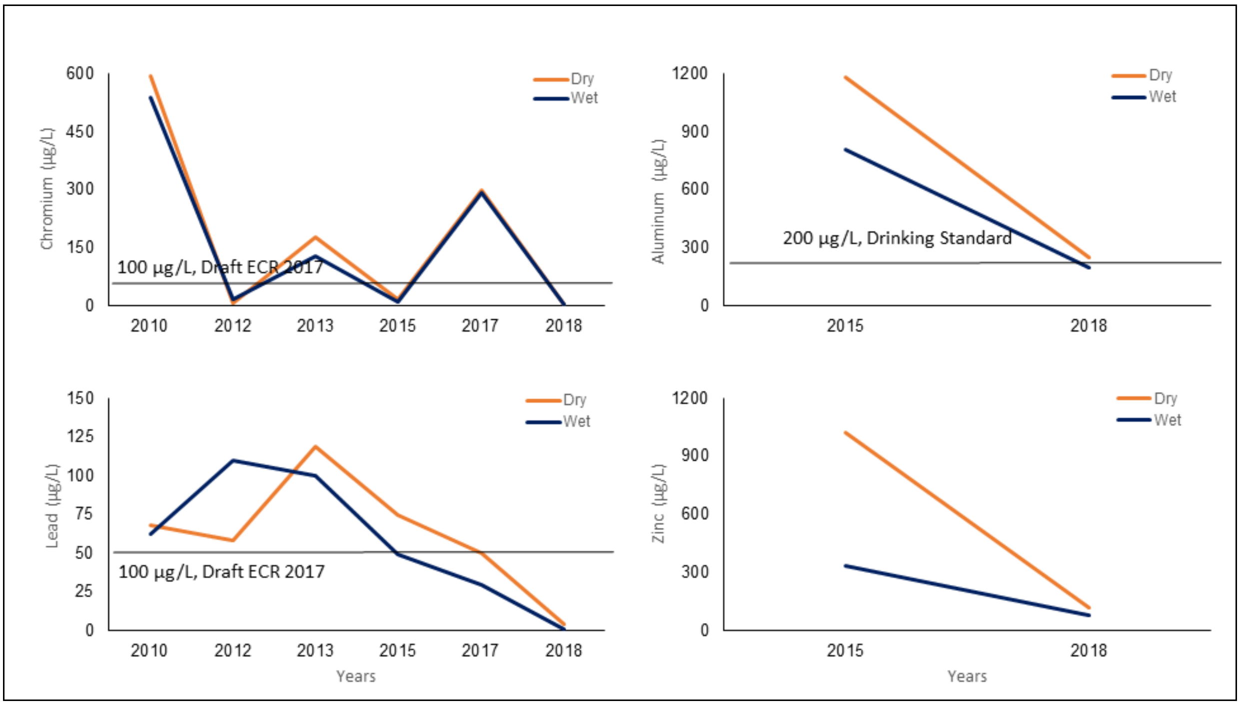
In term of heavy metal pollution, Cr, Al, Pb and Zn were observed. Of them the first two, Cr and Al were considered as the metals coming from leather industry exclusively. The rest two were observed for getting the sense of other textiles and dyeing pollution. The metal pollution status of Buriganga River is presented in **Table 2.5**.

Table 2.5: Status of metals in Buriganga River

Sampling locations	Cr	Al	Pb	Zn
Standards for Inland Surface Water	100 µg/L	200 µg/L	100 µg/L	5000 µg/L
Baschila bridge	3	201	1	80
Showari ghat	2	197	1	80

Source: CEGIS Survey, June 2018

Trend analysis proved that total Cr concentration in Buriganga River is decreasing. Before 2012, total Cr was found around 600 µg/L which reduced to 3 µg/L in 2018. Al was also found in decreasing trend (**Figure 2.5: Cr and Al**). Similar to Al, Zn also showed declining tendency. Only, Pb showed temporal variations. After 2013, Pb as well was reducing in River Buriganga (**Figure 2.5: Pb and Zn**).



Source: CEGIS Survey, June 2018; Island and Azam, 2015; Moniruzzaman et al., 2012.

Figure 2.3: Trend of Metals (Cr, Al, Pb, Zn) Concentrations in the Buriganga River

The variations of heavy metal concentrations are mainly due to different collection spots and seasons. Total Cr concentrations were found lower than the standard level (100 µg/L) given by Draft ECR (2017) in the current study. Chromium concentration in Buriganga River ranged 2-3 µg/L. This low amount of Cr was because of withdrawal of tannery industries from Hazaribagh area together with upstream freshwater availability due to rainy season during the survey. Previously, Cr was found higher in concentration in this river. During the operational period of tannery industry, Cr raised up to around 4000 µg/L in dry period near Hazaribagh (Azim et al., 2009). In another study, Cr was found in an average 270 µg/L at Baschila Bridge and 313 µg/L at Showri ghat (Mottalib et al., 2017). Khan et al. (1998) found the concentrations of Cr from 0.01 to 0.50 µg/mL in the water of the GBM (Ganges-Brahmaputra-Meghna) estuary, values that are lower than the present study.

Concentration of Aluminum did not show any indication of its pollution in the water quality of Buriganga River. The concentration ranged from 197-201 µg/L. In any previous study, Al was not considered as an indicator of leather industrial pollution. The variation in Al concentration is presented in **Table 2.5**.

In the present study, in all the observed locations, Pb concertation was found around 1 µg/L, which was very much lower than standard limit of inland surface water quality (100 µg/L, Draft ECR’ 2017). This low amount of Pb concentration in Buriganga River indicated that this metal did not pollute that river enough. However, in some earlier study, it was found that, average Pb concentration was about 65 µg/L, which was still lower than the Draft ECR (2017). Alam et al. (2003) found that Pb concentration varied between 0.1-0.7 µg/L in rainy season and 5-14 µg/L in dry season, which were a bit higher than the present study. Khan et al. (1998) found that the concentration of Pb ranged from 0.012 to 0.431 µg/mL, which were much lower than the EQS Standard. The present study findings are similar to the previous study of 0.003 mg/L (3 µg/L) for the water samples collected from the same river at the same locations (Mokaddes et al., 2013).

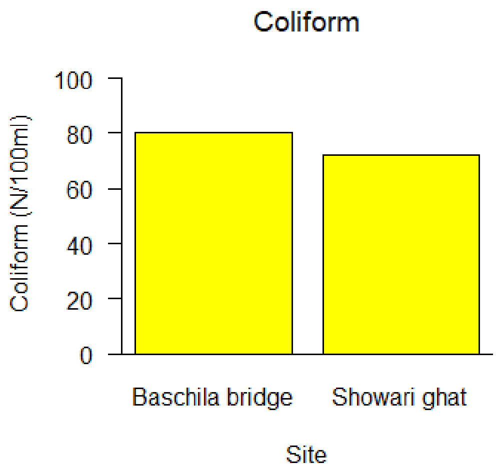
The concentration of Zn did not show any spatial variations in Buriganga River. During the study, in all the observed locations, around 80 µg/L of Zn was found. However, in an earlier study (Mokaddes et al., 2013) it was found that Zn was even less in amount (18 µg/L). Therefore, it was noticeable that leather industry is not related to the Zn concentration in Buriganga River. Other industrial activities, such as engineering workshops, and electroplating might be the reasons of behind this temporal variation of Zn. Standard surface water quality for zinc is 5000 µg/L.

Microbiological characteristics of water quality

According to Lika et al. (2010), fecal micro-organisms are mainly brought to aquatic environments through the discharge of untreated domestic wastewater. Also, fecal coliform bacteria can enter rivers through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from human sewage. However, their presence may also be the result of plant material, and pulp or paper mill effluent (Doyle and Erickson, 2006).

The maximum amounts of total coliforms in the samples of Buriganga were 80 N/100ml and 72 N/100ml in Baschila Bridge and Showari ghat respectfully (**Figure 2.6**). According to Draft ECR, 2017, the number of total coliforms of ≤5000 individuals/100ml is allowed for fish culture. Thus, all total coliform counts in this study complied with the Banglades Standard.

In the earlier study, it was found that around 9000 CFU/100ml was the average concentration in Buriganga River (Pramanik and Sarker, 2013). The fecal contamination of water from slums located along the course of the river-bed could be the reason for the high values in the earlier study.



Source: CEGIS Survey, June 2018

Figure 2.4: Status of fecal coliforms in Buriganga River

Water Quality Index (WQI) of Buriganga River

Chakraborty et al., 2013 assessed the WQI for Buriganga River near the point of Hazaribagh channel. NSFWQI was used to determine the water quality index of Buriganga River. According to the NSFWQI, Buriganga River water quality index became very poor in quality, as it scored 23.09, which is in between 0-25 water quality classes (**Table 2.6**).

Table 2.6: Classes of water in respect to Water Quality Index (WQI)

WQI	Buriganga River	Water Class
0-25	**23.09**	**Very bad**
25-50		Bad
50-70		Medium
70-90		Good
90-100		Excellent

Source: Chakraborty et al., 2013

2.2.2 Land resources

The study area mainly falls under Young Brahmaputra and Jamuna Tract (AEZ-8) which covers almost 81% of total area, followed by a slight portion of Madhupur Tract (AEZ-28). Medium low land covers the major area of Hazaribagh (58% of total area), followed by Medium high land (27% of total area) and low land (15% of total area). Clay texture dominants in the textural class of the study area's soil, which is followed by loam.

Approximately, 8.6 kilometer river length (from Baschila Bridge to Babu Bazar Bridge) was considered as study area where the width was 2 kilometer. Urbanization was the major feature of land use in this tannery estate (76.6% of total area) which is situated on both bank of the river. Agricultural practices occupied next in the land use (13.1% of total study area) which was on the right bank of the river. Tannery industry was found in the left bank of the river. Detailed land use of Hazaribagh Tannery is presented in **Table 2.7** and **Figure 2.7**.

Table 2.7: Land Use of Hazaribagh Tannery Estate

Land Use	Hazaribagh Tannery Area (ha)		Total area (ha)	% of Total Area
	Left Bank	Right Bank		
Tannery Aarea	78	0	78	2
Agriculture (NCA)	0	484	484	13
Water Bodies	32	271	303	8
Settlement	1,562	1,265	2,827	77
Total Area (ha)	**1,672**	**2,020**	**3,692**	**100**

Source: CEGIS field information and Satellite image, 2015.

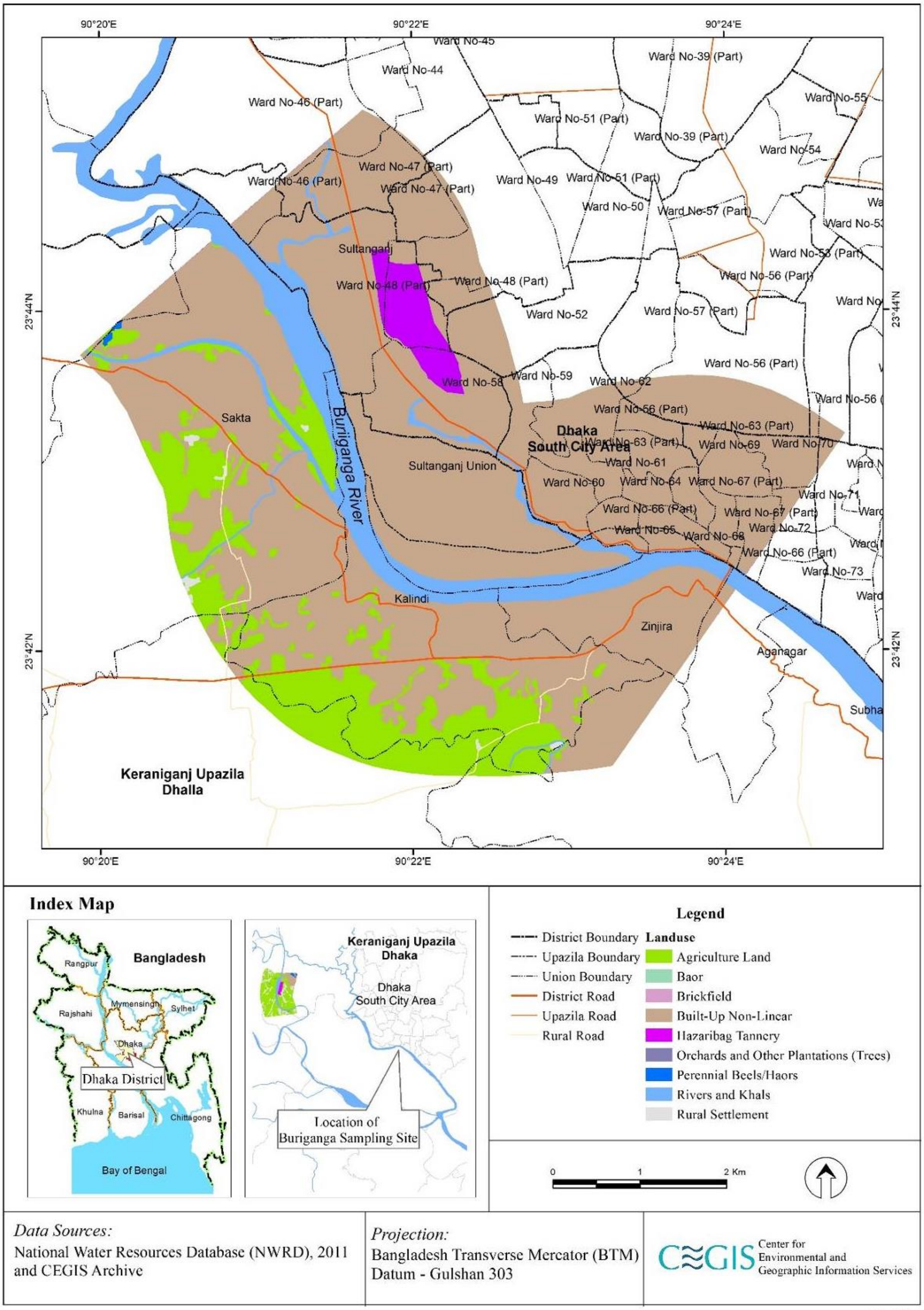


Figure 2.5: Land use map of Hazaribagh Tannery Estate

2.2.3 Soil quality

Soil quality of Hazaribagh Area deteriorated to alarming condition (Mondal et al., 2017). This study also tried to see the soil quality of the Hazaribagh Tannery Areas. Total Cr was present in all the soil samples of Hazaribagh tannery area. The maximum accumulation was found in the main drainage soil while the minimum was in the river bed sediment of the Buriganga River. River levee soil and agricultural land soil (almost 2 km away from the riverbank) was also found contaminated by Cr. In all the observed cases (obtained from laboratory analysis), Cr concentration exceeded maximum allowable concentration (MAC) in soil 100 ppm (Kloke, 1980). Only main channel plant sample was found to be contaminated, which was also out of MAC value (1-2 ppm) in plant (Kloke, 1980). Presence of Cr in soil, sediment and plant in the Hazaribagh area is presented in **Table 2.8**.

Table 2.8: Presence of Chromium (Cr) in soil, sediment and plant in Hazaribagh Tannery Estate

SL	Sampling point	Site Characteristics	Cr in Soil (ppm)	Cr in Plant (ppm)
1	Main Drainage	This was the major outlet of tannery wastes. Soil and plant sample was collected to have chromium contamination in soil and plant.	386.9	112.4
2	River bed/ Sediment	River bed sample was collected from Showari subsequent floating plant (water hyacinths) was also collected.	109.0	N.D.
3	River levee	River levee soil and plant sample was collected form in between main channel and river bed sample collecting point.	241.0	N.D.
4	Agricultural Field	This site is situated in the opposite bank of the Buriganga River which is single cropped land. Soil and plant sample was collected to have chromium contamination in soil and plant.	275.0	N.D.

Note: N.D. - Not Detectable. Soil (MAC)-100 ppm. Plant (MAC) - 1-2 ppm.

*** Soil and plant samples were collected from 3rd to 4th June, 2018 following standard sampling procedure (Soil survey manual, 2017). These samples were sent to SRDI, Dhaka laboratory for analysis. To determine total Cr, soil and plant analysis was done by digestion method followed by AAS analysis (Weil and Brady, 2016).*

Soils near Hazaribagh Area were soaked with untreated tannery wastes and pollutants since 90's. This consequence created severe Cr load in the soils of this area. Time series data showed how the concentration of Cr increased in the soils of Hazaribagh Area (**Figure 2.8**) (Nuruzzaman et al., 1995; Ullah et al., 1999; Elahi et al., 2010; Karim et al., 2013; Mondol et al., 2017). All of these soil samples were taken from within half kilometer of the main lagoon of tannery estate of Hazaribagh during dry season in different years. But even in wet season, Cr concentration (26,664 ppm) was higher than the MAC (Mondol et al., 2017). Soil sampling of this report was done in wet season of 2018 at that time the main drainage channel was alsmost dead. Besides this, local people raise a part of the low land for their house construction. In consequence of this, new soil might be taken place the previous contaminated one which might be a reason of low concentration in Cr presence in soil in CEGIS study.

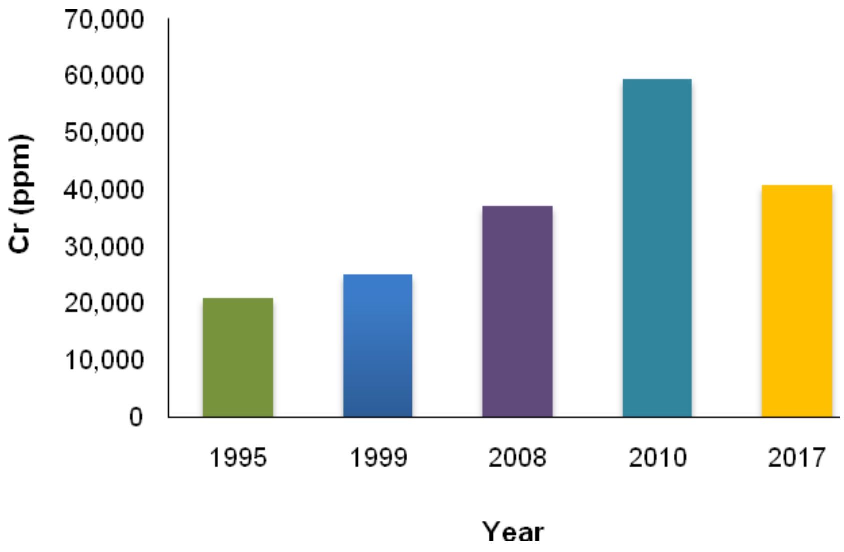


Figure 2.6: Time series data of Cr concentration in Hazaribagh soil

In all cases, result showed that Cr concentration was much higher than MAC in soil (100 ppm) (Kloke, 1980). The concentration was increasing since 1995 to 2010. After 2010, Cr concentration started to fall due to shutting down of tannery industries in Hazaribagh. Findings of the study showed that, there was a decreasing tendency of Cr concentration in soil, though it was still higher than MAC value **(Table 2.8**). The reason behind this decreasing trend might be the shutdown of sources (tannery industries) and continuous flash out of soils during monsoon.

The sediment pollution load also gives an improving situation after the trend analysis (Mohiuddin et al, 2011; Islam et al., 2014; Mohiuddinn et al., 2015; CEGIS field analysis, 2018). In 2010 Cr concentration was maximum which is decreasing afterwards and gets minimum at 2018 **Figure 2.9**. This might be ahother indication of decreasing pollution load of Cr in the Buriganga river sediemt due to shut down of tannery industries in the vicinity of this river. But still the mean concentration is higher that the average shale value and continental upper crust value 90 ppm (Turekian and Wedepohl,1961) and 92 ppm respectively (Rudnick and Gao, 2003).

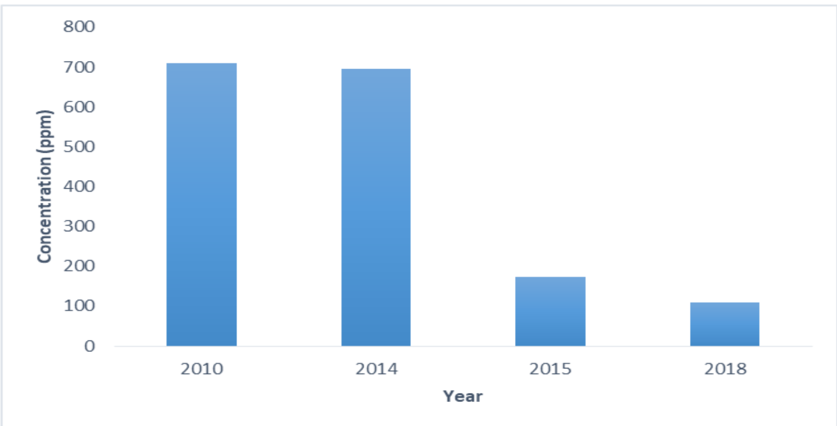


Figure 2.9: Time series data of mean Cr concentration in the Buriganga River sediment

Cr was not the only concerned pollutant observed in tannery area soils. A large amount of salt is used during the processing of raw hides. In most of the cases these salts exposed to the environment in untreated condition. Therefore, EC concentration increased. Presence of excessive salt in soil (>4 ds/m) is harmful for plant growth (Ponnamperuma, 1985). More than 505 ppm of chloride (Cl^-) and 7.2 dS/m EC was found in soil solution of Hazaribagh in1995 (Nuruzzaman et al., 1995), which was found at 6.2 at 2017 (Mondol et al., 2017). This might be due to management issues related to reduced use of salt for preserving hide.

Remarks:

Both soil and sediment quality analysis showed a clear indication of decreasing Cr presence in 2018. Cr presence was found to be maximum in 2010 when the tannery industries were in full swing. The accumulation starts to decreas afterwards with the beginning of shuting down of the industries.

2.3 Biological Environment

2.3.1 Plankton Status

Zooplanktons are the primary consumers of a food web that starts from the water body. Normally, Zooplanktons eats Phytoplankton. In Buriganga River, very low concentration of Zooplanktons was present. The composition followed only Metanauplius, Cyclops and Filinia. On an average, only 720 Zooplanktons were present in each cubic meter of water. In a river, average zooplankton per cubic meter should be 2000-3000 at least. The composition and concentration of Zooplankton in Buriganga River are presented in **Table 2.9.**

Table 2.9: Composition of Zooplankton in Buriganga River

River	Zooplankton	Concentration
Buriganga	*Metanauplius*	1 per ml of water sample
	Cyclops	1 per ml of water sample
	Filinia	1 per ml of water sample
Total Concentration		**720 Zooplankton/cubic meter**

Source: Field Survey at June 2018.

In the Buriganga River, there was no benthic community during the field visit of June 2018. The bed materials were full of sand and plastics at the sampling point with some mixture of sludge.

2.3.2 Fisheries Resources

Suitable riverine habitat condition for fish depends primarily on connectivity of water bodies (river-river/river-khal-beel/river-khal-floodplain), spatial and temporal water flow and velocity, substrates, water quality (mainly DO, pH, BOD, COD, and TDS), aquatic vegetation, etc. The widely known Hazaribagh Tannery Industry was constructed on the left bank of the Buriganga River. As local fishermen informed, this river shows completely different scenarios in view of fish habitat status in dry and wet seasons. This is because river water becomes highly polluted in the dry season and habitation for most of the fishes becomes critical. When pollution becomes diluted in the wet season some fishes back to the habitat and graze there (Ahmad, M. K., et al., 2010). The river passes beside the Dhaka City having multiple sources of pollution. Among the pollutants coming from different sources, industrial pollutants are the major causal factors for deteriorating water quality as well as habitat quality not only for themselves but also for their heavy metal contents (Ahmad, M. K., et al., 2010). Laboratory tests have proven that the water in most parts of the Buriganga River contains no Dissolved Oxygen (DO) and is therefore totally devoid of aquatic life (Khan, 2012, Daily Star Report). Fishes are highly sensitive to such pollutants and heavy metals, which are supposed to be mutagenic trace element for various riverine fish species. One of the worst conditions in respect of fish habitat was found around the Hazaribagh Tannery Area (HzTA) where fishes are not found in dry season.

Habitat Condition

Habitat suitability for assemblage of fish community was analyzed on the basis of measured water quality parameters, such as, water temperature, DO, pH, TDS and BOD. Standards for water temperature, DO, pH and BOD defined in ECR (1997); for TDS in Tabata et al., 2007; Srivastava and Sinha, 1996 are considered in assessing habitat suitability. The sensitivity scores will be calculated through normalizing the deviation of observed values from the standard value by applying UNDP developed normalization method. Finally, habitat suitability was calculated by using Sudarsan's index method (Sudarsan, 1995). More or less satisfactory suitability scores for pH and TDS were found in two sampling locations of the Buriganga River (**see Water Quality Section**). However, the suitability scores for water temperature, DO and BOD were very low. It thus clearly portrays that the habitat suitability of two sampling locations in the Buriganga River is very low, although an improving trend has found from 2010 to 2018 (**Figure 2.10**).

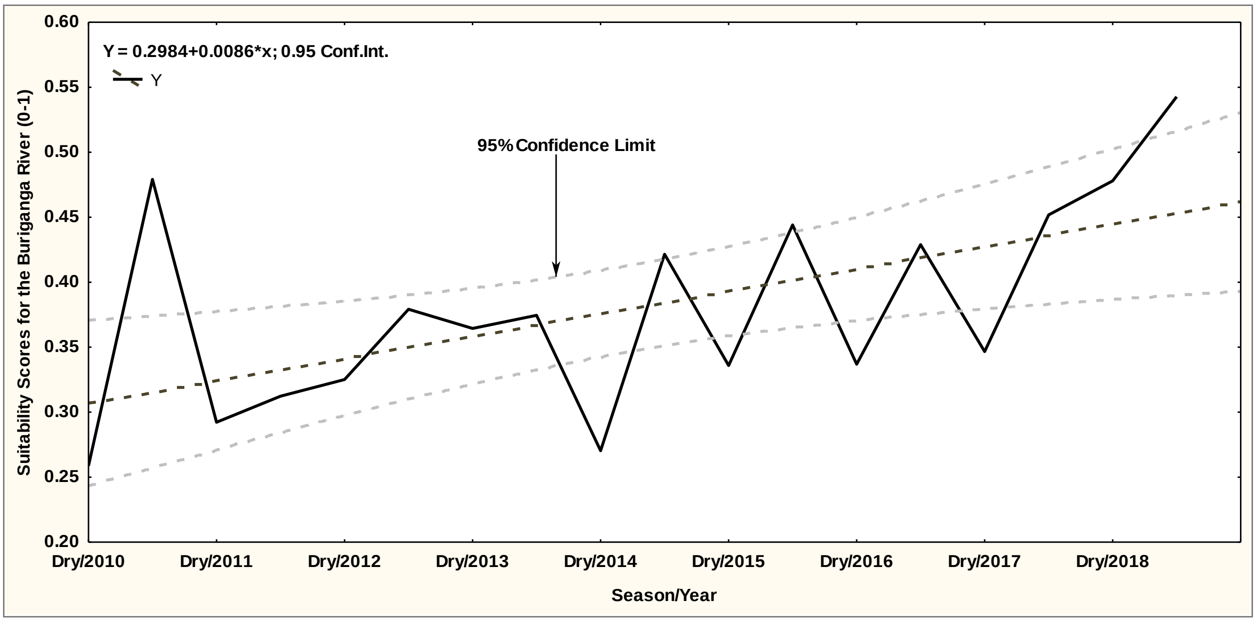


Figure 2.10: Exponential smoothing series with linear trend of habitat suitability scores for the Buriganga River

Source: CEGIS Field Survey, 2017 (Physical Environment Section)

<u>*Habitat Assessment*</u>

The estimated total fish habitat area is about 628 ha, which is solely contributed by the capture fishery in HzTA. No culture fishery habitat was found in the HzTA. Fish habitat distribution is given in **Table 2.10.**

Table 2.10: Breakdown of fish habitats in the HzTC

Sl. No	Habitat Category	Habitat Type	Area (ha)	
			Left Bank	Right Bank
1	Capture	River and Khal	32	269
2		Perennial Beel	0	2
3		Floodplain	0	325
		Total=	**32**	**596**

Source: Land Use Satellite Image, 2015

<u>*Fish Migration and Movement*</u>

Local fishermen informed that fish migrates to the Buriganga River from nearby habitats mostly during monsoon season when pollution becomes diluted with the augmentation of water flow. No pre-monsoon fish migration is reported in the river. With increasing river flow, Major Carps, Large Catfish, etc. big sized fish species migrate through these river systems. Major migratory fish species are *Labeo rohita*, *L. goniu*s, *L. calbasu*, *Catla catla*, *Xenentodon cancila, Osteobrama cotio, Rita rita, Sperata aor, Mystus cavasius, Mystus tengara, Mystus vittatus, Wallago attu, Ompok pabda, Ailia punctata, Pangasius pangasius, Bagarius bagarius*, etc. (Baki, et al., 2017). Insignificant number of Small Indigenous Species (SIS) of fishes use this river for their localized movement.

<u>*Fish Diversity*</u>

More than 50 (fifty) species have been recorded in the Buriganga River particularly in the wet season. Baki, et al. (2017) identified a total of 56 fish species belonging to 41 genera, 20 families and 9 orders from the upper Buriganga River. In August, number of species reached 56, which started to decline in September. Shannon-Weiner diversity index of the collected fishes (seasonal) indicated a diverse distribution and the species richness variation across the river sites ranged from 1.825 to 3.843 (Baki, et al., 2017). He also recorded the highest fish diversity during the monsoon, whereas diversity was lowest during the winter. According to their findings, Cypriniformes were the most dominant orders constituting (18) 32% of the total fish population followed by the Siluriformes (17) 30%, Perciformes (12) 21%, Channiformes (3) 5%, Clupeiformes (2) 4%, Synbranchiformes, Beloniformes, Osteoglossiformes, Cyprinodontiformes were the least numerous orders constituting only 2% each of the total fish population. Three species, namely *Channa punctatus*, *Heteropneustes fossilis* and *Colisa fasciata* were found abundantly throughout the year while *Osteobrama cotio, Oreochromis mossambicus, Pseudambassis lala* in August only. Two exotic species, such as *Oreochromis mossambicus* and *Hypophthalmichthys molitrix* were observed in the monsoon season. The available fish species are given in **Appendix-C**.

Furthermore, about 28 fish species were identified in the Buriganga Rivers during field visit where Kholisha, Shing and Kajuli fish attained the highest percentage in relative composition (**Figure 2.11**).

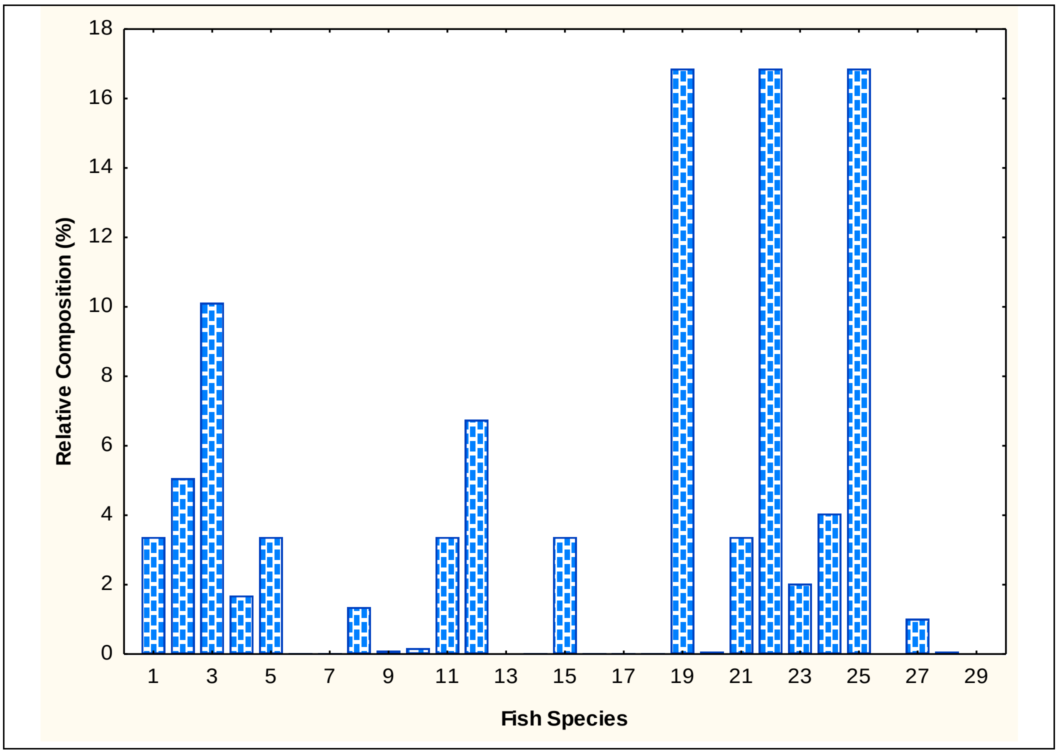


Figure 2.7: Fish Composition of the Buriganga River at Baschila Bridge Point

Source: Field survey, CEGIS (2018)

1.Tit Punti; 2.Chanda; 3.Ichha Chingri; 4.Chela; 5.Mola; 6.Rui; 7.Catla; 8.Gulsha; 9.Guchi Baim; 10.Tara Baim; 11.Kakila; 12.Dhela; 13.Gozar; 14.Shole; 15.Taki; 16.Ayre; 17.Boal; 18.Baghaire; 19.Shing; 20.Potka; 21.Batasi; 22.Kajuli; 23.Piyali; 24.Sarpunti; 25.Kholisha; 26.Chital; 27.Veda; 28.Foli

Heavy Metal Bioaccumulation to Fish

Historical Trend in Heavy Metal Bioaccumulation to Fish

The historical observations from previously conducted different investigation on heavy metal bioaccumulation into fish for the Buriganga River shows that the maximum, average and even minimum concentration of Chromium had been decreased from the year of 2012 and the concentration of Cd, Pb and Ni had been decreased from 2008 (**Figure 2.12**).

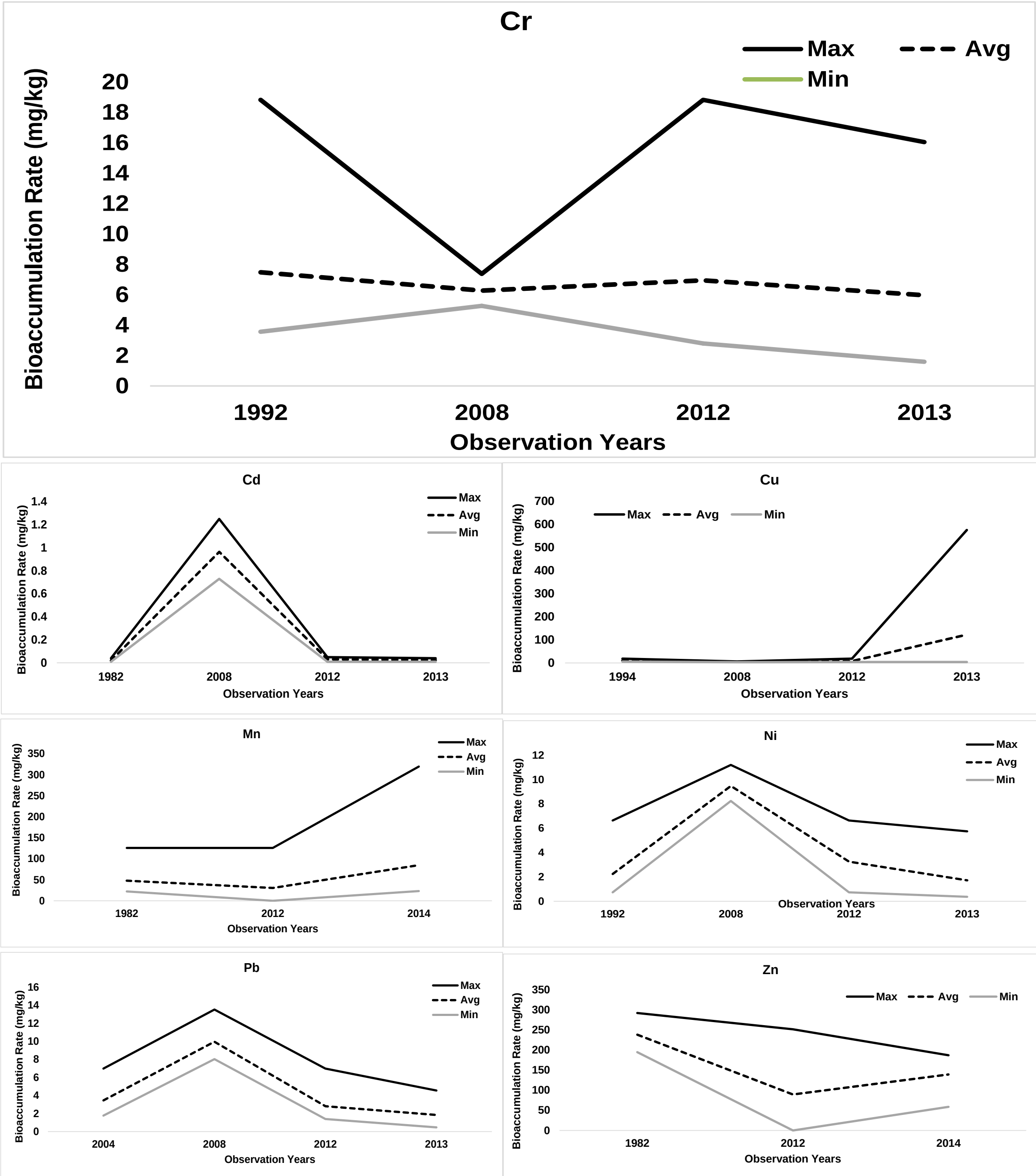


Figure 2.12: Historical Trend of Heavy Metal Bio-accumulation to Fish based on Literature Review

Seasonal Variation in Heavy Metal Bioaccumulation to Fish

Insignificant variation was found in heavy metal bioaccumulation in fish in case of the Buriganga River among pre-monsoon, monsoon and post-monsoon season (**Table 2.11**).

Table 2.11: Seasonal Variation in Heavy Metal Bioaccumulation in to Fish

Seasons	Fish Species	Cr	Cd	Cu	Ni	Pb
Pre-monsoon	*Channa punctatus (Taki)*	5.73	0.86	5.27	9.71	10.31
	Cirrhinus reba (Tatkeni)	6.75	0.76	5.09	10.54	8.03
	Glossogobius giuris (Baila)	6.13	0.81	4.46	11.21	9.58
	Gudusia chapra (Chapila)	6.27	0.83	4.25	9.25	9.12
	Mystus vittatus (Tengra)	5.47	1.09	5.2	9.47	12.32
	Pseudeutropius atherinoides (Batashi)	7.34	0.95	4.92	8.95	8.95
Monsoon	*Channa punctatus (Taki)*	5.85	0.97	5.37	10.25	8.85
	Cirrhinus reba (Tatkeni)	7.12	1.12	4.54	8.93	9.52
	Glossogobius giuris (Baila)	6.07	0.96	6.07	9.35	8.71
	Gudusia chapra (Chapila)	5.28	1.05	4.38	9.65	13.52
	Mystus vittatus (Tengra)	5.27	1.13	3.54	10.03	12.47
	Pseudeutropius atherinoides (Batashi)	6.27	1.25	5.19	8.25	9.05
Post-monsoon	*Channa punctatus (Taki)*	5.39	0.82	5.28	9.58	8.16
	Cirrhinus reba (Tatkeni)	7.11	0.73	3.36	9.35	9.27
	Glossogobius giuris (Baila)	7.05	0.85	4.57	8.65	11.45
	Gudusia chapra (Chapila)	7.38	1.07	6.34	8.41	10.12
	Mystus vittatus (Tengra)	6.28	1.17	4.19	8.73	10.25
	Pseudeutropius atherinoides (Batashi)	6.24	0.93	4.45	10.26	9.54
STDEV =		**0.71**	**0.15**	**0.77**	**0.78**	**1.54**

Source: Ahmad, M. K., et al., 2010

Fish Production Assessment

The estimated total fish production is about 480 Metric Ton (MT), which is solely contributed by capture fishery in HzTA. Breakdown of fish production in the study area is given in **Table 2.12.**

Table 2.12: Breakdown of Fish Production from Different Habitats in the HzTA

Sl. No	Habitat Category	Habitat Type	Production (Ton)	
			Left Bank	Right Bank
1	Capture	River and Khal	4	32
2		Perennial Beel	0	4
3		Floodplain	0	440
		Total =	**4**	**476**

Source: FRSS, 2016-17

2.3.3 Ecological Resources

The study area occupied different types of ecosystem like rivers, levees, urban settlements, roads, crop fields etc. Each of those supports different ecological resources as well different types of flora and fauna.

Status of Vegetation

Plant diversity varies within the study area according to its land condition and human interventions. Vegetation density of most of the area were found low due to extreme urbanization especially at Hazaribagh Site and the floral composition was dominated with small grasses and herbs. Among this type, *Croton bonplandianum*, *Amaranthus spinosus*, *Heliotropium indicum*, *Solanum sisymbriifolium*, *Cynodon dactylon*, *Imperata cylindrica* etc were most common. *Eichhornia crassipes* was the only dominated aquatic floral species observed in Buriganga River and its tributaries.

Aquatic floral diversity of this area was found moderate (compare to a standard vegetation status) in status, for presence of land type and rainwater, which holds water for a certain period of a year. Existence of aquatic plant community was concentrated in stagnant water of ponds and ditches. Water hyacinth (Kochuripana), Water cabbage (Topa pana) and Duckweed (Khudipana) were common among the free-floating communities. However, the species richness was low at Buriganga River near Hazaribagh Site rather than the Dhaleshwari River at Harindhara.

Submerged plants disappeared from the Buriganga River reaches near Hazaribagh. Heavy amount of industrial waste deposition on riverbed and low penetration of light for polluted dark water disfavor growth of submerged vegetation in rivers surrounding the Dhaka City.

Figure 2.13: Existing vegetation pattern of Hazaribagh Area

Status of Wildlife

Wildlife composition along the Hazaribagh Tannery area were not referable due to heavy urbanization and huge human intervenyions in the study area, which thereafter, lead the wild fauna to relocate them from there. However, some rodents like House Shrew, House Mouse and little number of mongooses were available within the area. Avifauna commonly occurring within the Hazaribagh Area were House Crow (*Corvus splendens*), House Sparrow (*Passer domesticus*), Pied Starling (*Lamprotornis bicolor*) and Black Kite (*Milvus migrans*). Their populations decreased due to squeezing of habitats for rapid urbanization.

2.3.4 Agricultural resources

Agricultural Production

Agricultural practice was found on the right bank of the Buriganga River. Around 484 ha of land was under cultivation in the area during the visit, of which 72% was single cropped and 28% was double cropped land (CEGIS field information and Satellite image, 2015). Vegetables were the main production of the area. Summer vegetables were grown in Kharif I, while winter vegetables were grown in Rabi season. Cropping intensity of the area was 128%. As the river water quality wasn't meeting the irrigation water quality, irrigation of these crops was mostly dependent on subsurface irrigation. Total cropped area was about 618 ha of which summer vegetable was grown in 159 ha and winter vegetable was grown in 459 ha land. Approximately, 7,098 metric tons crop was produced in this area, where summer vegetable production was 1,590 metric tons and winter vegetable production was 5,508 metric tons.

Higher concentration of Cr leads to delayed maturity and stunted growth for wheat while late flowering and maturity with dark green color for rice (Chamon et al., 2005). Reduction in rice production in tannery area and use of tannery effluents was also observed (Elahi et al., 2010). Rice yield production reduced up to 43.6% due to heavy metal toxicity with Hazaribagh Soil was observed before by Chamon et al., (2005). Heavy metals (Cr, Pb, Cd etc) destroy enzymes and interfere with or inactivate enzymes of living cells (Rahman, 1992) and hence their discharge into the environment must be carefully controlled and minimized. The reduced agricultural production of Hazaribagh Area was the accumulation of these results.

Irrigation

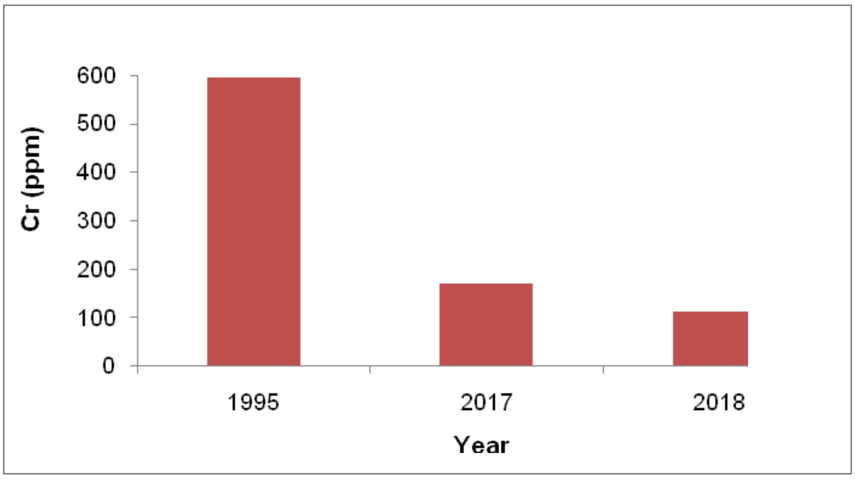
Water quality of the Buriganga River was not fit for irrigation (details are given in water quality section). This might be a combined effect of various industries in the levees of this river. But it was already assumed that leather industries have a high potentiality to degrade water quality (Zhang and Zhang, 2006).

Nearly 40-45 L fresh water/kg raw hide or skin is used by tanneries for processing finished leather (Sundar et al., 2000). For this requirement groundwater mining is a common issue in leather industries. Due to excessive withdrawal of groundwater for leather processing, the groundwater table of Dhaka City declines more than a meter every year (Zahid, 2017). As a result, there is a chance of the contamination of deeper aquifer (Bashar and Islam, 1999). The adjacent river water was polluted by some heavy metals due to mixing of untreated tannery effluent. Since, shallower groundwater of most of the areas of Bangladesh is contaminated by arsenic, excluding Pleistocene terrace areas covering Dhaka City, it is very important to save this aquifer from any sort of contamination (Ahmed et al., 1998). If the ground water is contaminated, crops will also be contaminated through irrigation water and capillary rise of water through soil pores. This scenario leads bio accumulation of carcinogenic metals.

Bioaccumulation

Bioaccumulation simply means the gathering of any substance in an organism, faster than its catabolism and excreation. Bioaccumulation was only found in the main channel of

Hazaribagh. It might be the result of years of Cr deposition in that area. Agricultural land and river levee area was free from Cr accumulation. But results showed that Cr bioaccumulation was a common scenario of Hazaribagh Area even in recent past (Mondol et al., 2017). As Cr is a by-product of tannery industry, bioaccumulation was also reported in early stages of tannery industries of Hazaribagh (Nuruzzaman et al., 1995). **Figure 2.14** shows Cr bioaccumulation status in Hazaribagh area.



Source: CEGIS Survey, June 2018

Figure 2.14: Chromium (Cr) Bioaccumulation at Hazaribagh Area main Channel

The good news was that, no bioaccumulation trace was found in river (floating plants), river levee and agricultural land. Only a couple of years back, bioaccumulation was found in these areas (Mondol et al., 2017). This might be a reason of washout of the area through rain water. Rainwater increases the upstream flow of the Buriganga River which helps to dilute Cr concentration of water; as a result, Cr bioaccumulation process is restricted in floating plants now a days.

2.4 Socio-economic Condition

2.4.1 Socio-economic Resources

Socio-economic characteristics including demography, settlement and housing, public utilities, economy and employment status in the study area are presented in this section. These indicators help to conceptualize the socio-economic condition of the study area. As the current situation of Hazaribagh did not reflect the actual scenario of operation phase of tanneries, therefore, secondary information of fully operational phase of Hazaribagh Tannery Industry is assumed and recalled through literature review and secondary information.

Area and Location

There were 8 thanas under Dhaka District; those were cutting through the study area delineation for the Hazaribagh Tannery Industry. The following **Table 2.13** shows detail of the study area.

Table 2.13: Locations of the study area along with coverage of Upazilas

District	Thana	% of Upazila Coverage
Dhaka	Bangshal	92
	Chak Bazar	100
	Dhanmondi	39
	Hazaribagh	79
	Kamrangir Char	100
	Lalbagh	89
	New Market	28
	Shahbagh	28

Source: Spatial GIS analysis, CEGIS 2017

2.4.2 Population, Demographic Profile and Ethnic Composition

Population and Household

The study area has a population of 1,085,204 living in 232,800 households. The average size of household was 4.7. Size of the household varied among the study upazilas from 4.2 to 7.8 members per household. Composition of the household membership in terms of male and female were in favor of male, thus the overall sex ratio was found 138 that indicated there were average 138 male against per 100 female members (BBS, 2012). This might have occurred due to number of working labors in the tannery industries.

Table 2.14: Demographic Scenario of the Study Area

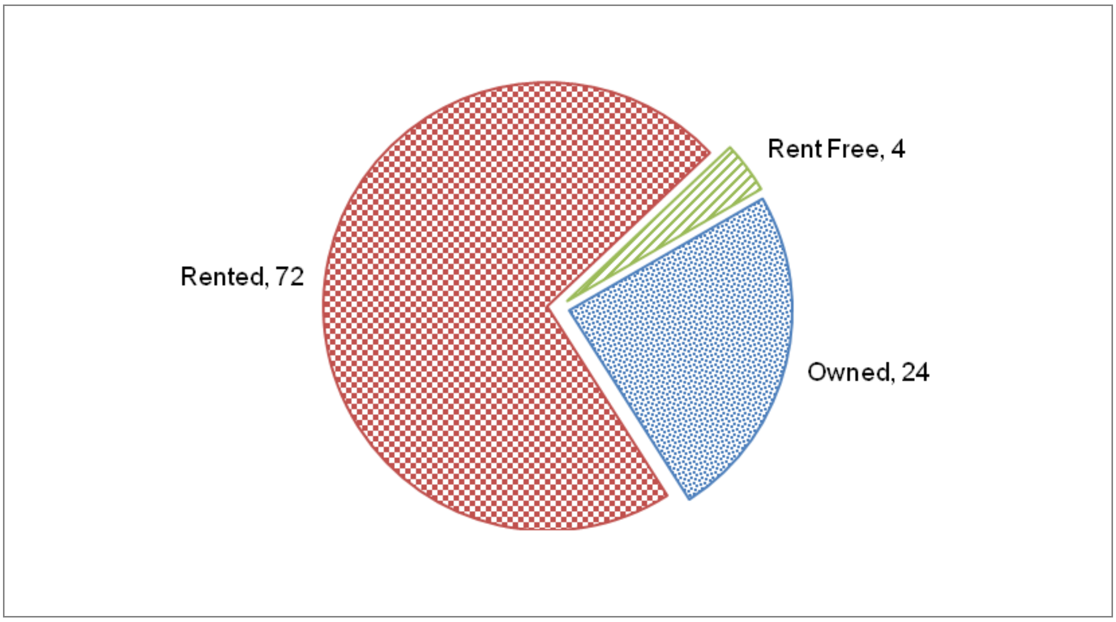
Upazila	Households	Population			Sex Ratio	HH size
		Both	Male	Female		
Bangshal	35,706	188,514	121,388	67,126	181	5.3
Chak Bazar	34,161	171,751	111,111	60,640	183	5.0
Dhanmondi	14,055	62,561	33,672	28,889	117	4.5
Hazaribagh	38,154	161,931	87,906	74,025	119	4.2
Kamrangir Char	23,789	102,955	56,067	46,888	120	4.3
Lalbagh	81,839	361,237	194,775	166,462	117	4.4
New Market	2,425	15,347	10,129	5,218	194	6.3
Shahbagh	2,672	20,907	13,825	7,083	195	7.8
Total/Average	**232,800**	**1,085,204**	**628,873**	**456,331**	**138**	**4.7**

Source: Population and Housing Census 2011, BBS, 2012 estimated by CEGIS, 2017

2.4.3 Settlement and Housing

Housing Tenancy

In the study area, 72% of households resided in rental houses and 24% in their own houses (**Figure 2.15**). A number of migrant working labors and employees of different government and non-government organizations resided in rental basis in the study area either with family or as a bachelor.

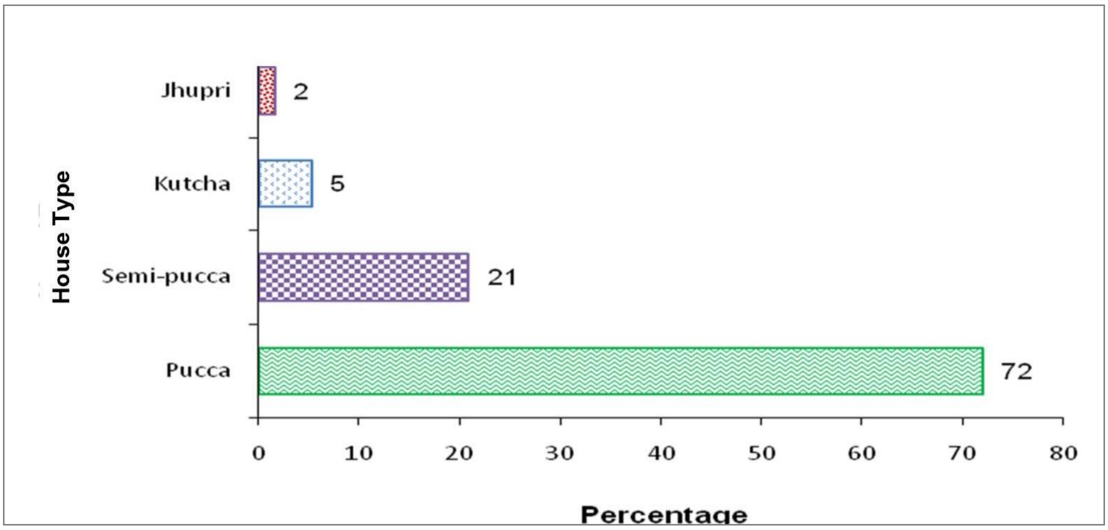


Source: Population and Housing Census 2011, BBS, 2012

Figure 2.15: Housing Tenancy in the Study Area

Housing Condition

The housing conditions of the study area as represented in the BBS, 2012 showed that highest (72%) percentages of households resided in pucca houses and 21% of household resided in semi-pucca houses **(Figure 2.16).**



Source: Population and Housing Census 2011, BBS, 2012

Figure 2.16: Distribution of Households by Type

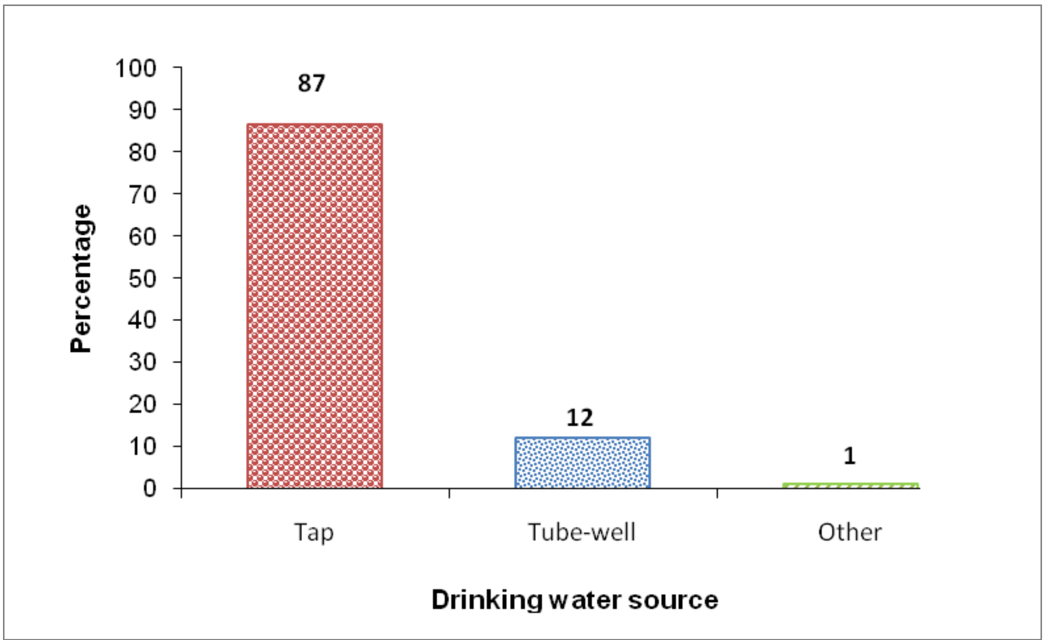
Traffic and transport

Due to load and unload of leather and raw materials, a number of trucks stood besides main road of Hazaribagh which create huge congestion for moving towards Jhigatola to Rayerbazar, Hazaribagh and Pilkhana connecting roads. Except to the loading and unloading trucks, the adjacent light vehicles i.e. CNG, rickshaw, motorbikes and private cars were found available in the connecting roads.

2.4.4 Public Utilities

Water Supply for Drinking and Domestic Utilize

About, 87% of households used supply water both for drinking and domestic purposes whereas only 12% population used tube well water (BBS, 2012). During field survey, people stated that almost all the households used supply water both for drinking and domestic purposes in the study area. However, the tannery industries and some households residing on the bank side of the Buriganga River used tube well water for business and domestic purposes.



Source: Population and Housing Census 2011, BBS, 2012

Figure 2.17: Households by Drinking Water Facilities

2.4.5 Economy and Employment

Income and Expenditure

Household income and expenditure is an important economic indicator to measure the economic condition and sustainability of households. According to the information of local people, it is found that household income of the study area was higher compared to the national nominal income of households but not adequate in comparison with the expanse of living. In the study area, income of most of the households (50%) were over BDT 30,000/month. In terms of expenditure, highest percentages (40%) of household expended BDT 20,001 to BDT 30,000 per month. The scenario of income and expenditure are shown in **Table 2.15**.

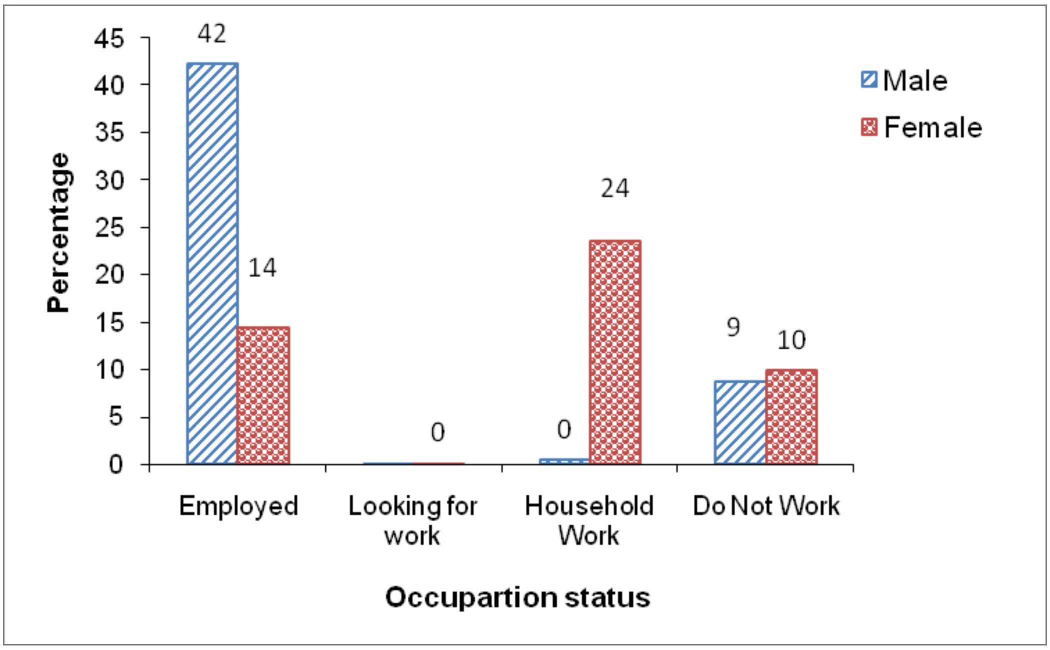
Table 2.15: Household Monthly Income and Expenditure in the Study Area

Range of Amount in BDT	% of Household in income Level	% of Household in expenditure level
<10,000	-	4
10,001 - 20,000	15	20
20,001 - 30,000	35	40
>30,000	50	36

Source: RRA by CEGIS, 2018

Occupation and Employment

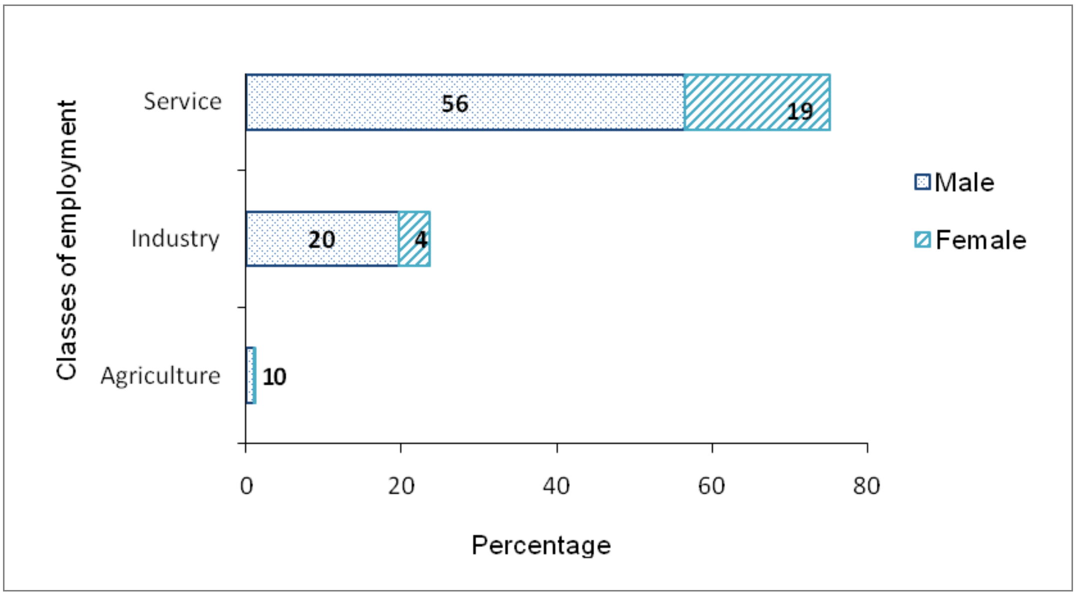
About 20% of the total population belong to the workable groups in which about 56% of the workable population are employed and still 19% of those population do not work yet (Figure 2.18).



Source: Population and Housing Census 2011, BBS, 2012

Figure 2.18: Employment Status among the Male-Female

Among the three major sectors of employment, it was found that 75% of total employed population was engaged in services followed by 24% industrial workers or employees (**Figure 2.19**). During RRA almost similar result was depicted.



Source: Population and Housing Census 2011, BBS, 2012

Figure 2.19: Occupation Status among the Studied Population

Social Standard

Due to bad odour, well off families were not eager to come to Hazaribagh Area either for rented in or for meeting the relatives. So, building owners did not get expected rent from the tenants in Hazaribagh area. Their apartments became vacant due to unavailability of sober tenants. Tin Shed structures and furniture were fragile due to deterioration of air quality. Also, congestion in drainages due to disposal of solid waste of the tanneries may create drainage congestion, even in a very small duration of raining. Consequences of these obstacles, it found less civic facilities (i.e. school, college, hospital etc.) in Hazaribagh area which indicated poor social standard of that area.

In synopsis of socio-economic aspects, it is observed that overall drainage, bad odour and community health have been improved over time after shifting the tannery industries from Hazaribagh. Therefore, the standard of living and associate civic facilities is also getting updated and people are showing their interest to reside in Hazaribagh area. As a result, apartment developers are investing to open mega projects in Hazaribagh. Also, standard of children education is upgraded by establishing new standard schools for junior sections.

3. Environmental and Social Status of Hemayetpur Tannery Area

3.1 Introduction

Environmental and social situation of Hemayetpur Tannery Area was evaluated following the same environmental settings used in the evaluation of Hazaribagh situation. In addition, the data collection time was also the same (June 2018).

3.2 Physical Environment

3.2.1 Water Availability of Dhaleshwari River

The Savar tannery estate project is situated besides the Dhaleshwari River, which is governed by the upstream Bangshi River. It was presumed that the effluent will be discharged to the river after treatment. As such, the water availability will play a vital role in assimilating and further dilution of effluent of the tannery. In this context, water availability is pre-requisite to understand the situation. In order to work out the availability (75% and 80% dependable flow) of water, the discharge data of Dhaleshwari River at upstream of the Savar tannery was collected from North-Central Hydrological Region Model run by by CEGIS.

It is observed from the analysis that the maximum discharge of the Dhaleshwari River at the point was about 761 m^3/s in 1998 during flooding and minimum was 74 m^3/s in 1994 shown in **Figure 3.1**. It was also observed from the monthly average discharge that the average maximum discharge varies from the month of July to September and minimum varies from November to March and increases from April as shown in **Figure 3.2**. Besides, another analysis through the Weibull Distribution method that the dependable monthly average flow of 75% and 80% i.e. availability of water in the river is shown in **Figure 3.3** which will aid further dilution of effluent of the tannery.

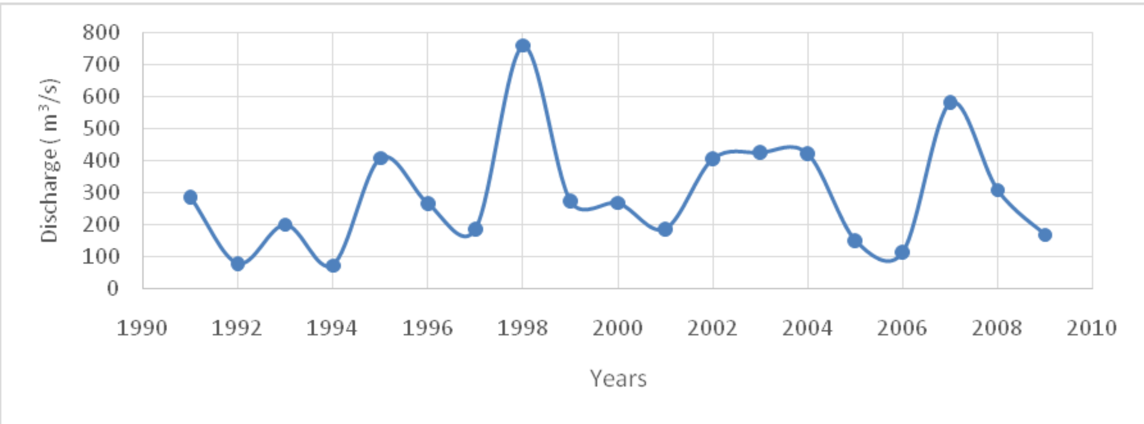


Figure 3.1: Historical Maximum Discharge of the Dhaleshwari River (1991-2013)

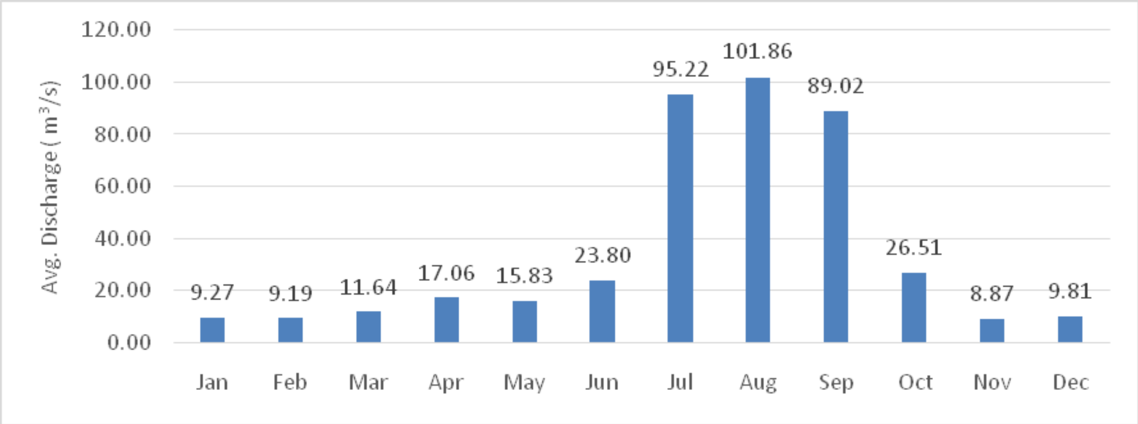
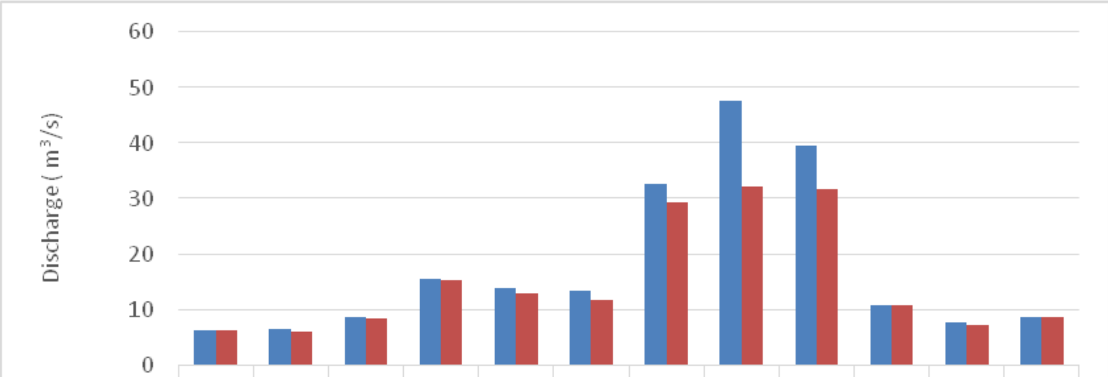


Figure 3.2: Monthly Variation of Average Discharge of the Dhaleshwari River (1991-2013)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
75% Flow	6.46	6.56	8.79	15.65	13.93	13.57	32.74	47.76	39.57	10.88	7.76	8.89
80% Flow	6.45	6.14	8.64	15.38	13	11.85	29.43	32.2	31.68	10.83	7.42	8.82

Figure 3.3: Dependable Average flow analysis of Dhaleshwari River (1991-2013)

3.2.2 Quality of Savar Tannery Effluents

Tannery industries are one of the highest water polluting industries in Bangladesh. The Savar Tannery Estate is withdrawing the water for consumption from groundwater sources. Wastewater effluents are discharged into the Dhaleshwari River after treated by CETP, which varies greatly based on the processes involved, raw materials, and products. Generally, water consumption is greatest in the pre-tanning areas, but significant amounts of water are consumed also in the post-tanning processes. At the present situation, the industrial pollution is being dumped through three sources viz. CETP, Domestic Water and Solid Waste Disposal Yard. The quality of the effluents is evaluated in this section.

Physical Characteristics of Water Quality

Color is one of the important physical parameters for examining purity of water and determine how much organic material or impurities are in the water. The **Hazen Color Scale** made it possible to compare a sample of wastewater against a standard solution of diluted platinum cobalt. The color scale used for measuring water quality can also be referred to as the **Pt-Co** (Platinum-Cobalt) / APHA (from American Public Health Association) / HU (Hazen Units) color scale. It ranges from 0 (clean or distilled water) to 500 (very dark, polluted water). Both domestic and CETP discharge recorded color around 77 Hazen during discharge (**Table 3.1: Color**). However, wastewater color of the solid waste disposal yard were around 200 Hazen. Most importantly, this wastewater was being released into the Dhaleshwari River in many ways. The dumped leathers in contact with rainwater formed this color.

With growing population, industrialization and urbanization, the Odor problem has been assuming objectionable proportion. Toxic Odor causes pollution to environment. Removal of Odor from leather tanneries is important to preserve safety and occupational health and public annoyance. Such Odor from domestic and effluent causing gases identified mostly presence of Ammonia, Hydrogen Sulfide and Volatile Organic Compounds (VOCs) in the wastewater which can be measured in Odor units per unit volume (OU/m^3).

Odor for domestic wastewater were recorded as 8 OU/m^3 where it came to 1 OU/m^3 for treated effluent only. In contrary, the highest Odor (50 OU/m^3) was generating from the solid waste dumping yard (**Figure 3.1: Odor).** Solid part of leathers is rotten in contact with water, which produced chronic Odor. As per ECR, 1997, the standard limit for Odor causing NH_3 is 1-5 ppm and H_2S is 0.02-0.2 ppm. Presence of hide, skin, un-hairing & liming, de-liming, pickling causing severe Odor in domestic discharge. The CETP discharge emits relatively lower Odor than domestic discharge. Other sources were from chemical storage in tannery (HCHO, CH_4 etc. gases come out) and some organic foul gases form hides/skins during processing.

Temperature was relatively normal for domestic, CETP and disposal yards discharge according to the tannery effluents standrads for Bangladesh **(Table 3.1: Temperature)**.

DO levels in domestic water and disposal yard were very low (0.2 mg/L) primarily due to various biological and chemical waste being mixed with the water sources. By contrast, the treated water had comparatively high DO (**Table 3.1: DO**) than the previous two sources, which was even too low to be disposed into inland natural water bodies. The ECR, 1997 standard limit is 4.5 mg/L at least.

Table 3.1: Physical characteristics of the effluent quality of Savar Tannery Estate

Sampling locations	Color	Odor	Temperature	DO	pH	Turbidity	TSS
Tannery Effluent Discharge Standard	**15**	**Odorless**	**20-33**	**4.5-8**	**6-9**	**15**	**100**
Unit	**Hazen**	**-**	**ºC**	**mg/L**	**Value**	**NTU**	**mg/L**
Domestic water	77	8	26	0.2	8.1	1858	57
Treated effluent	76	1	31	2.5	8.0	500	127
Solid mixed liquid	200	50	31	0.2	7.8	650	350

Source:CEGIS Survey, June 2018, Department of Environment, 2017-2018

All the waters of domestic, effluents and disposal yard, were found to be slightly alkaline in nature (pH around 8.0). However, the pH value completely met the ECR’ 1997 Criteria (pH value 6-9) (**Table 3.1**).

Based on the scientific studies, a maximum turbidity of 15 NTU, roughly corresponding to 0.5m visual clarity was recommended to avoid significant effects on native fish migration by Ausseil and Clark (2007b). The turbidity level of the domestic water was found to be very high compared with the treated water since huge amounts of suspended solids were excluded from the treated water due to the treatment process (**Table 3.1: Turbidity**). However, the turbidity of the tannery effluent was too high for life supporting water body e.g. Dhaleshwari River.

The presence of various organic and non-organic wastes leads to an increase in total suspended solids. Total suspended solids of dumping place were found to be high (357 mg/L) compared to the treated water (127 mg/L). TSS in effluents was high enough as the standard of TSS is 100 mg/L (Draft ECR' 2017) only for the disposal of tannery effluents in natural water body.

Chemical Characteristics of Water Quality

Inorganic indicators of water quality

Both domestic water and treated effluent show the TDS levels that exceeded national standard limit (2100 mg/L; ECR, 1997), which is likely due to the presence of various chemical ions used in tannery industries. Furthermore, it was revealed that TDS concentration of solid mixed liquid in disposal yard, even 3 times higher (6100 mg/L) of concentration than the ECR' 1997 limit. Chemical ions of leathers and untreated water from CETP increase TDS in liquid from disposal yard.

Table 3.2: TDS Concentrations of the Effluent of Savar Tannery Estate

Sampling locations	TDS (mg/L)
Tannery Effluent Discharge Standard	**2100**
Domestic water	4800
Treated effluent	5190
Solid mixed liquid	6100

Source: CEGIS Survey, June 2018

Department of Environment, 2017-2018

Organic indicators of water quality

BOD levels (92 mg/L) for domestic water was found to be very high than the national standard limit (30 mg/L; Draft ECR' 2017). On the other hand, BOD levels for the domestic water and solid mixed liquid was even higher than the same standard limit.

Table 3.3: Status of Organic Pollutants in the Effluent Quality of Savar Tannery Estate

Sampling locations	BOD (mg/L)	COD (mg/L)
Tannery Effluent Discharge Standard	**30**	**200**
Domestic water	92	320
Treated effluent	127	558
Solid mixed liquid	350	1903

Source: CEGIS Survey, June 2018

Department of Environment, 2017-2018

In case of COD levels, all the three sources exceeded the national standard limit of 200 mg/L. COD levels of the water from disposal yard were found to be significantly higher (1903 mg/L) compared with the treated effluent and domestic water, which were slightly higher than the standard limit (220 and 558 mg/L).

Total Chromium Concentration in Effluents of STE

Total chromium levels were found to be absent in the domestic water almost. By contrast, it was high (3.2 mg/L) in both treated effluent and the water from disposal yard, exceeding national standard limit of 1.0 mg/L.

Table 3.4: Status of metal pollutants in the effluent of Savar Tannery Estate

Sampling locations	Total Cr (mg/L)
Tannery Effluent Discharge Standard	**1 mg/L**
Domestic water	0.005
Treated effluent	3.2
Solid mixed liquid	10.0

Source: CEGIS Survey, June 2018

Department of Environment, 2017-2018

3.2.3 Water Quality of Dhaleshwari River

Water quality of Dhaleshwari River was studied only to draw the baseline situation of Savar Tannery Area. Water quality of the river was assessed in terms of physical, chemical and biological characteristics of the water. The details are described below.

Physical Characteristics of Water Quality

Similar to Buriganga River, exactly same parameters were observed to understand the physical characteristics of Dhaleshwari River water quality. The status of physical characteristics of Dhaleshwari River is presented in **Table 3.5.**

Table 3.5: Physical Characteristics of the Water Quality of the Dhaleshwari River

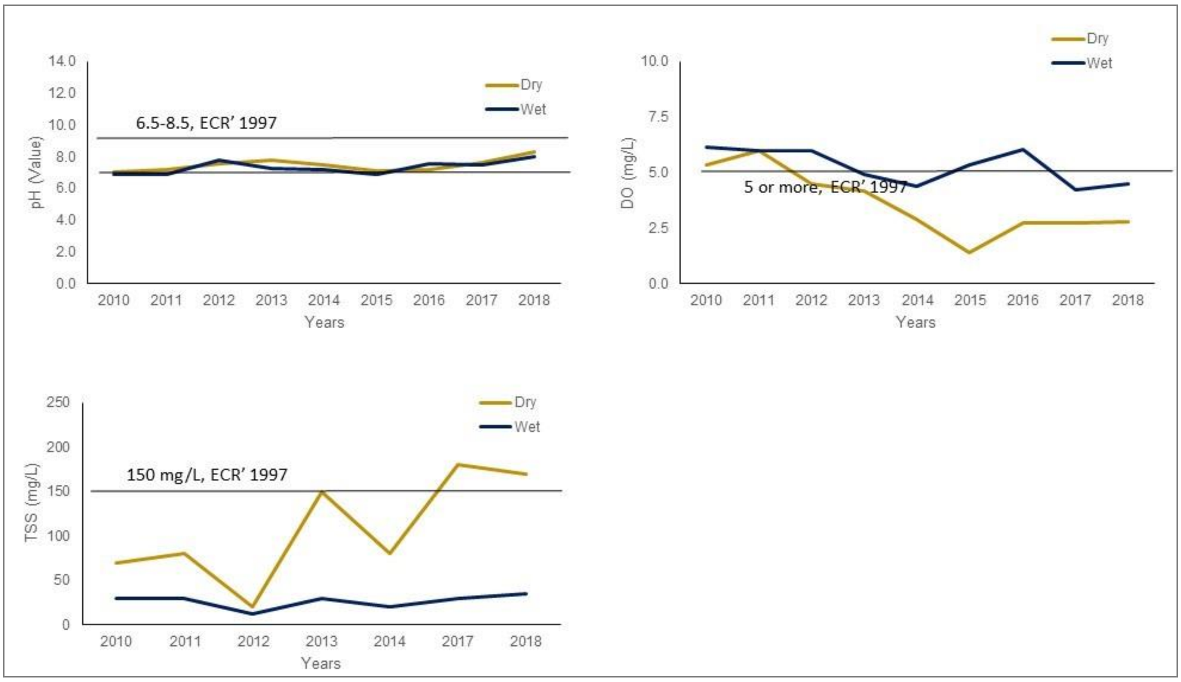
Site	Color	Odor	Temperature	DO	pH	Turbidity	TSS
Standards for Inland Surface Water Quality	15	Odorless	20-30	5 or more	6.5-8.5	15	150
Unit of measurement	Hazen	-	^{0}C	mg/L	Value	NTU	mg/L
Singair bridge	13	0	32	4.0	8.0	15	15
Milkyhata	15	0	33	6.0	8.1	10	14

Source: CEGIS Survey, June 2018

Tannery effluent changes water quality exclusively. Organic matters of rawhide and skin are the main reason of changing watercolor. Dhaleshwari River water color is also changing as the tannery effluent comes into the river though CETP and from domestic water transporting drainage system. This study found that water color of Dhaleshwari River did not show any spatial variation. At 200m upstream and downstream of Savar Tannery Area, the water color became the same and scored around 15 Hazen (**Table 3.5: Color**). On the other hand, there was no odour in the water of Dhaleshwari River as the water was found odourless (**Table 3.5: Odor**). The improvement of the quality of color and odor of Dhaleshwari River was because of the increase of freshwater availability during the survey time (Summer, 2018).

In Dhaleshwari River, temperature was recorded a little bit higher (32^{o}C and 33^{o}C respectively) at both the observed locations of Singair Bridge and Milkyhata than the standard inland surface water temperature (30^{o}C) (**Table 3.5: Temperature**). It seems like, at the downstream of the river, lots of biological activity and the presence of nutrients, which make the water temperature comparatively higher than the other portion of the river. In another study (Islam et al., 2012), it was found the same. Water temperature changes with the time of the year and also following the season. Water temperature of Dhaleshwari River was found lower in the post-monsoon than the monsoon and the pre-monsoon season. In most cases, it was just above 30ºC, which was within the standard limit for the uses of all purposes.

Adequate DO is necessary for survival of aquatic organism and decomposition of waste by microorganism (Rahman et al., 2012). The DO concentration ranged in between 4.0 mg/L and 6.0 mg/L. It was noticeable that DO level showed spatial variation in the river. The downstream (4.0 mg/L) of the river had low DO than the upstream (6.0 mg/L). High organic load from tannery industry mostly deposited at the downstream of the river as the river has very weak tidal influence. In 2012, Islam et al., found that the range was around 5.7 mg/L to 7.3 mg/L, which was suitable for the aquatic organisms to survive. However, this finding got an indication of low DO (4.0 mg/L) at the downstream of the river. A trend analysis was also done to see the DO concentrations of the Dhaleshwari River. Since 2012, DO level during dry season was not meeting ECR standard. On the other hand, DO level was more than the minimum requirement of 5.0 mg/L in the wet season until 2017. After that, DO level was found lower than the recommended value for Bangladesh inland water bodies (**Fgure 3.4: DO**).



Source:CEGIS Survey, June 2018

Department of Environment, 2010-2017

Figure 3.4: Trend of Physical (pH, DO and TSS) Characteristics of Water Quality of the Dhaleshwari River

Water quality of Dhaleshwari River was found without any acidic and base condition. Ph value ranged in between 8.0 to 8.1. Trend analysis also showed that since 2010, pH value alwayed complied with the ECR range of 6.5-8.5 (**Figure 3.4: pH**).

Water of Dhaleshwari River was not found turbid enough to harm any aquatic organisms. The overall concentration was even less equal or less than 15 NTU, which was very good in condition. This condition could be the effect of increasing of upstream flow during the last summer (2018). In addition, there were very low activities on the bank of the Dhaleshwari River, which could also be the reason of this low turbidity.

Amounts of suspended solids in Dhaleshwari River were quite low in concentration, which ranged 14-15 mg/L. This amount of solid is almost same as the recommended concentration for drinking water in Bangladesh (10 mg/L, ECR’ 1997). DoE found almost same concentration (around 20 mg/L) in 2012. Trend analysis indicated that TSS was more than 150 mg/L in the dry season for the last couple of years in Dhaleshwari.

Chemical Characteristics of Water Quality

Inorganic Indicators of Water Quality

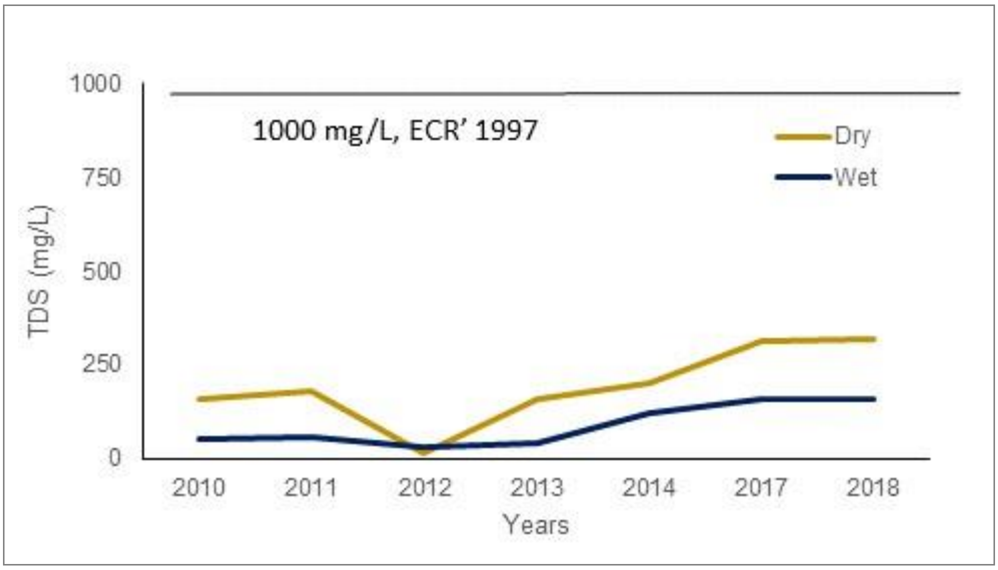
Amount of TDS in Dhaleshwari River was found comparatively higher than the Buriganga River. In addition, there was a spatial variation in TDS concentration in Dhalsehwari River. At the upstream of the river (200 meter upstream from CETP), TDS was around 160 mg/L while at the downstream it was around 200 mg/L (**Table 3.6: TDS**.) However, the concentration was not high enough considering the standard for waste from industrial units or project waste (2100 mg/L). Earlier studies also supported the same. DoE showed around 220 mg/L at 2017 while Sunny et al showed 240 mg/L at 2017. Since 2010, TDS concentration in Dhaleshwari River always met the ECR criteria (1000 mg/L) (**Figure 3.5**).

This study did not find any salinity issue in Dhaleshwari River especially in the summer season.

Table 3.6: TDS and Salinity status of the Water Quality of the Dhaleshwari River

Site	TDS	Salinity
Standards for Inland Surface Water Quality	1000 mg/L	0.0 ppt
Singair bridge	160	0.0
Milkyhata	200	0.0

Source: CEGIS Survey, June 2018



Source: CEGIS Survey, June 2018

Department of Environment, 2010-2017

Figure 3.5: Trend of TDS in Dhaleshwari River

Organic Indicators of Water Quality

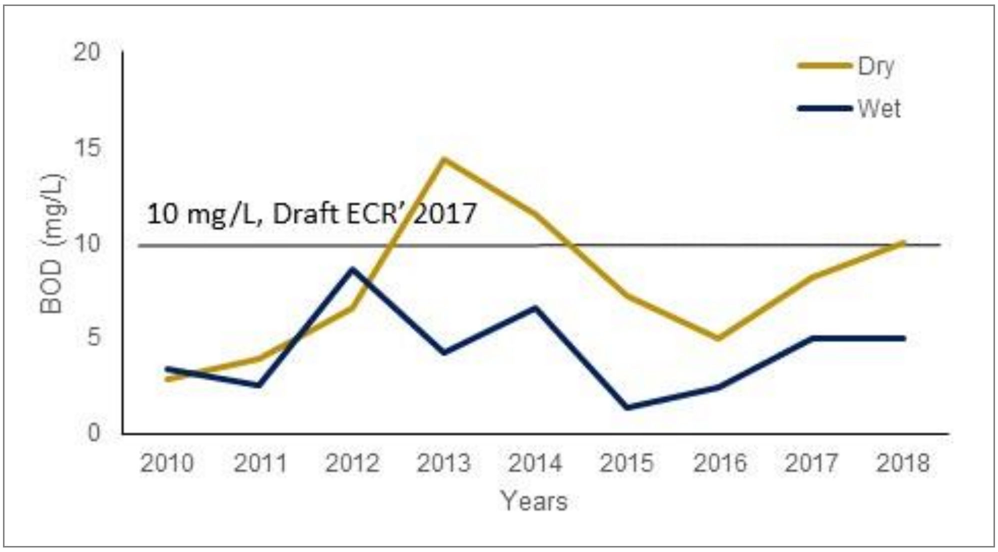
When BOD level is high, DO Level decreases, because the oxygen available in the water is being consumed by the bacteria (Sawyer et al., 2003). Low DO availability in the water, fish and other aquatic organisms may not survive. In the study, BOD values were found around 10.0 mg/L while it was very low (around 2 mg/L) at the same river in 2012 (Islam et al., 2012). According to the inland surface water quality (ECR' 1997), the BOD concentration should not be more than 10.0 mg/L. Since 2016, oxygen demand of Dhaleshwari River was increasing and still prevails the same condition (**Figure 3.6**).

The COD concentration of Dhaleshwari River was found around 50.0 mg/L. Observing the result of BOD, it became visible that there were other nutrients in the Dhaleshwari River. The BOD and COD statuses are presented in **Table 3.7.**

Table 3.7: Status of organic pollution of the Dhaleshwari River

Site	BOD	COD
Standards for Inland Surface Water Quality	10 mg/L	25 mg/L
Singair bridge	12	48
Milkyhata	10	52

Source: CEGIS Survey, June 2018



Source: CEGIS Survey, June 2018

Department of Environment, 2010-2017

Figure 3.6: Characteristics of BOD in Dhaleshwari River

Inorganic Minerals of Water Quality

Phosphate content in the river water ranged from 0.5 mg/L to 1.0 mg/L during monsoon period, and at the upstream of the river, it exceeded the standard of 0.5 mg/L (good aquatic ecosystem). Islam et al., 2012 revealed that the average phosphate concentration of Dhaleshwari River was lower than 0.5 mg/L in all three seasons. In contrary, nitrate concentrations (1.0-4.5 mg/L) complied completely with the Draft ECR 2017 (5.0 mg/L). It could be due to the wide agricultural practices along the riverbank. The excessive nitrogen can cause over-production of planktons and as they die and decompose, they use oxygen and therefore the DO content of water goes down and the oxygen dependent organisms finally struggle to survive (Momtaz et al., 2010). **Table 3.8** shows the phosphate and nitrate status of the Dhaleshwari River with its standard limit. Nitrate was found higher in the dry season while phosphate was higher than the standard limit over the whole years (**Figure 3.7**).

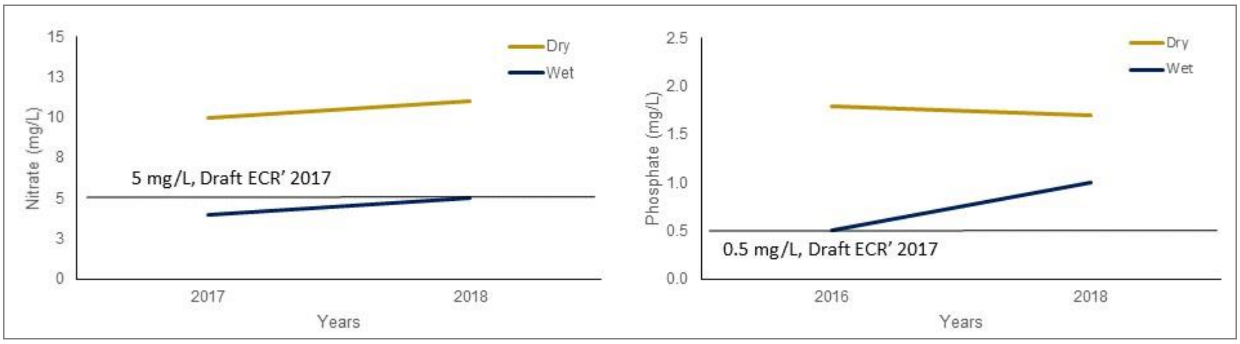
Ammonical-nitrogen concentration was found slightly lower as ECR' 1997 recommended level of NH_3-N for inland surface water is 1.5 mg/L. At Singair Bridge and Milkyhata the concentration was found 0.3 mg/L and 0.1 mg/L respectively.

Sulphate concentration was comparatively low in Dhaleshwari River. The range was 20-31 mg/L (**Table 3.8: Sulphate**). In addition, sulphate did not show any spatial variation in this river. The standard value for sulphate is 400 mg/L (ECR'1997).

Table 3.8: Status of Chemicals in the Dhaleshwari River

Sampling locations	PO_4^{3-}	SO_4^{2-}	NO_3^-	NH_4-N
Standard for Inland Surface Water Quality	0.5 mg/L	400 mg/L	5 mg/L	1.5 mg/L
Singair bridge	1.0	20	5.0	0.30
Milkyhata	0.5	31	1.3	0.10

Source: CEGIS Survey, June 2018



Source: CEGIS Survey, June 2018

Department of Environment, 2010-2017

Figure 3.7: Status of Phosphate and Nitrate Concentrations in Dhaleshwari River

Dissolved Metals Status in Dhaleshwari River

All the concentrations of Cr were found lower than the standard level (100 µg/L) given by Draft ECR (2017). Average chromium concentration in Dhaleshwari River was 2.0 µg/L in the current study. This very low amount of Cr was because of increase of freshwater availability in monsoon. Previously, Cr was found higher (440 mg/L) in concentration in this river (Ahmed et al., 2009).

Concentration of Al did not show any indication of its pollution in the water quality of Dhaleshwari River. The concentration ranged 210-270 µg/L. In any previous study, Al was not considered as an indicator of leather industry pollution. The variation in Al concentration is presented in **Table 3.9: Aluminum**.

Table 3.9: Status of Metals of the Dhaleshwari River

Sampling locations	Cr	Al	Pb	Zn
Standards for Inland Surface Water	100 µg/L	200 µg/L	100 µg/L	5000 µg/L
Singair bridge	2	208	1	80
Milkyhata	2	270	1	80

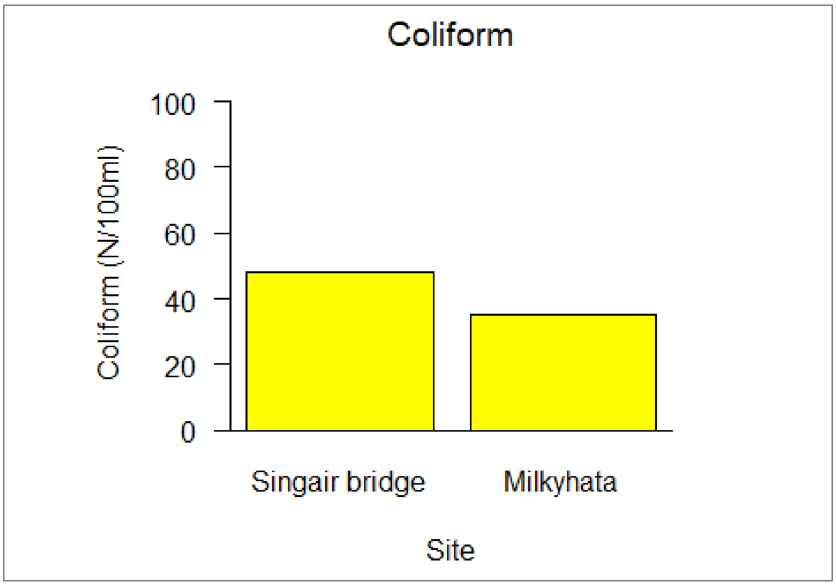
Source: CEGIS Survey, June 2018

In the present study, in all the observed locations, Pb concentration was found around 1 µg/L, which was very much lower than standard limit of drinking water quality (100 µg/L, Draft ECR' 2017). This low concentration of Pb in Dhaleshwari River indicated that this metal did not pollute that river enough. However, one of the earlier studies found around 50 µg/L of average Pb concentration in Dhaleshwari River (Ahmed et al., 2009). The concentration varies following dry and wet season in a year.

The concentration of Zn did not show any spatial variations in Dhaleshwari River. During the study, in all the observed locations, around 80 µg/L of Zn was found. Status of Pb and Zn concentrations of Dhaleshwari River are presented in **Table 3.9** also**.**

Microbiological Characteristics of Water Quality

Fecal coliform status of Dhaleshwari River is presented in **Figure 3.8.**



Source: CEGIS Survey, June 2018

Figure 3.8: Status of Fecal Coliforms in Dhaleshwari River

Water Quality Index (WQI) of Dhaleshwari River

The NSFWQI was developed for Dhaleshwari River based on primary information collected in the last Summer (June 2018). The detail process of the index analysis is presented in **Table 3.10**.

Table 3.10: Water Quality Index Calculation

Parameters	Tested Results	Water Quality Factor	Weighting Value	Total
Dissolved Oxygen Sat (%)	75	81	0.17	14
Fecal coliform (colony/100ml)	45	54	0.16	9
pH	4	9	0.11	1
BOD (mg/L)	12	28	0.11	3
Temperature change (ºC)	2	85	0.10	9
Total phosphate (mg/L)	1.06	39	0.10	4
Nitrate (mg/L)	4.5	68	0.10	7
Turbidity (mg/L)	15	67	0.08	5
Total solids (mg/L)	15	83	0.07	6
Overall Water Quality Index				58

The overall water quality index became 58, which indicated **Medium** (**Table 3.11**) quality of water of Dhaleshwari River.

Table 3.11: Classes of Water in Respect to Water Quality Index (WQI)

WQI	Dhaleshwari River	Water Class
0-25		Very bad
25-50		Bad
50-70	**58**	**Medium**
70-90		Good
90-100		Excellent

3.2.4 Odor of Savar Tannery Estate

Odour can be defined as the “perception of smell” or in scientific terms as “a sensation resulting from the reception of stimulus by the olfactory sensory system” (CPCB, 2008). Whether pleasant or unpleasant, Odor is induced by inhaling air-borne volatile organics or inorganic.

Unlike conventional air pollutants, Odor has distinctly different characteristics, which, to an extent, can be comparable with noise pollution. Similar to noise, nuisance is the primary effect of Odor on people. Some such characteristics are:

- Substances of similar or dissimilar chemical constitution may have similar Odor. Nature and strength of Odor may change on dilution.
- Odor of same strength blends to produce a combination in which one or both may be unrecognizable. Odor travels downwind.
- Constant intensity of Odor causes an individual to quickly loose awareness of the sensation and only noticed when it varies in intensity.
- Fatigue for one Odor may not affect the perception of dissimilar Odor but will interfere with the perception of similar Odor.
- An unfamiliar Odor is more likely to cause complaint than a familiar one.
- Likes and dislikes often depend on association of the scent with pleasant or unpleasant experiences.

Odors may result from raw hides and skins, putrefaction, and from substances including sulfides, ammonia and volatile organic components. Therefore, the production of raw hides and skins depends on animal population and slaughter rate and is related mainly to meat consumption. The whole process involves a sequence of complex chemical reactions and mechanical processes.

The process of making leather has always been associated with Odor and pollution, and as it seemed to be an inevitable consequence of the activity at the time, in some cultures people engaged in this industry rarely enjoyed a high social status. In other words, Odor is one of well-known words used for being descriptive the leather industry. Most Odor complaints against industry have centered on animal products processing activities.

Sources of Gases

Worldwide tanning industries are known as obnoxious for discharging high pollutants and degrade the ambient environment. In Bangladesh, tanning industry is one of the fast growing industries. The experts of World Bank (Nishat A. 2001) have determined the top-ten most environment polluting industries of this country. These are the tannery industry (21%), the pulp and paper industry (15%), pharmaceuticals industry (13%), fertilizer industry (12%), industrial chemicals (9%), textile industry (6%), food industry (6%), metal industry (5%), cement industry (4%), petroleum (3%), and others (6%).

There are about 220 leather industries in Bangladesh, 85% of them are located in the Western part of capital city Dhaka. Since the last decades of industrialization, Bangladesh is facing the environmental degradation of Buriganga River and other linked rivers due to receiving the discharged green solid and liquid wastes from the tanning industries.

The solid and liquid effluent comprise of decaying flesh, soluble proteins, fat, toxic chemicals, dissolved lime, suspended and dissolved solids, organic matters, dyestuffs and coloring pigments, heavy metals like chromium etc. from the tannery industries produce Odorous components. Gaseous air pollutants like hydrogen sulphide (H_2S), ammonia (NH_3), volatile organic compounds etc. are produced in different stages of leather processing which are directly merged to atmosphere (Hashem M. A. 2015).

After shifting of the tannery in Savar, around 200 tanneries are established for production. At present 180 tanneries are working. As mentioned earlier, the main constituents of Odorous gases in tannery are VOC’s (evolving during the action of enzymes causes decomposition and oxidation of the hides and skin), NH_3 and H_2S (evolving during the unhairing and deliming process of tanning in the processing of leather). Out of these the NH_3 and H_2S both are toxic gases which are responsible for the odor in the tannery. The NH_3 having strong pungent and H_2S having fouling smell both giving odor in and around the tannery environment. From Zahn et al. (2001), it is found that a typical tannery will have VOC—100 ppm, NH_3— 40 ppm and H_2S—30 ppm (Panda R.C. 2012). Based on these loads, this work designs scrubbing systems for abatement of these toxic gases.

Assessment of Odor

In recent times, Odor has been a key issue of community concern near to the tannery site. In addition, with the changing of tannery site, the complaints from nearby communities of Savar tannery estates are increasing. Given the established understanding of Odor matters around the site, a quantitative assessment of odor has not been undertaken within this study.

An Odor emission often consists of a complex mixture of many Odorous compounds. Usually, Odor sensory methods, are normally used to measure such Odor. A value in OU is a ratio. The OU strength is the number of times the mixture must be diluted (at standard temperature and pressure) to reach the detection limit. OU_E (European odor unit) – A value in OU_E is a mass measurement. One OU_E is the mass of pollutant that, when evaporated into $1m^3$ of odorless gas (at standard conditions) results in a mixture with concentration equal to the detection threshold for that pollutant. European odor units (OU_E) are more commonly used and olfactometry measurements give odor concentrations in OU_E $/m^3$. The Z_{50} value (threshold concentration) is expressed in odor units (OU_E m^{-3}).

There is no sensory method OU standard Odor yet fixed in ECR, 1997 and subsequent amendments. Neighboring country like India has done a lot of work on these issues in the guideline of “Guidelines on Odor Pollution & its Control” (CPCB, 2008). In ECR 1997, the major chemical constituent of Odor are identified and fixed their limit at Schedule-8. **Table 3.12** shows the limit of two important chemical components (Ammonia and Hydrogen Sulfide) release from tannery industries.

Table 3.12: Standard for Odor of ECR, 1997, SCHEDULE – 8

Parameter	Chemical	Standard Limit (ppm)
Ammonia	NH_3	1 – 5
Hydrogen Sulfide	H_2S	0.02 – 0.2

Note:Following regulatory limit shall be generally applicable to emission/exhaust outlet pipe of above 5 meter height

$Q = 0.108 \times He^2Cm$ (Where Q = Gas Emission rate Nm^3/hour)

He = Height of exhaust outlet pipe (m)

Cm = Above mentioned limit (ppm)

A number of studies following for known compounds, the Odor strength can be reliably estimated by measuring the concentration of the chemical, while, for mixtures of unknown substances, sensory method is preferred. In fact, USEPA has fixed the limit for Odor's chemical components differently at different states along with Odor Unit (OU) or Dilution Threshold (D/T). Therefore, this study has been conducted based on three major Odor generating chemical components e.g. VOCs, NH_3 and H_2S release form tannery industries.

Measurement of Odor

Of the five senses, the sense of smell is the most complex and unique in structure and organization. Sense of smell is accomplished with two main nerves. The olfactometry nerve (first cranial nerve) processes the perception of chemicals. The trigeminal nerve (fifth cranial nerve) processes the irritation or pungency (sensation) of chemicals. The entire trip, from nostril to signal in the brain, takes as little as 500 milliseconds.

During the field investigation, the stakeholders informed about notorious smell from the Savar Tannery Estate. Experience from Hazaribag Tanneries, the nearby communities of this tannery were making demand about controlling the Odor pollution. They were demanding to protect the areas from Odor pollution. The Odor measurement methods are mainly two types.

Instrumental methods have relied mainly on the application of Gas Chromatography (GC), including Gas Chromatography-Mass Spectrometry (GC-MS) is capable of the efficient separation required for analysis of complex mixtures of Odour.

The sensory methods are very much subjective. Each of the Odorant has a unique odor and Odor detection threshold which means that compounds, even if present at the same concentration, may have markedly different odor impacts.

Dispersion Modelling

AERMOD is steady-state plume model. The modeling system consists of one main program (AERMOD) and two pre-processors (AERMET and AERMAP). The major purpose of AERMET is to calculate boundary layer parameters for use by AERMOD. AERMAP is terrain pre-processor. In general, AERMOD models a plume as a combination of two limiting cases: a horizontal plume (terrain impacting) and a terrain following plume. Therefore, for all situations, the total concentration, at a receptor, is bounded by the concentration predictions from these states. In flat terrain the two states are equivalent. By incorporating the concept of the dividing stream height, in elevated terrain, AERMOD's total concentration is calculated as a weighted sum of the concentration associated with these two limiting cases or plume states (US EPA, 2004). However, the Odor dispersion modeling has been conducted with this AEMOD modeling system.

Modelling Domain

Modelling has been conducted for a receptor grid of 10x10 receptor points at 100 m resolution, which equates to a receptor grid of 1 x 1 km. The extent of this modelling domain encompasses the Savar Tannery Site and surrounding areas. Given the varying land uses surrounding the site, the receptors were spaced equally distance from each other. Since the pollutant contour line will be presented through isophelts, specific discrete receptors were not identified during the modeling process.

Dispersion Meteorology

A site-specific meteorological dataset was not collected for assessing the direction of wind. Meteorological data of Dhaka International Airport was processed for preparing the surface meteorological file preparation. Moreover, ready upper air data for a whole year of 2015 to 2016 was processed though AERMET software.

AERMET processes three types of data: 1) hourly surface observations that are typically, but not exclusively, collected at airports 2) twice-daily upper air soundings collected by the National Weather Station; and 3) data collected from an on-site or site-specific measurement program or prognostic meteorological data processed through a processor such as the Mesoscale Model Interface (MM5). However, the regional meteorological conditions were assessed after analysis of meteorological processed AERMAT data of one year through WORPLOT.

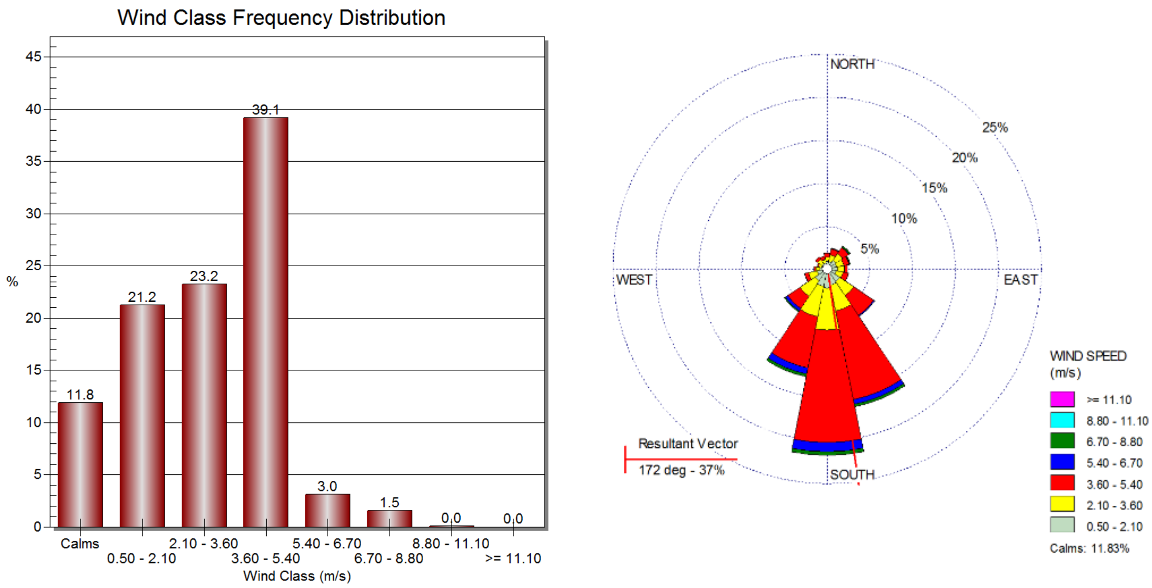


Figure 3.9: Wind Histogram and WindRose diagram at Savar Tannery Estate

Figure 3.9, Shows a wind rose at the Site for the year 2016. Windrose diagram shows around 12% of the total wind recorded clam. Wind moves toward Northward maximum period of a year.

Elevation Data as Model Input

AERMAP was used as a pre-processor in order to load the elevation data sets and then AERMOD analyzed the data. AERMAP required the use of gridded data to calculate terrain height scale for the receptor locations. The terrain data required by AERMAP was obtained from SRTM and land cover data was obtained from USGS, AERMOD simulated a horizontal plume under stable conditions and also an elevation-following plume in order to account for varying elevation in the area.

Emission of Odorants

Emissions from the tanneries were represented as volume sources. Volume sources constitute a generic method of representing fugitive emissions, such as those that are released into an aerodynamic wake, such as fugitive emissions from houses.

Within the model, volume sources were defined by location (i.e. easting, northing and height), and the amount of initial horizontal and vertical dispersion, as defined by two separate parameters, σy and σz.

Emission rates were modelled based on typical published literature of reputed journals or report. In order to generate hourly emission rates, total emission quantities were divided by 2x8760 (the number of hours in a year), and treated as a constant emission rate within the model Noting this, the emissions reflect average emissions and are considered generally representative of net emissions across the Site at a given time and long-term average emissions.

These emissions do not reflect short-term localized emission peaks that may arise from a specific tannery, CETP or land fill areas. In this sense, long-term average predictions are considered more robust in the estimation of pollutant levels near the Savar Tannery Estate.

Table 3.13: Rate of emission of the Odorant from tannery industry

Locations	Unit	Sources	VOC	NH_3	H_2S	Sources
Tanneries	g/s	Volume	0.1442	0.01258	0.0189	(Panda R.C. 2012)
CETP	g/s	Volume	-	0.00007	0.0958	(Panda R.C. 2012)
Solid Waste Landfills	g/s	Volume	0.0001	0.09350	0.0121	(Ying D. 2012)

Dispersion Modelling Results

This section provides the results of the dispersion modelling undertaken for the Project. Results have been presented both in tabulated form, as well as contour isopleths. The pollution criteria are incremental, meaning that they apply to the incremental impact from emissions from the pollutant source alone. However, the maximum concentration of each of the Odorant pollutants is predicted through AERMOD modeling process (**Table 3.14**).

Table 3.14: Maximum concentration of the Odorant pollutants disperse from Savar Tannery Estate

Odourant Chemicals	Duration	Peak Concentration (μg/m^3)	Coordinate (Xm)	Coordinate (Ym)
VOC	1-HR	134.6	218888.80	2632022.25
NH3	1-HR	186.4	218688.80	2631922.25
H2S	1-HR	82.4	218788.80	2632022.25

Dispersion of VOCs

Volatile Organic Compounds are emitted in finishing operation including formaldehyde, benzine acetone, butyl acetate, isopropyl alcohol etc. In tanneries operators frequently handle organic solvents with bare hand and without nose mask; they are suffering in various difficulties like abdominal pain, diarrhea, convulsion and respiratory problem. Although most of the developed countries have reduced the use of formaldehyde (H-CHO) as well set a permissible level in leather. Tanneries of Bangladesh also use formaldehyde and other organic solvents. The maximum dispersion area of VOCs concentration has been shown in **Figure 3.10**.

Figure 3.10: Maximum Concentration of VOC after Dispersion from Savar Tannery Estate

The VOCs are the atmospheric air pollutants. They are involved in photochemical oxidation by ozone as well as UV radiation. VOC emitted from the tanneries, has short-lived and typical life-time of a few hours in day time. The primary reaction of emitted formaldehyde in the air is direct photolysis and photo chemically produced hydroxyl radicals. In the urban atmosphere, VOC is an important precursor in smog formation where it reacts with oxides of nitrogen (NOx) and other compounds like Peroxy Acetyl Nitrate (PAN) and smog decreases the visibility.

Dispersion of H_2S

In tannery, normally unhairing and liming takes about 18–20 hours. During long time chemical reaction as well as mechanical agitation produces H_2S gas. The H_2S gas comes out from the hollow axle of drum/from open paddle which is directly mixed with air inside the tanning industry. It is a colorless gas and is slightly heavier than air. It has a strong Odor of rotten eggs. In tannery, operators are used to work without nose mask and frequently inhale gaseous H_2S and are suffering from difficulties. High concentration of H_2S (> 900ppm) for one-minute causes instant coma and death. The maximum dispersion area of H_2S concentration has been shown in **Figure 3.11.**

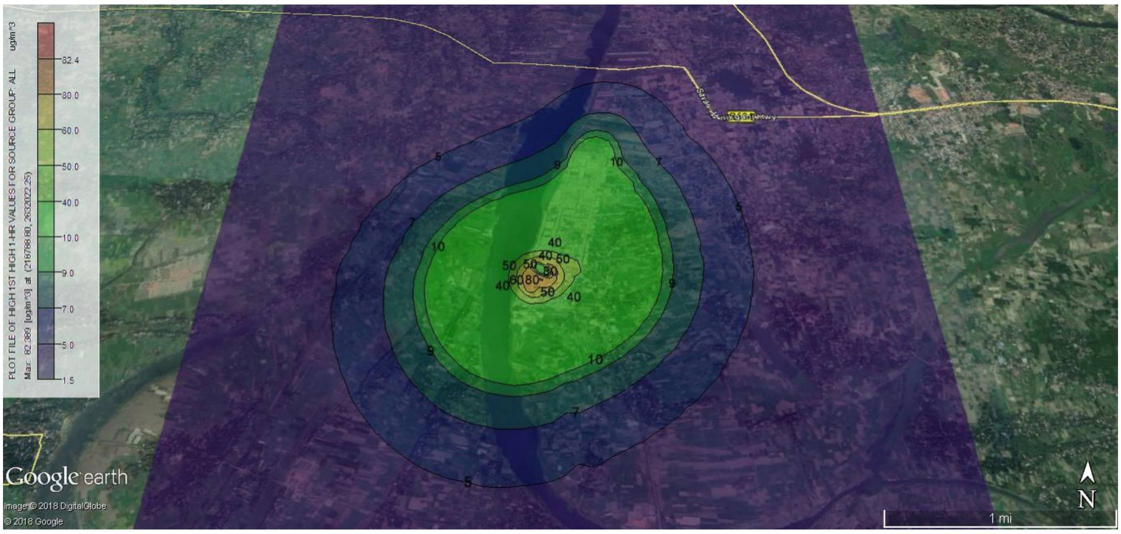


Figure 3.11: Maximum Concentration of H_2S after Dispersion from Savar Tannery Estate

H_2S is not only produced in liming but also produced when spent lime liquor is mixed with the acidic ranges spent tanning liquor like spent chrome tanning or spent pickle liquor. It is the conventional practice to discharge spent lime and chrome tanning liquor simultaneously at the same stream continuously H_2S gas is produced.

People in the tannery areas inhale the poisonous H_2S gas. The fluxes of H_2S led to toxic levels of H_2S at atmosphere by the atmospheric photochemical reaction. Besides, ozone shield destroys and increase the greenhouse methane gas.

Dispersion of NH_3

Ammonia is a highly hydrophilic base and it has irritating properties. It effects on human being due to its alkaline corrosiveness; it's gaseous or liquid form can irritate the eyes, respiratory tract and skin. Ammonia and its hydroxide are corrosive, can rapidly penetrate to eye and may cause permanent injury.

In tanneries, operators frequently handle the delimed pelt or leather and waste liquor with bare hands and foot as well as without nose mask. Besides, persons who are engaged in other works are exposed to inhale gaseous form of ammonia from inside the tannery. As a result, person who are directly or indirectly involved in the tanneries are getting contact with ammonia or its hydroxide are suffering from many difficulties. The maximum dispersion area of NH_3 concentration has been shown in **Figure 3.12.**

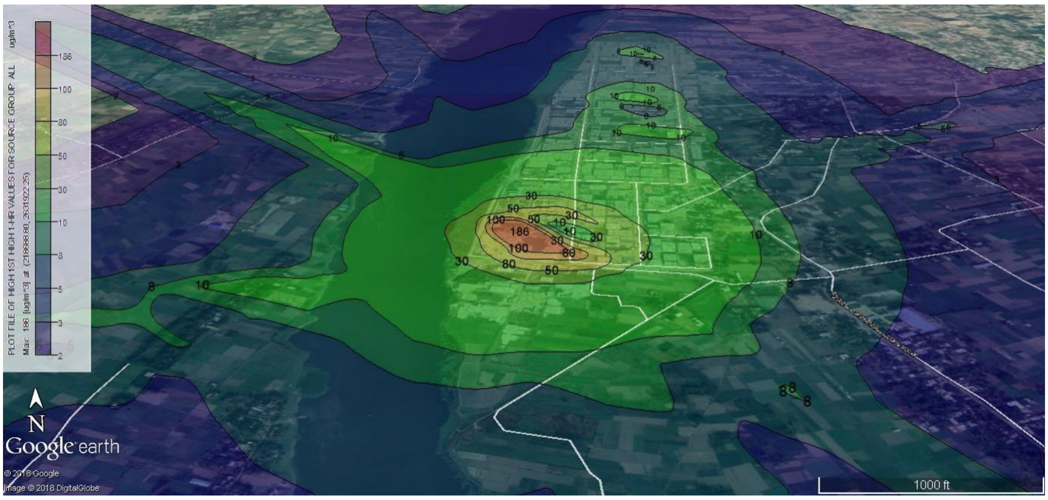


Figure 3.12: Maximum Concentration of NH_3 after Dispersion from Savar Tannery Estate

Ammonia is lighter than air, as a result after emitting from any source, it directly merged into atmosphere. It has a short atmospheric lifetime of about 24 hrs. Once ammonia is emitted to atmosphere, it could undergo conversion to NH_4^+ aerosol due to its highly reactive nature and quickly deposited near to the sources of emission. The conversion of ammonia (NH_3) to ammonium ion (NH_4^+) in aerosol is dependent on the concentration of acids in atmosphere. Formed ammonium salts at atmosphere are the main components of smog aerosols; it effects on cloudiness of the atmosphere as well as earth radiation budget.

3.2.5 Land Resources

The study area is entirely fallen under Young Brahmaputra and Jamuna Tract (AEZ-8), where Medium high land dominants (71% of total area) in the land type followed by medium low land (25% of total area). Loam is the major soil texture of the study area soil which covers almost (95% of total area), the remaining area's soil texture is clay loam.

Around 7.2 kilometer river length was considered as study area in Hemayetpur Tannery Industry where the width was similar like Hazaribagh Tannery Estate. Agricultural practice was the major land use (60.7% of total area) of that area, which was found on both bank of the river. Settlement covers next in the land use (26.8% of total area) where urbanization was entirely found on the left bank of the river. Besides, some brick field and orchard were also found in the study area. Detailed land use of Hemayetpur Tannery is presented in **Table 3.15** and **Figure 3.13.**

Table 3.15: Land Use of Hemayetpur/Savar Tannery Estate

Land Use	Hemayetpur Tannery Area (ha)		Total area (ha)	% of Total Area
	Left Bank	Right Bank		
Tannery area	72	0	72	2.8
Agriculture (NCA)	499	1,077	1,576	60.7
Water Bodies	28	181	209	8.1
Settlement	365	332	697	26.8
Brickfield	14	12	26	1.0
Orchard and other plants	0	16	16	0.6
Total Area (ha)	**977**	**1,619**	**2,595**	**100.0**

Source: CEGIS field information and Satellite image, 2015.

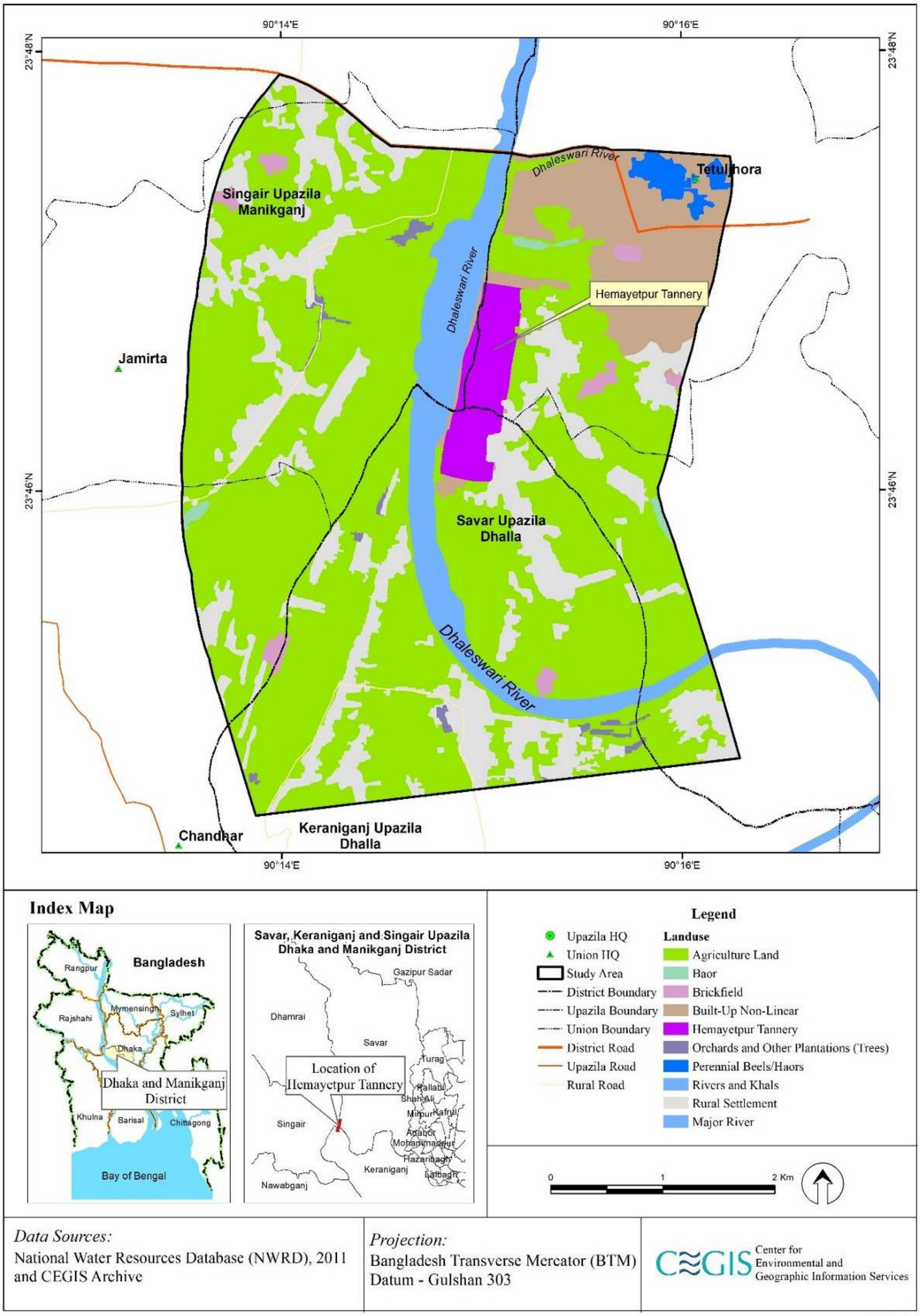


Figure 3.13: Land Use Map of Hemayetpur/Savar Tannery Estate

3.2.6 Soil Quality

Tannery industry started working in the Hemayetpur Area in 2015. As this estate installed a centralized ETP system and central collection pond, theoretically there was very limited chance of pollution spreading in the vicinity of the estate. Unfortunately, pollutants leaked out of the premises.

Study found Cr presence in all the soil samples. The maximum accumulation was found in main drainage soil while the minimum was in agricultural land at the opposite bank of the river. River levee soil and sediment was also found contaminated with Cr. The main drainage and river bed sample exceeded Maximum Allowable Concentration (MAC) (100 ppm) in soil (Kloke, 1980). Cr concentration in river levee soil sample was close to the MAC value, while presence of Cr was also found in the opposite bank agricultural soil. But in all cases, no Cr accumulation was found in the plant samples. Presence of Cr in soil, sediment and plant in the Hemayetpur is presented in **Table 3.16**.

Table 3.16: Presence of Chromium (Cr) in soil, sediment and plant in Hemayetpur Tannery Estate

SL	Sampling point	Site Characteristics	Soil (ppm)	Plant (ppm)
1	Main Drainage	This is the main disposal pond of solid and liquid tannery wastes. Soil and plant sample was collected to have chromium contamination in soil and plant.	17,225	N.D.
2	River bed/ Sediment	River bed sample was collected from the downstream of tannery estate to analyze chromium concentration in sediment subsequent floating plant (water hyacinths) was also collected to find the presence of chromium. .	131.5	N.D.
3	River levee	River levee soil and plant sample was collected form in between main channel and river bed sample collecting point. This area is extensively used for vegetable cultivation during Rabi season.	71.0	N.D.
4	Agricultural Field	This site is situated in the opposite bank of the Dhalweswari River which is double cropped land. Soil and plant sample was collected to have chromium contamination in soil and plant.	46.7	N.D.

Note: *N.D. - Not Detectable. Soil (MAC)-100 ppm. Plant (MAC) - 1-2 ppm*

*** Soil and plant samples were collected from 11th to 13th June, 2018 following standard sampling procedure (Soil survey manual, 2017). These samples were sent to SRDI, Dhaka laboratory for analysis. To determine total Cr, soil and plant analysis was done by digestion method followed by AAS analysis (Weil and Brady, 2016).*

3.3 Biological Environment

3.3.1 Plankton Status

In Dhaleshwari River, good production of Zooplanktons was observed. The composition followed only Metanauplius, Cyclops, Diaptomus and Diaphanosoma. In an average, 5,520 Zooplanktons were present in each cubic meter of water. The composition and concentration of Zooplankton in Dhaleshwari River are presented in **Table 3.17**.

Table 3.17: Composition of Zooplankton in Dhaleshwari River

River	Zooplankton	Concentration
Dhaleshwari	*Metanauplius*	14 per ml of water sample
	Cyclops	6 per ml of water sample
	Diaptomus	2 per ml of water sample
	Diaphanosoma	1 per ml of water sample
Total Concentration		**5,520 zooplankton/cubic meter**

Source: Field Survey at June 2018.

In the Dhaleshwari River, there was no benthic community during the field visit of June 2018. The riverbed materials were a mixture of sludge with low amount of soils.

3.3.2 Fisheries Resources

In case of the Dhaleshwari River, habitat suitability for fish has degraded due to poor condition of connectivity of water bodies, spatial and temporal water flow and velocity, substrates, water quality, aquatic vegetation, etc. Fish habitats are suitable from the month of July to September, and decline in the months of December to March. The river receives a large amount of industrial waste and agricultural pesticides. Although, the condition becomes worst from post-monsoon up to next monsoon season. However, the polluted bed material from Singair Bridge to lower stream in the vicinity of Tannary Industry results in decreasing the suitability for benthic fish community round the year. On the other hand, low water quality (having very low level of Dissolved Oxygen, described in water quality section) of the surface water results in unavailability of free floating and bentho-pelagic fish species during dry season.

Figure 3.14: Discharge of Industrial Effluent into the Dhaleshwari River

Suitability levels for pH and TDS were found satisfactory in two sampling locations of the Dhaleshwari River (**see Water Quality Section**). However, the suitabilities for water temperature and BOD were negatively scored in both the sampling sites. Although negative score for DO was found in case of Milkyhata, positive score was in case of Singair Bridge location. It thus clearly portrays that the habitat suitability of two sampling locations in the Dhaleshwari River is also very low and has remained more or less similar from 2010 to 2018 (**Figure 3.15**).

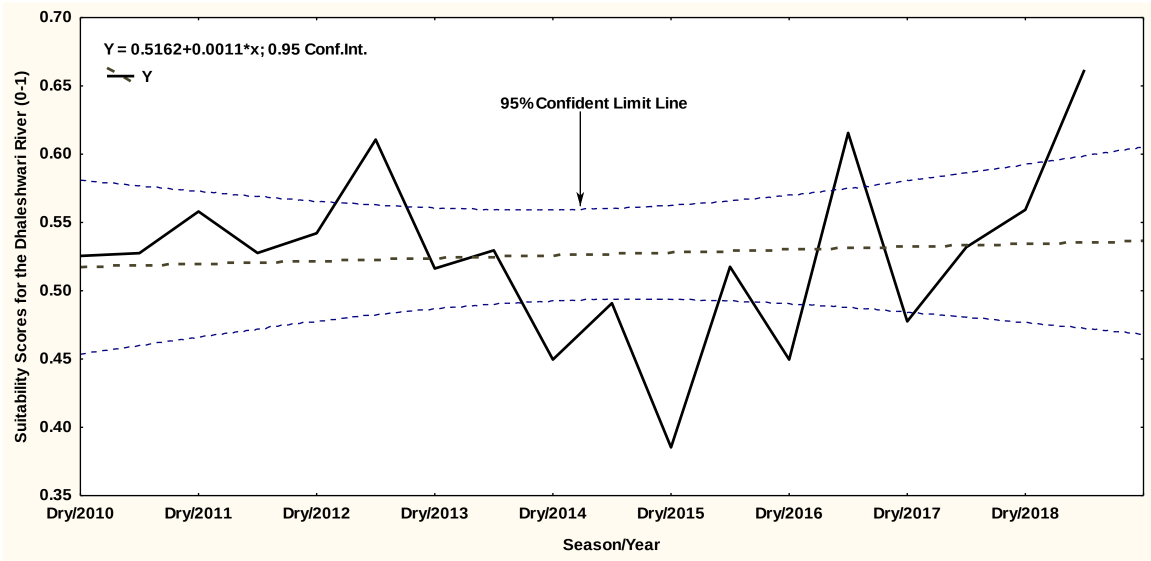


Figure 3.15: Exponential Smoothing Series with Linear Trend of Habitat Suitability Scores for the Dhaleshwari River

Source: CEGIS Field Survey, 2017 (Physical Environment Section)

A significant breach of protective bank was observed about 125m adjacent to the Solid Waste Disposal Station indicates that high Chromium (Cr) directly falls into the river system (**Figure 3.14**). Both air and water temperatures play important role in the physicochemical, metabolic and physiological behaviors of the aquatic system (Ali, et al., 2008). Different trace elements become hazard when it causes various lethal effects on physiological and cellular mechanism (**Table 3.18**).

Table 3.18: Hazards of Trace Elements or Ions

Name of Elements/Ion	Hazardous Effects on Fish
Arsenic (As)	Dermatitis, Muscular paralysis, Damage to liver and kidney, Loss of hair, Gangrene, Cancer
Cadmium (Cd)	Kidney damage, Cancer
Chromium (Cr)	Skin ulcer, Kidney inflammation, Cancer
Mercury (Hg)	Nerve damage, Kidney damage
Nitrate (NO_3^-)	Diseases of domestic animals (above 75 ppm), Harmful for baby (above 67 ppm)

Source: Environmental Chemistry, A. K. Be (2009)

Habitat Assessment

The estimated total fish habitat area was about 1,308 ha, where capture fishery isabout 99% and culture fishery contributes the rest in Hemayetpur Tannery City (HmTC). Fish habitat distribution in the study area is given in **Table 3.19.**

Table 3.19: Breakdown of fish habitats in HmTC

Sl. No	Habitat Category	Habitat Type	Area (ha)	
			Left Bank	Right Bank
1	Capture	River and Khal	0	178
2		Perennial Beel	22	0
3		Floodplain	420	679
		Sub-total =	***442***	***858***
4	Culture	Baor	6	3
		Sub-total =	***6***	***3***
		Grand Total Area =	**448**	**861**

Source: Land Use Satellite Image, 2015

Fish migration and movement

Local fishermen informed that fish migrates to the Dhaleshwari River from nearby habitats mostly during augmentation of water flow in the monsoon season. No pre-monsoon fish migration was informed or reported through the Dhaleshwari River. With the increase of river flow, larger fish species under following guilds, such as Major Carp, Large Catfish, etc. migrate through the river. A minimum number of Small Indigenous Species (SIS) of fishes uses the river for their localized movement.

Fish diversity

More or less similar number of fish species was found in the catches. The local fishers informed that fish species in the Dhaleshwari River and other habitats around the river similar to the species found in the Buriganga River. Fish diversity and their composition varied predominantly with changing habitat condition during wet and dry seasons. Field findings revealed that fishes were found more in the upstream, at and around the Singair Bridge location, than found in the downstream of the river, which was close to the Tannery Industry. It was informed that fish composition also varies with water quality (**Figure 3.16**). Fish species, such as *Heteropneustes fossilis, Mystus vittatus, Puntius ticto, Cirrhinus reba, Glossogobius giuris*, *Channa punctatus*, etc. are sensitive to heavy metal rich waters in the range of moderate to low level. On the other hand, fish species, such as *Labeo rohita, Trichogaster fasciata, Gudusia chapra, Mastacembelus pancalus, Gagata youssoufi,* etc. are highly sensitive to heavy metal rich waters, especially to Chromium. The following major fish species were identified in the Dhaleshwari River System (**Appendix-D**).

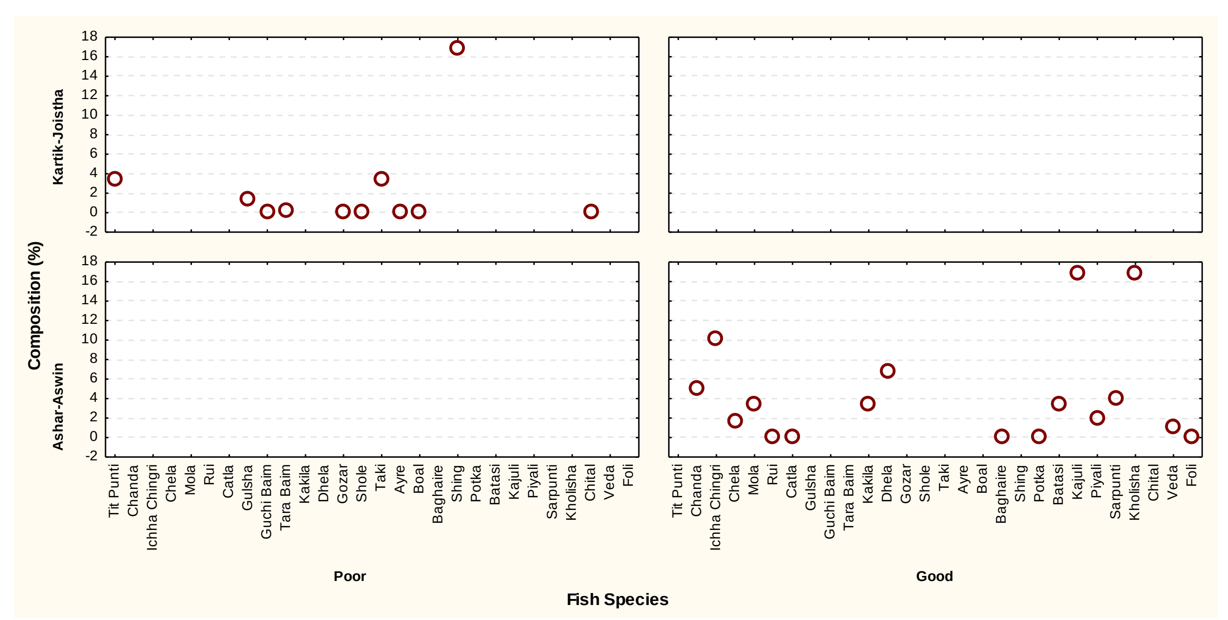


Figure 3.16: Fish species composition of the Dhaleshwari at Singair Bridge Point

Source: Field survey, CEGIS (2018)

Fish Production Assessment

The estimated total fish production was about 1,568 metric ton (MT), which was shared mostly by the capture fishery (about 99%) and the rest was shared by the culture fishery in HmTA. The breakdown of fish production of the study area is given in **Table 3.20.**

Table 3.20: Breakdown of fish production in HmTA

Sl. No.	Habitat Category	Habitat Type	Production (Ton)	
			Left Bank	Right Bank
1	Capture	River and Khal	0	21
2		Perennial Beel	48	0
3		Floodplain	568	919
		Sub-total =	***616***	***940***
4	Culture	Baor	8	4
		Sub-total =	***8***	***4***
		Grand Total =	**624**	**944**

Source: FRSS, 2016-17

3.3.3 Ecological resources

Status of vegetation

Floral density and diversity were higher at Harindhara Tannery Estate and its surroundings than Hazaribagh Site. The Tannery Estate had very low vegetation coverage as their continuing the civil construction activities which caused barrier to grow vegetation. Only the corridors and river levees were vegetated with wild herbs like *Richardia scabra*, Croton sp, Crozophora sp, Polygonum, *Imperata cylindrica*, *Physalis minima* etc. The Tannery Estate ground did not possess big trees.

Figure 3.17: Existing vegetation pattern of the Haringdhara Site

Except the tannery site, homestead vegetation was observed at opposite bank of Dhaleshwari River at Milkyhata Village. Most of the households were vegetated by local cultivated plants and wild shrubs and herbs occupy a small portion of the coverage. Presence of wetland trees like Pitali (*Trewia nudiflora*), Baroon (*Crataeva nurvala*), Hizol (*Pongamia pinnata*) were remarkably found near watersides as well as margins of settlements. According to the vegetation survey, several tree species were present and their composition was similar all over the study area. Common cultivated Plants were Raintree (*Samanea saman*), Chambol (*Albizia richardiana*), Mahogony (*Swietenia mahogany*), Silkoroi (*Albizia procera*), Jarul (*Lagerstromia speciosa*), Aam (*Mangifera indica*), Chatim (*Alstonsia scholaris*) etc and these species occupied top canopy. Shrubs and Herbs occupied lower canopies and species composition were similar to river levees and Tannery Estate Corridor.

Cropfield possessed numerous wild herbs which contributed to enrich floral diversity of this area. The Hazaribagh Site lacks crop field for urbanization but opposite bank of Harindhara Site had some cropfields. Different crops variety and cropping patterns are discussed in the agricultural section of this report. Except cultivated varieties, major weed species growing with the crop in this area were *Euphorbia hirta, Rorippa indica, Cynodon dactylon, Marsilea quadrifolia, Calotropis gigantea, Heliotropium indicum, Amaranthus spinosus, Centipeda orbicularis, Cyperus sp., Crotons bonplandianum, Chenopodium ambrosoides, Ethulia conyzoides etc.* Though crop field vegetation possesses least diversity of plants but this type of vegetation provides feeding habitats for wildlife.

Status of wildlife and their distributions

Most of the local faunal communities disappeared from the Harindhara Tannery Estate during the development of land. There were no wild mammals or reptiles commonly occurred within the Estate ground. But, some rodents like Shrew Mouse and Mongoose were occasionally sighted within the sub-urban areas just outside of the Tannery Estate boundary. According to local people, sometimes polluted water from tannery estate runoff at the surrounding areas and caused population deterioration of amphibians and reptiles within the surrounding areas. The impact was also severely followed at surrounding reaches of Dhaleshwari River. The situation improves during peak monsoon when concentration of pollutants is low and abundance of wild fauna increases at this time. Occurrence of Ganges dolphin was informed by the local people only during peak monsoonbut not stay for more than two months (July and August).

Birds occupied the higher number of species than other classes and were the major terrestrial faunal group. Species richness of terrestrial local avifauna was mainly concentrated in settlements and the natural vegetation along the Dhaleshwari River.

Some birds were observed at Harindhara Tannery Estate during field visit. A colony of 20-30 numbers of Cattle Egrets was roaming at Solid Waste Dumping Site (**Figure 3.18**). In addition to this, a number of Asian Pied Starling and some Black Drungo were observed within the Tannery Estate. As per local people, the land of the Tannery Estate was the feeding ground of local birds like Bee Eater, Spotted Dove, Bristled Grass Bird, Greater coukal, Rufous Treepie etc before land development. Common Lizards within the site was Common Skink (*Mabuya carinata*) and the Garden Lizard (*Calotes versicolor*). The population of Grey Monitor (*Varanus bengalensis*) was healthy but now disappeared from the location. The population of snakes was not very rich as the river water was polluted during last decade due to industrial pollutants, and they had little shelter in this landscape due to urbanization. **Figure 3.19** represents some of the wildlife within the Harindhara Tannery Estate and different distance of its surrounding areas.

Figure 3.18: Egrets observed at solid waste dumping site at Harindhara Tannery Estate

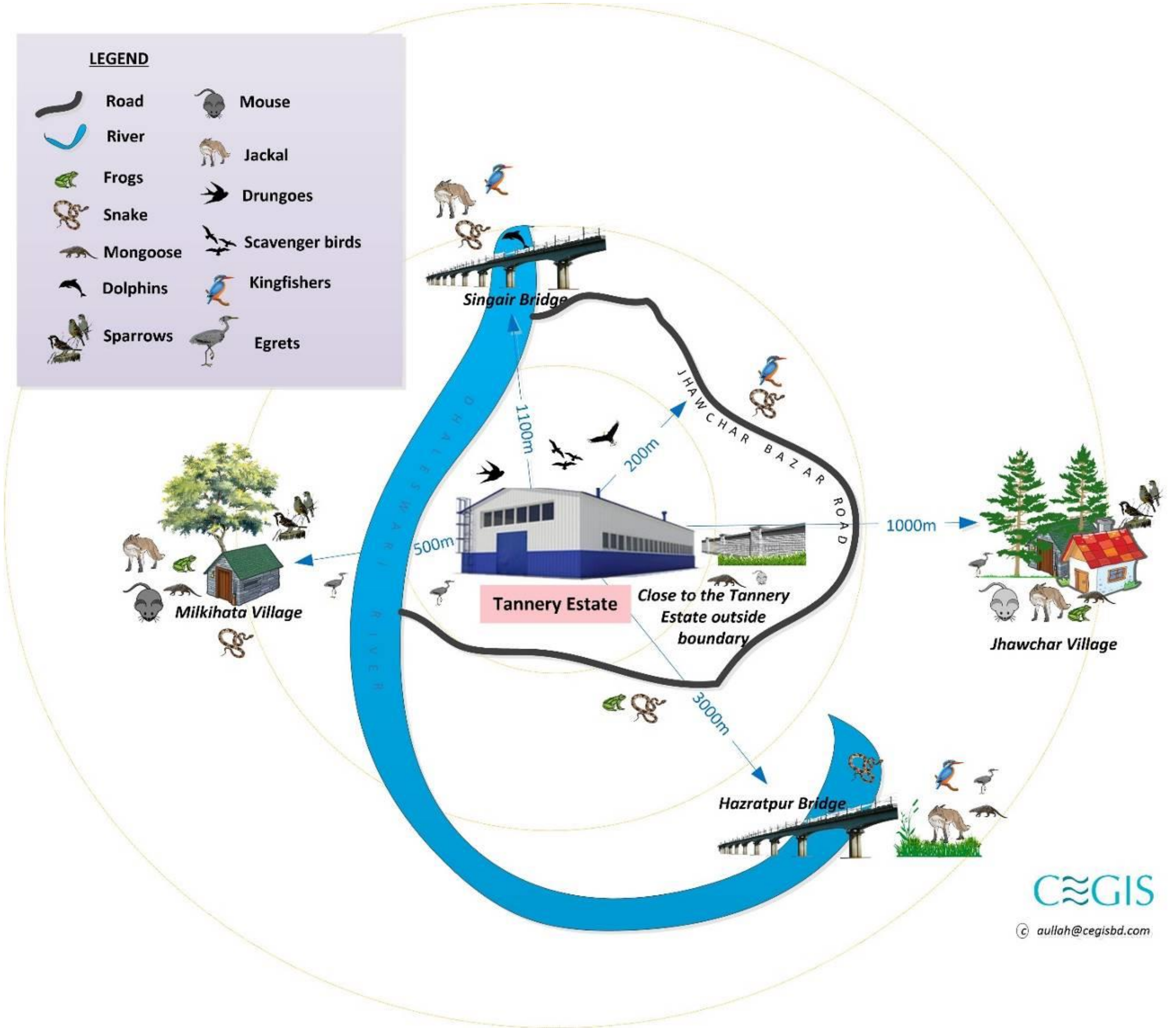


Figure 3.19: Wildlife distribution within the Harindhara Tannery Estate

Bioaccumulations of heavy metals in plant and animal body

Heavy metals are accumulated by a plant which can affect plant physiological activities as well as enter in food chain of an animal. Chromium is a common chemical effluent that is used in leather processing and contaminates water and soil, and transfer to plant and animal body through bio-accumulation. The tannery industries discharge polluted water to nearer river systems and this water is directly absorbed by the aquatic plants like Water Hyacinth (only dominant free-floating hydrophyte in Dhaleshwari and Buriganga). The polluted water from tannery fall in Dhaleshwari and Buriganga Rivers which intrudes into soil at nearer fields and the plants absorb polluted water through its root systems. Animals accumulate heavy metal through consuming plant body. Although Cr is an essential trace nutrient that is required in small amounts for carbohydrate metabolism but becomes toxic at higher concentrations (hexavalent ion Cr^{+6}, Solomon, 2006).

Table 3.21 shows the Chromium concentration in sample plant bodies which were collected from different locations of the study area.

Table 3.21: Chromium concentration of plant bodies along the study area

Species Name	Sample collection location	Cr concentration (mg kg^{-1})
Cyperus rotundus	Dumping site of Harindhara	Not Detected
Cynodon dactylon	Dumping site of Harindhara	Not Detected
Eichhornia crassipes	River water at downstream of Harindhara Tannery Estate	Not Detected
Polygonum sp.	River levee close to Harindhara Tannery Estate	Not Detected
Oryza sativa	Agricultural field at opposite bank of Harindhara Tannery Estate	Not Detected
Polygonum sp.	Dumping Canalbank of Hazaribagh Tannery Area	112.4
Eichhornia crassipes	Buriganga River Water at Showari Ghat	Not Detected

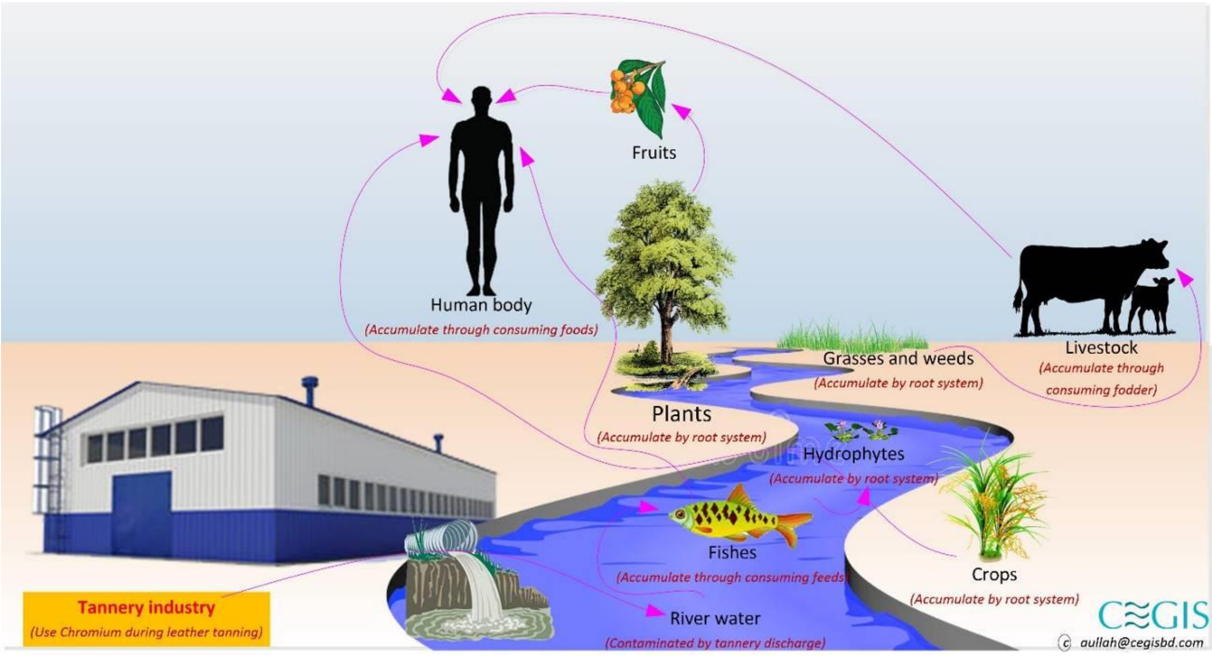


Figure 3.20: Bioaccumulation of heavy metals from tannery waste

3.3.4 Agricultural resources

Crop cultivation was found in both bank of the Dhaleshwari River. Approximately, 1,575 ha land was under cultivation of which 70% land was single cropped and 30% was double cropped. Summer vegetable and HYV Aman was found in Kharif I and Kharif II season respectively, while winter vegetable, Boro and Maize were grown in the Rabi season. Cropping intensity of this area was 130%. Farmers claimed that they used river water for irrigation purpose previously. But after the installation of the tannery estate, they don't use this water for irrigation anymore. Total cropped area was about 2,051 ha of which rice was grown in 199 ha and non-rice crop was grown in 1,852 ha land. Approximately, 18,749 metric ton crop was produced in this area, where rice production was 664 metric tons and non-rice production was 18,086 metric tons.

Farmers of Hemayetpur area mainly dependent on subsurface irrigation instead of surface irrigation. According to the farmers, river water quality deteriorated severely in last three to four years.

3.4 Socio-economic Condition

3.4.1 Socio-economic Resources

Socio-economic characteristics including demography, settlement and housing, public utilities, economy and employment status in the study area are presented in this section. These indicators help to conceptualize the socio-economic condition of the study area. Findings of this chapter are prepared and presented based on the secondary and primary information. The secondary information was collected from the Population and Housing Census 2011, Bangladesh Bureau of Statistics (BBS), 2012 and the primary information from the field survey.

Area and location

There were 3 upazilas under 2 districts; those were cutting through the study area. The following **Table 3.22** shows detail of the study area.

Table 3.22: Locations of the study area along with coverage of upazilas

District	Upazila	% of Upazila Coverage
Dhaka	Keraniganj	5.0
	Savar	2.4
Manikganj	Singair	4.5

Source: Spatial GIS analysis, CEGIS 2017

3.4.2 Population, demographic profile and ethnic composition

Population and household

The study area has a population of 96,603 living in 22,285 households. The average size of household was 4.2. Size of the household varied little among the study upazilas from 3.9 to 4.5 members per household. Composition of the household membership in terms of male and female were in favor of male, thus the overall sex ratio was found 111 that indicated there are average 111 male against per 100 female members (BBS, 2012).

Table 3.23: Demographic scenario of the study area

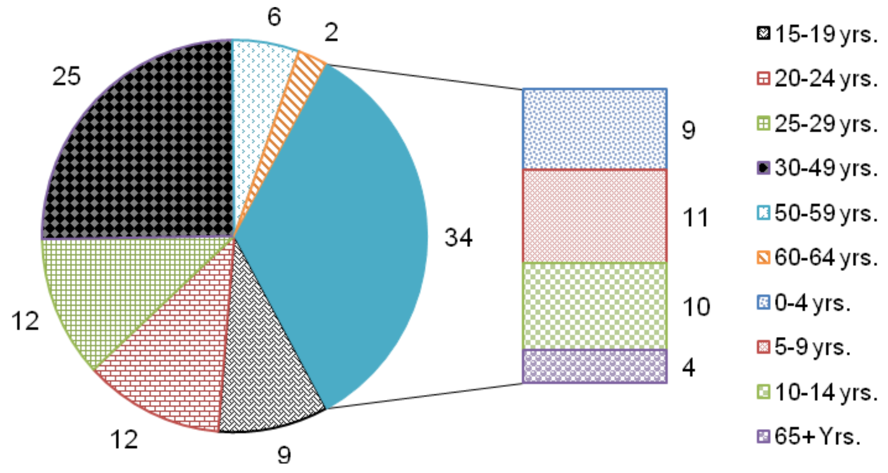
Upazila	Households	Population			Sex Ratio	HH size	Density (per sq-km)
		Both	Male	Female			
Keraniganj	9,658	43,108	22,891	20,218	113	4.5	5,226
Savar	9,472	36,556	19,487	17,070	114	3.9	5,431
Singair	3,155	13,939	6,829	7,110	96	4.4	1,450
Total/Average	**22,285**	**93,603**	**49,207**	**44,398**	**111**	**4.2**	**3,807**

Source: Population and Housing Census 2011, BBS, 2012 estimated by CEGIS, 2017

Age Structure

The study area seemed to be dominated by middle age (from 25 years old to 49 years old) population and about 37% of populations belong to this age group. The highest 25% of the total population were found to be belonging to the age group 30-49 years old and lowest 2%

were from the age group 60-64 years old. About 34% of total population was children and aged population, those are depending on potential workforce in the family (**Figure 3.21**).



Source: Population and Housing Census 2011, BBS, 2012

Figure 3.21: Percentage of population by age group

The ILO (International Labour Organization) categorized the age distribution of population for high growth. Population age of 15 to 64 years is considered as potential labor force whereas populations below 14 years and above 65 years old are considered as dependent. Thus, the study area consisted of about two-third potential labor forces as against one-third dependent population.

Ethnic composition

About 41 ethnic households reside in the study area at Keraniganj and Savar Upazila in Dhaka District. Among the ethnic groups, Monipuri, Monda and Sawtal were considered as a main group. In total 149 ethnic population resided in those 41 households (BBS, 2012). Detail of population of ethnic group is presented in **Table 3.24.**

Table 3.24: Demography of ethnic groups

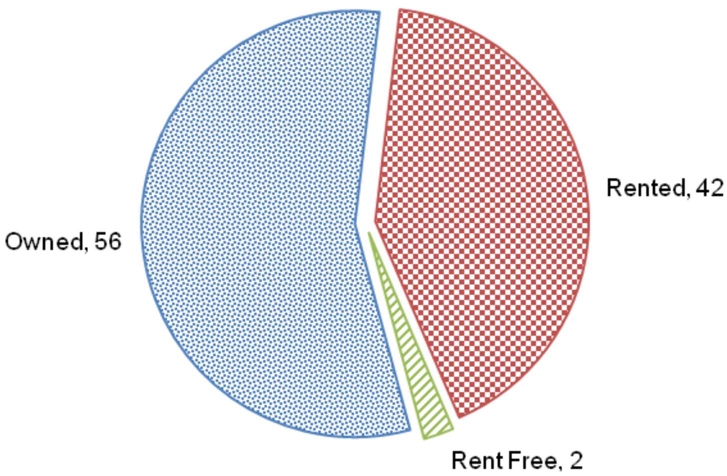
Upazila	Households	Population		
		Both	Male	Female
Keraniganj	11	51	26	25
Savar	30	98	52	46
Total/Average	**41**	**149**	**78**	**71**

Source: Population and Housing Census 2011, BBS, 2012 estimated 2018.

3.4.3 Settlement and Housing

Housing tenancy

In the study area, 56% of households resided in their own houses and 42% in rented houses (**Figure 3.22**). The percentage of rented households increased after implementing the project especially in Savar Upazila. According to BBS 2012, 71% household resided in rental basis in Savar Upazila.

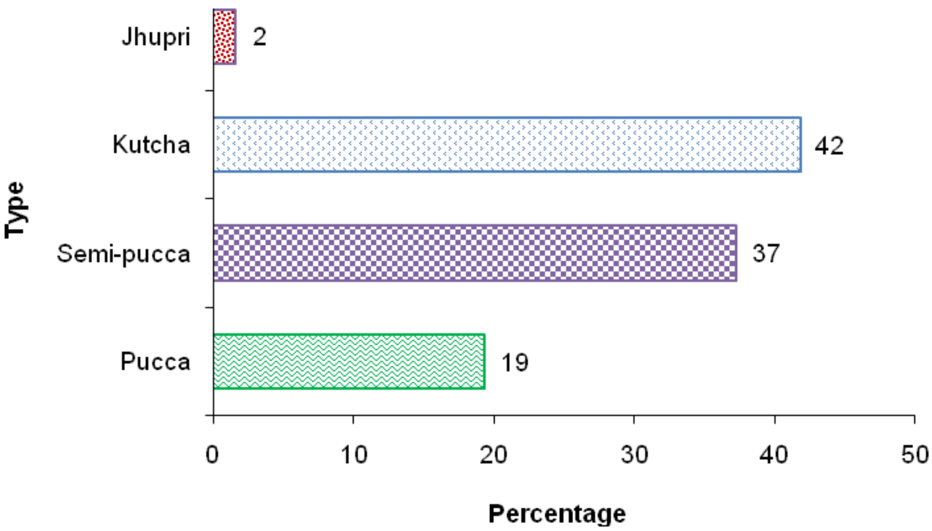


Source: Population and Housing Census 2011, BBS, 2012

Figure 3.22: Housing tenancy in the study area (%)

Housing condition

The housing conditions of the study area as represented in the BBS, 2012 showed that highest (42%) percentages of households resided in kutcha houses. About 19% of household resided in pucka houses (mostly in Keraniganj and Savar Upazila). After implementing the project, number of semi-pucca and pucca houses increased in project surrounding under Savar Upazila, where labors and employee of tanneries reside (**Figure 3.23**).



Source: Population and Housing Census 2011, BBS, 2012

Figure 3.23: Distribution of households by Type

Social Standards

There was a residential area namely 'Jamjam City' adjacent to the Tannery Industries where some housing has been developed. Owner of those houses stated that previously they got some well-off families as tenants, some of those already left and remaining are ready to leave the houses due to acute bad odour of the tannery industry and inconvenient environment of living as well. In this regard, their apartments/flats became vacant due to unavailability of sober tenants. Sometimes the owners rent it out to any kind of tenants to meet up their economic requirements which become burden to them in terms of maintenance aspect. At the same time, demand of commercial intervention increased in the study area whereas residential demand decreased so land price of residential plot was decreasing in the study area.

As the residence in the surrounding community is not developed to the expected level, development of civic facilities (i.e. school, college, hospital etc.) halted to some extent which also deteriorated the social standard in surrounding communities.

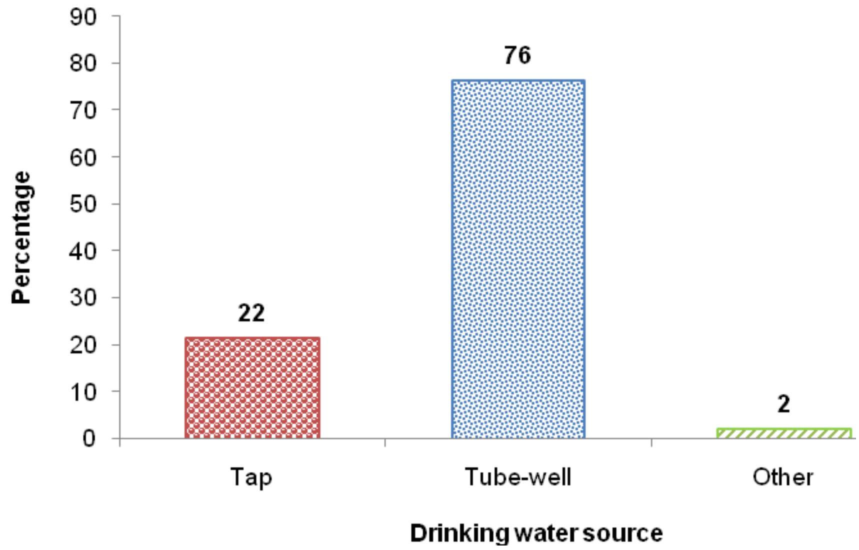
Traffic and Transport

Most important, Dhaka–Manikganj Road is located within the study area. There were also some important internal pucca road those were playing important role for internal communication. According to the local people, traffic volume was high in most of the roads while Dhaka–Manikganj Road was found to be stuck with a number of heavy and light vehicles in most of the times. All types of vehicle i.e Bus, Truck, Lorry, Car, CNG auto rickshaw, motorbikes were available in Dhaka- Manikganj Road while truck, car, CNG, rickshaw and auto-bikes were found to be moved to local roads.

3.4.4 Public utilities

Water Supply for Drinking and Domestic Utilize

About, 76% of households used tube well for meeting up the demand of water both for drinking and domestic purposes whereas only 22% population in urban area used supply water (BBS, 2012). Most of the tube wells were privately owned and it needed about BDT 10,000 to BDT 15,000 for installing the tube well. Before establishing the tannery industries, groundwater layer of the study area was about 80 to 100 feet which has now increased to over 160 feet in the close vicinity of tannery industry.



Source: Population and Housing Census 2011, BBS, 2012

Figure 3.24: Households by drinking water facilities

3.4.5 Economy and employment

Income and Expenditure

Household income and expenditure is an important economic indicator to measure the economic condition and sustainability of households. According to the information of local people, it is assumed that household income of the study area is higher compared to the national nominal income of households but not adequate in comparison with the expanse of living. In the study area, income of most of the households generally varied from BDT 20,001 to BDT 30,000/month. In terms of expenditure, highest percentages (40%) of household expended BDT 10,001 to BDT 20,000 per month. The scenario of income and expenditure are shown in **Table 3.25**.

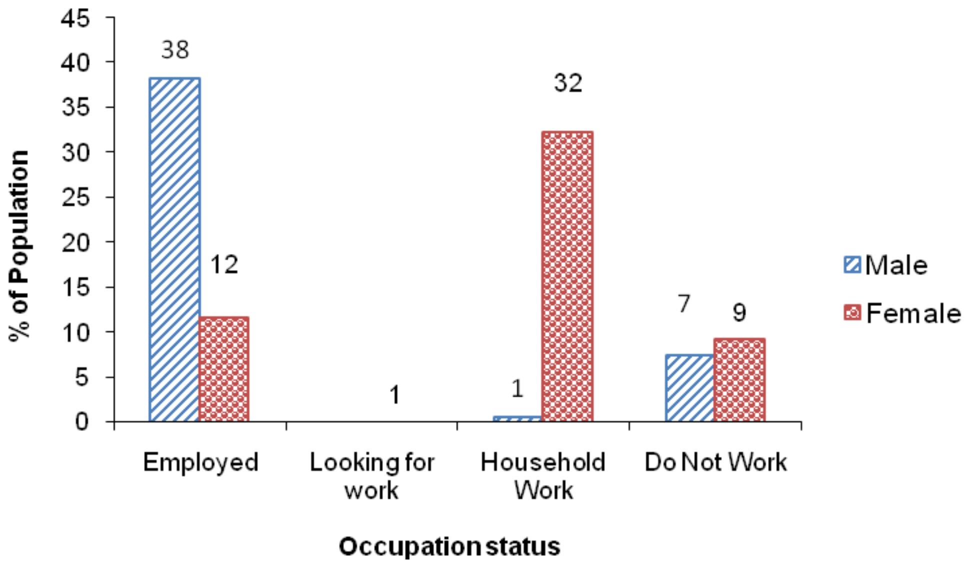
Table 3.25: Household monthly income and expenditure in the study area

Range of Amount in BDT	% of Household in income Level	% of Household in expenditure level
<10,000	2	15
10,001 - 20,000	35	40
20,001 - 30,000	45	30
>30,000	20	15

Source: RRA by CEGIS, 2018

Occupation and employment

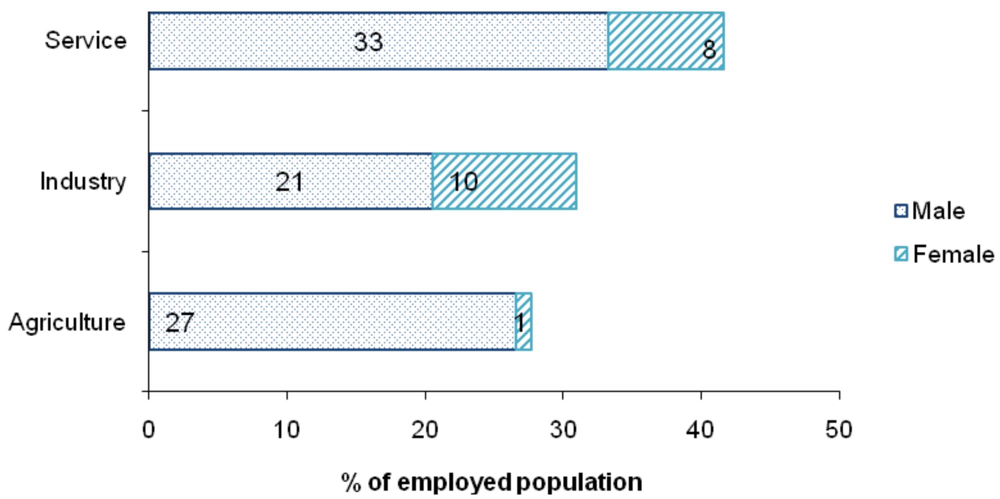
About 48% of the total population belongs to the workable groups in which about 48% were employed (38% male and 12% female) or involved in economic activities. The economic activities are divided in three major sectors i.e. service, industrial workers and agricultural occupant (**Figure 3.25**). Local people stated that female is mainly found to be engaged in household work, however a significant percentage of them worked in garments, brickfields and so on.



Source: Population and Housing Census 2011, BBS, 2012

Figure 3.25: Employment status among the Male-Female

Among the three major sectors of employment, it was found that 41% of total employed population was engaged in services followed by 31% working in industries and 28% in agricultural activities (**Figure 3.26**). During RRA almost similar result was depicted.



Source: Population and Housing Census 2011, BBS, 2012

Figure 3.26: Occupation status among the studied population

4. Existing Wastes Management Facility at STE

4.1 Introduction

This chapter assessed waste generation status and its management aspects in Savar Tannery Estate. In addition, a short picture of the effectiveness of the environmental management plans are drawn here to understand the pressures and issues on the existing natural resorces.

4.2 Waste Generation Status

The overall scenario of waste generation status of Savar Tannery Estate is depicted here quantitatively.

4.2.1 Liquid waste

Total liquid waste generation of Savar Tannery Estate varies 10,000-33,000 cubic metres per day. This variation depends on off peak and super peak of tannery industry. The off peak is the usual duration of the year except Eid-Ul-Fitre and Eid-Ul-Adha. These two festivals are the peak season of tannery industry and leather managers in Bangladesh. During the visit (June 2018) only 10,000-12,000 cubic metres of liquid wastes per day was producing as that period was under the off peak of tannery industry. Three different types of liquid wastes are generated in Savar Tannery Estate. Those are-

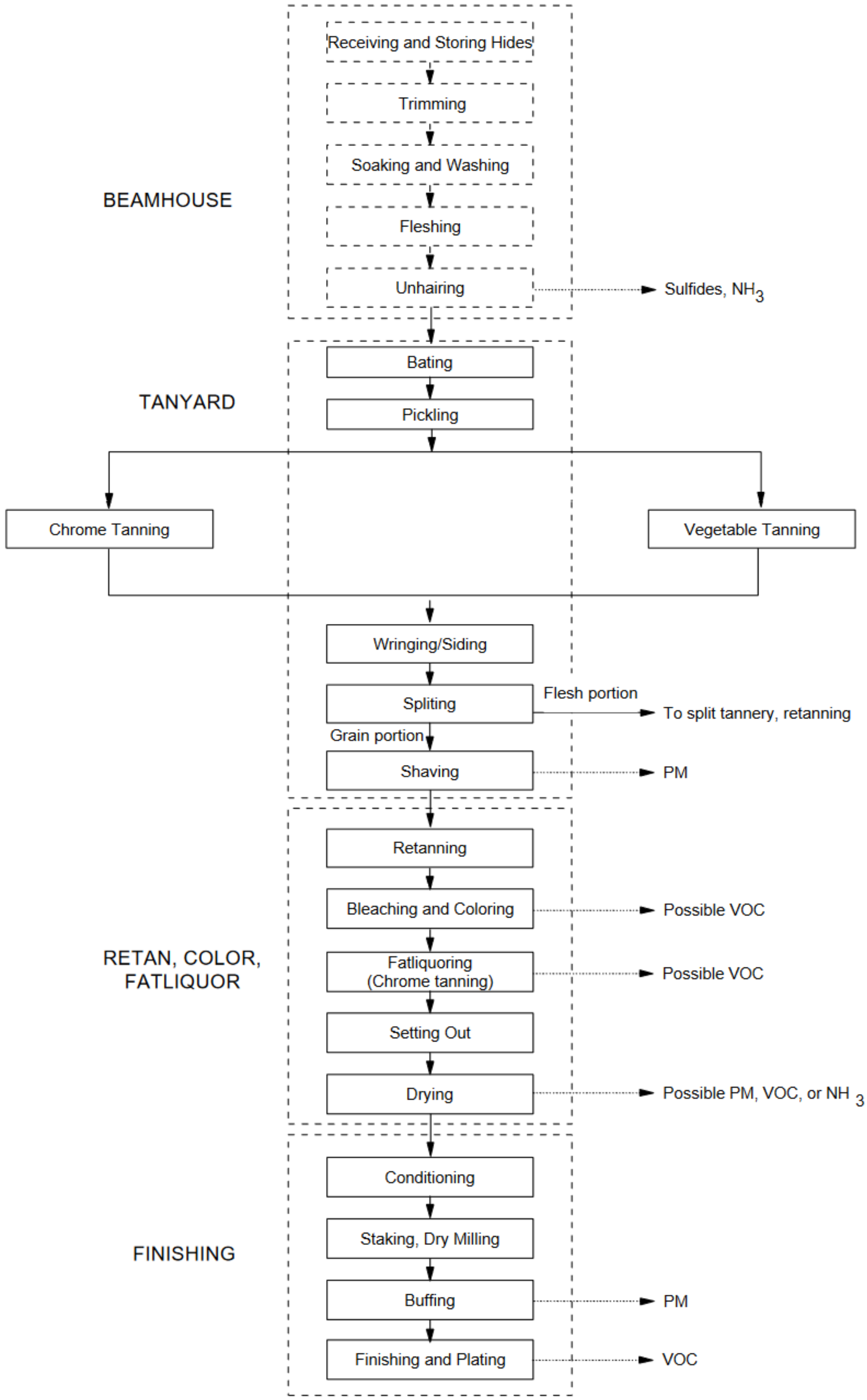
i. Cr contaminated liquid waste;

ii. Contaminated waters by chemicals except Cr; and

iii. Domestic water from offices and kitchens

4.2.2 Solid waste

During leather manufacturing process and subsequent effluent treatment process tannery industries generate a huge volume of solid wastes. Tanning refers to the process by which collagen fibers in a hide react with a chemical agent (tannin, alum or other chemicals). However, the term leather tanning also commonly refers to the entire leather-making process. The solid waste basically generates from the Beam-house (pre-tanning process) which includes soaking, liming/unhairing, fleshing, splitting, de-liming, bating, decreasing and pickling process. Tanning Process includes basically chrome tanning, Re-tanning Process includes Shaving, Neutralizing, Re-tanning, Fat liquoring, Dyeing, setting out, Drying and finishing process includes Conditioning, Staking, Milling, Spreading on toggle frame, Buffing, Impregnation, Coating, Ironing and Polishing. A general flow diagram of chrome tanning process to finish leather is presented in **Figure 4.1**.



Source: https://www3.epa.gov/ttnchie1/ap42/ch09/final/c9s15.pdf

Figure 4.1: General flow diagram for leather tanning and finishing process

Table 4.1: The proportion of the types of tannery solid wastes generated from processing of 1 ton of raw hides

SL	Nature of solid waste	Quantity (Kg/Ton)
1	Salt from handshaking	80
2	Salt from solar pans	220
3	Hair (pasting ovine)	100
4	Raw trimmings	40
5	Lime sludge (mostly bovine)	60
6	Fleshing	120
7	Wet Blue trimmings (grain splits)	30
8	Chrome Splitting (bovine)	65
9	Chrome Shaving (mostly bovine)	95
10	Buffing Dust (including shaving bovine after crust)	65
11	Dyed trimmings	35
12	Dry sludge from CETP	125
Total		**1035**

Source: Alamgir et al., 2017

However, per ton solid waste generation varies from 850 kg to 1035 kg. The volume of solid waste generation from raw hides and skins per day at Savar Tannery Estate is presented in **Table 4.2.**

Table 4.2: Solid waste generation scenario

SL	Seasons	Waste generation (Ton/day)	Cr contaminated waste (kg)/Ton
1	Off peak	25	2-6
2	Super peak	100	

Source: BSCIC, June 2018; Savar

Note: Off peak: *availability of raw hide and skin during normal time of the year.* ***Super peak:*** *During Eid Ul Fitre and Eid Ul Adha, especially the muslim festives when cow and other livestocks are slaughtered most.*

Therefore, it is estimated that, during off peak, the Cr contaminated soild waste generation varies from 50-150 kg/day while it reaches upto 200-600kg/day during super peak season. But, at Savar tannery estate there was no seperate system to handle Cr contaminated soild waste and other solid wastes.

4.3 Management Plans/Facility

The main wastes of leather industries are the chemical and soild wastes. More than 40 different chemicals are used to get finished leather products. Of them, only 20% of the chemicals are soaked by leathers and rest of the chemicals are washed as liquid wastes. In addition, 25-100 tons of solid wastes are generated each day during the operation period of tanneries. Therefore, considering the magnitude of tannery pollution, several management plans were adopted and are still being updated.

4.3.1 Common Effluent Treatment Plant (CETP)

A Common Effluent Treatment Plant (CETP), costing about US$ 1.3 million, has set up to reduce the amount of pollutants from the effluents to be disposed. Facilities such as water, gas, electric supply, and a solid waste management system had to be provided by the government free of cost under the project.

The maximum capacity of the plant is 25,000 cubic metres/day. However, the capacity of CETP for treating Cr is only 1000 cubic metres/day. The rest of the effluents are treated for other nutrient removals such as BOD, COD and nutrients.

Figure 4.2: Design View of Common Effluent Treatment Plant (CETP) and Dumping (Disposal) Yard

Effectiveness: The CETP has been installed at the Savar Tannery Estate with lots of difficulties and challanges. The most feared one was the faulty design, which means incapable of treating salinity from the effluents. The second one is overflow of the CETP. The total number of tanneries are 155. Less than half of the factories are operational in the tannery estate right now but are already producing more than half of the projected waste amount. For instance, 70 tanneries produced around 15,000 cubic metres of liquid effluents per day which will be more than 33,000 cubic metres when all the 155 tanneries will be started their factories in fullswing. But the capacity of the CETP is exactly 25,000 cubic metres per day. Unnecessary water consumption for leather processing by labors were also the reason for CETP overflow.

4.3.2 Solid Waste Disposal Yard

A solid waste disposal yard of around 5.5 acres are established just beside the CETP. The disposal yard proposed by Chineese company is displayed at the **Figure 4.2**: **Dumping site**.

Effectiveness: The solid waste dumping yard was supposed to be the covered one. However, in real picture, there was no intervention in favour of complete development and get ready for the dumping of tannery solid wastes. Moreover, the overflow from CETP flashes the soild wastes into the river Dhaleshwari sometimes. The bank of the disposal yard is not fully protective, therefore, effluents with high Cr concentrations falls in Dhaleshwari. The situation is even wosre in the rainy season. In a nutshell, this solid waste dumping yard is not effective enough to save the surrounding environment properly.

Figure 4.3: Solid waste disposal yard

4.3.3 5.0 MW Sludge Power Generation System (SPGS)

Occupying approximately over 50 thousand sq. ft of land, there was a provision of SPGS capable of generating power of 5MW/hour and will be constructed with CETP. It has the capacity of treating 80MT dry sludge. Preliminary assessment suggests that the capacity of the solid waste-dumping yard would be exhausted within 2 years after receiving solid waste/sludge from both the CETP and tannery industries. Accordingly, in July 2013 the 2nd Revised Development of Sludge Project Proposal (RDPP) approved the integration of SPGS with CETP. The main objective behind installation of SPGS is minimization, optimization and ease of handling of sludge and management of solid waste generated from adjacent tannery area. Power generation will be a useful by-product for this process. Activated with a mixer fuel capacity of 250 ton/day, coal design amount of 50.00 ton/day can generate 5.46 MW/hour electricity from 200 ton/day sludge (using design mixing ratio as 20.00% and 80.00%, supplied amount of steam 28.20 ton/hour).

Figure 4.4: Layout Plan of SPGS (replacing Dumping Yard) building integrally with CETP

Effectiveness: This study found that there was **no SPGS** at the Savar Tannery Estate. Therefore, all the generated soild wastes from tanneries and CETP are being dumped at the open disposal yard, which is situated next to the CETP. There were no systematic plans in dumping soild wastes and its management in that yard. Open motorized vehicles are used for transporting solid wastes from tanneries and are dumped directly. Rainwater mixes with the wastes and produces chronic odor, which disperse in the surrounding areas.

4.3.4 Systematic drainage system

A concreted drainage system has been developed to transport both tannery and domestic effluents. Among these, the liquid wastes from leather processing network are completely covered and connected to CETP. In the covered system, Chromium contaminated liquids and other liquid waste come to CETP separately for the treatment. On the other hand, domestic effluents (kitchen, bathing, washing non-hazardous materials) come to the Dhaleshwari River directly without having any treatment and the drainage system is open drainage network.

Effectiveness: The above stated drainage system has been developed completely and are in functional mode. However, there was some issues about overflowing of the drainage and Cr contaminated liquid wastes spread outs. Mostly, Cr contaminated water comes into roads and open space and are contacted with labours and the roadside vegetation. Therefore, there is a huge chance of bio-accumulation of Cr into surrounding vegetation and leachets into groundwater aquifers. Therefore, this issue may pose serious public and environmental health risks. In addition, the manholes are open, which let the contaminated effluents come into the surface ground during any overflow period.

4.3.5 Internal road network development

Savar Tannery Estate is a well designed and planned BSCIC for Leather industries. Total 195 industrial units are distributed within the 144 acres of land where the rest (56 acres) of the lands are distributed among CETP, Disposal yard, Administrative building, Drainage system, and Electricity sub-station etc. Therefore, well connected road network has been also established in this Tannery Estate. Well connected road network not only supports the waste management plan but also provides better services in transporting raw and processed leathers simultaneously.

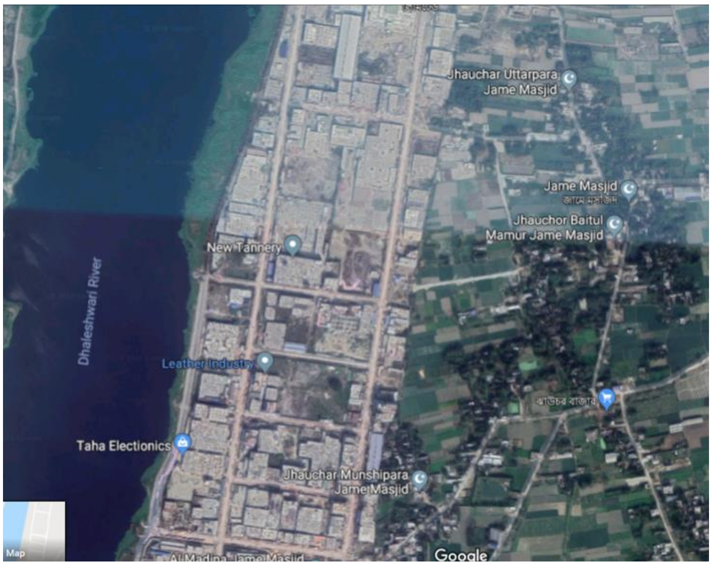


Figure 4.5: Internal road network system

Effectiveness: Inside the tannery estate, most of the roads are found in very bad conditions. Instead of paved road, there was only mud roads. In addition, the roads are damaged due to heavy truck and vehicles movement. In the rainy season, the situation even wose.

Figure 4.6: Real picture of internal roads of Savar Tannery Estate

4.4 Status of waste management facilities of STE

The waste management facilities and its present condition in terms of its performance and management gaps are assessed here and presented in Table 4.3.

Table 4.3: Status of the existing waste management facilities in Savar Tannery Estate

Environmental Management Aspects	Current Status of Management Facilities	Performance Status
Effluents treatment	Common Effluent Treatment Plant (CETP)	• Poor performance of the CETP as Color, TDS, DO, BOD and Cr concentrations do not meet the Standard for Effluent Discharge from Tannery Industries (SCHEDULE 10- Tannery: ECR 1997/Draft ECR 2017). • Performance of the CETP are not consistent as well.
Domestic water treatment	No facility existed	• Disposed into Dhaleshwari River directly without any treatment.
Solid waste management	Dumping Yard	• There is no infrastructural development to manage solid wastes as per the design. • Open solid waste disposal. • Solid mixed liquid with high Cr concentrations (10mg/L) are directly discharged into the Dhaleshwari River from the dumping yard.
Odor reduction	No facility existed	• At present, there is no odor management practices in the tanneries of Savar Estate.
Drainage system	Piped drainage system	• Piped drainage systems are constructed. • Insufficient capacities of the drainage system to carry all the liquid wastes are generated in the STE. • Overflow occurs during the peak season of the tannery activities.

Environmental Management Aspects	Current Status of Management Facilities	Performance Status
		• Pollutes the land surface by Cr and other chemicals.
Internal roads network	Kutcha roads system	• Internal roads network is not paved yet. • Water logged situation prevails during rainy season.
5.0 MW Sludge Power Generation System (SPGS)	No facility existed	• No such facility is existed in the tannery estate.
Occupational health and safety monitoring and training facility	No facility currently	• No such facility is existed in the tannery estate to monitor the health status of labors, workers and the surrounding communities.
Institutional Framework for CETP Management and Reporting	No facility currently	• At present, there is lack of cooperation among CETP Operator, BSCIC Savar, Savar Tannery Owners and DoE to Monitor, Manage and Reporting about the functionality of CETP properly.

5. Impact Prediction for Hemayetpur Tannery Estate

5.1 Impact on Water Quality

Tannery activities mostly affected aquatic ecosystem with its huge amounts of liquid and solid waste generation and its disposal into natural environment. The common practice of liquid waste management in Bangladesh is to dilute the pollutants into the inland water sources due to lack of technology and cost effective. Before release of liquid wastes, meeting the ECR' 1997 standard for Waste from Industrial Units or Projects Waste is mandatory. The current CETP of Savar tannery estate is dysfunctional with some challenges in performance and management aspects. The impact, therefore, were analyzed considering increase of pollution load from both CETP discharge and solid mixed liquid waste discharged into the Dhaleshwari.

5.1.1 Changes in physical quality of the water

Colored water of more than 200 Hazen was being discharged into Dhaleshwari River. The total effluent load is around 25,000 m^3/day (BSCIC, June 2018). This huge colored water is changing the watercolor of Dhaelshwari River gradually. In addition, nuisance smell (detais is in impact of Odor section) of water is another issue that is aggravated by the discharge of CETP as well. Continuous releasing of color water into the river will eventually turn the water colored (blackish/bluish) with chronic bad smell. Colored water hinders the light penetration into water column. The lower the light penetration, the lower the photosynthesis. In the water body, hence, DO concentration availability become low. Furthermore, low light also results in destruction of Phytoplankton. This phytoplankton is the primary producers of the aquatic ecosystem. Both the nutrients and the energy are being transferred into the food web through this phytoplankton. Phytoplankton is being consumed by the primary consumers Zooplankton and Zooplankton are the main food for small fishes and insects thriving in water body.

High TDS of the discharge, at least 3 times higher than the ECR' 1997. This high TDS is the result of high organic materials especially rawhides and skin, parts of leathers, fats etc. This huge amount of organic materials into water demands high DO supply. Therefore, decomposition process of TDS uses DO in water and reduce the concentration of DO to a critical limit. It was found that biochemical oxygen demand of the Dhaleshwari River was more than the recommended value (6 or less mg/L) for inland fish community. Therefore, TDS for longer period will reduce the river dilution capacity and hence will increase the BOD value of the river further. This change will finally reduce the DO value less than the critical limit for fish survival (4.0 mg/L). Low DO of less than 4.0 mg/L, therefore, will diminish all the fish community, aquatic organisms especially Phytoplankton and Zooplankton. This change will affect the fish community from another direction of food scarcity in the river water.

5.1.2 Changes in chemical status of the water

Nitrate and Phosphate are the limiting nutrients of Phytoplankton growth in aquatic environment by reducing and increasing their production in a water body. In freshwater, phosphate usually act as the limiting nutrient while in marine environment the Nitrate is doing the same. However, this theme largely depends on the aquatic environment and its biological community. In some cases, both nutrients can play same role. Therefore, concentration of these two nutrients is vital in keeping the ecological integrity of aquatic ecosystem intact. At the moment, Dhaleshwari River has the nitrate concentration of around 5.0 mg/L and phosphate concentration around 1.5 mg/L. These values are already at its highest limit for the inland surface water bodies (Draft ECR'2017). Loading of more nitrate and phosphate from another human causing source will cause blooming of Cyanobacteria. Blooming of Cyanobacteria in any aquatic environment is the destruction of the aquatic organisms and its functionality. Therefore, river ecosystem will lose its normal dynamisms and ultimately ecosystem services.

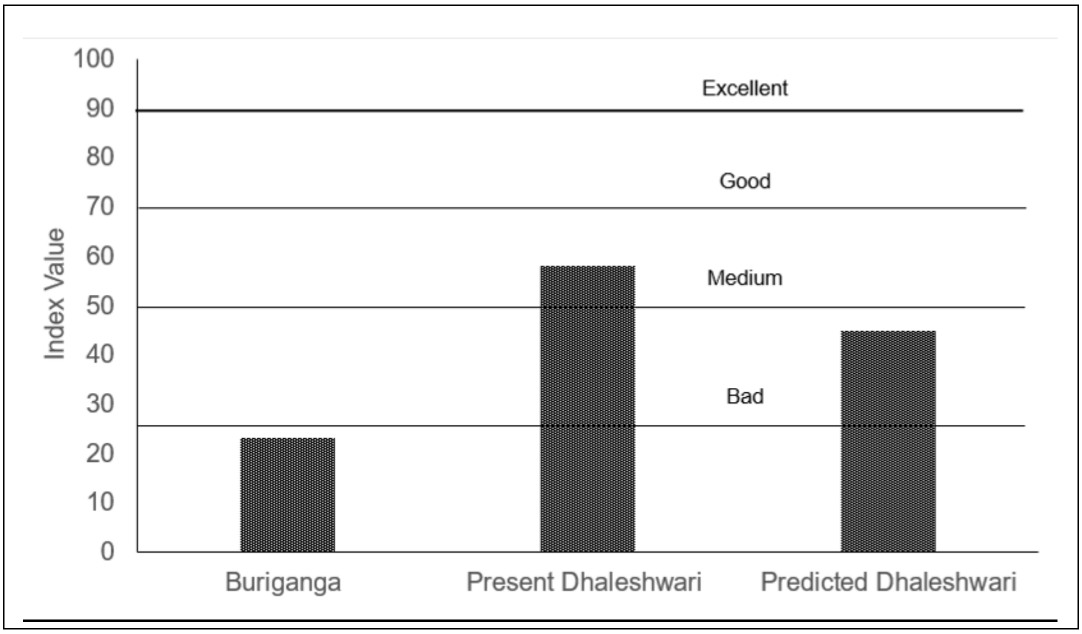
5.1.3 Changes in metal status of the water

Among the heavy metals (Cr, Pb, Al and Zn), Cr is the main element that is being used in leather industries of Bangladesh because of its quick tanning capacity. Chrome tanning uses a solution of chemicals acids and salts (including chromium sulphate) (**see list of chemicals in Appendix E**) to tan the hide. Savar Tannery Industry also follows this chrome tanning process as it is both time and cost effective in process. This Cr is highly toxic to the human body. Excessive toxic Cr discharge into Dhaleshwari River will eventually harm the populations those are residing near the Savar Tannery Estate by itching and other skin diseases. At this moment, concentration of Cr is very low in Dhaleshwari River. In addition, the Cr mixed effluents are being discharged into the river through CETP. However, in this study it is found that around 3.2 mg/L of Cr is being released even after the treatment while the recommended value is only 2.0 mg/L. This almost double concentration is polluting the Dhaleshwari River and its surroundings slowly. Furthermore, this river has very low tidal influence during the winter period because of its low freshwater availability and encroachment at the upstream. Continuous dumping of high Cr into Dhaleshwari River will increase the concentration at an alarming rate within a decade (lessons learnt from Hazaribagh Tannery Area). Discharge of high Cr into river, will lead to the increase of Cr concentration in riverbed or bank sediments. It ultimately enters into food chain through Phytoplankton and Zooplankton.

The effluent from solid waste disposal yard has enormous effect on bioaccumulation of Cr into the plants and fishes of Dhaleshwari River. This disposal yard was supposed to be a closed system. Instead of that, somehow the disposal yard and Dhaleshwari River are now connected through plastic pipes and damaged embankment. Therefore, effluent with 10.0 mg/L of Cr is now being released into Dhaleshwari River directly. The above situation will be intensified more in the near end. This story will exacerbate the situation of heavy metal pollution in Dhaleshwari River.

5.1.4 Changes in WQI

The water quality index of Buriganga River was found in very poor condition. In contrary, the present Dhaleshwari River was found in moderate condition. However, after analyzing the long time impacts of tannery activities on Dhaleshwari River under the present management scenario, it is presumed that the WQI would be in the range of 25-50 at least (as TDS, DO, BOD, COD, Nitrate, Phosphate and Chromium are releasing in high concentration) which indicated the bad quality of water. The **Figure 5.1** present the evaluation of tannery impacts on water quality of Dhaleshwari River.



Source: CEGIS Survey, June 2018. Preddicted time is One decade at least.

Figure 5.1: Comparison of WQI among Buriganga, Dhaleshwari and predicted Dhaleshwari River condition

5.2 Impact on Planktons

At the current moment, the status of Zooplanktons in Dhaleshwari River was found in moderate condition. However, continuous dumping of high organic mixed effluents and intense colored effluents will make the water condition worse. The situation will even worsen during the winter period due to upstream freshwater unavailability. Therefore, fish community especially the small fishes will face food scarcity. Finally, total food chain of the aquatic ecosystem will be destroyed and hence the animal community of the water.

5.3 Impact of Odor

As odors are subjective and perceived differently by different people, no clear odor detection limit can be defined for any gas. However, according to literature the odor threshold value for H_2S is 0.5 ppm, or 0.7 μg/m^3. Odor affects human beings in a number of ways. Strong, unpleasant or offensive smells can interfere with a person's enjoyment of life especially if they are frequent and / or persistent. Major factors relevant to perceived Odor nuisance are:

- Offensiveness
- Duration of exposure to Odor
- Frequency of exposure to Odor
- Tolerance and expectation of the receptor

Though foul Odor may not cause direct damage to health, toxic stimulants of Odor may cause ill health or respiratory symptoms. Secondary effects, in some, may be nausea, insomnia and discomfort. Very strong Odor can result in nasal irritation; trigger symptoms in individuals with breathing problems or asthma. An important study state that "air pollutants from tanneries and their concentrations causes mild, moderate and severe forms of bronchial asthma and the prevalence rate among the children, adolescent, adults and old age population during the period of 2006 to 2009. The children were affected 10–15%, adolescent about 15%, adults about 20-25% and old age about 8-12% were found. Almost all the persons affected by mild type were reversible to normalcy after inhalation of bronchodilators; severe form of bronchial asthma response to moderate state.50% of severe form of bronchial asthma (status asthmaticus) died during the period of study. Simple test like peak flow meter identified the affected persons and the spirometry study proves the severity" (Gnanasekaran S. J. Chem. Pharm. Res., 2010). On the economic front, loss of property value near Odor causing operations/ industries and Odorous environment is partly a consequence of offensive Odor.

5.4 Impact on Soil Quality

Cr concentration at Hemayetpur, at this moment, is similar to the initial condition of Hazaribagh at early 90's **(Figure 5.2).** Presence of Cr is also found in the river levee and agricultural land soil. Though, it is still under the MAC value of soil but possibility of spreading out of Cr pollution can't be avoided, if the pollution trapping mechanism will not perform properly soon.

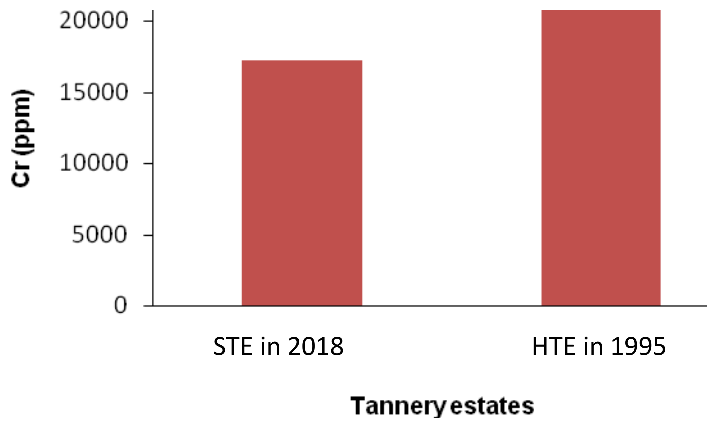


Figure 5.2: Comparative scenario of Cr concentration in Hemayetpur and early stage of Hazaribagh

EC in soil is 4.3 dS/m at Savar Tannery estate, which is slightly over the marginal range. There is no salt separation facility in the CETP, Savar Tannery Estate. So, salt can be spread out to the surrounding environment and would increase soil and water salinity gradually. This slightly marginal range can be found extremely high unless the rainwater washout the soils during the study period. Long term research is necessary to find out the real scenario of EC in STE and nearby area.

5.5 Impact on Fisheries Resources

5.5.1 State and pressure for Chromium (Cr)

Yarsan and Saleh (2013) evaluated the metal pollution in the Red Sea coast of Hodeida, Yemen Republic through measuring the concentrations of Fe, Cu, Ni, Pb, and Cd in water, sediment, and some vital organs of sea catfish, *Arius thalassinus.* They informed that due to feeding and living in the aquatic environment fishes are particularly vulnerable and heavily exposed to pollution because they cannot escape from the detrimental effects of pollutants (Yarsan and Saleh, 2013). Authman, Adams, Khallaf and Zaki (2015) reviewed the account of the toxic effects of heavy metals on fish and suggested that Fish, in comparison with invertebrates, are more sensitive to many toxicants and are a convenient test subject for indication of ecosystem health (Authman, Adams, Khallaf and Zaki, 2015). Heavy metals are produced from a variety of natural and anthropogenic sources (Bauvais et al., 2015).

Ahmed *et al*. (2015) found that the concentrations of Cr in fish, crustacean, and shellfish samples collected from the Buriganga were in the range of 1.59±0.93 to 16.05± 1.48 mg/kg. The lowest concentration, 1.59±0.93 mg/kg, was measured in crustaceans while the highest concentration, 16.05±1.48 mg/kg, was measured in shellfish (gastropod Mollusca). Among the fish species, the highest concentration was measured in *M. pancalus* (7.18±1.38 mg/kg). This study suggested that there is high Cr pollution. This might have resulted from the effluent coming from the tannery industries near the Buriganga River (Mohanta et al. 2010; Ahmad et al. 2010). More or less similar level of Cr was found by Islam et al., 2015 in case of *G. giuris, C. faciata, H. fossilis* and *C. punctatus*. More Cr concentration was found in case of *L. rohita* by Ahmed et al in 2016. Chromium concentration was found above the permissible limit of approximately 0.2 mg/kg dry wt as recommended by FAO (1976). Concentration of Cr in fish and shrimp was reported to exceed the safe limit of FAO in an Indian river by Giri and Singh (2014).

5.5.2 Impact Assessment

The increasing trend in releasing the untreated solid, liquid and chemical wastes of domestic, industries, clinics and pathologies indicate that the habitat quality of Dhaleshwari River would be declining as happened in case of the Buriganga River. It is also expected from the experience of the Buriganga River that bottom dwelling omnivorous, like Boicha (*Trichogaster fasciata*), would be rich in chromium (Cr) content through ingestion from the aqueous environment. Cr would also act as the cumulative body poisons for Shingh (*Heteropneustes fossilis*). *Cr* can cause loss of respiratory epithelium showing erosion of epithelial cells with necrosis and DNA damage in catfish. Effect of chromium as a whole can be fatal to humans (Coad, 1979; Berra, 2001). High Cr pollution can increase risk of lung cancer for Guchi Baim (*Mastacembelus pancalus*). In case of *Glossogobius giuris* like fish species, the overall toxic impact on organs like gill, kidney and liver may seriously affect the metabolic, physiologic activities and could impair the growth and behavior of fish. Heavy Cr concentration would restrict oxygen metabolism in gills, liver, and kidney in small fishes, like *Puntius ticto*.

5.5.3 Sensitivity of fish to heavy metal

Chromium (Cr) is one of the major discharged heavy metals of the tannery industry. The sensitivity of fish species to Cr varies from species to species. It depends on the accumulation process and adaptive capacity of different fish species. *Heteropneustes fossilis, Mystus vittatus, Puntius ticto, Cirrhinus reba, Glossogobius giuris*, etc. are not highly sensitive to heavy metal. On the other hand, *Labeo rohita, Trichogaster fasciata, Gudusia chapra, Mastacembelus pancalus, Gagata youssoufi, Channa punctatus*, etc. are the major fish species which are highly sensitive to heavy metals, especially to Chromium (Cr). However, first group would be harmful to human health due to bio-magnification. The following table shows the adaptive process for mostly studied fish species against heavy metals (**Table 5.1**).

Table 5.1: Order of heavy metal accumulation and sensitivity of different fish species

Name of Fish Species	Heavy Metal Accumulation Hierarchy	Reference	Sensitivity to Cr
Labeo rohita	Zn>Mn>Cr>Cu>Ni>Cd	• Ahmed et al,2010b,2016 • N. V. Bhatkar,2010 • Begum et al,2013, • Khan et al,2014	High
Trichogaster fasciata	Cu>Cr>Ni>Pb>As>Cd	• Islam et al,2014,2015 • Ahmed et al,2015 • Mohiuddin et al,2011	High
Gudusia chapra	Pb>Ni>Cr>Cu>Cd	• Ahmed et al,2010	High
Mastacembelus pancalus	Zn>Mn>Cu>Cr>Ni	• Mohanta et al,2010, • Ahmed et al,2015 • Javed et al,2013	High
Heteropneustes fossilis	Cu>Cr>Ni>Pb>As>Cd	• Rahman et al,2012 • Islam et al,2015, • Begum et al,2013 • Mormede et al 2001	High
Ailia coila	Zn>Mn>Cu>Cr>Ba>As	• Ahmed et al,2015 • Authman et al,2015 • Muriel 1996	High
Gagata youssoufi	Zn>Mn>Ba>Cu>Cr>Pb	• Ahmed et al,2015 • Authman et al,2015 • Nemcsók et al,1981	High
Channa punctatus	Cu>Pb>Ni>Cd>Cr>As	• Islam et al,2014,2015 • Ahmed et al,2015 • Authman et al,2015 • Varanka et al,2001	Low
Mystus vittatus	Pb>Ni>Cr>Cu>Cd	• Ahmed et al,2010 • Authman et al,2015 • Weber et al,1997	Moderate
Puntius ticto	Zn>Mn>Ba>Cu>Cr>Pb	• Ahmed et al,2016 • Authman et al,2015 • Kakkar et al,2010	Moderate
Puntius chola	Zn>Mn>Ba>Cu>Cr>Pb	• Ahmed et al,2016 • Authman et al,2015 • Niyogi et al,2008	Low
Puntius sophore	Zn>Mn>Ba>Cu>Cr>Pb	• Ahmed et al,2015 • Dhanakumer et al,2015 • Hasan et al,2011	Low
Cirrhinus reba	Ni>Pb>Cr>Cu>Cd	• Ahmed et al,2010 • Authman et al,2015	Low
Glossogobius giuris	Zn>Mn>Ba>Cu>Cr>Se	• Ahmed et al, 2016, 2010 • Authman et al, 2015	Low

5.6 Impact on Ecological Resources

5.6.1 Impact on Flora

Buriganga and Dhaleshwari River were rich in biodiversity in terms of both floral and faunal composition. Now, the industrial wastes (solids and liquids) are disrupting its ecological integrity in huge rate. At this moment, high concentration of pollutants is bioaccumulating in the aquatic and terrestrial plants at Buriganga River. Cr initiates severe cell membrane damage and degradation of photosynthetic pigments which results in declining plant growth

(Panda and Choudhury, 2005). High concentration of different pollutants is disfavor for proper growing of aquatic flora. Huge pollutants deposition on riverbed causes severe impact on submerged plant due to hampering germination. Moreover, very few species of free-floating plants are observed in both Buriganga and Dhaleshwari River water. Domination of Water Hyacinth indicates the impacts from chemical pollutants of river system. Because the Water Hyacinth have high resistance to chemical pollution and this hydrophyte is able to accumulate a significant amount of Chromium from water. For instance, species diversity of aquatic plants has been reduced at Buriganga River. The situation will also arise at Dhaleshwari River if there is no control of pollutants discharge in the river. Although the point source of chemical pollutants in river systems surround the Dhaka City, (from different industries, urban household and navigational vessels in addition to tannery industries) so it is unable to confirm the impacts from Chromium on terrestrial plant's physiological activities at the study area without any scientific experiment within this short time. However, many researches ensured the effects of Cr to the plants. Accumulation of Cr by plants can reduce growth, induce chlorosis in young leaves, reduce pigment contents, alter enzymic functions and damage root cells and caused ultrastructural modification of chloroplast and cell membrane (Mcgrath, 1985; Panda and Patra, 1997, 1998, 2000; Panda and Das, 1999; Panda, 2003; Panda et al, 2002, 2003; Choudhury and Panda, 2004; Hu. Et al, 2004). On the other hand, over propagation of water hyacinth resulted due to high nitrate and phosphate concentration in the river. After lifetime, water hyacinth dies and deposits into bottom of the river, which would ultimately reduce DO level of the Dhaleshwari River. In the end, the resuspension of bed materials will increase the nitrate and phosphate concentration of the river again. The low DO at the bottom of the river will also influences the release of phosphate into water body.

5.6.2 Impact on Fauna

There were some direct impacts of tannery industry on faunal diversity. In the Amphibian group, the species Common Toad (*Bufo melanostictus*) and Indian bullfrog (*Hoplobatrachus tigerinus*) were not seen any more within the tannery estate boundary at Harindhara. This will imbalance the ecosystem a bit. Nevertheless, disappearance of common snakes like Checkered Keelback (*Xenochrophis piscator*) has also enhanced the ecosystem imbalance of that area. In the case of Hazaribagh Tannery Area, ecological balance has disrupted both chemical pollution as well as climax urbanization.

Chromium contamination in river water does not build up in fish when consumed, but will accumulate on the gills, thus, causing negative health effects for aquatic animals; chromium uptake results in increased mortality rates in fish (Sneddon C., 2018). Cr induced respiratory problems, a lower ability to fight disease, birth defects, infertility and tumor formation. As a result, the fish population is reduced. Ganges River Dolphin is sensitive to water quality occurrence of which depends on both water quality and fish abundance. This impact is limited to the occurrence of this aquatic mammal at the Buriganga and Dhaleswari River. However, as per peoples' perceptions, the situation was severe in the case of the Buriganga River near Hazaribagh before one to two years and now the dolphin occurrence time has elongated (3-4 months in peak monsoon) due to minimization of the spillage of effluents in river water after banning the tannery industry there.

5.6.3 Landscape capacities to supply Ecosystem Services in and around the Hemayetpur tannery area

The major landuses in the tannery area during the year 2000 were multiple crop land (1733 ha), rural settlement (715 ha) and rivers/khals (110 ha) (**Table 5.2 and Figure 5.3**). During 2015, some of the rural settlement and multiple crops area were converted to built-up area. However, the landuses in 2018 did not change much except establishment of tannery area in built-up areas (**Table 5.2 and Figure 5.3**).

As expected, the capacity of different landuses to provide relevant ES varied considerably across those land-uses. **Appendix-F** shows the assessment matrix that was constructed during the participatory scoring exercise**. Figure 5.4** further visualize those ES components at landscape scale. Relatively higher capacity supporting services were obtained by landuses like rivers/khals, multiple crop area and settlement area during 2000. All the mentioned landuses maintained maximum level of biodiversity and habitat quality in the area. It is important to note that there was no tannery industry at that time. Areas occupied for brickfield had no biodiversity and habitat quality value. Like supporting ES, provisioning services was also highest from rivers/khals followed by multiple crop area. However, different ES components under the provisioning ES varied considerably between contrasting landuses in the area. The supply of fish and irrigation water was highest from rivers/khals, whereas multiple crop land and rural settlement had the capacity to provide agricultural crops in the area. The ES service capacity of the landscape during 2015 were little less in terms of provision services as some of the rural settlement and multiple crops area were converted to built-up area. Interestingly areas of cultivated trees increased during this period which had good contribution in regulation air quality, biodiversity and habitat quality (**Figure 5.4 and Appendix-F**).

During 2018, Hemayetpur Tannery was installed by converting some of the built-up areas. The tannery effluent has significant detrimental effect on surrounding landscape. Thereby impacting ecosystem services of the surrounding area. Polluted water discharge to the nearby water bodies' significantly deteriorating water quality (e.g. rivers/khals) even after installation of effluent treatment plant (ETP). This is further reducing fish production. Water purification capacity is also declining. For irrigation purpose, people were using good quality surface water from rivers/khals. However, after installation of tannery industry, people are now using groundwater as the surface water quality is not good. Therefore, provisioning, regulating and supporting services near the tannery area landscape (e.g. rivers/khals, rural settlement) were declining (**Figure 5.4 and Appendix-F**).

Table 5.2: Area of landuses in three different time period

Landuses	Area (ha)		
Years	**2000**	**2015**	**2018**
Baor	6	9	9
Brickfield	27	26	26
Built-Up Non-Linear	-	298	227
Cultivated Trees	4	16	16
Multiple Crop	1733	1575	1575
Perennial Beels/Haors	-	22	22
Rivers and Khals	110	178	178
Rural Settlements	715	470	470
Hemayetpur Tannery	-	-	72

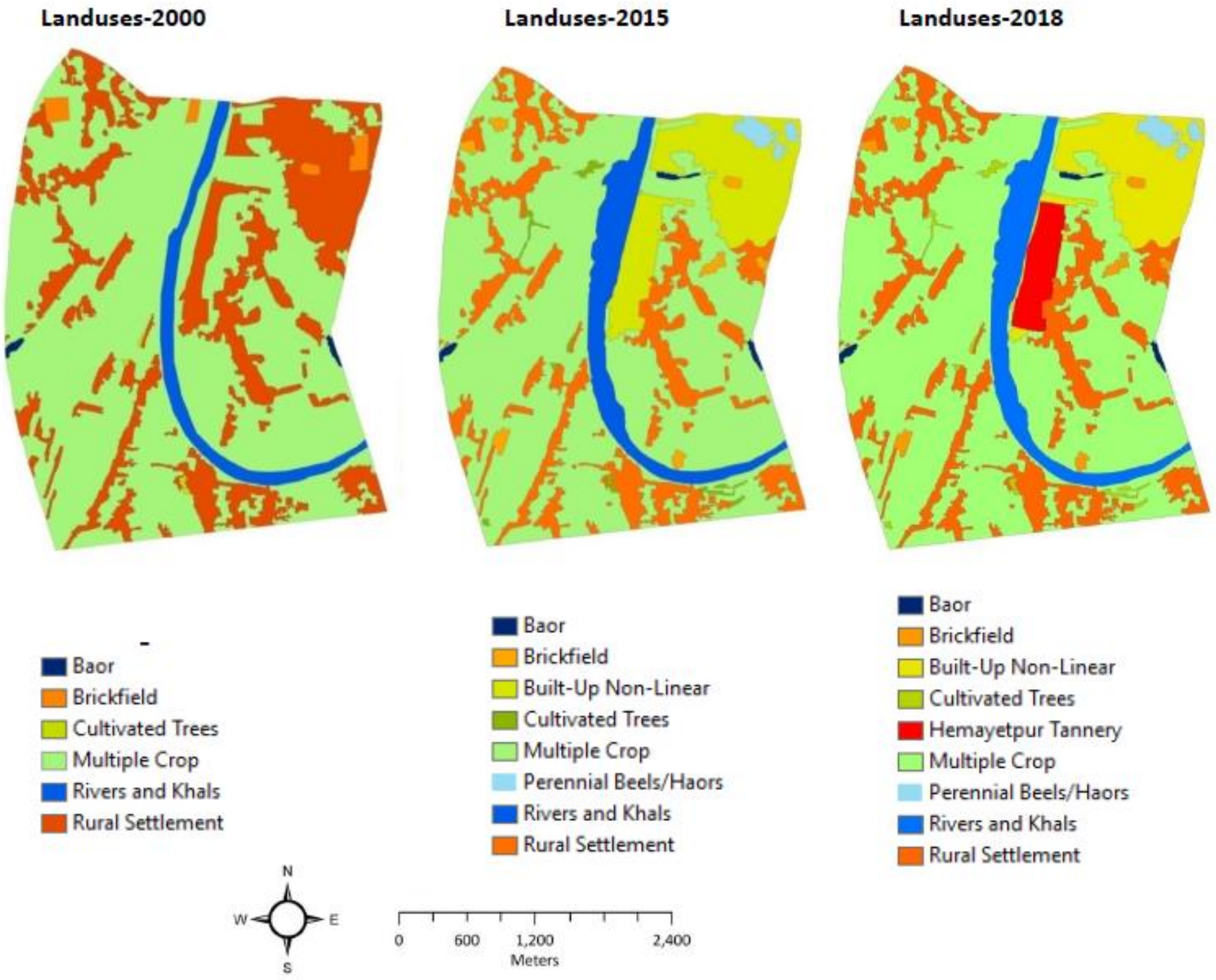


Figure. 5.3: Landuse maps of the study area in three different time periods

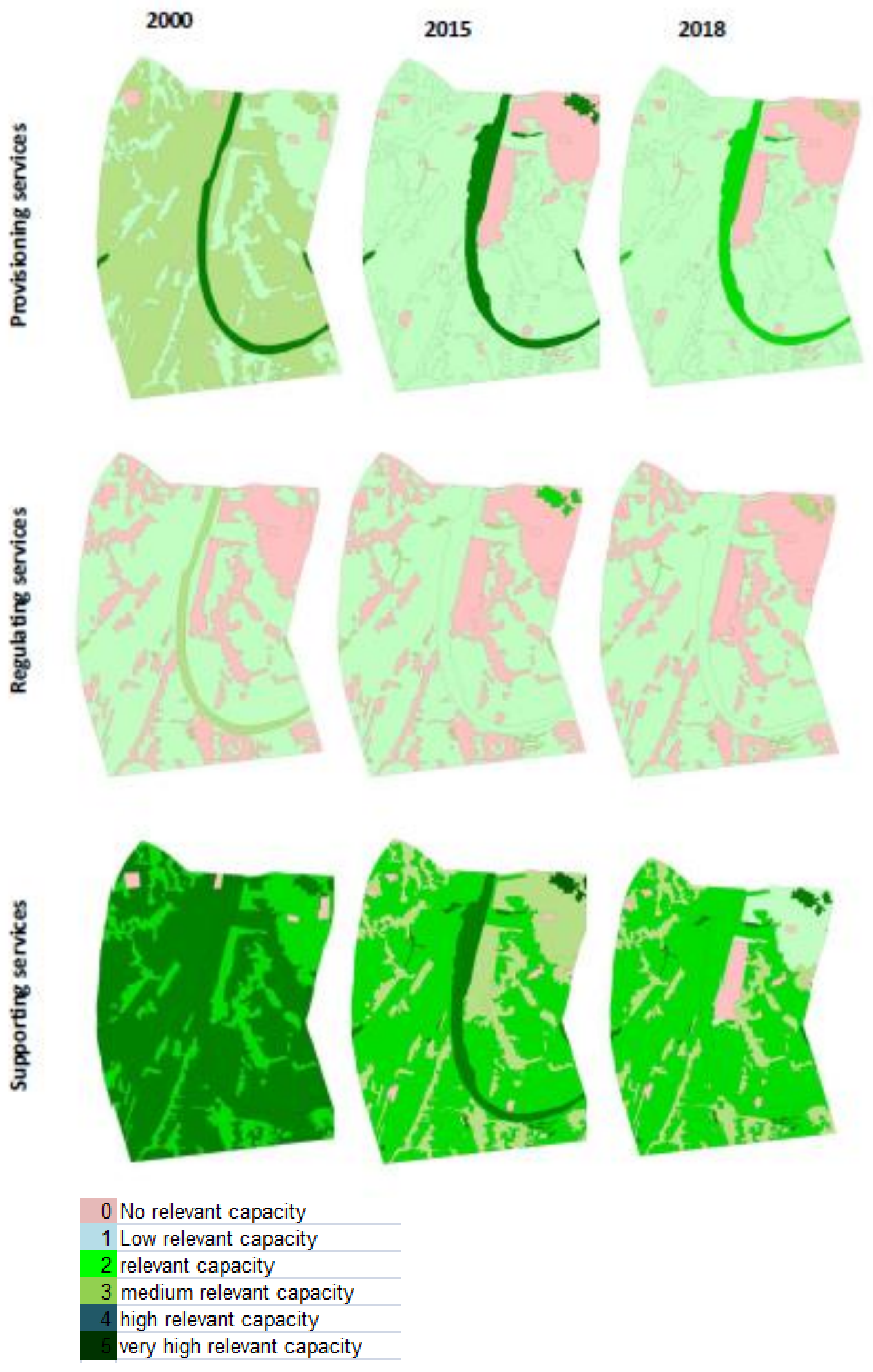


Figure 5.4: Ecosystem service capacity of different landuses of the study area

5.7 Impact on Agricultural Resources

5.7.1 Bio-accumulation

Chromium has a tendency to bioaccumulate in plants through food chain. Though, it depends on some criteria (e.g. bioavailability, redox, pH, cation exchange capacity, dissolved oxygen, temperature etc) but Cr toxicity is responsible for chlorosis and necrosis in plants (Cervantes et al., 2001). Cr competes with Mg and Fe in the porphyrin ring (Mengel and Kirkby, 2001). Cr exposure results into complete loss of growth in lateral roots while lesser concentration starts damaging root cap, stomata and cotyledonary hair seem to be collapsed and plasma membrane appears to be detached from the cell wall under cytological studies (Mariappan et al., 2001**)**.

There is still no trace of Cr bioaccumulation in Hemayetpur Tannery Estate, even not in main disposal pond. As the samples were collected in monsoon season, there might be chance of washing out the top soil Cr. Therefore, Cr presence in plant was not observed. It is also to be noted that, tannery industries activities were started in this area only for coupleof years. So deeper layer accumulation might not be happened within this stipulated time. But possibilities can’t be avoided. If, Cr throw out continues in uncontrolled manner, slowly and surely it would accumulate in soil and ultimately bioaccumulate in plants through food chain. A well documented conclusion might be drawn after a full-scale year-round research.

5.7.2 Irrigation

Agriculture is common land use on both bank of the Dhaleshwari River, where farmers were used river water for irrigation purpose previously. But local farmers claim that the river water quality is completely unfit for irrigation in recent days. As a result, they have to go for subsurface irrigation which ultimately increase the overall production cost. Besides, if ground water extraction is not monitored, there is a chance of polluting deeper aquifers. These pollutants will ultimately be taken by crops through irrigation.

5.7.3 Crop loss

Approximately, 18,749 metric tons of crops are being grown in the study area of Hemayetpur Tannery. If, the pollutants spread into the environment in uncontrolled manner, soils of the surrounding area will be affected. According to Chamon et al., 2005, rice yield production is reduced upto 43.6% in heavy metal contaminated Savar tannery estate soil. If precautionary measures will not be taken, similar scenario might be created in Hemayetpur tennary area.

Concluding Remarks

- High Cr concentration in soils of agricultural field could be found in the long run.
- Reduction of per year crop yield as Cr destroys enzymes in plant cells and reduced overall production.
- Increase of frequency of carcinogenic Cr exposure to human during irrigation of crops.
- Chance of Cr bioaccumulation in human body through food of the area.
- Increase of surface water unavailability leads to surface water scarcity situation.
- Overall soil fertility loss of the area.

5.8 Impact on Socio-economic Condition

5.8.1 Human health

Health of working labors and surrounding community may be deteriorated due to the harmful effect of chromium and others chemicals those are discharged from the tannery and mixed to the surrounding water bodies.

If those chemicals include in the food cycle, may cause genetic disorder, birth defects and cancer diseases. The chemicals absorbed into the skin may create scope for allergic and different skin diseases. Chromium absorbed through the lungs into the blood system and malfunction the kidneys and the liver of human body (Source: Political economic study on tannery industry development and subsequent effect on river pollution in Bangladesh, September 2013). These diseases may increase the health cost of the people living in the study area, subsequently cost of living may need to be increased for the survivors.

The improper drainage system and unhygienic environment in the tanneries may cause different types of skin diseases and respiratory diseases of the working labors.

5.8.2 Labor and working condition

Labors were not conscious to use Personal Protective Equipments (PPEs) in Hazaribagh which caused different types of short term and long-term diseases.

Statuses of labors suffering from diseases as per different research findings are as follows:

As per the studied documentation of a paper published in 2007, high rates of suffering cancers among tannery workers including lung cancer, testicular cancer, soft tissue sarcoma, pancreatic and bladder cancer. International Agency for Research on Cancer under World Health Organization considered leather dust as carcinogenic to humans, which is generated by mechanical tanning operations such as buffing leather impregnated with chemicals.

Society Environment and Human Development (SEHD), a Dhaka based Non - Government Organization (NGO) had also reported that about 90% of tannery workers in Hazaribagh die before they reach the age of 50 due to toxic working environment. More than 90% of tannery workers suffer from some kind of diseases, from asthma to cancer, due to chemical exposure, according to a survey by SEHD in 2008.

Considering above mentioned issues it can be assumed that the workers of Savar Tanneries may face both short term and long-term negative impact if there is lack of consciousness and monitoring system to use PPEs.

5.8.3 Standard of living

In terms of standard of living, surface water and ground water are important resources that can be contaminated by the chemical expulsion into the surrounding water bodies. These chemicals are too harmful to collapse human body as well as issue of high cost and supreme technology to filter it from drinking water. If the existing CETP cannot function well in the tannery industries, then it may deteriorate the water resource system of the project surroundings.

In addition, ground water level can be deteriorated gradually by the extraction of huge volume of ground water in the tennaries. This deterioration is already observed during field survey, boring over 160 feet for installing a tube well that was 80 to 120 feet before 3 or 4 years.

The tanneries may also deteriorate the air quality, which may affect the poor housing structures and human body as well. Longibity of furniture and housing materials those are made by tin, iron and metal can be lessen due to the chemical (may be H_2S, NH_3) explosion in the surrounding air of the project area.

Exposure of acute bad smell from the tanneries may deteriorate the living environment in the project surrounding areas. The well-off families may not be eager to reside in the project surroundings, even they may rarely come to visit their relative's residence those are located beside the tanneries. In that regard, land price of the housing plots surroundings of the tannery industries can be fallen down, even it may be tough to get buyer of those land.

5.8.4 Force changes of livelihood

Discharge of chemical to the Dhaleshwari River from the tannery industries may forceto shift fish habitat from the tannery influential water bodies. Therefore, fishermen community of the surrounding area may be forced to shift their location of fish capturing or may change their livelihood due to unavailability of fish with in their territory of the Dhaleshwari River. For the affected fishermen, adoption of alternative livelihoods could be difficult and challenging.

5.8.5 Waste management due to increase population

Proposed tannery project may increase in migration of population in the project surroundings. That may create pressure on sewage and municipal waste management because there may not have sufficient arrangement for this huge population. Also, dumping of households' waste and other solid wastes to the hither and thither may create drainage congestion which may degrade environment and hygiene condition in the project surroundings.

5.9 Impact Evaluation of Savar Tannery Estate

Impacts evaluation was performed using the method of Future without Project (FWOP) and Future with Project (FWIP) framework. The following **Table 5.3** presents impacts especially on water quality, planktons, fishes, flora and fauna, agriculture and socio-economic condition of Savar tannery area.

Table 5.3: Impact evaluation of Savar Tannery Estate

IEC	Present condition	Future without project (FWOP)	Future with project (FWIP)	Magnitude of the impact
Physical Environment				
Physical quality of the water	• Color of the water reaches to its highest acceptable limit of 15 Hazen. • Dissolved oxygen reduces to the threshold limit of 4.0-5.0 mg/L of a water body. • Water becomes turbid to its highest acceptable limit of 15 NTU standards for inland surface water quality.	• Water color will be remaining same in the Dhaleshwari River. • Dissolved oxygen may remain in the same range as it now in Dhaleshwari River. • Turbid condition will be reduced in the long run under this FWOP scenario.	• Releasing of color and odor enriched effluents into the river for a longer period will eventually turn the water colored (blackish/bluish) with chronic bad smell. • Colored water hinders the light penetration into water column. The lower the light penetration, the lower the photosynthesis into water column. • Insufficent DO in the water column. • Low light diminishes phytoplankton then the nutrients and energy shortage into food web of fish firstly.	-4
Chemical status of the water	• Oxygen demand to decompose biochemical and chemical matters in the water of Dhaleshwari River is already high than the recommended level by DoE in ECR. • Both phosphate and nitrate concentrations in Dhaleshwari River has already been reached to its highest allowable limit by ECR Standard, DoE.	• Demand of DO by the water body will be reduced due to the reduction of organic loads. • Phosphate and nitrate concentration will be remained same as there are lots of agricultural practices with other human interventions on the both side of the river.	• Loadings of 25000m^3 of effluents per day with high BOD and COD into the river, will increase the river decomposition rate and then ultimately the reduction of DO drastically. In the long run, the situation could be even worse for the survival of any aquatic organisms. • Loading of more nitrate and phosphate from another human causing source will ultimately, increase the concentration that even may cause blooming of Cyanobacteria. • Blooming of Cyanobacteria in any aquatic environment is the destruction of the aquatic organisms and its functionality.	-2

IEC	Present condition	Future without project (FWOP)	Future with project (FWIP)	Magnitude of the impact
Metal status of the water	• All the observed metals (Cr, Pb, Al, Zn) are met the national standards of Bangladesh given by DoE except Aluminum.	• Metal concentrations may vary slightly but should be in allowable limit.	• Discharge of partially treated effluents into the river will eventually increase the Cr concentrations than the recommended value. • Chance of Cr bioaacumulation will be increased and may enter into the food chain through Phytoplankton and Zooplankton. • Effluent with 10.0 mg/L of Cr is now being released into Dhaleshwari River directly. The above situation will be intensified more in the near future. This story will exacerbate the situation of heavy metal pollution in Dhaleshwari River.	-3
Water Quality Index	• Water quality of Dhaleshwari River is in moderate condition. During dry season some aquatic animals struggle to survive, and the same animals will be able to thrive during wet season as freshwater availability improve the water quality and finally river health.	• Under this scenario, water quality of Dhaleshwari River will be same as it is now (moderate). In some aspects, water quality will be improved as well.	• Continuous loadings of organic pollutants, chemicals and metals into Dhaleshwari River along with minimal management, the overall river water quality will be degraded enough like Buriganga river status during the operation of Hazaribagh tanneries.	-3
Soil Quality	• Cr concentration in soil at Hemayetpur main discharge point, at this moment, is similar to the initial condition of Hazaribagh at early 90's (Chapter 5: Figure 5.2). Presence of Cr is also found in the river levee and agricultural land soil. It is still under the MAC value of soil. • EC in soil is 4.3 dS/m at Savar Tannery estate, which is slightly	• Soil quality will not be deteriorated in terms of Cr pollution.	• Nearby river levee and surrounding area agricultural soil might be contaminated if pollutant trapping mechanism will not perform properly for a long time.	-3

IEC	Present condition	Future without project (FWOP)	Future with project (FWIP)	Magnitude of the impact
	over the marginal range.			
Sediment Quality	• At present Cr presence in the Dhaleshwari River sediment (131.5 ppm) is higher than that of in the Buriganga river sediment (109 ppm). This is a clear indication of disposing of untreated Cr mixed water into the river.	• The river sediment will not be contaminated with Cr.	• If this practice (disposal of untreated pollutant) will not be stopped, the sediment contamination will be increased and will not be enable to support benthos and plankton as well as the other dependent living beings.	-4
Biological Environment				
Habitat Condition and Quality for Fish Resources	• Water temperature has been increased to become unfavorable for fish occurrence. • DO, Turbidity and TDS quality show the degrading trend. • High heavy metal loaded water was found in the vicinity of the tannery area.	• Habitat condition and quality will remain same as the base condition in the downstream of the river, particularly in the vicinity of the tannery state.	• DO level will be lowered soon if current practice is going on at a level unsuitable for fish habitation along with other aquatic organisms. • Turbidity and TDS will be increased due to increasing decomposition of organic refractory detritus matters of raw hide and skin of animals. • Water temperature will consequently be increased to become unfavorable for fish occurrence. • Food and nutrients will become unavailable for foraging invertebrates and fishes. • Habitat will become heavy metal loaded environment and subsequently biologically dead in respect of fish and other aquatic organisms.	-4
Fish Health	• High risk to bio-accumulation of chromium (Cr) to gills, liver, and kidney of bottom dwelling omnivorous fishes, detritus feeders and even neritic fishes.	• Low risk to bio-accumulation of other heavy metals to mentioned fishes.	• Bottom dwelling omnivorous fishes would highly be impacted by high Cr from the water environment through ingestion. • Cr would act as the cumulative body poisons for detritus feeder fishes. • Risk of lung cancer would be	-3

IEC	Present condition	Future without project (FWOP)	Future with project (FWIP)	Magnitude of the impact
			increased for *Mastacembelus pancalus* along with other fishes. • Respiration will be affected through erosion of epithelial cells with necrosis and DNA damage in catfish. • Metabolic and physiologic activities will be affected with toxic effect on gill, kidney and liver of fish species like *Glossogobius giuris*. • The growth of fish will be retarded and behavior will be altered. • Oxygen metabolism could be restricted in gills, liver, and kidney in small fishes, like *Puntius ticto.*	
Natural Mortality of Fish	• No available data.	• Natural mortality due to exposure effect of other heavy metals from other sources.	• Natural mortality of small fishes, bottom dwelling fishes, catfishes, etc. would be increased.	-3
Fish composition and distribution	• Fish composition has been varied with water quality. Fish species, such as *Heteropneustes fossilis*, *Mystus vittatus, Puntius ticto, Cirrhinus reba, Glossogobius giuris, Channa punctatus*, etc. has become available during dry season being moderately to poor sensitive heavy metal rich waters. On the other hand, *Labeo rohita, Trichogaster fasciata, Gudusia chapra, Mastacembelus pancalus, Gagata youssouf*i, etc. have become available during wet season because of being highly sensitive to heavy metal rich waters.	• Distribution of fish species would be as same as in case of present condition without project through the Dhaleshwari River.	• Chanda, Ichha Chingri, Chela, Mola, Rui, Catla, Kakila, Dhela, Baghair, Potka, Batasi, Kajuli, Piyali, Sarpunti, Kholisha, Veda, Foli, etc. will shift their grazing habitat in the Dhaleshwari River close to the Hamayetpur Tannery area.	-4

IEC	Present condition	Future without project (FWOP)	Future with project (FWIP)	Magnitude of the impact
River Productivity	• The productivity of the Dhaleshwari River has been decreased.	• The productivity of the Dhaleshwari River would be decreased if present practice continues.	• The productivity of the Dhaleshwari River would be decreased if present practice continues.	-5
Plant Species composition	• Plant community is dominated with naturally undergrowth herbs and planted trees and crops.	• Terrestrial species composition of the area would be changed due to urbanization. and very few natural vegetation would be followed at urban area which will be dominated with exotic ornamental species.	• Changing trend of terrestrial vegetation is as same in FWOP. In the case of aquatic vegetation, high Cr resistant species (i.e: water hyacinth) would be dominated in river water.	-3
Faunal species composition	• The river water still supports some water dependent birds and aquatic animals including Dolphin and fishes.	• Faunal species are already in declining trend which would be continue in future for loss of required habitat due to urbanization.	• With the trend of FWOP, water dependent birds, reptiles and amphibians are suspected to reduce due to increasing Cr concentration in river water. Cr induced respiratory problems, a lower ability to fight disease, birth defects, infertility and tumor formation of fish and decrease fish population which impacts on water dependent birds like herons, egrets and cormorants.	-3
Wildlife disturbance	• Birds and other terrestrial wildlife are as usual at surrounded area except the tannery estate. No reptiles and amphibians are occurred inside the tannery estate. Some local birds like mynas, sparrows, starlings, egrets, herons are occasionally found within the tannery ground.	• Habitat loss bound to wildlife human collision and reduced wildlife population with the change of land cover.	• The trend is as usual like FWOP. But the situation would be worst for living aquatic fauna like dolphins, frogs etc. if not taken any step to stop untreated discharge from tannery industries.	-3
Cr bioaccumulation in plant body	• There is no detection of Chromium in sampled plant bodies because the water and	• No Cr bioaccumulation is suspected in plant body as the point source as well as	• It is suspected to occur the bioaccumulation in plant body through the polluted soil and water if	-2

IEC	Present condition	Future without project (FWOP)	Future with project (FWIP)	Magnitude of the impact
	soil are not such polluted yet as the Tannery estate is running recently.	tannery effluents will be absent.	continue the spillage of untreated water from the tannery estate during full swing operation.	
Bio-accumulation in Crops	• Right now, no evidence of Cr bio accumulation is visible in the locality.	• There will be no chance of Cr bio accumulation in the surrounding area.	• There is still no trace of Cr bioaccumulation in Hemayetpur Tannery Estate, even not in main disposal pond. As the samples were collected in monsoon season, there might be chance of washing out the top soil Cr. Therefore, Cr presence in plant was not observed. It is also to be noted that, tannery industries activities were started in this area only for couple of years. So deeper layer accumulation might not be happened within this stipulated time. But possibilities can't be avoided. If, Cr throw out continues in uncontrolled manner, slowly and surely it would accumulate in soil and ultimately bio accumulate in plants through food chain. A well-documented conclusion might be drawn after a full-scale year-round research.	-3
Irrigation	• Agriculture is common land use on both bank of the Dhaleshwari River, • Local farmers claim that the river water quality is completely unfit for irrigation in recent days. • Subsurface irrigation is practiced at present.	• River water could be used for irrigation purpose.	• River water will be unfit for irrigation in the long run.	-2
Crop loss	• Approximately 18749 metric tons crop is grown in the surrounding area of Hemayetpur	• No crop loss will be occurred due to heavy metal pollution	• If, the pollutants spread into the environment in uncontrolled manner, soils of the surrounding area will be	-3

IEC	Present condition	Future without project (FWOP)	Future with project (FWIP)	Magnitude of the impact
	tannery area.		affected. According to Chamon et al., 2005, rice yield production is reduced up to 43.6% in heavy metal contaminated Hazaribagh tannery estate soil. If precautionary measures will not be taken, similar scenario might be created in Hemayetpur tennary area.	
Socio-economic Condition				
Chronic Odor	• Acute odor deteriorates the air condition and create uncomfortable situation for the people residing in the surroundings.	• Usual bonding alike other area (except to the tannery) will be observed while outsider relatives may regular visits in this area.	• Bonding among outsider relatives will be weaker and in coming future relatives may rarely come to visit, due to bad odor.	-4
Drainage Congestion	• Drainage condition of the study area is not yet upgraded considering the population volume of the tanneries while the volume of household and industrial discharge is increased.	• Drainage congestion situation may deteriorate alike other non-tannery industrial area, if the relevant authority does not take any required interventions.	• Drainage congestion will be poorer while all the tanneries will be functioned.	-3
Community Health	• Impact of tanneries is not much visible to the present diseases profile. However, due to bad air quality, it becomes uncomfortable to inhale after establishing tannery industry.	• Diseases profile and its concentration was almost similar to the Hemayatpur and nearby area (with similar socio-economic condition and environment condition) without the tannery industry. Problem for breathing in will not be observed extremely.	• Compared the findings between Hemayatpur and nearby area (with similar socio-economic condition but located far from the tanneries), more cases of skin diseases, Jaundice and kidney related diseases can be highlighted in Hemayatpur area.	-2
Change in livelihood	• The crop land was developed for establishing tanneries. Therefore, profession of agriculture farmers depending of that land is somehow shifting to the alternative's livelihood. Also,	• In future without tannery industries, deterioration of the waterbody will also be increased due to existing surrounding industries, but not much as for the tanneries.	• In future, the intensity and area of deterioration of the waterbody will be increased among the study area and further more. Therefore, existing fishermen community of the study area will be under threat of shifting to	-2

IEC	Present condition	Future without project (FWOP)	Future with project (FWIP)	Magnitude of the impact
	the tanneries have some negative impact to the fish habitat of the surrounding waterbody which insist to seek alternative livelihood for those affected fishermen.	Therefore, shifting of fishermen/farmers communities to the others may not be observed in considerable numbers. Also, some of those communities may adapt to the alternative livelihood for their betterment rather to the forced.	the outside or may convert to the alternative livelihood. Similar types of impact may observe to the farmers who will use surface water for irrigation.	

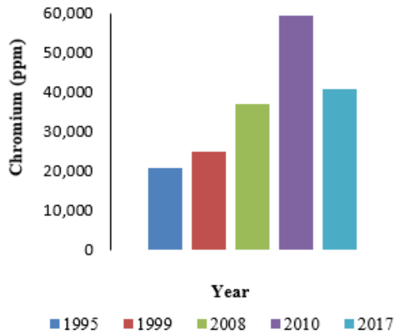
**No impact (0); Negative Impact (-); Positive Impact (+); Low Impact (1); Medium low Impact (2); Medium Impact (3); High Impact 4; Very High Impact 5.*

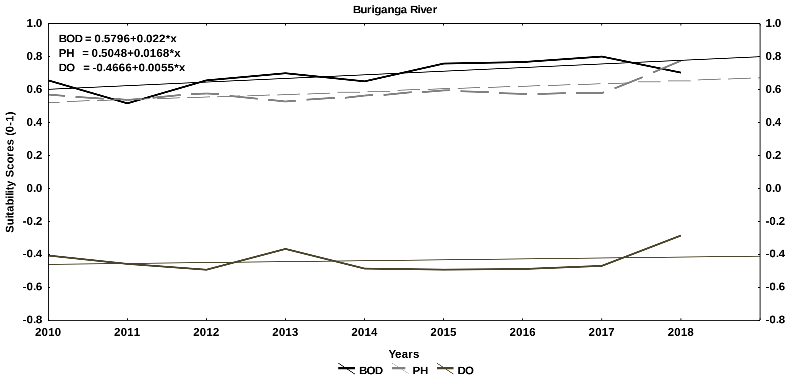
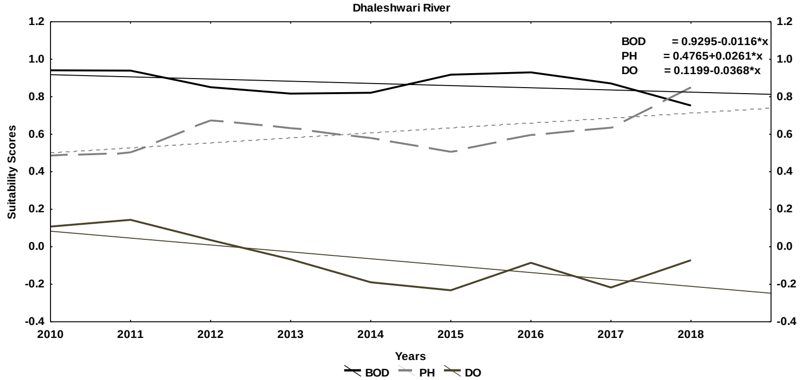
6. State of Environment of Two Sites Tannery Estate

This chapter represents a comparative analysis of the state of the environment of Hazaribagh tannery area and the Hemayetpur tannery area. The comparison was performed based on the present (June 2018) condition of the environment and socio-economic condition of the mentioned areas. The results of situation analysis are presented in **Table 6.1**.

Table 6.1: Comparison status of environment of two sites tannery estates

Indicator	Comparison of State of Environment of Two Tannery Estates	
	Hazaribagh Tannery Area	**Hemayetpur Tannery Area**
Water Quality		
Water Quality	• Very poor DO (less than 2.5 mg/L) concentration in Buriganga River to sustain fish community and other aquatic life forms. Earlier the summer season DO statues was even lower than the present condition; • High turbid water in terms of the standard provided by ECR' 1997; • Total suspended solids reduced to comply with the ECR' 1997; • pH range is quite good for fisheries resources; • Both in dry and wet season, TDS complies with the ECR' 1997; • Dry period BOD is still higher than the safe limit of 10 mg/L while COD is high in all the seasons; • Phosphate is two/three times higher than the recommended 0.5 mg/L in all the seasons while nitrate c fully complied with the standard value of 5.0 mg/L; • All the Chromium, Lead, Aluminum and Zinc are found within the safe range for Inland Surface Water Quality Standard;	• DO availability in Dhaleshwari River was found 4-6 mg/L which is the minimum requirement for the survival of aquatic fishes; Any further degradation of DO will be a problem for the fish community; Dry season DO is found much lower than the recommended value since 2017; • In the Dhaleshwari River, pH, turbidity and suspended matters still support aquatic ecosystem to keep its dynamism functional. During dry season, suspended matters increase only; • Both in dry and wet season, TDS complies with the ECR' 1997; • Dry period BOD is still higher than the safe limit of 10 mg/L; • Phosphate level is high in all the seasons since 2017 while nitrate is higher than the standard 5.0 mg/L in dry season only; • All the Chromium, Lead, Aluminum and Zinc are found within the safe range for Inland Surface Water Quality Standard except Aluminum;
Soil Resource		
Soil quality	• Soil quality of Hazaribagh is already deteriorating to alarming condition. High Cr presence in river levee, river bed and agricultural soils of tannery industry; • After 2010, Cr concentration started to decrease when the	• Cr concentration in main lagoon of Hazaribagh in 1995 is close to Hemayetpur's present Cr concentration in main disposal pond. Cr concentration in river levee is close to MAC value of soil Cr concentration and opposite bank, agricultural land soil's Cr

<table>
<tr><th rowspan="2">Indicator</th><th colspan="2">Comparison of State of Environment of Two Tannery Estates</th></tr>
<tr><th>Hazaribagh Tannery Area</th><th>Hemayetpur Tannery Area</th></tr>
<tr><td></td><td>tannery industries started to stop their activities in that area;

</td><td>concentration is almost half of MAC value. Riverbed sediment Cr concentration is already exceeding MAC value;</td></tr>
<tr><td colspan="3">Fisheries Resources</td></tr>
<tr><td>Habitat Condition and Quality</td><td>• Restricted foraging area for fish;
• Habitat suitability for fish is under serious stress due to low level of DO (almost zero) in the Buriganga River caused by the decomposition of huge organic refractory detritus matters on the riverbed;
• Suitability respecting Turbidity has been improving from 2015, but declining in respect of TDS. The dark color water of the Buriganga River and high turbidity for increased organic detritus in water column capture more heat than captured by clean water, which resulted in increasing water temperature during dry season having adverse impact on fish;
• Habitat suitability respecting water temperature has been increasing from 2015 to 2017;
• A fine steady increasing trend of habitat suitability has been found in respect of pH. The suitability has been increasing more from 2013 to 2018;
• An increasing suitability trend was found in case of BOD;</td><td>• The foraging area has become restricted in the downstream of the river particularly in the vicinity of the Tannery State;
• DO level shows the decreasing trend day by day;
• Turbidity and TDS have been increased due to increasing decomposition of organic refractory detritus matters of rawhide and skin of animals;
• Water temperature has been consequently be increased to become unfavorable for fish occurrence;
• Although an increasing suitability trend has been found in respect of pH, the suitability varies highly from year to year;
• An increasing suitability trend was found in case of BOD, though the suitability level was higher than found in the Buriganga River;
• Habitat has become heavy metal loaded environment and subsequently biologically dead in respect of fish and other aquatic organisms;</td></tr>
</table>

<table>
<tr><th rowspan="2">Indicator</th><th colspan="2">Comparison of State of Environment of Two Tannery Estates</th></tr>
<tr><th>Hazaribagh Tannery Area</th><th>Hemayetpur Tannery Area</th></tr>
<tr><td></td><td>
</td><td>
</td></tr>
<tr><td>Fish Health</td><td>According to the historical trend of heavy metal bioaccumulation into fish for the Buriganga River, the maximum, average and even minimum concentration of Chromium had been decreased from the year of 2012 and the concentration of Cd, Pb and Ni had been decreased from 2008;
In 2015, the concentrations of Cr in fish, crustacean, and shellfish samples were in the range of 1.59±0.93 to 16.05± 1.48 mg/kg;
Among the fish species, the highest concentration of Cr (7.18±1.38 mg/kg) was measured in M. pancalus, G. giuris, C. faciata, H. fossilis and C. punctatus.</td><td>Although there was no literatures on investigating the heavy metal bioaccumulation in fish body, it is suggested from the experiences of the Buriganga River and the observed concentration of heavy metal in water of the Dhaleshwari River that bottom dwelling omnivorous fishes are highly being sensitive to high Chromium (Cr) from the water environment through ingestion.</td></tr>
<tr><td>Natural Mortality of Fish</td><td>Natural mortality has increased due to retarded growth and malfunctioning of internal organs, like gills, kidney and liver.</td><td>Natural mortality of small fishes, bottom dwelling fishes, catfishes, etc. has been increased.</td></tr>
<tr><td>Fish Composition and Distribution</td><td>Three species, namely Taki, Shingh and Boicha are abundant throughout the year while Chela, Tilapia, Lal Chanda in August only.</td><td>Chanda, Ichha Chingri, Chela, Mola, Rui, Catla, Kakila, Dhela, Baghair, Potka, Batasi, Kajuli, Piyali, Sarpunti, Kholisha, Veda, Foli, etc. have shifted their grazing habitat in the Dhaleshwari River close to the Hamayetpur Tannery City area.</td></tr>
<tr><td>River Productivity</td><td>River productivity has been reduced with the deterioration of physico-chemical properties of the Buriganga River water, decreasing fish composition, fish distribution, poor fish health, retarded growth and increased natural mortality.</td><td>The productivity of the Dhaleshwari River has being decreasing because of unavailability of fish particularly during dry season.</td></tr>
</table>

Indicator	Comparison of State of Environment of Two Tannery Estates	
	Hazaribagh Tannery Area	**Hemayetpur Tannery Area**
Ecological Resources		
Plant Composition	• Planted trees are sporadically exist within the tiny urban passages with very low density; naturally grown vegetation composite only with small grasses and mere number of seasonally grown herbs at road slopes and marsh ridges; plant health is not well;	• Plant community is dominated with naturally undergrowth herbs and planted trees and crops surround the STE which health is still well; • No referable vegetation exist within the STE except two or three species of grasses;
Faunal Composition	• Faunal diversity and population have already in declined due to lack of healthy and dense vegetation within the urban passage; occurrences of terrestrial fauna are limited with sparrows, crows, myna, mice and rats which are in declining trend from a long time; aquatic fauna like dolphins and fishes are highly vulnerable due to water pollution from different sources;	• Terrestrial faunal occurrence is still usual within the village site at the right bank of Dhaleshwari (Opposite site of STE). Their occurrence is limited surround settlements of the STE and only some species of local birds are roaming within the STE; • Amphibians and reptiles are scared within the STE; The river water still supports some water dependent birds and aquatic animals including Dolphin and fishes;
Wildlife Disturbance	• Birds and other terrestrial wildlife are as usual at surrounded area except the tannery estate. Reptiles and amphibians are not dwelling inside the tannery estate due to chemical pollution; • Some local birds like mynas, sparrows, starlings, egrets, herons are occasionally found within the tannery ground but not nesting at there; • Occurrence of dolphins are common within the peak monsoon at the river reach beside STE and they are also facing vulnerability due to water pollutions by other industries situated along the river banks; tannery waste is not major concern in this regards;	• Rapid urbanization have already grab the habitat suitability of wildlife from a long ago both aquatic and terrestrial. But the aquatic habitat condition is in little bit improving trend due to banning of tannery industry at this area and thus occurrences of dolphins and fishes at Buriganga are increasing in some extents near the HzTE area although the condition is not still satisfactory;
Cr Bioaccumulation in Plant Body	• Cr have detected in plant bodies which revealed the soil is still polluted from the earlier pollutants from tannery industries; but Cr bioaccumulation is expected to be minimized in future as the point source as well as tannery effluents will be absent;	• There is no detection of Chromium in sampled plant bodies because the water and soil is not such polluted yet as the Tannery estate is running recently;
Agriculture Resources		
Cr Bioaccumulation in crops	• According to the primary data of this report (laboratory test), evidence of Cr bioaccumulation is found in main channel of Hazaribagh tannery industry. Cr bioaccumulation was documented in different scientific papers (Mondol et al., 2017). It reflects that, Cr presence is still causing harmful effects even	• There is no proof of Cr bioaccumulation is found in this surrounding area;

Indicator	Comparison of State of Environment of Two Tannery Estates	
	Hazaribagh Tannery Area	**Hemayetpur Tannery Area**
	after shutting down the tannery industry;	
Irrigation	• Irrigation water quality of the Buriganga River is under standard level due to presence of different heavy metals; • Tannery industries are the source of undecomposed organic matter (rawhide, skin, flesh etc.). These organic matters increase BOD load of the irrigation water; • EC, TDS, COD, Turbidity is higher than allowable range for irrigation; • The color turned to darkish due to high BOD, untreated chemical and dyeing color deposition;	• Farmers use river water couple of years ago, when the tannery estate was not in full swing. Cr concentration and EC in river water is not exceeding MAC value. It is claimed by the farmers that, river water turned into darkish color with bad odor during post monsoon season when the water is very much needed for irrigation;
Crop Loss	• Crops near Hazaribagh tannery industry show narcotic symptoms due to heavy metal consumption. Farmers already face yield loss due to heavy metal contaminated soil;	• Crops in surrounding area are not showing narcotic symptoms due to heavy metal accumulation (during crop sampling, 2018).
Socio-economic Status		
Chronic Odor	• Bonding among outsider relatives are going to be normal, which was weaker due to acute odor of tanneries;	• Acute odor of Hemayetpur tanneries are spread out to the surrounding communities. Therefore, their outsider relatives are unwilling to visit their sites, which intends to weaken the bonding with relatives;
Drainage Congestion	• After shifting the tanneries, disposal of solid waste volume is drastically decreased which causes improving situation regarding drainage congestion;	• Inadequate drainage system for sudden pressure of tannery workers deteriorates the existing drainage condition. Also, disposal of solid waste and liquid discharge of the tanneries exaggerate the worse condition;
Community Health	• Health condition is improving regarding skin diseases and jaundice after shifting the tanneries. It is assumed that trend of suffering respiratory problem will also be gradually decreased.	• Compared the findings between Hemayetpur and nearby area (with similar socio-economic condition but located far from the tanneries), more cases of Skin diseases, Jaundice and Kidney related diseases are highlighted to the surrounding villages of Hemayetpur tannery industry;
Standard of Living	• No change in drinking water is observed as all the households used supply water for drinking; • Fragility in tin shed houses and iron/rode/metal based furniture is decreasing, even not observed after shifting the tanneries. Also, renowned apartment developers are interested to take project in	• People uses tube well water for drinking and the water table is declining after establishing tanneries as tanneries use groundwater; • Tin shed houses and iron/rode/metal based furniture are

Indicator	Comparison of State of Environment of Two Tannery Estates	
	Hazaribagh Tannery Area	**Hemayetpur Tannery Area**
	Hazaribagh area; • Some proposed public and private civic facilities have intended to develop which make hope to the owners for getting sober tenants of their housing structures;	becoming fragile after establishing tannery industry; • Land value and apartment value is gradually decreased to the close vicinity of Hemayetpur tannery industry. It becomes rare to get sober tenants in the close vicinity of the tannery industry;
Change in Livelihood	• The commercial features of Hazaribagh is somehow converted to residential features. That is why some supporting livelihood based on the tanneries have been converted to others as required;	• Fishermen community were still common in the area, but they alleged decreasing of fishes due to tanneries. Some of these community members already shifted their captured area and others are intended to shift other areas or to engage in alternative livelihood that intention is also observed among crop farmers;

7. Future Management Suggestions

This chapter brings some of the aspects/sectors to be managed appropriately in favor of green tannery industrialization at Savar, Bangladesh. The solutions have emerged basically from the expert's judgements having the sense of different impacts the Dhaleshwari River is going to face in future. The goal of identifying future management solutions is to prevent pollution and improve the current environmental and social situation of the Savar Tannery Area.

7.1 Performance Improvement of the CETP

CETP and related issues

- Identification and installation of salt treatment facility as current CETP doesn't deal with the salinity issues.
- Assess the capacity of the existing CETP rearding volume and its treatment quality based on discharged effluent characteristics.
- Storing of extra effluents in separate reservoirs and treat later as per capacity of existing CETP provided it is capable of treating current effluent and meets National Standards as applicable. If not possible, a new CETP shall be installed to treat the total volume of effluent and simultaneously meet compliance requirements.

Environmental Compliance

- Water quality testing performance monitoring of the CETP (**Detailes in Appendix: G**).
- Effluents should be treated to meet the standard recomended in SCHEDULE 10: ECR 1997/Draft ECR 2017.
- Domestic water treatment and discharges into Dhaleshwari meeting the SCHEDULE 8: ECR 1997/Draft ECR 2017.

7.2 Managing Odor Problem

- Prohibiting the use of internationally banned solvents.
- Adding manganese sulfate to treat effluent, as needed, to facilitate the oxidation of sulfides.

7.3 Managing Soild Wastes

- Cr contaminated (hazardous wastes) solid wastes shall be crushed and liquids will be treated through the CETP. In addition, to manage these hazardous waste a Chain of Custody (CoC) shall be developed and implemented.
- Soild wastes that are not contaminated by Cr shall be dumped into Government approved dumping site also following CoC.

- Domestic liquid wastes shall be treated properly to meet the SCHEDULE 8: ECR 1997/Draft ECR 2017 before discharging into natural water bodies.
- Domestic solid wastes shall be dumped finally into Government approved dumping site through Savar Municipality and a CoC to be maintained.
- Drying of washed leathers on the open roads must be prohibited.
- Solid wastes collection and transportation vehicles must be air tight to reduce the Odor of the area.

7.4 Enhancing Ecological Resources

- A proper plantation plan shall be prepared and implemented immediately along the roadsides, factory grounds and other possible places of the tannery estate area. Local plant species shall be given priority for plantation to favor wildlife as CSR activities.

7.5 Improving Socio-economic condition

Occupational Health and Safety (OHS)

- Measures shall be taken to remove drainage congestion in the industry area and improve hygiene system during handling of raw materials and different chemical usage.
- Personal Protective Equipments (PPEs) shall be used by working labors. These PPEs shall implement OHS measures as required for safe work environment.

Community living standard

- Instead of using groundwater as the main source of water for washing tannery products, surface water sources shall consider and be used sustainably.

Force change of livelihood

- There may the possibility to change the livelihood of fishermen community in the project surroundings, so the tannery industries/government should take necessary measures to manage this problem effectively.

Research on social issues

- A research study should be taken to identify the real reasons behind the shortage of drinking water in the shallow tube-wells during dry season of the surrounding area of Savar Tannery Estate.
- Another research project to identify the reasons behind the quick damages/corrosion of Tin and Iron sheet made infrastructures in the neighbouring area.

7.6 Resources Monitoring

In addition with implementing the suggested measues, this study also suggests to monitor the environmental and social resources to keep track of any degradation of environmental resources, non-functionality of ecosystem dynamisms and the impacts on human well beings due to the savar tannery activities. Therefore, a Monitoring Framework is also suggested and presented in **Appendix G: Environmental and Social Monitoring Plan** following the responsible agenices and individual resource monitoring schedule.

7.7 Institutional Framework

An effective institutional framework shall be developed among BSCIC Savar, CETP Operator, Tannery Owners and DoE as surveillance authority to manage the environmental and social quality of savar tannery activities in a sustainable manner. The Proposed Institutional Framework is presented in **Figure 7.1**.

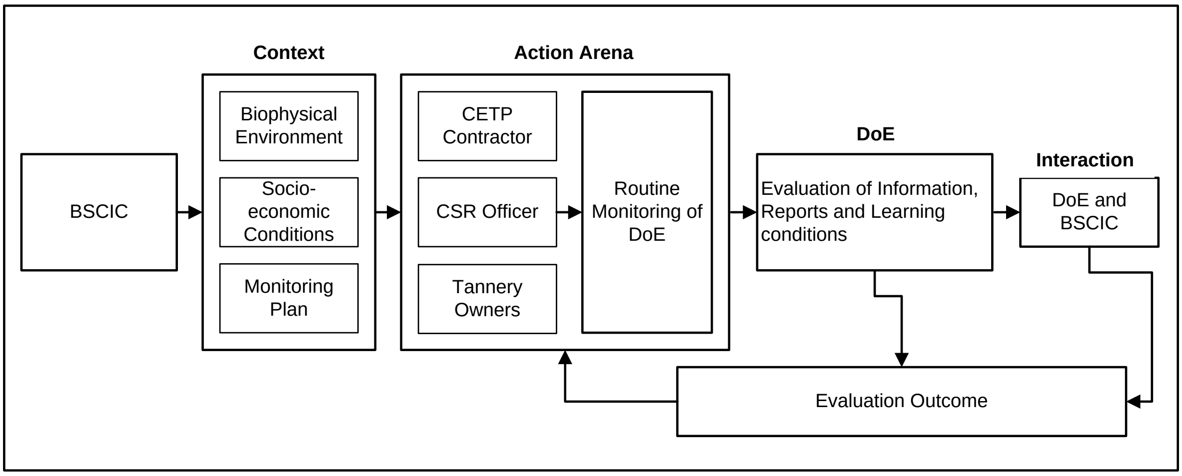


Figure 7.1: Proposed Institutional Framework

8. Conclusions

8.1 Conclusions

In Bangladesh, tannery industry has been reforming to meet compliance with the national standards. Now, DoE has initiated a study to outline the status of tannery activities. This study focuses to find the improvement of the environmental and the social status surrounding the Hazaribagh Tannery Estate (HTE) and simultaneously examining the environmental and social compliance performance and safegurds of Savar Tannery Estate (STE).

In HTE, significant improvement of environmental and social quality was identified in the study. Study results revealed that there was no odor in the air, no drainage congestion and water logged condition. On the contrary, improvement of river habitat for fishes during the wet season was good. At this moment, no organic and chemical pollution of tannery industries into the River Buriganga. However, oxygen availability for aquatic life forms in the Buriganga River is not suitable yet. In addition to that, Cr concentrations into soils of riverbed, river levee and the surrounding environment of the discharged main canal still prevails in toxic conditions. The Cr concentrations may be due to heavy deposit during long operation period of tanneries of the site.

At the very first, the STE is not ready yet to support the tannery industries for their smooth production. Internal road systems are found still in muddy conditions where water logged situation prevails most of the time. Scientific evidences have been found regarding the poor performance of CETP in both its managing capacity and maintaining quality of treatments.

Another major issue is the solid waste management of the tannery industries. Solid waste (hazardous and non-hazardous) is dumped into nearby dumping sites. Chromium has already contaminated the water and land of dumping sites, which later disposes directly without treatment into the Dhaleshwari River.

Beside these environmental concerns, numerous socio-economic disputes are also informed from the tannery labors and the surrounding communities. Chronic odor situation, skin diseases and vomiting are the common illness over there. Lack of proper drainage facility also hampers social life.

Above all, Savar tannery activities are polluting environmental and social quality of life in an alarming magnitude right now. In future, these impacts could be irreversible and enormous to manage efficiently. Therefore, suggested measures (In Chapter 7) shall be implemented with great care timely. This will also assist this nation to meet the SDGs Goals (8, 9, 11 and 14).

References

Adriano; B. Alloway; H.E. Doner; C. Keller; N.W. Lepp; M. Mench; R. Naidu and G.M. Pierzynski. (eds) Vienna, Austria. I: 260-61UNB, November, 2003. pp.96-108.

Ahammed, S. S., Tasfina, S., Rabbani, K. A. and Khaleque M. A., 2016. An investigation in to the water quality of Buriganga. International Journal of Scientific and Technology Research, Volume 5, Issue 03.

Ahmad, M. K., Islam, S., Rahman, S., Haque, M. R., Islam, M. M., 2010. Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. Int. J. Environ. Res. 4, 321–332.

Ahmed et al., 2015. Human health risk assessment of heavy metals in tropical fish and shellfish collected from the river Buriganga, Bangladesh. Environmental Science and Pollution Research. Volume 22, Issue 20, pp 15880–15890.

Ahmed, K. M., Hassan, M. A., Sharif, S. U. and K. S. Hossain. 1998. Effect of Urbanisation on Groundwater Regime, Dhaka City, Bangladesh. *Jour Geol Soc of Ind.*52: 229-238.

Ahmed, M. K., Ahamed, S., Rahman, S., Haque, M. R. and Islam, M. M., 2009. Heavy metal concentrations in water, sediments and their bio-accumulations in fishes and oyster in Dhaleswari River. Asian J. Water Environ. Pollut. (in press).

Alam, A. M. S., Islam, M. A., Rahman, M. A., Siddique, M. N. and Matin, M. A., 2003. Comparative study of the toxic metals and non-metal status in the major river system of Bangladesh. Dhaka Univ. J. Sci., 51 (2), 201-208.

Alamgir, A. A. A.; Debnath, K.; Hossain, D.; and Jalil D. M. A., 2017. Solid Waste Management of Tannery Industrial Estate, Dhaka. Sixteenth International Waste Management and Landfill Symposium/ 2 - 6 Margherita di Pula, Cagliari, Italy / © 2017 by CISA Publisher, Italy.

Ausseil O and Clark M. (2007b). Recommended water quality standards for the Manawatu-Wanganui Region: technical report to support policy development. Horizons Regional Council Report N. 2006/EXT/806. ISBN: 1-877413-89-5.

Authman, Adams, Khallaf and Zaki, 2015. Use of Fish as Bio-indicator of the Effects of Heavy Metals Pollution. Aquaculture Research and Development 2015, 6:4 http://dx.doi.org/10.4172/2155-9546.1000328.

Azim, M. A.; Quraisi, S. B. and Islam, R. 2009. Impact of dumping untreated wastewater on water quality of the river Buriganga, Bangladesh. *Dhaka University Journal of Science*, 57(1): 101-106.

Azom, M.R.; Mahmud, K.; Yahya, S.M.; Sontu, A. and Himon, S.B., 2012. Environmental Impact Assessment of Tanneries: A case study of Hazaribagh. Bangladesh Journal of environmental impact, 3: 152-156.

Baki, M. A.; Hossain, M. M.; N. A. B. and Asaduzzaman, M.; 2017. Fish Species Diversity, Fishing Gears and Crafts from The Buriganga River, Dhaka. Bangladesh J. Zool. 45(1): 11-26, 2017.

Banani, 2013. Political economic study on tannery industry development and subsequent effect on river pollution in Bangladesh, Doctoral Dissertation. http://id.nii.ac.jp/1342/00000976/.

Bashar, K. and Islam, S., 1999. Assessment of Groundwater Vulnerability of the Northern Part of Dhaka City and Surrounding Areas. *Bangl. Jour.l of Geol.*15:1-15.

Bauvais et al., 2015. Bioremediation of Heavy Metals from Contaminated Sites Using Potential Species: A Review. IJEP 37 (1): 65-84.

Begum, D. A. and Ahmed, K. M. T., 2010. Water Quality Aspects in and around Dhaka City", Proc. of International Conference on Environmental Aspects of Bangladesh (ICEAB10), Japan, pp. 175-178, 2010.

Bora, C., 2018. Causes and Effects of Industrial Water Pollution, Help Save Nature, PP. 1-5. https://helpsavenature.com/industrial-water-pollution.

Burkhard, B., Kroll, F., Müller, F., Windhorst, W., 2009. Landscapes' capacities to provide ecosystem services—a concept for land-cover based assessments. Landscape Online 15, 1–22.

Burkhard, B., Kroll, F., Nedkov, S., Müller, F., 2012. Mapping ecosystem service supply, demand and budgets. Ecol. Ind. 21, 17–29.

Cervantes C, Campos-Garcia J, Debars S, Gutierrez-Corona F, Loza-Tavera H, Carlos-Tarres-Guzman M and Moreno-Sanchez R., 2001. Interaction of chromium with microgenesis and plants. FEMS Microbiol. Rev. 25: 335-347.

Chamon, A.S., M.H. Gerzabek, M.N. Mondol, S.M. Ullah, M. Rahman and W.E.H. Blum., 2005. Heavy metal uptake into crops on polluted soils of Bangladesh. I. Influence of crop and crop varieties. J. Comm. Soil Sci. Plant analysis. 36: 907-924.

CPCB, 2008. Guidelines On Odour Pollution & Its Control. Parivesh Bhawan, East Arjun Nagar, Delhi – 1100 32: Central Pollution Control Board, Ministry of Environment & Forests,Govt. of India.

DoE (Department of Environment), 2000. Report on water quality of selected rivers in Bangladesh for 1990-91 and pollution trend since 1984. Ministry of Environment and Forestry, Government of Bangladesh.

DoE, 2001. The general overview of pollution status of Bangladesh, Department of Environment, Dhaka, Bangladesh.

DoE, 2010-2016. Surface and Ground Water Quality Report. Ministry of Environment, Forest and Climate Change, Government of the People's Republic of Bangladesh.

DoE, 2012. Water Quality Annual Report. Department of Environment, Ministry of Environment Forests and Climate Change, Government of the people's republic of Bangladesh.

Doyle, M. P., and M. C. Erickson. 2006. "Closing the door on the fecal coliform assay." *Microbe* 1:162-163. ISSN 1558-7460.

ECR, 1997. Environment Conservation Rules, 1997, Bangladesh.

Elahi, S.F., Chamon, A.S., Faiz, B., Mondol, M.N. and M.H. Rahaman, 2010. Specification of heavy metals in soils, plants and water in Bangladesh. Bangladesh. J. Agric. and Environ. 5 (2):79-97.

EQS, (Environmental Quality Standards) 1991. Department of Environment, Government of the Peoples' Re-public of Bangladesh. 44.

FRSS, 2017. Yearbook of Fisheries Statistics of Bangladesh. Fisheries Resources Survey System (FRSS), Department of Fisheries, Bangladesh. Volume 33; 116p.

Giri and Singh, 2014. Risk assessment, statistical source identification and seasonal fluctuation of dissolved metals in the Subarnarekha River, India. Journal of Hazardous Materials. Volume 265, 30 January 2014, Pages 305-314.

Gnanasekaran S., Subramani K. , Thaminum Ansari A.,. J. Chem. Pharm. Res.,2010, . "Ambient air pollution from the leather tanneries in Vellore district in reference to the Asthma." *Journal of Chemical and Pharmaceutical Research* 2(5): Pp:153-160.

Hasan, S., Rajia, A. K., Kasi, and Latifa, G. A., 2009. Comparative study on the water quality parameters in two rural and urban rivers emphasizing on the pollution level. Global Journal of Environmental Research 3 (3): 218-222.

Hashem M. A., Arefin M. S., Jor A., 2015. "Gaseous Air Pollutants and its Environmental Effect-Emittedfrom the Tanning Industry at Hazaribagh, Bangladesh." *American Journal of Engineering Research (AJER), e-ISSN : 2320-0847 p-ISSN : 2320-0936* 138-144.

Islam, M. S., S. Han, M. K. Kawser, S. Masunaga, 2014. Assessment of trace metal contamination in water and sediment of some rivers in Bangladesh. J. Water & Env. Tec. 12 (2): 225-234.

Islam, M.R.; Lahermo, P.; Salminen, P.; Rojstaczer, S. and Peuraniemi, V., 2000. Lake leaching from tropical soils. Bangladesh Environmental Geology, 39: 1083-1089.

Islam, M.S., Meghla, N.T., Suravi and Mamun, S.A., 2012. 'Status of water quality in the Dhaleshwari River and its effect on aquatic organism', Journal of Environmental Science and Water Resources, Vol. 1, No. 8, pp.192–201.

Jahan, M. A. A., Akhtar, N., Khan, M. S., Roy, C. K., 2014. Islam and Nurunnabi; Characterization of tannery wastewater and its treatment by aquatic macrophytes and algae; Bangladesh Journal of Scientific and Industrial Research; Bangladesh J. Sci. Ind. Res. 49(4), 233-242.

Jeong S. J., 2011. "CALPUFF and AERMOD Dispersion Models for Estimating Odor Emissions from Industrial Complex Area Sources." *Asian Journal of Atmospheric Environment; Vol. 5-1* doi: 10.5572/ajae.2011.5.1.001.

Khan, H.R., 2006. Assessment of SPWAC (Soil-PlantWater-Air Continuum) Quality within and around Dhaka city. Report submitted to the Director of the Centre for Advanced Studies and Research in Biotechnological Sciences, University of Dhaka, Bangladesh. P. 127.

Khan, Y. S. A., Hossain, M. S., Hossain, S. M. G. A. and Halimuzzaman, A. H. M., 1998. An environment of trace metals in the GBM Estuary. J. Remote sensing. Environ. 2, 103-113.

Kibria, M. G., Kadir, M. N., 2015. Buriganga River Pollution: Its Causes and Impacts. In: International Conference on Recent Innovation in Civil Engineering for Sustainable Development (IICSD- 2015). [online] Gazipur: DUET. Available at:

https://www.researchgate.net/publication/287759957_Buriganga_River_Pollution_Its_Causes_and_Impacts.

Kloke A., 1980. Orientierungslaten fur tolerier Gesamtgehalteeiniger. Element in Kulturboder. Mitteilungen der VDLUfA. Heft1-3: 9-11

Lika, M., Nelaj, E. & Gjoni, V., 2010. Evaluation of Microbiological Water Situation from 2005 to 2008 in Shkumbin River, Albania. Republic of Macedonia, Ohrid. .

Mariappan V., Balamurugan T. and Rajan M. R., 2001. Irrigational utilization of treated tannery effluent and its impact on growth and some biochemical characteristics of certain crop plants. Ecol. Environ. Cons. 7: 205-210.

Mc Grath S.P., 1985. Chromium and Nickel. In: Allaway BJ (eds) Heavy Metals in Soils, pp.139-155. Chapman and Hall, London UK.

Mengel K and Kirkby E.A., 2001. Element with more toxic effect. In: Principle of plant nutrition. Kluwer Academic Publisher, London, pp. 656-670.

Miti, S.S., Hossain, S. M. N. and Rahman, M. L., 2009. A study on the Industrial River Pollution in DEMDP area and planning Approaches. The Jahangirnagar Review, Part I, 33, pp.259-270.

Mohiuddin, K.M., Ogawa, Y., Zakir, H.M., Otomo, K. and Shikazono, N., 2011. Heavy metals contamination in the water and sediments of an urban river in a developing country. Int. J. Environ. Sci. Technol. 8(4): 723-736.

Mohiuddin, M. K, Alam, M. M., Ahmed, I. and Chowdhury, A. K., 2015. Heavy metal pollution load in sediment samples of the Buriganga River in Bangladesh. J. Bang. Agril. Unv. 13 (2): 229-238

Mokaddes, M. A. A.; Nahar, B. S. and Baten, M. A., 2013. Status of Heavy Metal Contaminations of River Water of Dhaka.

Momtaz, H, Alam A.K.M.R. and Hoque S., 2010. A comparative study of phytoplankton diversity in relation to water quality of migratory birds visiting and non-visiting wetlands of Savar. Bangladesh J. Environ. Res., 8: 31-38.

Mondol, M. N., Asia, A., Chamon, A. S. and Faiz, S. M. A., 2017. Contamination of soil and plant by the Hazaribaghh tannery industries. J. Asiat. Soc. Bangladesh, Sci. 43 (2): 207-222.

Nishat A., Shamim P., Faisal I., Junaid J. 2001. "Industrial Pollution." In *Bangladesh Environmental OutLook*, by M. Ullah, A.K.E. Haque (Eds) A. Nishat. Dhaka: Centre for Sustainable Development.

Nuruzzaman, M., Gerzabek, M.H. and Ullah, S.M., 1995. Studies on heavy metal and microbiological pollution of soils, sediments and water systems in and around Dhaka City. Berichtan die Österr. Akademieder Wissenschaften, ÖFZS. 123 – 321.

Panda R.C., Rai C. L., Sivakumar V., Mandal A. B., 2012. "Odour Removal in Leather Tannery." *Advances in Chemical Engineering and Science* 2, 199-203.

Panda SK, Khan M. H., 2003. Antioxidant efficiency in rice (Oryza sativa L.) under heavy metal toxicity. J. Plant Biol. 30:23-29.

Ponnamperuma, F. N. N., 1985. Chemical kinetics of wet land rice soils relative to soil fertility. In wetland soils: Characterizations, Classification and Agriculture, IRRI, Philipine.

Pramanik, B. K. and Sarker, P. C., 2013. Evaluation of surface water quality of the Buriganga River. Journal of Water Reuse and Desalination, Vol. 3.2

Rahman S. and Hossain, F., 2008. Spatial assessment of water quality in peripheral rivers of Dhaka City for optimal relocation of water intake point. Water Resour Manage 22:377–391.

Rahman, K., 1992. Industrial pollution and control for sustainable development. Training manual on environmental management in Bangladesh. Department of Environment, pp. 184-206.

Rudnick, R. L. and Gao, S., 2003. Composition of the continental crust. Treatise Geochem. 3: 1-64.

Sarkar, M. A. R., 2013. Prospects and Challenges of Industrialization in Bangladesh, PP. 1-5. http://bea-bd.org/site/images/pdf/078.pdf.

Sawyer, C.N., McCarty, P.L. and Parkin, G.F., 2003. Chemistry for Environmental Engineering and Science, 5th ed., McGraw-Hill, New York. Stanitski, C.L., Eubanks, L.P., Middlecamp, C.H.

Sneddon, C., 2018; Chromium and its negative effects on the environment; available at https://serc.carleton.edu/NAGTWorkshops/health/case_studies/chromium.html, last accessed 9th June, 2018.

Sohel M.S.I., Mukul S.A, Burkhard B., 2015. Landscape's capacities to supply ecosystem services in Bangladesh: A mapping assessment for Lawachara National Park. Ecosystem Services 12, 128–135.

Soil Survey Manual, 2016. Soil Science Division Staff, United States Deparment of Agriculture. Handbook No. 18.

Solomon, F., 2006. *Impacts of Metals on Aquatic Ecosystems and Human Health*; MINING.com, 2006.

Srivastava RK and Sinha AK., 1996. Water quality of the river Gangaat Phaphamau (Allahabad): Effect of mass bathing during Mahakumb, Envtal. Toxi. Water Quality 11(1): 1-5.

Sundar, V. J., Ramesh, R., Rao, P. S., Saravanan, p., Sridharnath, B. and Muralidharan, C., 2000. Water management in leather industry. *Jour. Sci. Indus. Res.* 60: 443-450.

Tabata M, Ghaffar A, Eto Y, Nishimoto J and Yamamoto K., 2007. Distribution of heavy metals in interstitial waters and sediments at different site in Ariake bay, Japan, E-Water 5: 1-24.

Tinni, S. H.; Islam, M. A.; Fatima, K. and Ali, M. A., 2014. Impact of Tanneries Waste Disposal on Environment in Some Selected Areas of Dhaka City Corporation. J. Environ. Sci. & Natural Resources, 7(1): 149 –156, 2014, ISSN 1999-7361.

Turekian, K. K. and Wedepohl, K. H., 1961. Distribution of the elements in some major units of the earth’s crust. Geo.l Soci. America Bullet. 72:175-192.

Ullah, S. M., M.H. Gerzabek, M.N. Mondol, M.M. Rashid and M. Islam., 1999. Heavy metal pollution of soils and water and their transfer into plants in Bangladesh. In. Proc. of extended Abstracts. 5th International Conference on the Biogeochemistry of Trace Elements (Wenzel, W. W., D.C.

UNIDO (United Nations Industrial Development Organization), 2005. Cost of Tanned Waste Treatment. 15th Session of the Leather and Leather Products Industry Panel. Leon. Mexicom, 17-18.

Weil, R.R. and Brady, N.C., 2016. The nature and properties of soil (15th Ed.). Pearson publication, New York.

Yarsan and Saleh, 2013. The Important Terms of Marine Pollution “Biomarkers and Biomonitoring, Bioaccumulation, Bioconcentration, Biomagnification”. Yarsan and Yipel, J Mol Biomark Diagn 2013, S1 http://dx.doi.org/10.4172/2155-9929.S1-003.

Ying D., Chuanyu C., Bin H., Yueen X., Xuejuan Z., Yingxu C., Weixiang W., 2012. "Characterization and control of odorous gases at a landfill site: A case study." *Waste Management, 32 (2012) ELSEVIER* 317–326.

Zahid, A., 2017. Impact of Tanneries on Groundwater Environment of Dhaka City. LAP LAMBERT Academic Publishing, OmniScriptum GmbH & Co. KG, Bahnhofstrape 28, 66111 Saarbrucken, Germany.

Zhang, M and Zhang, M., 2006. Assessing the impact of leather industry to water quality in the Aojing watershed in Zhejingprovice, China. *Environ. Moni. and Assess.*115:321-333.

Appendix A: Reconnaissance Field Visit

General Overview

An appropriate methodology is the utmost priority of a quality research and reconnaissance field visit is the backbone of developing a good methodology of the study. Having this sense, this study conducted a reconnaissance field visit in both the study areas of Hazaribagh and Savar Tannery Estate on 18th April 2018. A total of five professionals from CEGIS having different academic background visited the places. During the visit, study members mainly focused on geographical settings of the area especially physical environments, tannery industrial units, CETP, solid waste disposal yard and the management approaches. A number of issues were observed that will be considered in this study. The issues identified so far are given bellow-

- Kutcha[2] road network inside the new Tannery Estate;
- Low capacity of pipeline drainage system in carrying chromium mixed water;
- Open drainage system for domestic water (water except hide and skin wash)
- Waterlogged roads;
- Solid waste mixed water in mud roads;
- Tannery solid waste transportation by local van (open condition);
- Roadside storage of tannery solid waste;
- Open solid waste dumping;
- Partial functional CETP status;
- Untreated effluent release into solid waste dumping site;
- Solid waste mixed untreated effluent draining into Dhaleshwari River;
- Domestic water discharge into Dhaleshwari using pipe;
- Unhygienic working environment in most of the tannery especially in washing and processing unit;
- Chronic Odor in the air;
- Black color of Dhaleshwari River water;

Observing these issues at new Tannery Estate, study team selected indicators to evaluate the physical, biological and social environment that might be affected by tanneries wastes directly and/or indirectly. Under these three different aspects, numerous variables will be analyzed by selecting quantitative and qualitative indicators. The details of each indicator to be evaluated are discussed in the section of 2.2 Environmental and Social Baseline (Chapter: Approach & Methodology).

[2]A *kutcha road* is a dirt track made by mud. Sometimes it is mixer of mud and sand.

The study team has portrayed the baseline settings of different components in a more generic view in the following sections.

Pollutions Sources, Treatment Facilities and Disposal Points

During the reconnaissance field visit, the study team observed the physical features as well as the tannery and CETP operating systems of tannery estate especially Savar Tannery Estate. As we all know that Hazaribagh Tannery Estate has been shut down in respect of production of finished leather and leather goods, therefore there is no direct polluting sources from tannery at present. On the other hand, the main goal of shifting tannery estate from Hazaribagh to Savar has not been fulfilled so far due to a number of reasons.

At the very **first**, within the timeframe, most of the tanneries failed to complete physical infrastructure. However, somehow, these industries have started productions and therefore, management of leather products are not in good shape. For instance, drying of leather is done here and thereof the Tannery Estate. The **second** thing is that pipeline connection from tanneries to CETP is not sufficient to carry all the effluents to CETP. Therefore, effluents overflow and is mixed with domestic open network which finally pollutes tannery environment especially roads. The **third** issue has been found is the transportation of tannery solid waste outside the tannery for selling and for dumping into disposal yard. In both the cases, tannery owners use open local van due to which few portions falls on the roads and get mixed with water. Later, it increases the bad Odor. In the disposal yard, the dumping site is completely open and mixed with effluents.

Fourthly, the CETP is not functional fully due to saline water coming from the washing of raw hide and skin in tannery. Saline water treatment facility was not in the design of CETP. Therefore, effluents from CETP are being released at night directly to solid waste disposal yard due to low efficiency of CETP. This creates very bad smell in the air by rotten leather. **Lastly**, these solid mixed effluents are being released into Dhaleshwari River directly through cutting the earthen barricade of disposal yard. Moreover, there is high chance of leaching heavy metals (Cr) and other pollutants into Dhaleshwari and into groundwater. Domestic water is also released into Dhaleshwari River without any treatments.

Having all these issues, Savar Tannery Estate, is running in full swing, which ultimately are increasing pressures on natural resources of the adjacent environment. Some photographs of the observed situation are presented in **Figure A.1**.

(a) Leather drying in field

(b) Open drainage

(c) Open manhole

(d) Waste disposal yard

(e) Effluent in disposal yard

(f) Liquid mixed solid waste

(g) Domestic water

(h) Discharge point

(i) Domestic water

Figure A.1: Photographs of Savar Tannery Estate and its Various Issues

Biological Resources

The tannery site is vegetated with very few undergrowth herbs like Cynodon, Amaranthus, Crotonetc those exist in scattered form. Ongoing construction activities, frequent vehicle movements and haphazard dumping of tannery waste are the main cause behind lower abundance of plant. River levees nearby the Tannery Estate are densely dominated with undergrowth plants and tall grasses like Polygonum, Xanthium, Crozophora, Cyperus, Croton, Enhydra, Veiver etc. Sludge dumping pond does not contain any flora while river water was observed to have scatter distribution of Water hyacinth. No big tree was observed within the BSCIC Tannery Estate.

Among the faunal communities, birds are the prime and Little Egret, Common Myna, Drungo, Sparrow which was observed within the riverside, waste dumping area and road sides of the Tannery Estate. No other terrestrial wild animal was found during the visit. No aquatic mammals were observed in river water surrounding the Tannery Estate due to highly deterioration of water quality.

The surrounding areas hold rare vegetation hence the urbanization is taking place. Usual homestead, crop field and riverine vegetation were found on the opposite bank of the Dhaleshwari River.

Figure A.2: Flora Composition and Avifaunal Community those are Commonly Observed during the Visit

The tannery industrial area is located beside the Dhaleshwari River, which serves as the major capture fish habitat for the surrounding area. The local people reported that there are more than 50 riverine fish species in the river system.It was found, however, that the habitat quality of river have become highly susceptible to heavy metal rich pollutants, which are, supposed to be mutagenic trace element for various riverine fish species (**Figure A.2**). About 125m breach of protective bank was observed at a place adjacent to the Solid Waste Disposal Station indicating that high Cr rich pollutant directly falls in to the river system.


Figure A.3: Proximity of Dhaleshwari River System to Heavy Metal Discharge

Socio-economic Set-up

Some positive and negative findings of the Hazaribagh and Savar Tannery Industries were observed during reconnaissance field visit. CETP has been set up to manage the liquid wastes centrally and to discharge the treated water to Dhaleshwari River considering systematic approach. In addition, according to the tannery industry owners' underground drainage network has been developed to manage liquid waste of the industries so that it cannot deteriorate the environment.

(a) Effluent Pumping Station

(b) Mechanized way to filter solidwaste from effluents

Figure A.4: Equipment Facilities in CETP

However, road network and extorting drainage network has not yet properly developed. In addition, CETP is not properly functioning due to fault in design and poor construction material as well. Solid waste is not properly managed that create unpleasant smell in the surrounding areas of the industries whereas a housing city (Jamjum Housing City) has been developed just beside the tannery industries. In addition, workers are not using Personal Protective Equipment (PPE) properly.

Appendix B: Matrix-Evaluation of Socio-Economic Status

Parameters	Issues	Problem	Way to assess impact	Data collection way
Human Health & Safety	Effect of chemical disposal	• Chemicals, metals and other substances (mentioned in physical environment: water quality section: Hemayetpur) that causes long term negative impact health degradation of workers and community; • Workers suffer different types of skin diseases frequently but they do not have proper medical facilities	• Identify excessive concentration of chemical over environmental standard and assessing its impact on human health through secondary information; • Identify workers way of taking medical facilities in skin diseases and general ailments	• Result of tests on primary data and literature review or interview with relevant experts; • RRA with workers
Labor & Working Condition	Using PPE and awareness	• Unsafe handling the chemicals causes skin diseases as well as long term negative health impacts	• Observation and discussion about working condition	• Field observation and RRA with workers
Drainage Congestion & Odor	backflow/overflow chemical containing water due to drainage congestion	• Severe Odor of chemicals and leather spreads out inside and surroundings of the industries • Skin diseases occurs due to moving/walking on that chemical containing water	• Identification of the causes of back flow/over flow of chemical containing water	• Field observation and RRA with workers
Employment & Acceptance of Neighbor	Employment status, Neighbors attitude towards workers	• Discrepancy arises in terms of enrollment, salary, work load distribution and so on; • Neighbors have negative attitudes on tannery workers	• Identification of workers availability and discrepancies by the discussion of workers; • Assessment of neighbors attitude towards tannery workers	• RRA with workers/and neighbors
Solid Waste Management	Disposal of solid wastes	• Open disposal of solid waste causes obnoxious Odor; • During monsoon, discharge of solid mixed liquid contaminates water quality of Dhaleshwari River	• Identification of the way of solid waste disposal and its negative impact in the surroundings	• RRA with workers and BSCIC Savar
Drinking Water	Lowering of drinking water table	• During dry period, water scaricity occurs for the shallow tube wells only	• Discussion with surrounding local communities	• RRA with local community

Appendix C: Available fish species in the Buriganga River

Sl. No.	Order	Family	Scientific Name	English Name	Local Name	IUCN Status, 2015
1	Synbranchiformes	Synbranchidae	*Monopterus cuchia*	Cuchia	Kuchia	VU
2	Beloniformes	Belonidae	*Xenentodon cancila*	Cancila	Kakila	LC
3	Osteoglossiformes	Notopteridae	*Notopterus notopterus*	Grey Featherback	Foli	VU
4	Cyprinodontiformes	Cyprinodontidae	*Aplocheilus panchax*	Blue Panchax	Techoukka	LC
5	Channiformes	Channidae	*Channa punctatus*	Spotted Snakehead	Taki/Lathi	LC
6			*Channa striatus*	Stripped Snakehead	Shole	LC
7			*Channa orientalis*	Asiatic Snakehead	Gozar	LC
8		Cyprinidae	*Labeo rohita*	Rohu	Rui	LC
9			*Labeo gonius*	Gonius	Gonia	NT
10			*Labeo calbasu*	Calbasu	Kalibaus	LC
11			*Catla catla*	Catla	Catla	LC
12			*Cirrhinus cirrhosus*	Mrigel	Mrigel	NT
13			*Cirrhinus reba*	Reba	Tatkini	NT
14			*Hypophthalmichthys molitrix*	Silver Carp	Silver Carp	DD
15			*Amblypharyngodon mola*	Mola Carplet	Mola	LC
16			*Osteobrama cotio*	Cotio	Chela	NT
17			*Puntius chola*	Swamp Barb	Chalapunti	LC
18			*Puntius sophore*	Spotfin Swamp Barb	Punti	LC
19			*Pethia conchonius*	Rosy Barb	Taka Punti	LC
20			*Pethia ticto*	Ticto Barb	Tit Punti	VU
21			*Rasbora daniconius*	Slender Rasbora	Darkina	EN
22		Cobitidae	*Botia dario*	Queen Loach	Rani	EN
23			*Botia lohachata*	Y-Loach	Rani	EN
24			*Lepidocephalichthys guntea*	Guntea Loach	Gutum	LC
25	Siluriformes	Claridae	*Clarias batrachus*	Walking Catfish	Magur	LC
26			*Rita rita*	Rita	Rita	EN
27		Bagridae	*Sperata aor*	Long Whiskered Catfish	Ayre	VU
28			*Mystus cavasius*	Gangetic Mystus	Golsha Tengra	NT
29			*Mystus tengara*	Tengara Mystus	Bujuri	LC
30			*Mystus vittatus*	Striped Dwarf Catfish	Tengra	LC
31		Siluridae	*Wallago attu*	Wallago	Boal	VU
32			*Ompok pabda*	Pabda Catfish	Madhu Pabda	EN

Sl. No.	Order	Family	Scientific Name	English Name	Local Name	IUCN Status, 2015
33		Heteropneustidae	*Heteropneustes fossilis*	Stringing Catfish	Shing	LC
34		Schilbeidae	*Ailia coila*	Gangetica ailia	Kajuli	LC
35			*Clupisoma Garua*	Garu Bacha	Gharua	EN
36			*Eutropiichthys vacha*	Vacha	Bacha	LC
37			*Silonia silonia*	Silond Catfish	Shilong	LC
38			*Pangasius pangasius*	Yellowtail Catfish	Pangas	EN
39		Sisoridae	*Conta conta*	Conta Catfish	Hara Macfish	NT
40			*Hara hara*	Moth Catfish	Kutakanti	LC
41			*Bagarius bagarius*	Gangetica goonch	Baghair	CR
42			*Gagata youssoufi*	Gang Tengra	Pathorchata	NT
43	Clupeiformes	Clupeidae	*Gudusia chapra*	Indian River Shad	Chapila	VU
44			*Tenualosa ilisha*	Hilsha Shad	Ilish	LC
45	Perciformes	Mastacembelidae	*Macrognathus aculeatus*	Lesser Spiny Eel	Tara Baim	NT
46			*Mastacembelus armatus*	Zig-zag Eel	Sal Baim	EN
47			*Macrognathus pancalus*	Barred Spiny Eel	Guchi Baim	LC
48		Cichlidae	*Oreochromis mossambicus*	Tilapia	Tilapia	DD
49		Anabantidae	*Anabas testudineas*	Climbing Bass	Koi	LC
50		Osphronemidae	*Ctenops nobilis*	Indian Gourami	Napit Khalisha	LC
51			*Colisa fasciata*	Banded Gourami	Khalisha	DD
52			*Colisa lalia*	Red Gourami	Lal Khalisha	DD
53		Gobidae	*Glossogobius giuris*	Tank Goby	Bele	LC
54		Ambassidae	*Pseudambassis lala*	High Fin Glassy Perchlet	Lal Chanda	LC
55			*Pseudambassis ranga*	Indian Glassy Fish	Chanda	LC
56			*Pseudambassis baculis*	Indian Glassy Fish	Chanda	NT

CR: Critically Endangered; EN: Endangered; VU: Vulnerable; NT: Not Threatened; LC: Least Concern and DD: Data Deficient

Source: M. A. Baki, et al., 2017

Appendix D: Major fish species in the Dhaleshawari river system

Species	Englishname	Local Name	Habitat	Local Abundance	IUCN Status, 2015
Xenentodon cancila	Freshwater garfish	Kakila	River	H	NO
Gudusia chapra	Indianrivershad	Chapila	River	M	NO
Amblypharyngodonmola	Molacarplet	Mola, Moa	River	M	NO
Catla catla	Catla	Catal, Catla	River, Pond	L	NO
Cirrhinusmrigala	Mrigal carp	Mrigel, Mirka	River, Pond	L	NO
Esomousdanricus	Flying barb	Darkina,Darka	River, Pond	H	DD
Labeo calbasu	Orange-finlabeo	Calbaus	River	M	EN
Labeo rohita	Roholabeo	Rui	River, Beel, Floodplain	H	NO
Puntius ticto	Ticto barb	Tit Puti		L	VU
Salmostomabacaila	Largerazorbellyminnow	Chela		H	NO
Salmostomaphulo	Finescale razorbelly minnow	Chela		H	NO
Lepidocephalusguntia	Guntea loach	Gutum		L	NO
Chanda lala	Highfinglassy perchlet	Choto chanda		M	NE
Chanda ranga	Indianglass-perchlet	Lal chanda		M	VU
Anabustestudineus	Climbingperch	Koi		L	NO
Channamarulius	Greatsnakehead	Gozar		M	EN
Channaorientalis	Walking snakehead	Cheng		M	VU
Channapunctata	Spotted snakehead	Taki		L	NO
Channa striata	Snakehead murrel	Shole		L	NO
Glossogobiusgiuris	Tank goby	Bele,Baila		M	NO
Rhinomugilcorsula	Corsulamullet	Ural, Korsula		L	NO
Colisafasciata	Banded gourami	Borokholisha		H	NO
Mystus aor	Longwhiskered catfish	Ayre	River	M	VU
Mystus cavasius	Gangetic mystus	Gulsa tengra	River, Beel	M	VU
Mystus seenghala	Giantriver catfish	Guizza ayre	River	H	EN
Mystus tengana	Tengaracatfish	Choto tengra	River, Beel, Floodplain	M	NO
Mystus vitatus	Strippeddwarfcatfish	Tengra		M	NO
Clariasbatrachus	Walking catfish	Magur	River, Beel, Floodplain	H	NO
Hateropneustesfossilis	Stinging catfish	Shing,Kanos		L	NO
Ailia coila	Gangetic alia	Baspata	River	H	NO
Clupisomagarua	Garuabacha	Ganggaira	River	M	CR
Eutropiichthysvacha	Batchwa vacha	Bacha	River	L	CR
Pseudeutropiusatherinoides	Potasi	Batashi	River	L	NO
Wallago attu	Freshwater shark	Boal	River, Beel	M	NO
Gagata cenia	Indian gagata	Jungla magur	River, Baor, Beel, Floodplain	L	NO
Macrognathusaculeatus	Lesser spinyeel	Tara baim		L	VU
Mastacembelusarmatus	Zig-zag eel	Sal baim , baim		M	EN
Mastacembeluspancalus	Barred spinyeel	Guchi		H	NO
Monopteruscuchia	Mudeel	Kuchia		M	VU
Notopteruschitala	Clownknifefish	Chital	River, Beel	M	EN
Notopterusnotopterus	Bronzefeatherback	Foli		H	VU
Tetraodon cutcutia	Ocellatedpufferfish	Potka		M	NO

CR: Critically Endangered; EN: Endangered; VU: Vulnerable; NT: Not Threatened; LC: Least Concern and DD: Data Deficient

Appendix E: Chemicals Used in Leather Processing

1. Beam house and Tan yard

Biocides
Biocides prevent the growth of bacteria which can damage the hides or skins during the soaking process

Surfactants
Surfactants are used to help with the wetting back of the hides or skins

Degreasers
Degreasers help with the removal of natural fats and greases from the hides or skins

Swell regulating agents
Swell regulating agents help prevent uneven swelling of the hides or skins during liming

Lime
Lime is used to swell the hides or skins

Sodium sulphide
Sodium sulphide chemically destroys the hair on hides or skins

Sodium hydrosulphide
Sodium hydrosulphide chemically destroys the hair on hides or skins. It does not create as much swelling as sodium sulphide

Low sulphide unhairing agents
Low sulphide unhairing agents help to reduce the amount of sulphides used in a tannery thus reducing the environmental impact of tanneries

Caustic soda
Caustic soda is used during the liming process to help swell the hides or skins

Soda ash
Soda ash is used during the soaking or liming processes to help raise the pH of the hides or skins

Ammonium sulphate
Ammonium sulphate is used during the deliming process and helps remove lime from the hides or skins

Ammonium chloride
Ammonium chloride is used during the deliming process and helps remove lime from the hides or skins

Sodium metabisulphite
Sodium metabisulphite is used during the deliming process and helps prevent the formation of toxic hydrogen sulphide gas during deliming. It also acts as a bleaching agent

Formic acid
Formic acid is used during the pickling process to lower the pH of the hides or skins

Sulphuric acid
Sulphuric acid is used during the pickling process to lower the pH of the hides or skins

Salt
Salt is used during the pickling process to prevent acid swelling of the hides or skins

Sodium formate
Sodium formate is used during the tanning process to assist with the penetration of chromium tanning salts into the hides or skins

Chromium sulphate
Chromium sulphate is the tanning agent used to make wet blue

Aldehyde tanning agents
Aldehydes are tanning agents used to make wet white

Magnesium oxide
Magnesium oxide is used during basification and raises the pH of the hide or skin to allow the chromium or aldehyde to chemically bind to the skin protein

Fungicide
Fungicides are chemicals that are used to prevent the growth of moulds or fungi on tanned hides or skins

2. Dyehouse

Surfactants / Wetting agents
Surfactants help in the wetting back of the wet blue in the dyehouse

Degreasers
Degreasers help remove grease or fats that may be present on the wet blue as a result of the wet blue coming into contact with machinery

Sodium formate
Sodium formate helps raise the pH during the neutralization process

Sodium bicarbonate
Sodium bicarbonate helps raise the pH during the neutralization process

Formic acid
Formic acid reduces the pH for the rechroming process or helps with chemically fixing dyehouse chemicals to the leather at the end of the dyehouse processes

Chrome syntans
Chrome syntans are used during rechroming to improve the softness of the final leathet

Chromium sulphate
Chromium sulphate is used during rechroming to improve the softness of the final leather

Syntans
Syntans are used to give properties such as softness, fullness, roundness to the leather

Resins
Resins are used to give fullness and a tight grain to the leather

Polymers
Polymers are used to give fullness and a tight grain to the leather

Dyes
Dyes are used to give the leather a colour desired by the customer

Dyeing auxiliaries
Dyeing auxiliaries help disperse the dyes evenly

Fatliquors
Fatliquors are oils that are added to leather to give softness to the final leather

3. Finishing

Acrylic resins
Acrylic resins give specific properties to the leather finish such as adhesion, water resistance

Butadiene resins
Butadiene resins give specific properties to the leather finish such as good coverage

Polyurethane resins
Polyurethane resins give specific properties to the leather finish such as good toughness and good lightfastness

Fillers
Fillers help fill small blemishes on the leather surface

Dullers
Dullers help reduce the gloss of the finish

Crosslinkers
Crosslinkers are used to toughen the leather finish and improve the water resistance properties of polyurethanes

Handle modifiers
Handle modifiers are used to give the leather surface a waxy or slippery feel

Nitrocellulose lacquers
Nitrocellulose lacquers are used in the top coat of a leather finish

Acrylic lacquers
Acrylic lacquers are used in the top coat of a leather finish

Polyurethane lacquers
Polyurethane lacquers are used in the top coat of a leather finish

Viscosity modifiers
Viscosity modifiers are used to increase the viscosity of a finish mixture

Pigments
Pigments are colouring agents that help hide defects on the leather surface

Dyes
Dyes are colouring agents that are used to slightly change the colour of the leather finish or to give the leather finish a more natural look

Defoamers
Defoamers are used to prevent bubbles from forming in the finish mixture

Appendix F: ES scoring matrix of Hemayetpur Tannery area

Year	Land-use/cover	Supporting services	Biodiversity	Habitat quality	Provisioning services	Fish production	Agricultural crops	Surface water supply	Regulating services	Water purification	Air Quality regulation
	Baor	3.50	3	4	3.67	4	3	4	2.00	4	0
	Brickfield	0.00	0	0	0.00	0	0	0	0.00	0	0
2000	Cultivated Trees	3.00	3	3	0.00	0	0	0	1.50	0	3
	Multiple Crop	3.50	3	4	1.33	0	4	0	1.00	0	2
	Rivers and Khals	4.00	4	4	3.67	4	2	5	1.50	3	0
	Rural Settlement	3.00	3	3	0.33	0	1	0	0.00	0	0
	Baor	3.50	3	4	3.67	4	3	4	2.00	4	0
	Brickfield	0.00	0	0	0.00	0	0	0	0.00	0	0
	Built-Up Non-Linear	1.50	2	1	0.00	0	0	0	0.00	0	0
2015	Cultivated Trees	4.00	4	4	0.00	0	0	0	2.00	0	4
	Multiple Crop	2.50	2	3	1.00	0	3	0	0.50	0	1
	Perennial Beels/Haors	4.50	4	5	3.33	5	0	5	2.50	5	0
	Rivers and Khals	4.00	4	4	3.67	4	2	5	1.00	2	0
	Rural Settlements	2.00	2	2	0.33	0	1	0	0.00	0	0
	Baor	3.50	3	4	2.67	3	2	3	2.00	4	0
	Brickfield	0.00	0	0	0.00	0	0	0	0.00	0	0

Year	Land-use/cover	Supporting services	Biodiversity	Habitat quality	Provisioning services	Fish production	Agricultural crops	Surface water supply	Regulating services	Water purification	Air Quality regulation
	Built-Up Non-Linear	1.00	1	1	0.00	0	0	0	0.00	0	0
2018	Cultivated Trees	4.00	4	4	0.00	0	0	0	2.00	0	4
	Multiple Crop	2.50	2	3	0.67	0	2	0	0.50	0	1
	Perennial Beels/Haors	3.50	3	4	2.00	3	0	3	1.50	3	0
	Rivers and Khals	2.50	2	3	2.33	2	2	3	0.50	1	0
	Rural Settlements	2.00	2	2	0.33	0	1	0	0.00	0	0
	Hemayetpur Tannery	0.00	0	0	0.00	0	0	0	0.00	0	0

Appendix G: Environmental and Social Monitoring Plan

Focus/Objects	Indicators/Parameters	Methods	Frequency	Responsible Organizations/Institutes
Water Quality of Dhaleshwari River and CETP treated effluents	○ Physical parameters: Watercolor, pH, DO, TDS, TSS and Salinity. ○ Non-ionic constitutes COD and BOD_5 at 20ºC. ○ Chemical parameters: Nitrate, Phosphate, NH_3 and Sulphate. ○ Metals: Chromium, Aluminum, and Lead.	In-situ test methods for physical quality assessment by handheld devices. Chemicals and metal samples will be collected from the pre-defined sampling points following standard sample collection and preservation methods (APHA Guidelines). Accredited laboratory of Bangladesh (DPHE/BCSIR/DoE/BUET) will be used to test the collected samples timely.	Quarterly	DoE/BSCIC Savar/Third party (CEGIS/Dhaka University/BUET etc.)
Water Quality performance monitoring of CETP	○ Physical parameters: Watercolor, pH, DO, TDS, TSS and Salinity. ○ Non-ionic constitutes COD and BOD_5 at 20ºC. ○ Chemical parameters: Nitrate, Phosphate, NH_3 and Sulphate. ○ Metals: Chromium, Aluminum, and Lead.	Sample collection and testing at the laboratory (DPHE/BCSIR/DoE/BUET/Dhaka University).	Monthly	DoE/BSCIC Savar/Third party (DPHE/CEGIS/Dhaka University/BUET etc.)
Soil Quality	○ Physical parameters: Salinity and EC; ○ Heavy metals: Chromium, Lead and Zinc;	In-situ test methods will be followed with appropriate handheld soil quality monitoring devices. Collection of soil samples from the predefined sampling points by Augur followed by laboratory test in Soil Resource Development Institute (SRDI).	Half yearly	DoE/SRDI/Third party (CEGIS/BUET/Dhaka University etc.)
Air Quality and Noise quality	○ VOCs, H_2S and NH_3	In the tannery estate and surrounding communities for at least 24 hours.	Quarterly	DoE/BSCIC/Third party (CEGIS/BUET)
Floral and Faunal (terrestrial and aquatic) status	Occurrence of Dolphin in river system.	Physical observation and quadrate sampling method for monitoring of floral status.	Half yearly	DoE/Academic Institutes/ Third party (CEGIS/BSCIC Savar etc.)

Focus/Objects	Indicators/Parameters	Methods	Frequency	Responsible Organizations/Institutes
		Faunal status will be monitored through indirect sampling of walk transects and desktop transects.		
	Cr bioaccumulation in plant body			
Fishery resources	○ Habitat Condition and Quality: Mentioned in water quality section; ○ Habitat Use by Fish: Breeding, Spawning, Nursing and Feeding; ○ Fish Diversity;	Length-based Catch Assessment Method for understanding habitat use and fish diversity;	Quarterly	DoE/Third party (CEGIS etc.)
	Bioaccumulation of Chromium in Fish Muscle, Gut and Kidney.	Fish muscles, gut and kidney will be collected, preserved and then measured heavy metals by Centre for Advanced Research in Science (CARS).	Annually	DoE/CEGIS/Dhaka University
Agriculture resources	Cr bioaccumulation in crop field vegetation and fruit trees.	Laboratory analysis following standard methods of measuring Cr.	Half yearly	DoE/BARI/ Third party (CEGIS /Dhaka University/Sher-E-Bangla Agriculture University etc.).
	Yield status of surrounding areas crops.	Yearly production rate in a given unit area of staple crops.	Seasonally	DoE/BARI/ Third party (CEGIS /Dhaka University/Sher-E-Bangla Agriculture University etc.).
Social aspects	Occupational health and safety	Discussion with the workers and the surrounding community. Physical observation regarding status of skin diseases, headache and vomiting among labors, staffs and surrounding communities.	Half yearly	ICDDR,B/ UNICEF/ BSCIC Savar/Local Government Institutes (LGI)/ DoE/Third Party (CEGIS, BDHS).
	Standard of living especially focusing on Drainage congestion, Drinking water quality and Housing materials (tin/iron sheet etc.).	Discussion with the workers and the surrounding community. Physical observation of the infrastructure.	Half yearly	ICDDR,B/ UNICEF/ BSCIC Savar/Local Government Institutes (LGI)/ DoE/Third Party (CEGIS, BDHS).
Livelihoods	Change in occupation	Consultation and discussion with local community.	Half yearly	BSCIC Savar/Local Government Institutes (LGI)/ DoE/Third Party (CEGIS, BDHS).