HASDEO BASIN

A Situation Analysis in the Context of Environmental Flows

Neha Bhadbhade, Latha Anantha and
Shripad Dharmadhikary

Forum for Policy Dialogue on Water Conflicts in India

HASDEO BASIN

A Situation Analysis in the Context of Environmental Flows

Neha Bhadbhade, Latha Anantha, Shripad Dharmadhikary.

FORUM FOR POLICY DIALOGUE ON
WATER CONFLICTS IN INDIA

Hasdeo Basin: A Situation Analysis in the Context of Environmental flows

Authors: Neha Bhadbhade, Latha Anantha and Shripad Dharmadhikary

Supported by: Arghyam, Benguluru, India

Layout: Rohan Jhunja

Cover Photograph: Shripad Dharmadhikary

Cover Design + Print: Mudra, 383 Narayan Peth, Pune 411 002

Published by: Forum for Policy Dialogue on Water Conflicts in India, Pune
c/o Society for Promoting Participative Ecosystem Management (SOPPECOM)
16, Kale Park, Someshwarwadi Road,
Pashan, Pune 411 008
Maharashtra, India
Tel: +91-20-2025 1168 / 2588 6542
Fax: +91-020-2588 6542
Email: waterconflictforum@gmail.com
URL: waterconflictforum.org ; conflicts.indiawaterportal.org

Copies are available at the above address

First published in June 2017

Citation: Bhadbhade. N., Anantha. L. and Dharmadhikary. S. (2017). *Hasdeo Basin: A Situation Analysis in the Context of Environmental Flows.* Forum for Policy Dialogue on Water Conflicts in India, Pune

Contributory Price: Rs. 200/-

Contents

List of Tables

List of Figures

List of Acronyms

ACWADAM	Advanced Centre for Water Resources Development and Management
BALCO	Bharat Aluminium Company Limited
BOD	Biological Oxygen Demand
BIS	Bureau of Indian Standards
CBD	Conventional on Biological Diversity
CECB	Chhattishgarh Environment Conservation Board
CEPI	Comprehensive Environment Pollution Index
CIFRI	Central Inland Fisheries Institute
COD	Chemical Oxygen Demand
CPA	Critically Polluted Area
CPCB	Central Pollution Control Board
CSEB	Chhattisgarh State Electricity Board
CWC	Central Water Commission
DO	Dissolved oxygen
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
ETP	Effluent Treatment Plant
IIT	Indian Institute of Technology
ISRO	Indian Space Research Organisation
MBPL	Madhya Bharat Paper Mill
MOEFCC	Ministry of Environment and Forests and Climate Change
MSL	Mean Sea Level
NRSC	National Remote Sensing Centre
NTPC	National Thermal Power Corporation
NTU	Nephelometric Turbidity Unit
PIL	Prakash Industries Ltd
TDS	Total Dissolved Solids
TPP	Thermal Power Plants
VOC	Volatile Organic Compounds
WQAA	Water Quality Assessment Authority

Foreword and Acknowledgement

The Forum for Policy Dialogue on Water Conflicts in India (Forum in brief) has recently completed its third phase of work. During the third phase of the Forum, one of the thematic activities taken up was "Evolving criteria and institutional framework for environmental flows in India". Water for sustaining and regenerating ecosystems seems to be the last priority in water use. Yet, our future will depend on how well we protect the ability of our ecosystems to provide us with all the water related eco-services that we need, especially, in respect of basic needs which requires water of sufficient quantity as well as quality on a sustainable basis. Thus, through this thematic activity an attempt was made to develop a framework based on important indicators and criteria that are necessary for allocation of water for sustaining the eco-services of river based on multi-stakeholder process.

The Hasdeo basin was chosen for the study for many reasons. Firstly, the Hasdeo basin is part of the Mahanadi basin, where the Forum has had a long interaction with the stakeholders through its action research in the previous phases. Secondly, there are a number of interventions on the Hasdeo in form of dams, barrages and anicuts, which have significantly modified the flows of the Hasdeo. Thirdly, the Hasdeo basin is heavily industrialised with major thermal and steel plants utilizing large amount of water in turn polluting the Hasdeo with their effluents. The upper catchment of the basin of has a number of coal mines that are a threat to the health of the basin. Lastly, a number of livelihoods depending on the Hasdeo like the fishing and riverbed farming have been affected due to the regulated flows in the river.

Through this report we have presented a situation analysis of the Hasdeo basin in the context of environmental flows. The publication is an attempt to briefly profile the basin in terms of key parameters like physiology, geology, hydrogeology, demography, land use and land cover, hydrology, ecology and biodiversity, large scale human interventions and its impacts on riparian ecosystems and livelihoods. From the feedback and request of the stakeholders in the basin, water quality testing was also carried out in the June and November 2016 to understand the status the water quality, which has been included in detail.

We have primarily used existing literature and secondary data to prepare this report. Important insights on the critical issues in the basin were drawn from field interviews with the stakeholder and riparian communities. Various government offices provided us valuable secondary data regarding the basin. We thank all the concerned officers for the support and co-operation. A number of individuals have helped us in shaping this report. We would firstly like to thank Laxmi Chauhan and Manish Rathod who have helped us tirelessly with the field work in gathering information and conducting field interviews with riparian communities and also conducting water quality tests. We would like to thank Satyprakash Jaiswal for collecting secondary data for this study and Alok Shukla and Ramlal Kariyam for providing us with useful information on the Hasdeo Aranya forest and also giving us the tour of the mining areas in the upper catchment of the forest. We would like to thank all the people in the basin who cooperated with us during the field interviews and provided us with the information for this report.

Similarly we also thank all the participants of the various stakeholder meetings, which we organised from time to time, for their critical feedback and also for providing valuable information insights about the basin and its issues.

We would like thank our other team members Partha Jyoti Das and Gorky Chakroborty for their contributions in this study. We would like to specially acknowledge the work and efforts put in by our interns towards the completion of this report. We would like to thank Prerna Prasad compiling the basic information about the basin, Shridhar for compiling detailed information on the human interventions in the Hasdeo basin, Seema Ravandale for carrying out detailed literature review on the secondary data available on the water quality and also carrying out the water quality tests in June 2016 and Nandini Upadhyay for her contribution in the hydrological analysis and GIS work in creating the basin maps.

We would like to thank the SOPPECOM team K.J.Joy, Pratima Medhekar, Sarita Bhagat, Craig Dsouza and Tanaji Nikam for their support and cooperation.

We would like to acknowledge the financial support and encouragement provided by Arghyam Trust, Bengaluru. We are also thankful to the Steering Committee members of the Forum for the insights and inputs that they provided during the various review meetings.

We thank Neeta Deshpande for the copy-editing, Rohan Jhunja for layout and Mudra for the production of the report.

Forum for Policy Dialogue on Water Conflicts in India

Pune, June 2017

Chapter 1

Environmental Flows

Unfolding the Concept

Background

From source to mouth, rivers perform physical, chemical and biological functions that sustain a number of ecosystems. Flow is the most important criteria to determine the river health index. About 40% of all the global rivers today are obstructed by large dams and about one-third of the sediment which is supposed to flow to the coastal plains does not reach due to these interceptions (CBD, 2010). Deforestation of the catchments, incorrect land use in the catchments for agriculture and infrastructure, dams and diversions for hydropower and irrigation, sand mining and over extraction of surface and groundwater are the main reasons for the distressing state of our rivers. Pollution has severely affected the quality of surface flows as well as that of groundwater. Among these, dams remain without doubt the most direct and significant modifiers of river flows and are responsible for the fragmentation of the river and damage to its ecology and morphology.

India is the world's third largest dam builder with more than 5100 large dams built to date (CWC, 2016). The timing, frequency, duration and magnitude of flows below the dam are decided by the operational pattern of the power project. The operation of a hydropower dam can be peaking or base load and can fluctuate between the two on a daily basis based on the power requirement and operational design of the project. In the case of dam cascades, it is found that the flow fluctuation at the lowermost dam in the series decides the fate of the river downstream. In case of dam cascades which are run-of-river projects, the river flow is diverted through tunnels leaving intermediate sections of the river completely dry.

Inland fisheries have experienced a direct setback because of large dams that restrict natural flow. According to the Central Inland Fisheries Institute (CIFRI), drastic modifications in the flow regimes and large abstractions have affected most fish species, especially carps which prefer flowing water. Larger dams are a major cause of degradation of the aquatic environment and disruption of communities dependent upon fishing. In India, natural flow of all major rivers have been regulated for fulfilling the demand for water of the agriculture and power sector, without paying any attention to the fisheries sector. As a result, rivers have lost their character and fisheries have suffered huge losses. (Dandekar, 2012)

Before 2007, the environmental clearances for river valley projects were given without taking into consideration the need for environmental flows (e-flows). As of now, the Ministry of Environment and Forests and Climate Change (MoEFCC) has started considering e-flows assessment as a part of Environmental Impact Assessment (EIA) studies and has made e-flows allocation mandatory for environmental clearances for river valley projects in India. A number of institutions have attempted to evaluate e-flows in the Himalayan and Eastern Himalayan river basins. However, most of these studies have shown a poor scientific understanding of the concept of e-flows and methodologies which downsize the water for ecosystem needs and therefore have arrived at values that are much lower than the flows required to meet the ecological needs of the river. Especially in the Indian context, the evaluation of e-flows is complex because the dependence on the river is not just for biological and social needs but also cultural and religious needs. It is therefore imperative to understand the concept of e-flows before it is applied to Indian rivers.

What are e-flows?

There are several interpretations of the concept of e-flows. Every river has its natural flow pattern which varies temporally and spatially. According to the Brisbane Declaration, e-flows are defined as the 'quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems' (International Water Centre, 2007). According to Dyson (2003) "environmental flows are defined as the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits, where there are competing water uses and where flows are regulated."

In the Indian context, the river needs to be maintained such that it is possible for the river to sustain riparian habitat, supply sediments and nutrients, recharge groundwater, support livelihoods, prevent saline intrusion and also provide for the cultural and spiritual needs of the people (Iyer, 2005).

It is of utmost importance to acknowledge that e-flows are eventually a compromise. Maintaining the river regime at a desired state is ultimately the decision of society. Maintaining rivers in a near pristine condition is difficult. However, with proper river basin management and policy interventions, it is definitely possible to maintain our rivers and streams such that they will benefit all.

Overview of assessment of e-flows

Over a couple of decades, more than 200 methods have been developed to evaluate e-flows (Tharme, 2003). Three important terms must be kept in mind when evaluating e-flows — 'method', 'approach' and 'framework'. Environmental flow assessment 'method' deals with specific assessment of only ecological requirements. An 'approach' is a way of deriving e-flows with the help of expert teams, and 'framework' refers to designing a broader strategy for e-flow assessment of flow management (Dyson, 2003). Before application of any methodology, it is important to remember the following key points (O'Keefe & Le Quesne, 2009) ,

1. The flow regime should take into account all types of flows, i.e. wet season, dry season, flood and drought flows.
2. There is no one correct method, approach or framework for evaluating e-flows. The approach will depend on what people desire from the river.
3. Environmental flows are not minimum flows.
4. Evaluation of environmental flows may not necessarily mean increase of flows in the river.
5. Environmental flow assessment is an adaptive process.
6. The choice of the approach and methodology would depend on the needs of the people, the urgency of the problem, the importance of the river, the type of the river, the needs met by the river since urban rivers would require a different approach, and criteria compared to rivers flowing through rural landscapes, and also data availability and resources.

7. Implementation is always a greater challenge than assessment. Even if environmental flows are implemented they can achieve their objectives only if other human activities like constructions of cascading hydropower projects, landuse and effluent disposal are stringently regulated.
8. Ultimately environmental flow assessment is both a scientific and a social process. It is important to educate the local people as to why the flows in the river are important, which should be done through proper river basin planning and management practices with a futuristic view.

Environmental flow assessment techniques that are used most commonly across the world are summarised in Table 1.1

Table 1.1: Summary of E-flow assessment methods, approaches and frameworks

Method	Approach	Framework
Look Up Tables	Functional Analysis	In-stream Flow Incremental Methodology (IFIM)
Hydrological Index (Desktop) Method	Building Block Methodology (BBM)	Downstream Response to Imposed Flow Transformation (DRIFT)
Hydraulic Rating Method		Catchment Abstraction Management Strategies (CAMS)
Habitat Simulation Method		

Source: Dyson, 2003

Environmental flow assessment in Hasdeo sub-basin

Currently, in India, environmental flow assessment is mandatory for obtaining environmental clearance for only new hydropower projects. But there is a necessity to derive e-flows also for rivers on which hydropower projects are already functional and for rivers which have no dams but are used extensively by humans for other purposes like industries, sand mining, fisheries, etc. During the third phase of the Forum, one of the thematic activities that was taken up was “Evolving criteria and institutional framework for environmental flows in India”. The study was an attempt to develop a framework based on important indicators and criteria that are necessary for allocation of environmental flows based on multi-stakeholder process. The Hasdeo sub-basin, which is a part of the Mahanadi basin, was selected for this thematic activity. The criteria for selecting the Hasdeo sub-basin are as below:

1. Water infrastructures like dams, barrages and anicuts on the river and its tributaries are present.
2. The basin is heavily industrialised with the presence of very large coals mines and thermal power plants.
3. The livelihoods of those dependent on the river have been affected.

Sites within the Hasdeo sub-basin selected for e-flow assessment

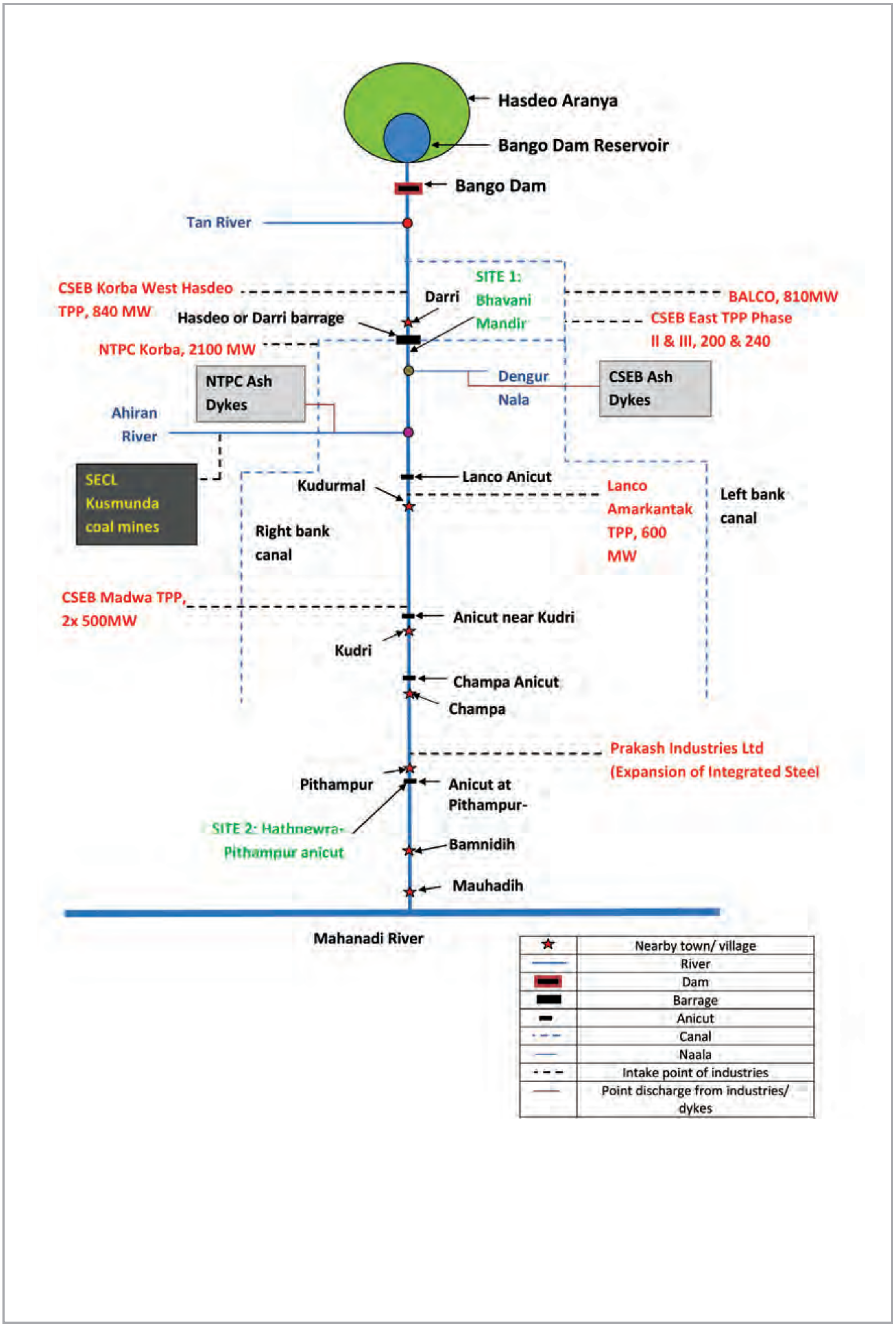
Since dams are direct modifiers of flows, it is important to assess e-flows and the downstream impacts. The major water infrastructures on the Hasdeo river are the Minimata Bango dam and the Hasdeo barrage. Two sites were selected to understand the downstream impacts of regulated flows on the Hasdeo river. Sites 1 and 2 are shown in Figure 1.1 .The first site is located at the immediate downstream of the Hasdeo barrage near Bhavani Mandir in Korba town. The flows recorded here were found to be extremely low. A small community of fishermen resides close to site 1. They fish in this stretch of the river for their livelihood and about half a kilometer downstream from the Hasdeo barrage people practice flood plain/riverbed cultivation. The second site selected is about 50 km downstream of the Hasdeo barrage near an anicut that connects Hathnerwa village (on the left bank) and Pithampur village (on the right bank). As evident from Figure 1.1, there are large industries in and around both these sites of the river which serves as one of the major water sources of water for these industries. As mentioned before, there is a grave requirement for e-flows to be formulated for rivers in India that serve multiple purposes like fisheries, industries, mining, etc. and based on these, sites 1 and 2 were selected.

Scope of the report

Against this background, the scope of this report is to present a broad situation analysis of the Hasdeo basin. The detailed approach used for development of the criteria and indicators for assessment of environmental flows in the Hasdeo sub-basin will be presented in a separate publication titled "E - Flows in Indian Rivers: Methodologies, Issues, Indicators and Conditions- Learnings from Hasdeo Basin"

In this report for presenting the situation analysis of the Hasdeo sub-basin, Chapters 2 and 3 provide an overview of the physiographic, topographic, climatic, and geologic characteristics and information about the demographics and the landuse/landcover pattern within the basin. The basin hydrology is discussed in detail in Chapter 4, followed by a description of the floral and faunal ecology found within the basin in Chapter 5. Chapter 6 delves into the various livelihoods of the people. Chapter 7 discusses in depth the large scale human interventions with respect to dams, coal mines and industries in the basin. Chapter 8 presents the hydrological analysis based on the flow data available in the basin. In Chapter 9, the status of both surface and groundwater quality is presented based on the tests carried out in June and November 2016. In Chapter 10, the impacts of the coal mines, dams and industries on the livelihoods and the riparian eco-systems are described based on the interviews conducted during the field visits conducted in December 2015 and March 2016. Chapter 11 finally discusses the way forward on the insights gathered from the situation in the Hasdeo sub-basin.

Figure 1.1: Flow diagram of Hasdeo river from Minimata Bango dam until its confluence with the Mahanadi river

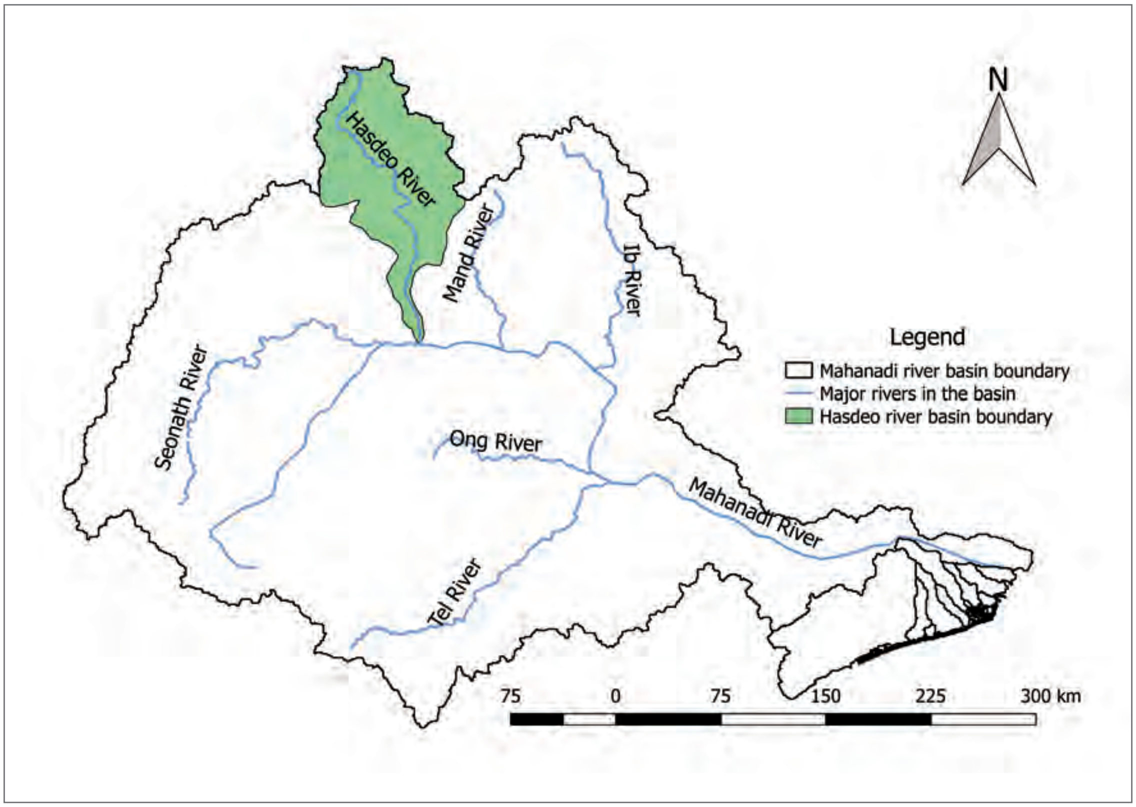


Chapter 2
Profile of the Hasdeo river basin

Background of the Mahanadi river basin

Mahanadi is one of the major peninsular rivers in East-Central India and has a total length of 858 km (CWC & NRCS, 2014). It flows through the states of Chhattisgarh and Odisha. The Mahanadi river basin is the eighth largest in the country having an area of 1,39,682 sq. km which constitutes 4.3% of the total area of the country (CWC & NRCS, 2014). The Mahanadi river basin is divided into three sub-basins: the upper, middle and lower. Sheonath, Hasdeo, Ong, Mand, Ib and Tel are the major tributaries of the Mahanadi. The upper Mahanadi basin is mainly drained by the Sheonath, Hasdeo, Mand; the Ib lies in the middle basin, and the Ong and Tel lie in the lower basin (CWC & NRCS, 2014).

Figure 2.1: Location of Hasdeo river basin within the Mahanadi river basin



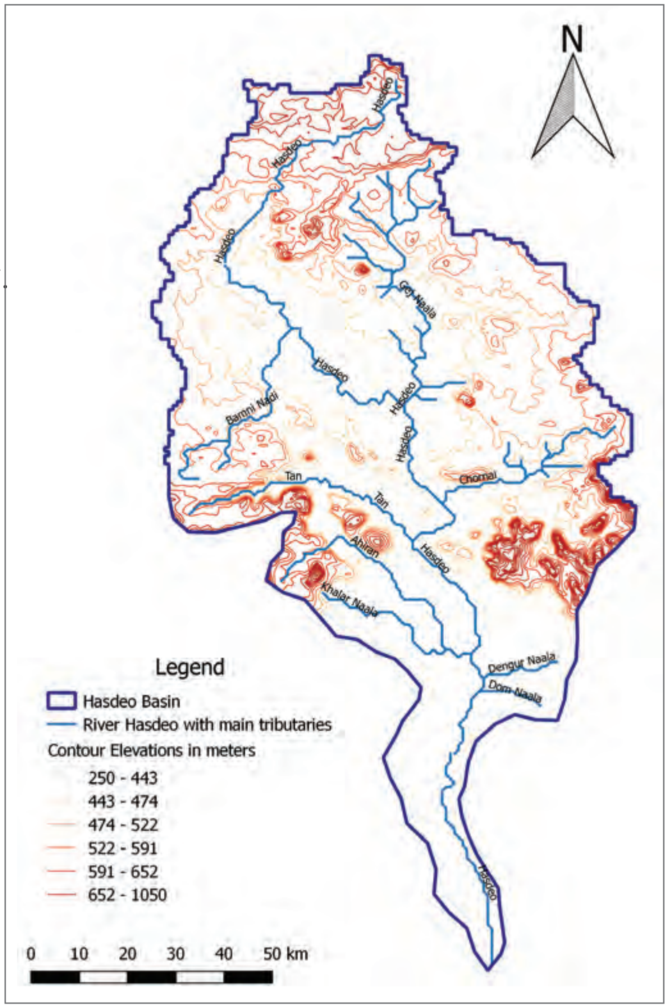
Hasdeo river basin profile

Physiographic and topographic characteristics

The Hasdeo river basin lies in the middle portion of the Mahanadi River basin as shown in Figure 2.1. The Hasdeo originates in Deogarh (1052 m above Mean Sea Level (MSL)) in Sonhat Taluka in the Koriya district of Chhattisgarh. It then flows through the Korba and Janjgir-Champa districts of Chhattisgarh before joining the Mahanadi at Mauhadih (Singh & Singh, 2010). The Hasdeo river basin covers the Koriya, Surguja, Korba and Janjgir-Champa districts. It contributes approximately 4.5 BCM of water to the Mahanadi. The total length of the Hasdeo is 333 km. The total area of the Hasdeo river basin is 10779 sq. km (Singh, 2013). Rivers Gej, Bamni and Chornai meet Hasdeo upstream of the Minimata Bango Dam, whereas Tan and Ahiran join downstream. Other than these major tributaries there are a number of large and small streams, locally called *naalas*, that join the Hasdeo along its course. The Hasdeo flows from north to south, and the basin is located between 21°45'N to 23°37'N latitude and 82°00' E to 83°04' E longitude.

The contour characteristics of the river basin are shown in Figure 2.2 (Singh, 2013). About 6% of the basin has a very high elevation which falls between 750 m to 1052 m above MSL. The lower elevations lie in the range of 142 m and 282 m above MSL, which falls under 10% of the area of the basin. Majority of the basin area, which is about 60% of the basin, lies between 423 m and 702 m above MSL.

Figure 2.2: Contour characteristics of Hasdeo basin



Climate and rainfall

The temperature in the river basin varies with the change in the topography and landuse. The upstream reaches of Hasdeo have good forest cover and therefore the temperature is lower than that in the downstream reaches. January is the coldest month with average maximum and minimum temperatures being 28.3°C and 13°C respectively. May is the hottest month with average maximum and minimum temperatures being 42.5°C and 26.3°C respectively. The annual rainfall in the basin is in the range of 1300-1500mm. The monsoon period is from June to October and 80% of the rainfall is received from June to August. The Chhattisgarh State Water Resources Department has a division called the 'Hydrology Project'. In the Hasdeo basin, the division has set up 14 rain gauge stations. Daily rainfall data from 2004–2013 was shared by the division, on request.

The maximum, mean and the annual rainfall for the 14 stations is summarised in Tables 2.1, 2.2 and 2.3. The relative humidity ranges from 93% to 25%. The average rate of evaporation ranges from 2.5 mm/day in December to 7 mm/day in April.

Table 2.1: Maximum rainfall (mm) recorded at 14 rain gauge stations in Hasdeo basin

Station Name	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Baikunthpur	136.3	82.4	127.2	74.8	140.6	105.7	86.4	112.2	105.6	NA
Baloda-Janjgir	161.4	129.2	115.3	122.3	117.2	140.3	156.4	98.3	92.2	84.7
Bhatapara	82.0	123.0	192.0	105.0	239.0	88.4	84.0	60.0	70.0	101.0
Bhilaigarh	138.0	161.7	323.0	130.0	140.0	62.0	NA	85.0	105.0	103.0
Champa	86.4	190.0	130.8	160.2	120.4	120.0	86.6	73.0	73.0	87.0
Darri-Korba	228.6	214.4	85.3	118.1	63.0	97.8	106.9	186.7	46.2	77.5
Hasdeo-Kudurmal	189.8	156.8	170.2	140.1	92.0	135.8	73.4	114.8	68.2	65.8
Hasdeo-Pipariya	107.6	60.4	108.2	70.0	102.0	120.0	105.0	95.0	30.0	NA
Jaijaipur	180.0	149.8	109.3	94.2	68.4	92.0	109.2	60.2	104.4	85.4
Janjgir	152.6	124.8	127.4	118.8	105.6	118.8	79.6	117.0	93.0	90.0
Katghora	218.6	185.6	108.4	165.4	165.4	63.4	130.0	193.6	NA	80.0
Manendragarh	320.0	83.0	77.0	44.0	85.0	148.0	91.0	104.0	85.0	NA
Tan-Magarha	156.0	117.0	145.4	82.0	94.4	150.0	91.2	108.6	94.6	84.2
Udaypur	43.9	44.3	78.7	66.0	NA	NA	NA	NA	NA	NA

(NA: Data not available) Source- Chhattisgarh Water Resources Department

Table 2.2: Mean rainfall (mm) recorded at 14 rain gauge stations in Hasdeo basin

Station Name	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Baikunthpur	3.5	2.9	2.9	2.7	4.5	3.4	2.6	5.9	4.2	NA
Baloda-Janjgir	3.9	4.5	3.4	4.5	2.0	3.3	4.8	4.3	4.5	4.1
Bhatapara	1.6	2.7	2.7	3.0	2.6	1.4	2.6	2.7	2.8	3.1
Bhilaigarh	3.0	3.0	4.4	3.7	3.8	1.0	NA	3.1	3.5	3.7
Champa	1.5	3.7	2.9	4.6	3.7	3.0	3.4	2.4	3.0	4.6
Darri-Korba	4.0	5.0	3.3	4.4	3.7	3.5	2.6	3.6	3.1	2.9
Hasdeo-Kudurmal	3.4	3.7	2.9	3.5	3.7	3.2	3.7	3.0	2.8	3.0
Hasdeo-Pipariya	3.3	3.2	3.5	2.5	2.8	2.1	2.1	3.2	0.7	NA
Jaijaipur	4.4	6.4	7.4	5.6	3.3	2.8	2.7	2.4	2.9	3.1
Janjgir	2.8	3.3	2.9	3.8	3.7	2.4	2.8	3.8	3.8	3.5
Katghora	3.1	4.1	2.9	3.3	3.9	2.3	3.2	4.3	NA	2.9
Manendragarh	4.0	3.2	3.2	2.4	2.8	2.6	2.5	4.0	2.7	NA
Tan-Magarha	2.8	3.8	3.4	2.5	3.3	3.0	3.0	4.0	3.4	3.9
Udaypur	2.3	1.3	2.7	2.8	NA	NA	NA	NA	NA	NA

(NA: Data not available) Source- Chhattisgarh Water Resources Department

Table 2.3: Annual rainfall (mm) recorded at 14 rain gauge stations in Hasdeo basin

Station Name	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Baikunthpur	1287	1068	1047	972	1566	1246	961	2158	1552	NA
Baloda-Janjgir	1445	1686	1254	1651	742	1208	1742	1580	1665	1496
Bhatapara	583	988	992	1113	952	528	954	994	1018	1126
Bhilaigarh	1114	1106	1614	1339	1390	368	NA	859	1288	1350
Champa	555	1365	1050	1677	1360	1103	1255	879	1092	1688
Darri-Korba	1449	1841	1198	1608	1366	1275	949	1310	1120	1063
Hasdeo-Kudurmal	1231	1359	1045	1293	1363	1165	1349	1108	1016	1085
Hasdeo-Pipariya	1204	1164	1262	901	1028	761	770	1160	145	NA
Jaijaipur	1078	1365	1138	1348	1220	1005	1000	880	1051	1124
Janjgir	1009	1222	1055	1396	1346	888	1015	1278	1393	1293
Katghora	1135	1505	1067	1211	1424	847	1120	1569	NA	1075
Manendragarh	1465	1158	1183	863	1031	931	916	1460	976	NA
Tan-Magarha	1020	1404	1229	898	1199	1104	1077	1478	1235	1312
Udaypur	489	483	979	1010	NA	NA	NA	NA	NA	NA

(NA: Data not available) Source- Chhattisgarh Water Resources Department

Geology

The Hasdeo river basin falls in the south-eastern region of the Chottanagar plateau. The Gondwana super rocks are predominantly found in the north, north-central and south-central region of the lower Hasdeo basin. Archean rocks are found mainly in the western and south-eastern region of the Hasdeo basin. The district-wise geological distribution in the Hasdeo basin according to the percentage of area it covers is shown in Table 2.4.

Table 2.4: District-wise geological distribution in the Hasdeo river basin

Aquifer type	Koriya		Surguja		Korba		Janjgir-Champa	
	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)	Area (sq. km)	Area (%)
Alluvium								
Laterite			622.91	3.95				
Basalt	11.35	0.97	219.74	1.39				
Sandstone	6460.17	97.24	6859.87	43.48	4115.70	62.15	180.66	4.66
Shale					81.47	1.23	2213.72	57.09
Limestone							1126.43	29.05
Granite								
Schist			8.47	0.05	23.48	0.35		
Quartzite								
Charnockite								
Banded Gneissic Complex	29.95	0.45	6782.96	42.99	2270.85	34.29	75.27	1.94
Gneiss	142.37	2.14	1283.98	8.14	130.25	1.97	281.56	7.26
Total	6643.84		15777.93		6621.75		3877.58	

Source: Dhiman et al, 2012

The major rock strata of the aquifers in Koriya, Surguja and Korba districts are composed of argillaceous rocks (containing high clay minerals such as kaolinite, montomorrillonite, illite, smectite and chlorite) and therefore do not have high transmitivity and yield (Dhiman et al., 2012). About 50% of the aquifers in the Janjgir-Champa district are composed of sedimentary rocks and have moderate yield potential.

Hydrogeology

The hydrogeological settings in the Hasdeo basin are dominated by soft sedimentary systems indicated by red in Figure 2.3. These are then followed by hard sedimentary systems and crystalline systems. Each of these systems possesses different characteristics with regards to aquifer settings. A summary of the aquifer characteristics is provided below.

- Soft sedimentary systems: These are the local systems with shallow aquifers hosted in the weathered zones with moderate to good yield.

- Hard sedimentary systems: These are local aquifer systems which can be weathered and fractured rocks. Groundwater yields can be low to moderate.

- Crystalline basement systems: These are local systems largely dependent on the weathered profile of the surroundings. Water quality issues related to this system usually revolve around fluoride concentration levels. Also, groundwater yields are usually the lowest from these hydrogeological formations.

Soil

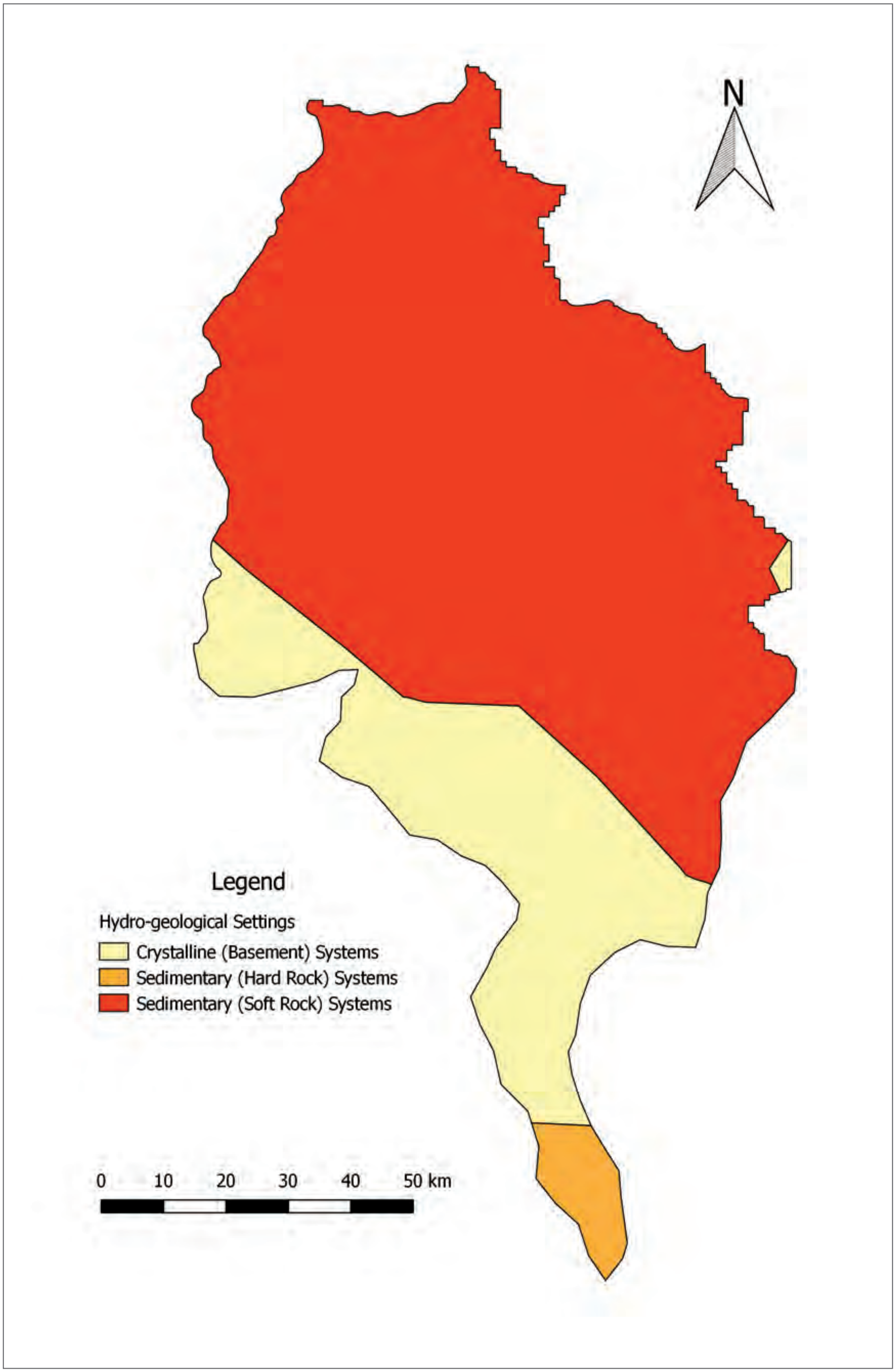
Soils in the Hasdeo basin are classified into 11 categories as shown in Table 2.5. Most of the soils in the basin are residual soils (Singh, 2013). The predominant soil type in the basin is fine loamy soil covering an area of 44% followed by loamy soil covering an area of 18%.

Table 2.5: Distribution of different soils found in Hasdeo basin

Soil Classification	Distribution	
	Area (sq. km)	Area (%)
Clayey	0.2	0.001
Clayey mixed	1040.5	10.0
Clayey skeletal	52.0	0.49
Coarse loamy	53.0	0.50
Fine	520.2	5.0
Fine loamy	4578.6	44.0
Fine skeletal	1560.8	15.0
Fine mixed	416.2	4.0
Loamy	1673.0	18.0
Loamy mixed	208.1	2.0
Loamy skeletal	104.0	1.0

Source: Singh, 2013

Figure 2.3: Regional hydrogeological settings of the Hasdeo river basin



Chapter 3
Demography and landuse/landcover

Districts and demography

Hasdeo flows through the districts of Koriya, Surguja, Korba and Janjgir-Champa. The highlights of each district are as below:

1. **Koriya:** The district of Koriya lies in the north-west region of Chhattisgarh. The total population is 6,58,917. The urban population is 31.2% and the decadal growth of the region is 12.4%. The number of females per thousand males which is called the sex ratio is 968. The literacy rate of the district increased by 7.6% during the decade. Total literacy rate is now 70.6%. Female literacy of the district is 60.6% (Census of India, 2011). About 59% of the land in the district is under forest cover. The district is rich in biodiversity and also has the Guru Ghasidas National Park and the famous Amrutdhara, Ramdhara and Gaurghat waterfalls.
2. **Surguja:** It is located in the northern part of Chhattisgarh. In terms of area it is the largest district in the state. The total population of the district is 23,59,886 people and the decadal growth is 19.66%. The percentage of urban population is 10.29%. The sex ratio of the district is 978. Total literacy rate of the district is 60%. Ambikapur is the largest town in the district with a population of 4,31,834 (Census of India, 2011). Nearly 58% of the land is under forest cover and has two famous wildlife sanctuaries, namely Semarsot and Timor Pingla. The major population comprises of the tribal population mostly belonging to the Pando, Korwa, Gond and Kol tribes.
3. **Korba:** It is located in the northern half of Chhattisgarh. The district gets its name after 'Korwa', the major tribal community that once inhabited this region of Chhattisgarh. The urban city of Korba, which is also a hub for some major thermal power plants in the country, forms the district headquarters. Korba also has one of the country's largest coal fields like the Gevra and the Kusmunda. The total population of Korba is 12,06,640 and the urban population is about 37%. The decadal growth in the district is 19.7%. Sex ratio is 969. Total literacy rate is 72.4%. Female literacy rate of the district is 61.9% (Census of India, 2011).
4. **Janjgir-Champa:** It is located on the central region of Chhattisgarh and is known for its agriculture, especially paddy. It was once called the rice bowl of India. The Hasdeo provides water for irrigation to almost the entire Janjgir-Champa districts through the left and the right bank canals built from the Hasdeo barrage situated in Korba. The total population in the district is 16,19,707. The urban population is about 13.9% and the decadal growth is 22.9%. The sex ratio is 986. The literacy rate is 73.1%. Female literacy rate of the district is 61.3% (Census of India, 2011).

Table 3.1 gives the administrative divisions of Koriya, Surguja, Korba and Janjgir-Champa districts. Table 3.2 summarises the demographics of each district. Figure 3.1 shows the district boundaries and the parts of these districts which lie within the Hasdeo river basin.

Table 3.1: Administrative divisions in Hasdeo river basin

District	Area (sq. km)	Number of Tehsils	Number of Development Blocks	Number of Towns	Number of villages
Koriya	6643.8	5	5	8	636
Surguja	15777.9	9	19	16	1750
Korba	6621.8	3	5	7	719
Janjgir-Champa	3877.6	10	9	15	892

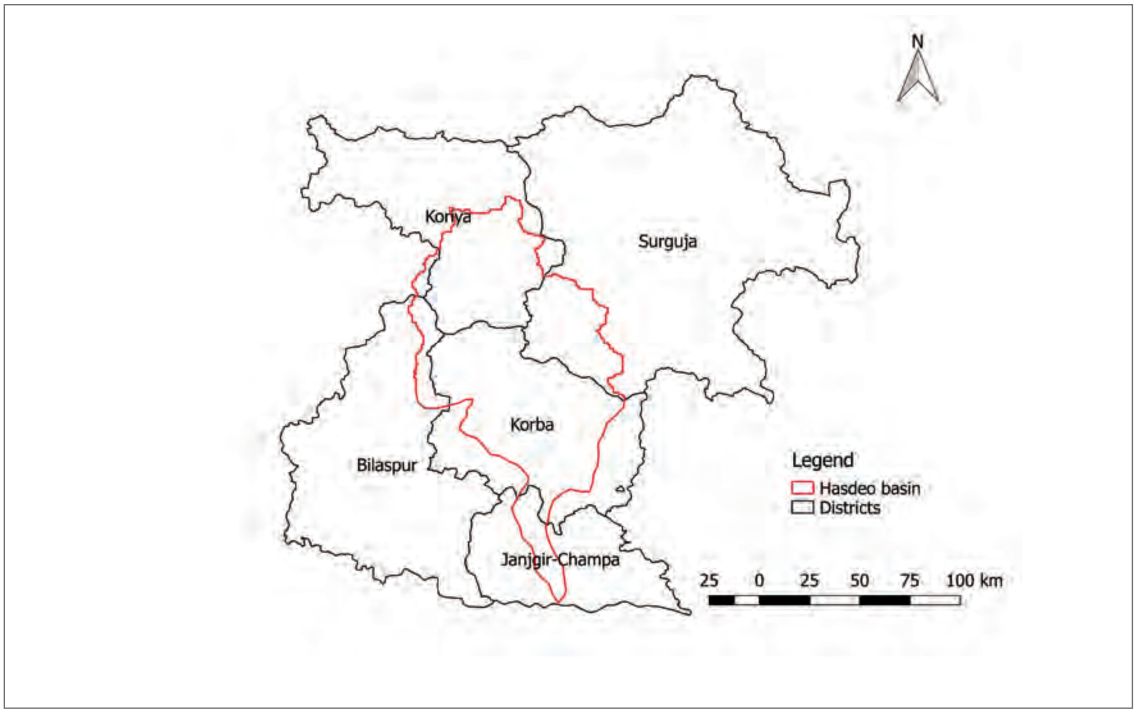
Source- Census,2011

Table 3.2: Demographics of the districts in Hasdeo basin

	Koriya	Surguja	Korba	Janjgir-Champa
Total population	659039	2261329	1206563	1620632
Urban population	205563	245017	446203	225199
Rural population	453476	2116312	760360	1395433
Number of males	334336	195145	612158	816057
Number of females	324703	1166184	594405	804575
Sex ratio	971	976	971	986
Decadal growth (%)	12.4	19.74	19.25	23.01

Source- Census,2011

Figure 3.1: District map of Hasdeo basin



Source: NRSC, 2015

Landuse/landcover

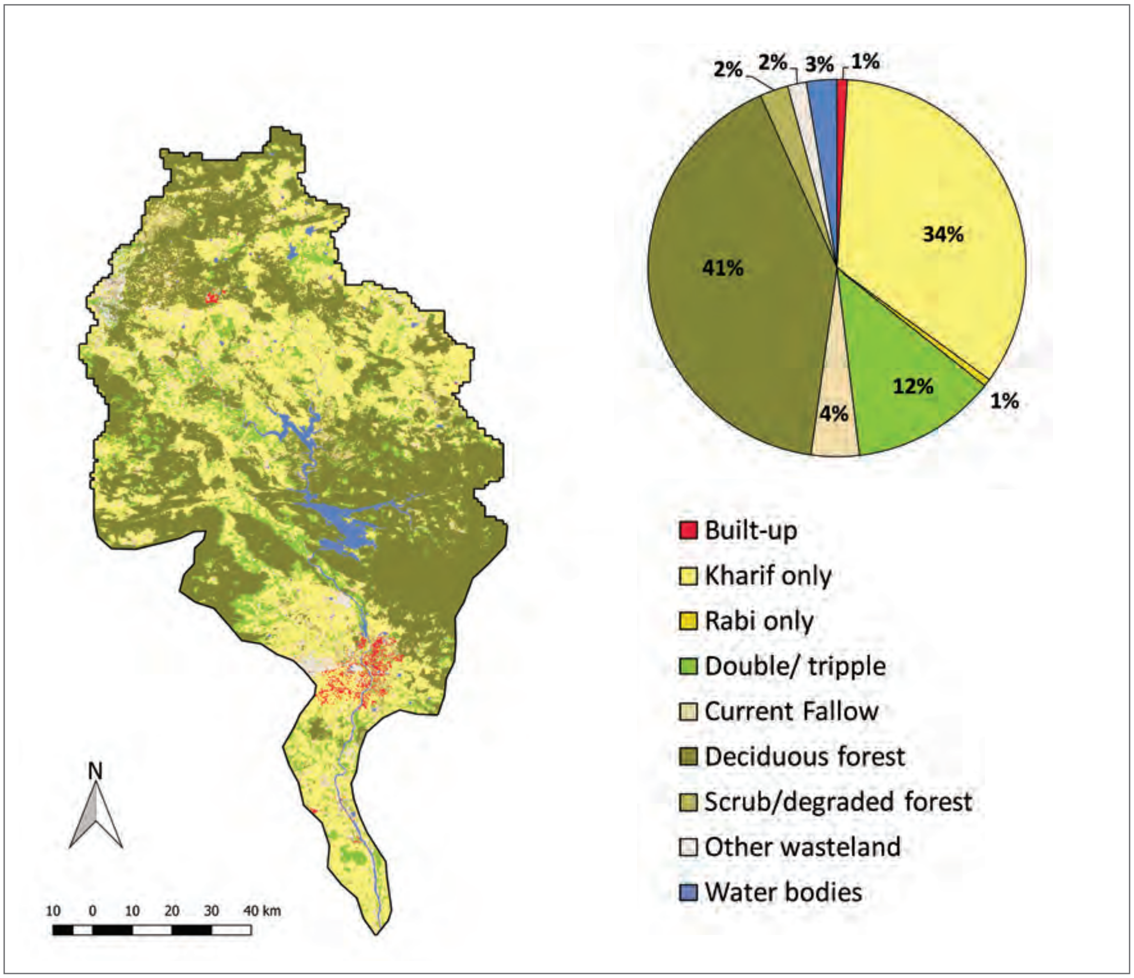
Depending upon the usage of the land, the landuse/ landcover in the Hasdeo basin are broadly classified under the following categories.

1. Agricultural land
2. Forest
3. Scrub/ Degraded land
4. Built-up land
5. Water bodies

Figure 3.2 shows the map of landuse/landcover in the Hasdeo basin. The map was plotted in QGIS using the landuse/landcover data from Bhuvan, the Indian geo-platform by Indian Space Research Organization (ISRO).

According to Figure 3.2, the agricultural land is categorised into three categories, namely: kharif only, rabi only, double/ triple cropped and fallow land. Currently there is about 34% land under kharif crops only and about 12% under rabi crops only.The deciduous forest land is about 41% and is mainly located in the northern and central region of the Hasdeo basin. The majority of the built-up area can be seen in the lower Hasdeo basin. Predominantly it represents the industrial area in Korba where some of the major thermal power plants of the country are located.

Figure 3.2: Landuse/landcover distribution in Hasdeo basin

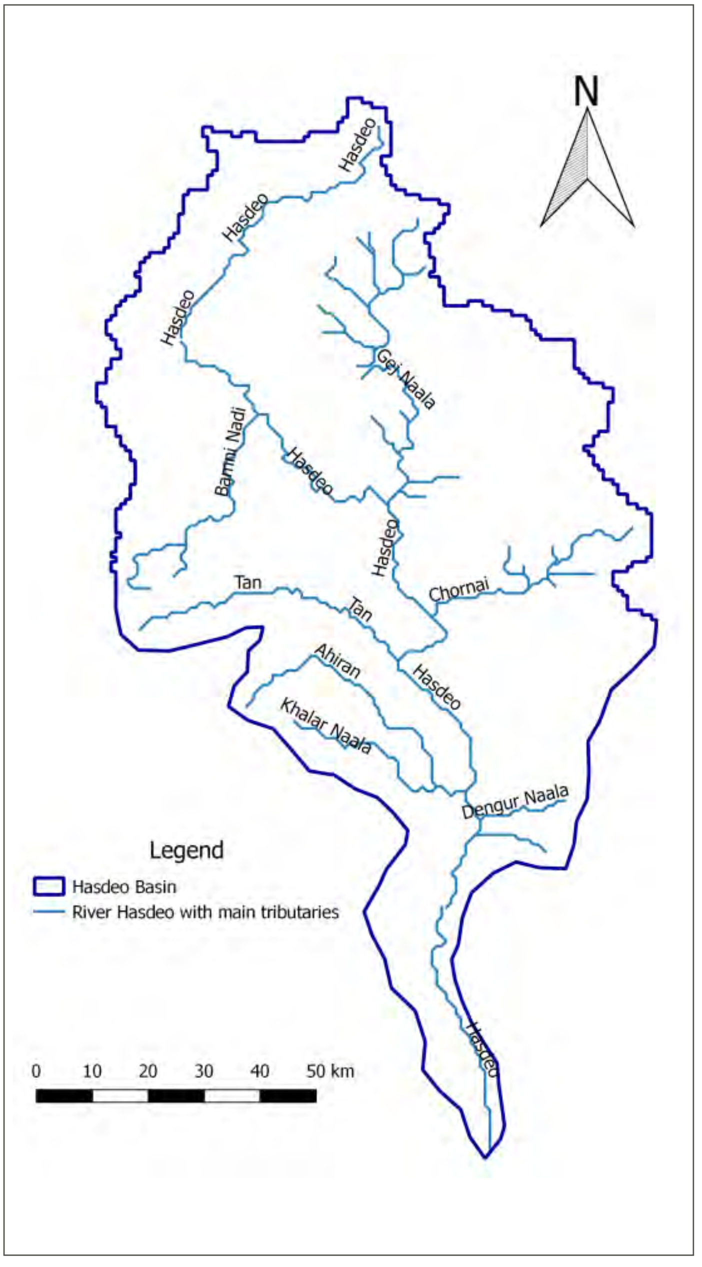


Chapter 4
Hydrology

Drainage system in the basin

From the river's origin in Koriya district, the river flows in the shape of an upturned 'S'. There are a number of tributaries joining the Hasdeo. Major tributaries of the Hasdeo are either perennial or seasonal (Singh, 2013). The main tributaries of Hasdeo are both namely Gej, Atem, Bamni, Tan and Ahiran. Figure 4.1 shows the map of the Hasdeo river basin with its major tributaries. The tributaries which contribute water directly to the main stream of the Hasdeo are: Halphali, Kauriya, Puraur, Anjan, Manasi, Bisrar, Chornai, Gudguda, Borai, Belgari, Dhengur, Kochandi, Dom, Koral, Khar, Gogi, Soi, Baniya, Dhunethi, Hasia, Katai, Phulsar, Nauwnar, Gongdei, and Bakai.

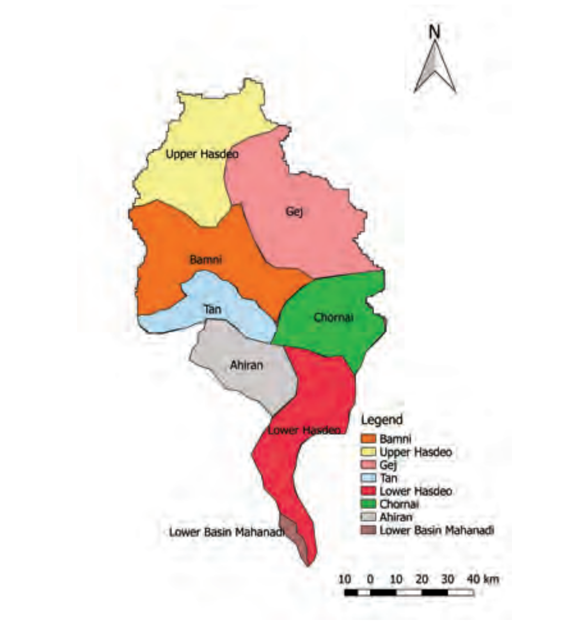
Figure 4.1: Map of Hasdeo river basin with major tributaries



Sub-watershed in the Hasdeo basin

The Hasdeo river basin is divided into eight watersheds. These are the Upper Hasdeo, Gej Nala, Bamni Nadi, Tan Nadi, Chornai, Ahiran Nadi, Lower Hasdeo and Lower Basin Mahanadi as shown in Figure 4.2. The area of each sub-watershed is given in Table 4.1 (Singh, 2013).

Figure 4.2: Sub-watersheds in the Hasdeo river basin



Source: Singh, 2013

Upper Hasdeo watershed

The Upper Hasdeo watershed is situated in the northern part of the basin between 23°8'N to 23°37'N latitude and 82°8'E to 82°33'E longitudes. Approximately 29% of the total area of the watershed is covered with dense forests and 85.66% is used for agricultural purposes (Singh, 2013). Hasdeo is the main river in this sub-watershed with smaller tributaries joining the main stream. Most of the water in the smaller tributaries comes from the natural springs originating in the forests. The Hasdeo flows through steep and narrow valleys with great force. The major population in this watershed is rural and they depend on minor forest produce and subsistence agriculture. There are a number of opencast mines in the watershed. The forests in the watershed are being degraded and the water bodies are becoming polluted due to mining activities. Deforestation poses a major threat to the natural and perennial springs (Singh, 2013).

Gej Naala watershed

The Gej watershed is located between 22°47'N and 23°33'N latitudes and 82°34'E and 82°56'E longitudes. It is the largest watershed which covers most of the area in the Koriya and Surguja districts. Gej is the main river which flows in the direction of north to south for 122 km until it meets the Hasdeo. The Jhink which is a major tributary of the Gej is a perennial source of water (Singh, 2013). Forest land is distributed in the northern, eastern and southern part of the watershed. About 10% of the area of the watershed is densely forested and about 28% of the area is being farmed. The local population is dependent mainly on agriculture.

Bamni watershed

The Bamni watershed is located between 22°47'N and 23°8'N latitudes and 82°7'E and 82°34' E longitudes. The Bamni, which originates in the Amarkantak hills, is the main river in this watershed. It meets the Hasdeo after flowing for 76 km through the terrain. About 26% of the area is covered with dense forest and 46% of the area is cropped. There are a few mines located in the watershed in its southern part. The local population is dependent mainly on forest produce, fishing and agriculture (Singh, 2013).

Chornai watershed

The Chornai watershed is located between 22°22'N and 23°47'N latitudes and 82°39'E and 83°4'E longitudes. Chornai, a perennial tributary of the Hasdeo, originates in the eastern part of Korba district. The total length of the Chornai is 87 km and most of the water of the Chornai flows into the Minimata Bango dam reservoir. The catchment area of the Minimata Bango dam which falls in the watershed is covered with forest. The Chornai watershed has the most forest cover in comparison to the other sub-watersheds present in the Hasdeo basin. Around 38% of the total area of the Chornai watershed is densely forested. These forests are called the ‘Hasdeo Arand’ or ‘Hasdeo Aranya’, and only about 5% of the area in the watershed is being farmed.

Tan watershed

The Tan watershed is located between 22º34'N and 22º47'N latitudes and 82º00'E and 82º37'E longitudes. The forested area of the watershed is 70%. Tan, as the name of the watershed suggests, is the main river which originates in the Maikal range. It is a perennial river which meets the Hasdeo below the Minimata Bango dam. The total length of the Tan river is 110 km. Out of the 70% of forest vegetation, about 36% is densely forested and 24% is farmed. The local population in the Tan watershed is dependent on forest produce and subsistence agriculture. The Tan river meets the Hasdeo river about ½ km downstream of the Minimata Bango dam.

Table 4.1: Area of the sub-watersheds of the Hasdeo river basin

Sub-watershed	Area (sq.km)
Upper Hasdeo	1448
Gej	2109
Bamni	1567
Chornai	870
Tan	1792
Ahiran	905
Lower Hasdeo	998
Lower Mahanadi	768

Source: Singh, 2013

Ahiran watershed

The Ahiran watershed is located between 22º22'N and 22º34'N latitudes and 82º10'E and 82º42'E longitudes. The Ahiran river originates in the Achanakmar region and meets Hasdeo below the Hasdeo barrage in the Korba district. About 16% of the total area is densely forested and 25% is farmed. Katghora is the largest town in the watershed. There are a number of large opencast mines in the watershed, namely the Kusmunda, Dipka, Gevra, Banki and Manikpur, operated mainly by the Southeastern Coalfields Limited. There are also a number of small scale industries that have come up in and around Katghora which impact the river seriously. Water from the Ahiran river is used by the industries which release their effluents into it, and which eventually makes its way into the Hasdeo.

Lower Hasdeo watershed

Lower Hasdeo watershed is located between 21º45'N and 22º22'N latitudes and 82º29'E and 83º4'E longitudes (Singh, 2013). Hasdeo is the main river in the watershed and a number of other smaller streams like the Dondro and Dhengur naala join the Hasdeo in the northern region of the watershed. This region is heavily industrialised and urbanised. The major industries in this watershed are the National Thermal Power Corporation (NTPC), the Chattisgarh State Electricity Board (CSEB) and the Bharat Aluminium Company Limited (BALCO). The Dhengur naala which joins the Hasdeo is severely polluted by the untreated industrial effluents being released into it. Flyash can be seen flowing through the naalas into the Hasdeo. The other intervention of the river in this watershed is the Hasdeo barrage. There are left and right bank canals constructed on the barrage which provide water for irrigation to the farmers in the Janjgir-Champa district.

Lower Basin Mahanadi watershed

Lower Basin Mahanadi watershed is located between 22º14'N and 21º45'N latitudes and 82º19'E and 82º34'E longitudes (Singh, 2013). The Mahanadi forms the lower boundary of the watershed. This watershed is irrigated by a system of canals. All the land in this region is being farmed. The district is called the '*dhaan ka katora*', which means the 'bowl of rice' (Singh, 2013).

Chapter 5
Ecology of the Hasdeo basin

The health of the ecosystems in the river basin and sub-watersheds is largely dependent on the landuse/ landcover patterns. The better the biodiversity within the watershed, the better is the landuse/landcover. Therefore biodiversity plays a key role in the overall health and functioning of the ecosystems. The natural ecosystems within the Hasdeo river basin are the forests, grasslands and riparian ecosystems. Biodiversity within these ecosystems is divided broadly into floral and faunal diversity. Forests as we know have rich biodiversity owing to very little human intervention. The northern region of the Hasdeo basin has very good forest cover. The district-wise forest cover in the Hasdeo basin has already been described in Chapter 3.

Plant biodiversity

Typically the forests found in the Hasdeo basin are *sal*, mixed *sal*, mixed miscellaneous and teak forests (Singh, 2013). The plant diversity found in these forests is listed in Table 5.1. Medicinal plants found in the Hasdeo basin are summarised in Table 5.2.

Table 5.1: Plant diversity in Hasdeo river basin

Local Name	Botanical name
Aam	*Mangifera indica*
Akol	*Ailangium salvifolium*
Alamtas	*Casia fistula*
Almond	*Prunus amygdalus*
Amla	*Embilica officinalis*
Anjan	*Hardwikia binata*
Anjeer	*Ficus carica*
Aonwla	*Phyllantus emblica*
Asan	*Terminalia aliptica*
Ashoka	*Saraca indica*
Bachain	*Melia azadirachta*
Baihra	*Terminalia bellerica*

Local Name	Botanical name
Bamboo species	*Dendrocalamus strictus, Bambusa bambos, Bambusa arundinaceae*
Bargad	*Ficus bengalensis*
Bel	*Aegle marmelos*
Ber	*Zizhyphus zuzuba*
Bhelwa	*Semecarpus anacardium*
Bija	*Plerocarpus marsupium*
Chandan	*Santalum album*
Chhatrak	*Alstonia scolaris*
Chhoela	*Butea monosperma*
Chironjee	*Buchania lanzan*
Dhawada	*Anogeissus latifolia*

Local Name	Botanical name
Dhobin	*Dalbergia paniculata*
Flem	*Caesalpinia bonducella*
Gorair	*Acacia caesia*
Guava	*Psidium guyava*
Gulal	*Ficus glomerata*
Haldu	*Adina cordifolia*
Harra	*Terminalia chebula*
Imli	*Tamarindus indica*
Jamun	*Eugenia heyneana*
Kachnar	*Bauhinia variegate*
Kadamb	*Anthocephalus cadamba*
Kahua	*Terminalia arjuna*
Katanj	*Pongamia pinnata*
Khair	*Acacia catechu*
Khamer	*Gmelina arborea*
Khenkara	*Garur pinnata*
Kikar	*Acacia arabica*
Koriya	*Holarrhena hantidysenerica*
Kumahi	*Careya arborea*
Kusum	*Carthamus tinctorius*
Lasoda	*Cordia mixa*
Litchi	*Litchi chinensis*
Lodh	*Symplocos racemosa*
Mahua	*Madhuca indica*
Mahul	*Bauhinia vahlii*
Maida	*Litsea chinensis*
Makar Tendu	*Ciospyrus ebenum*
Menda	*Randia duetorum*
Mithineem	*Murraya koenigii*

Local Name	Botanical name
Mulberry	*Morus alba*
Munga	*Erythrinia indica*
Nana	*Lagestoromea lanciota*
Neem	*Azadirachta indica*
Nilgiri	*Eucalyptus grandis*
Nimbu	*Citrus medica*
Pakri	*Ficus infectoria*
Palash	*Butea monosperma*
Pipal	*Ficus religiosa*
Piprol	*Gardenia latifolia*
Ramphal	*Annona reticulate*
Rattanjote	*Jatropha curcus*
Rohina	*Soymida febrifuge*
Rubber	*Ficus elastica*
Sagwan	*Tectona grandis*
Saj	*Terminalia tomentosa*
Sal	*Shorea robusta*
Salai	*Bosewellia serata*
Samel	*Bombax ceiba*
Sarai	*Shorea robusta*
Semal	*Bombax ceiba*
Senjhra	*Moringa oleifera*
Sheesham	*Dalbergia sisso*
Sheetaphal	*Annona squamosa*
Siris	*Albizzia lebbek*
Subabul	*Lauceenea leucocephala*
Tendu	*Diospyrus melanoxylon*
Tilsa	*Ougenia dalbergia*
Unjain	*Celastrus peniculata*

Source: Singh, 2013

Table 5.2: Medicinal plant diversity in Hasdeo river basin

Local Name	Botanical Name
Aak	*Calotropis gigantea*
Aavla	*Phyllanthus emblica*
Amaltas	*Cassia fistula*
Anantmool	*Hemidesmus indicus*
Apamarg	*Achyranthes aspera*
Bach	*Acorus calamus*
Bahera	*Terminalia bellirica*
Baybiding	*Embelia tsjeriumcottam*
Bechandi	*Dioscorea daemia*
Bel	*Aegle marmelos*
Bhilwa	*Semecarpus anacardium*
Bhringraj	*Eclipta alba*
Bhui Aavla	*Phyllanthus amarus*
Bidari Kand	*Pueraria tuberosa*
Chironjee	*Buchanania lanzan*
Dhavai Phul	*Woodfordia fruticosa*
Giloy	*Tinospora cordifolia*
Gurmaar	*Gymnema sylvestre*
Harra	*Terminalia chebula*
Hatjor	*Cissus quadrangularis*
Imli	*Tamarindus indica*
Indrajow	*Holarrhena antidysenterica*
Jatropha	*Jatropha curcas*

Local Name	Botanical Name
Kaalmegh	*Andrographis paniculata*
Kali Musli	*Curculigo orchioides*
Karanj	*Pongamia pinnata*
Kateri	*Solanum surattense*
Kevanch	*Mucuna pruriens*
Laal Gunja	*Abrus precatorius*
Maalkangni	*Celastrus paniculatus*
Mahua	*Madhuca indica*
Mahul Patta	*Bauhinia vahlii*
Makoy	*Solanum nigrum*
Mandukparni	*Centella asiatica*
Marorfalli	*Helicteres isora*
Nirgundi	*VItex negundo*
Palash	*Butea monosperma*
Punarnava	*Boerhavia diffusa*
Safed Musli	*Chlorophytum tuberosum*
Salparni	*Desmodium gangeticum*
Sarphonk	*Tephrosia purpurea*
Satavar	*Asparagus racemosus*
Shikakhai	*Acacia sinuata*
Tikhur	*Curcuma angustifolia*
Van Tulsi	*Ocimum gratissimum*
Vanjeera	*Vernonia anthelmintica*

Source: Singh, 2013

Faunal biodiversity

Wildlife

Chattisgarh has rich wildlife with a few endangered species. The state bird is the hill myna, and the state animal is the wild buffalo. According to the International Union for Conservation of Nature (IUCN) red list of threatened species, the wild buffalo falls is endangered (IUCN, 2016). Other wildlife found in the Hasdeo basin are tiger (*Panthera tigris*), wild boar (*Suscrofa*), leopard (*Panthera pardus*), Indian gazelle or chinkara (*Gazella banettii),* chital (*Axis axis*), nilgai (*Boselaphus tragocamelus*), sloth bear (*Melursus ursinus*), sambar (*Rusa unicolor),* gaur (*Bos gaurus*), barking deer (Muntiacini), four horned antelope or chousingha (*Tetracerus quadricornis*), langur (*Preshytia entellus*), dhole (*Cuon alpines*), jackal (*Canis aureus*), porcupine (*Erethizon dorsaum*), scaly ant eater, jungle cat (*Felis chaus*), Indian fox (*Vulpes bengalensis*) and hare (*Lepus nigrocollis*) (Singh, 2013).

According to Meetu Gupta, a wildlife conservationist working in the Hasdeo Arand forest, it is an elephant corridor which helps the elephants to migrate from Chhattisgarh to Jharkhand. An area of 384 sq.km had been reserved for elephants in the Hasdeo Arand forest, however, due to the expansion of coal mines, the habitat of the wild elephants has been encroached upon.

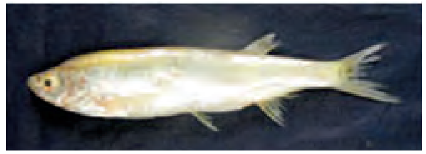
Avian biodiversity found in the Hasdeo basin consists of parrots, green pigeons, storks, darters, wood peckers, jungle fowls, quails, peacocks and gray partridges. Some reptile species are also found, such as lizards, chameleons and snakes. Deadly venomous snakes found are the common cobra, common kraits, and russell's vipers. In the non-poisonous variety, pythons are very common. The zoological survey of India has identified about 60 different species of butterflies in the state of Chhattisgarh, however no information could be found on the exact number of species found in the Hasdeo basin. Currently the Guru Ghasidas National Park which covers an area of 1440 sq. km is the protected park in the Hasdeo river basin. (Forest Department, Government of Chhattisgarh, 2015)

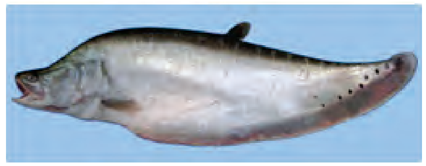
Aquatic biodiversity

The Hasdeo river used to be home to a number of fish species. According to some older fishermen, the fish used to enter Hasdeo from the Mahanadi and travel upstream. However, now due to dams and rapid industrialisation, there are not many fish species found in the Hasdeo, and the current population is also dwindling rapidly. In the first visit to Raipur, the e-flows team met ichthyologist Dr. Renu Maheshwari who has conducted studies on fish biodiversity in the Mahanadi river. However, she has not studied the fish population in the Hasdeo river. Also, other studies on fish specifically in the Hasdeo basin could not be found. In the second field visit in March, detailed field interviews were conducted with the fishermen who gave information on the local names of the fish found in the Hasdeo river. After an intensive web search, information with respect to scientific and common names of the fish and preferred habitats were found. These are summarised in Table 5.3. Apart from the names of the fish listed in Table 5.3, there were more fish species mentioned by the fishermen, but the common names of these fish could not be found. The local names of these fish are Singhar, Balm, Kari, Ghorcha, Kulsi, Dengna, Mangur, Parhan, Munda, Chingri, Puthi, Pacheri, and Revcha. The fishermen stated that the Pacheri, Revcha and Sirangi varieties of fish are not found in the river any more. No information was available on the riparian and aquatic plants.

Table 5.3: Fish species found in Hasdeo river as stated by the fishermen in the field interviews

Sr. no	Local name	Common name/ Zoological name	Description	Preferred Habitat	Comments	Picture
1	Bata	*Labeo bata*	Grows up to 25-35 cm in length. Herbivore that feeds of algae	Benthopelagic and migratory fish	Least concerned in IUCN list of threaten ed species	
2	Catla	*Catla catla*	Maximum length: 182 cm. Omnivorous with juveniles feeding on aquatic and terrestrial insects	Surface and mid-water feeders,	IUCN status is vulnerable	
3	Rohu	*Labeo rohita*	Rohu thrives well in all fresh waters below an altitude of approximately 549 m	Rohu is a bottom feeder and prefers to feed on plant matter including decaying vegetation.	Least concerned in IUCN list of threatened species	
4	Kotri	Swamp Barb, Pool Barb, Stigma Barb/ *Puntius sophore*	A very plentiful shoaling fish. It attains a length of 13 cm	It inhabits plains and submontane regions.	Least concerned in IUCN list of threatened species	

Sr. no	Local name	Common name/ Zoological name	Description	Preferred Habitat	Comments	Picture
5	Khoksi	*Channa punctatus*/ snakehead	Can grow up to 31 cm. Feeds on worms, insects and small fish	Found in ponds, swamps, brackish water, ditches and beels. Adults prefer stagnant waters in muddy streams. Spawning usually takes place at night in shallow water with a silty substrate	Least concerned in IUCN list of threatened species	
6	Sirangi	*Salmophasia bacaila* or *Oxygaster bacaila*/ Large Razorbelly Minnow	S. *bacaila* is a benthopelagic and potamodromous species. S. *bacaila* is an omnivorous surface feeder. Grows up to 18cm in length.	Usually found in slow running streams, but also occurring in rivers, ponds, inundated fields in sub-montane regions, and brackish waters. It is a migratory fish .	Least concerned in IUCN list of threatened species. Has disappeared from Hasdeo river	
7	Kotia	Bagrid Catfish / *Rita rita*	Feeds on insects, molluscs, shrimps and fishes	Inhabits rivers and estuaries, preferably muddy to clear water. Prefers backwater of quiet eddies. Found primarily in the main channel of large rivers	Over fishing is threat though is given Least concerned in IUCN list of threatened species	
8	Padhana	*Wallago attu*/ catfish	It is rather sluggish and stays at the bottom of water in search of food.	Inhabits large rivers, tanks and lakes. It is one of the largest, voracious and predatory of the local catfish which thrives well in rivers and tanks. The fish prefers muddy tanks subject to periodical flooding from a naala or river.	Nearly threatened in IUCN list of threatened species	

Sr. no	Local name	Common name/ Zoological name	Description	Preferred Habitat	Comments	Picture
9.	Mrigal	*Cirrhinus cirrhosus*	The fish generally is found in fresh rivers and streams and can tolerate high levels of salinity. It can grow upto 60 cm in length and weigh upto 2 kg	The fish can survive is flowing rivers and streams and prefers sandy and clayey substrates upto 100 cm depth of breeding.	Vulnerbale in the IUCN redlist of threatened species. Not found in Hasdeo river basin anymore.	
10.	Chilati	*Ostiobrama cotio*	Found in rivers and streams	Prefers fresh water and can survive in ponds.	Least concerned in IUCN list of threatened species.	
11.	Patola	*Notopterus chitala*	Generally grow upto 75cm and maximum length of 122 cm. Feed on mollusks and small fish	Adults prefer freshwater rivers, lakes, beels, naalas in the plains reservoirs, canals and pond	Nearly threatened in IUCN list of threatened species	
12.	Singhi	*Heteropneustes fossilis*	Can grow upto 30 cm. Omnivorous variety of fish	Found mainly in ponds ditches and marshes	Least concerned in IUCN list of threatened species.	

Source: Choubey & Qureshi, 2013; Singh, 2014; IUCN, 2016; Fish Base, 2016.

Chapter 6
Livelihoods in Hasdeo river basin

The major population in the Hasdeo basin is rural. Due to the rapid spread of industrialisation and urbanisation, a vast amount of land has been developed and encroached upon including tribal settlements. Thus a number of tribal people have been forced to move to the cities. However, the livelihood and sustenance of these tribes is dependent on agriculture, riverbed/flood plain farming, minor forest produce and fishing. This chapter aims to give an overview of the livelihoods. The detailed impacts on livelihoods due to changing landuse/landcover pattern from the field interviews and focus groups discussions will be discussed further in Chapter 10.

Agriculture

There are two distinct agro-climatic zones in Chhattisgarh. These are the Northern Hills and the Chhattisgarh Plains. In the Hasdeo river basin, the districts of Janjgir-Champa and Korba fall in the Chhattisgarh plains, while the districts of Koriya and Surguja fall in the Northern Hills region. Agriculture in the Chhattisgarh plains is predominantly irrigation fed, while in the Northern Hills it is rainfed. Generally agriculture is practiced only for subsistence in the Northern Hills. Agricultural holdings are small and mostly practiced on terraces and gentle slopes of the valley. Jeera phool is a unique variety of rice that is grown in the upper reaches. However, this variety is losing its inherent flavor and aroma due to rapid changes in the landuse because of deforestation and mining in the region. Other than paddy, maize, legumes, soyabeans, millets, groundnuts and sunflower are also grown. The major fruit crops grown are mango, cashew nut, guava, banana, papaya, lime, jackfruit, and litchi. Apart from these sitaphal, bel, ber, anola, and sapota are also grown as cultivated crops.

Minor forest produce and saw mills

Minor forest produce is an important means of livelihood and income for the tribals in the Northern Hills. It mainly involves collection of tendu patta, medicinal plants and flowers. Generally tendu patta is collected for 15 to 20 days in a year. People begin collecting the tendu leaves from 4 o'clock in the morning and continue till noon. Thereafter they spend their time packing them in bundles of 50 for which they get Rs. 1.35 for every bundle from the middleman as shown in Figure 6.1. These leaves are filled with tobacco from West Bengal and then processed to make beedis. The tribals also collect sal seeds from the forests of Surguja which is sold in the Market for Rs. 200/sack. The oil extracted from the seeds is used to make chocolates.

Figure 6.1: Gond tribal woman collecting tendu patta

In the year 1975–78, there were around 150–200 saw mills near the mountainous regions of the basin. Later on in order to stop the practice, auctioning of forest wood was stopped. The people who derived their livelihood via this medium gradually migrated to other regions or took up other jobs. At present only 25–50 saw mills are present in Ambikapur. The most important depots where the cut wood was stationed were Tara, Ambikapur and Balrampur. The jungles were also rich in Saguan which was constantly under the threat of theft. Since Saguan can be carved into any shape very easily as compared to Sal, there is a high demand for it in the furniture industry. Saguan fetched nothing less than Rs. 3000–3500/feet. Even the remnants (*Bhusi*) were sold at Rs. 150/sack. In order to sustain the livelihoods of the people who were dependent on the forests directly for their livelihoods, the government began distributing 'Van Patta Adhikar', but in the long run it only became a medium to capture the lands of the tribal populace. It was analogous to buying land from the tribals and handing it over to the corporates. So the government put an end to the livelihood generation activities of thousands of people in the region and transferred this right to the corporates in the name of conservation. Thus a region which was earlier conservation centric has now become a prey to a throwaway culture.

River fishing

If fishing is carried out in a sustainable manner, then fish diversity flourishes adding to the species richness of the region. This then brings a continuous source of income as well as fish protein to the most vulnerable group of the fisheries sector. The people practicing river fishing in the Hasdeo basin are steadily reducing in number owing to rapid industrialisation and pollution. Moreover the presence of dams and barrages in the river has reduced the flows causing a drastic decline in the fish population. Currently the Government of Chhattisgarh is promoting aquaculture in a huge way. At the Bango dam, reservoir fishing is promoted by the Fisheries Department of the state. A variety of Tilapia is bred with the help of Japanese technology. Due to the Bango dam and the Hasdeo barrage, fishing is restricted below the Hasdeo barrage. In Korba fishing is practiced in a small half km stretch right below the Hasdeo barrage which is called Bhavani Mandir. A fisherman community consisting of about 10–15 families reside here. They all belong to the Manjhi community and are dependent on the river for their livelihood. Below where the Dhengur naala joins the Hasdeo, the river gets extremely polluted and is not fit for fishing as there are no fish found in this zone. Fishing is also practiced downstream in the Janjgir- Champa districts near Hathnewra and Mauhadih.

Figure 6.2: (Left) Fisherman fishing in the Hasdeo near Pithampur. (Right) Fishermen near Bhavani Mandir in Korba building a boat for fishing.

Flood plain and riverbed cultivation

When the flow in the river decreases post monsoon, large parts of the riverbed are exposed. It is difficult to differentiate between the riverbed and flood plains because the flood plains have been encroached upon and now farming extends into the riverbeds. People on the banks of the river cultivate and grow a large number of crops like water melons, musk melons, cucumber, vegetables, pumpkins, etc. This is a very important source of livelihood and incomes, especially because many of those engaged in such cultivation are landless families. Nearly 5000 to 6000 families are dependent on flood plain cultivation. Compared to the Mahanadi, flood plain cultivation is not practiced extensively in the Hasdeo river basin. There are stretches of land along the river where people can be seen growing crops mainly for subsistence. On Hasdeo below the Hasdeo barrage, on the right bank canal at a place called Gerva Ghat, people practice flood plain cultivation. The area is about 100–200 acres. Vegetables like bottle gourd, cucumber, brinjal, cauliflower and tomatoes are grown. Flood plain cultivation is also practised along the banks of the Ahiran river. At Hathnewra, the river is braided and flows like a fork forming a sand bed. It remains flooded during the monsoon season. In October when the water there recedes, people farm on the exposed riverbed. They build temporary hutments on the flood plain and stay there till they finish harvesting the crops they have grown.

Figure 6.3: (Top) Flood plain and riverbed cultivation on Ahiran near Korba. (Bottom) Flood plain and riverbed cultivation on Hasdeo at Hathnewra

Chapter 7
Human interventions in the Hasdeo river basin

It is a well-known fact that some of the greatest civilisations in human history have thrived on the banks of rivers. There is no doubt that rivers are the lifeline for human civilisation. However, modern civilisations have changed river regimes and the face of the river basins threatening a number of ecosystems dependent on the river. In the Hasdeo river basin there are a number of human interventions which have caused ecological damage. These interventions are categorised broadly as:

1. Dams and other water infrastructures
2. Coal mines and thermal power plants (TPP)
3. Industries

Figure 7.1 gives an overview of the industries, coal mines and thermal power plants in the basin, including the various dams along the river.

Dams in the Hasdeo river basin

The major water infrastructures on the Hasdeo river are the Minimata Bango dam and the Darri or Hasdeo barrage. The Minimata Bango dam is of national importance. According to National Register of Large Dams (CWC, 2016), dams of national importance are defined as those with a height equal to or more than 100 m or having a gross storage capacity of 1 billion cubic meters (BCM) or greater. The Minimata Bango dam and the Hasdeo barrage were constructed under the Hasdeo Bango Major Irrigation Project. The project consists of four phases. The total irrigation potential created is 433.5 thousand hectares and the hydropower generation potential is 120 MW. Phase-I was completed in 1967 with the construction of Hasdeo barrage in Korba and a 4.1 km left bank canal to provide water to the Korba Super Thermal power plant. In Phase II, a 48 km right bank canal and a 22 km canal branching to Janjgir district. Phase II was completed in 1976.

The Minimata Bango dam was mainly constructed in Phase III approximately 50 km upstream of the Hasdeo barrage. The left and the right bank canals were extended by 32 and 19 km respectively. Phase IV began in the year 1980 with the extension of the canal systems to achieve the irrigation potential of 433.5 thousand hectares (India-WRIS, 2013). Although Phase IV has been declared to have been completed, lining of canals and development of the field channels is still under progress in many places. The total catchment area of the Minimata Bango dam is 6730 sq. km. The salient features of the Minimata Bango dam and the Hasdeo barrage are summarised in Table 7.1

Figure 7.1: Interventions in the Hasdeo basin

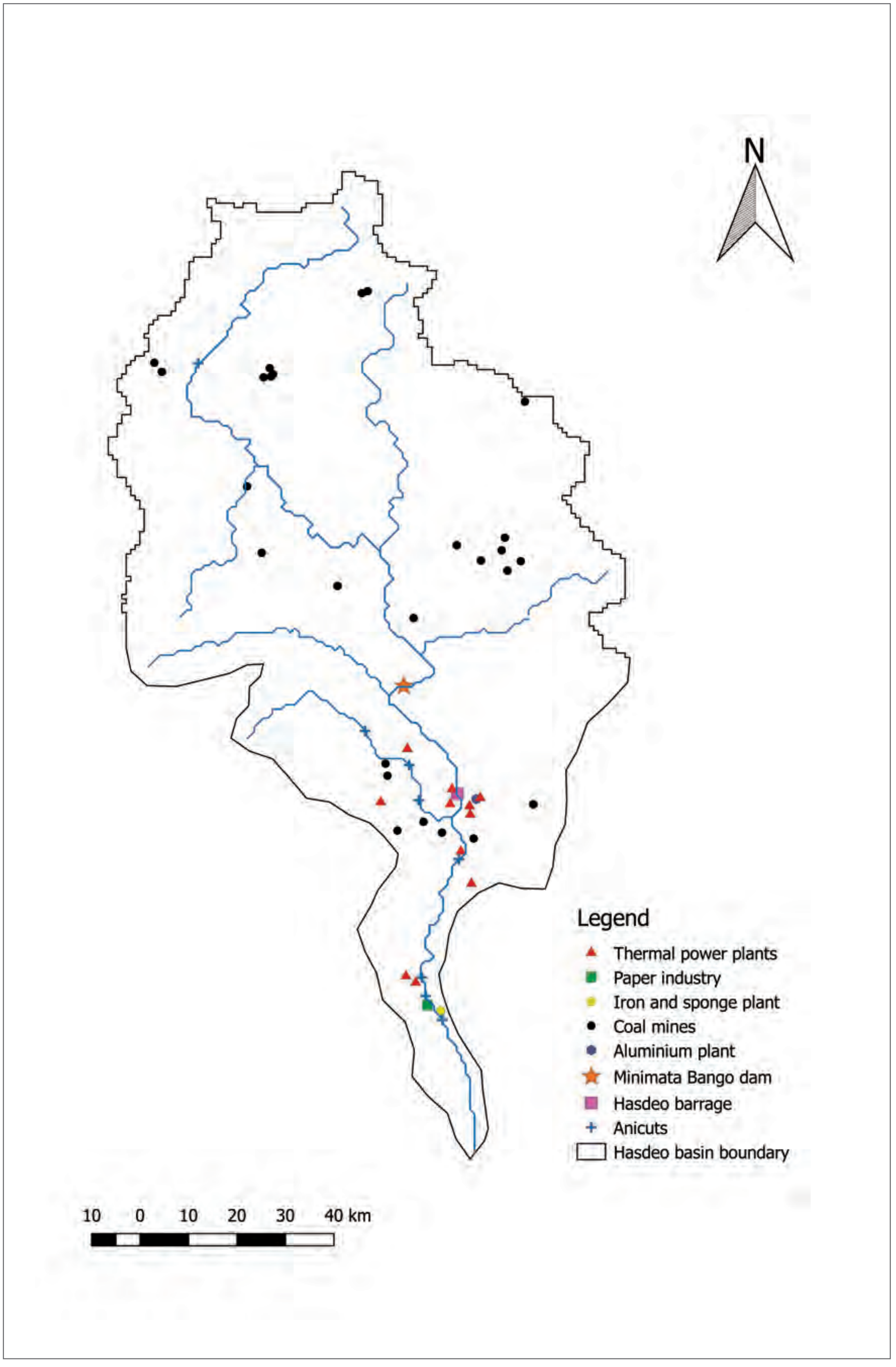


Table 7.1: Salient feature of Minimata Bango dam and Hasdeo barrage

Features	Minimata Bango Dam	Hasdeo Barrage
Year of completion	1990	1967
River	Hasdeo	Hasdeo
Type of dam	TE-Earthwork	TE-Earthwork
Height above the lowest foundation (metres)	87	17.15
Length of the dam (meters)	554.5	284
Gross storage capacity (MCM)	3417	80
Effective storage capacity	3046	81
Reservoir area (sq. km)	188	26
Purpose	Irrigation and Hydropower	Irrigation
Designed spillway capacity (m^3/sec)	42842	19820

Source: India-WRIS, 2012 & 2014

Anicuts

Apart from the Bango dam and Hasdeo barrage, there are four smaller anicuts that are built across the Hasdeo river. The description of these anicuts in summarised in Table 7.2 below.

Table 7.2: Anicuts on Hasdeo river

Name	Place	GPS Location	Purpose
Kudurmal anicut	Kudurmal	22.2846N, 82.6999E	Supplying water to Lanco Amarkantak Power Ltd
Kudri anicut	Kudri	22.0655N, 82.6315E	Supplying water to Chhattisgarh State Power Supply Ltd (CGSPCL).
Champa anicut	Champa	22.0313N, 82.6387E	Supplying water to Champa town
Pithampur-Hathnewra anicut	Pithampur (right bank) and Hathnewra (right bank)	21.9869N, 82.6695E	Supplying water to Prakash Industries Ltd iron and sponge plant

Source: Google Earth, 2016

Also from Figure 7.1 it can be seen that there are three anicuts on the Ahiran river. These are located near the towns of Mahora, Arda and Chatainaar, respectively. The exact purpose of these anicuts however is not clear.

Coal mines and thermal power plants

Coal mines

According to the Geological Survey of India (GSI), the state of Chhattisgarh has 39.5 billion tonnes of coal which is about 16% of the total coal deposits found in India. The coal is distributed in 12 different coal fields in the districts of Surguja, Koriya, Korba and Raigarh (GSI, 2004; Directorate of Geology and Mining, Chhattisgarh, 2011). Out of the four aforementioned districts, the first three lie in the Hasdeo river basin. Majority of the coal fields in the Hasdeo river basin belong to the South Eastern Coalfields Ltd, a subsidiary of Coal India Ltd which is an undertaking of the Government of India. Table 7.3 summarizes the coal mines under SECL as of March 31, 2014.

Table 7.3: Area-wise distribution of coal mines under SECL

Place	Type of mine		
	Underground	Opencast	Mixed
Hasdeo Arand	4	No mine	No mine
Chirmiri	6	1	1
Baikunthpur	5	No mine	No mine
Bisrampur	5	3	No mine
Bhatgaon	5	3	No mine
Korba	10	2	No mine
Kusmunda	No mine	1	No mine
Gevra	No mine	1	No mine
Dipka	No mine	1	1

Source: SECL, 2014

The total forest area diverted for the coal mines in the basin is estimated to be 3526 ha, out of which the Korba district has seen the maximum forest diversion of 2403 ha. The total annual water requirement for these coal mines is estimated to be 11.13 MCM. The water requirement for the Gevra opencast mine, in the Korba district, was not clear but there are 9 water sprinklers of 60 KL capacity and 5 water sprinklers of 28 KL capacity that are used in the mining operations. The main surface water sources for the coal mines are Hasdeo, Ahiran and Lilaghar (CMPDI, 2013; Ramky Enviro Engineers Ltd, 2010; Ramky Enviro Engineers Ltd, 2013; MoEF, 2007, Ecomen Laboratories Pvt Ltd, 2014). Table 7.4 provides the detailed descriptions of the coal mines in the Hasdeo basin

Coal mines in Hasdeo Arand forests

The Hasdeo Arand forests are spread over North Korba, Surajpur and the southern parts of Surguja district. It is one of the largest intact forest areas in Central India that lies outside the protected forest areas. The total area of the coal field is 1878 sq. km out of which 1500 sq. km area falls under thick forest cover. The forest has rich biodiversity and also serves as an elephant corridor allowing the migration of the elephants from Chhattisgarh to Jharkhand. The estimated coal reserves in the coal field are 5.179 billion tones. 30 coal blocks were marked by the state and allocated to private and public companies for mining. The Supreme Court ruled against these allocations and they were cancelled. Currently there are only three blocks that are operational in the Hasdeo Arand namely, Chotia, Parsa and Kete Basan. Chotia block is operated by Prakash Industries Ltd. The Parsa and Kete Basan blocks are operated jointly by the Adani group of companies and Rajasthan Vidyut Utpadan Nigam Ltd. In spite of being classified as a 'no-go' area the forest department has caved into the pressure from the state and the industries and is diverting forest land for coal mining. The entire process of land acquisition has been extremely unjust and non-transparent. In January 2016, the community forest rights of the tribals in the Parsa-Kete-Basan were cancelled (Das, 2016). The detailed impacts on livelihoods and ecology is discussed in Chapter 10.

Table 7.4: Forest area diverted and daily water requirement of coal mines in Hasdeo basin

Coal mine	District	Forest area diverted	Water requirement	Source of water	Comments
Chirmiri opencast mines (Ecomen Laboratories Pvt Ltd, n.d)	Koriya	333 ha	Total water requirement is 0.5 MCM for 24.25 million ton of mineable coal	Mine water	Saudham, Koriya and Balijhar naala are the local surface water sources
Nawapara underground mines (CMPDI, 2013)	Surguja	72 ha	610 m^3/day	Domestic supply through tube wells. Water for mining operations: Treated mine water	Average discharge from the mine is 18394 m^3/day. About 1655 m3/day of water is treated and reused while the rest is released into local land and drainage. About 20% of that enters the groundwater system.
Rehar Underground mine (Ramky Enviro Engineers Ltd, n.d)	Surguja	115 ha	521 m^3/day	Mine water	2921 KLD of discharge generated. Excess mine water discharge will be supplied to local agricultural fields
Mahan II Opencast mine	Surguja	52 ha	1490 m^3/day	270 m^3/day will be taken from groundwater and 1220 m^3/ day from mine water	Net mine discharge is 2.2 MCM out of which 0.45 MCM is used for mining operations. Mahan is the major surface water source
Parsa –Kete Coal block	Surguja	551 ha	5700 m^3/day	Mine water and groundwater	314 ha. of adivasi land has been acquired and the community forest rights were also cancelled. The area is drained by Hasdeo, Atem, Gej and Chornai rivers

Coal mine	District	Forest area diverted	Water requirement	Source of water	Comments
Manikpur Coal Project (Ramky Enviro Engineers Ltd, n.d)	Korba	372 ha	1.2 MLD	The mines take water from Hasdeo and the groundwater through tubewells. Some amount of mine water is reused and they also withdraw sotme amount of water from the left bank canal	Hasdeo is the major surface water body
Gevra Opencast mine (CMPDI, 2013)	Korba	1039 ha	Not sure about the exact water requirement but there are 9 water sprinklers of 60KL capacity and 5 water sprinklers of 28 KL capacity that are used in the mining operations	-	Mine discharge is about 9.53 MCM. Hasdeo is the major surface water body. The mine block is mainly drained by Laxman naala which joins Ahiran.
Kusmunda Opencast mine (MoEF,2007)	Korba	583 ha	16447 m^3/day	Surface water is taken from Ahiran and Hasdeo and other than that mine water and groundwater are also used.	Hasdeo and Ahiran are the major water sources
Dipka Opencast mine (MoEF, 2013)	Korba	409 ha	4360 m^3/day	885 m^3/day will be taken from Hasdeo, 650 m^3/day from groundwater and 2825 m^3/day from mine water	Kholar naala, Hasdeo and Lilagar river are the major water bodies in the vicinity of the mine block.

Industries in the Hasdeo river basin

The major industries are located in the lower Hasdeo watershed in Korba district. These industries are broadly categorised as

1. Thermal power plants
2. Aluminum and bauxite processing plants
3. Iron and Sponge plants
4. Paper mills

Thermal power plants (TPPs)

Chhattisgarh is known as the power hub of India owing to the major TPPs. These plants are located in the lower Hasdeo watershed in Korba district. The Economic Times (2015) reported that "in 2014-2015 the installed power capacity of Chhattisgarh reached 160,000 MW". The thermal power plants in Hasdeo basin along with their total capacity and water allocated to them are shown in Table 7.5.

Table 7.5: Thermal power plants in Hasdeo basin

Name of Company	Location	Installed Capacity (MW)	Water Requirement (MCM)
NTPC Super Thermal	Korba	2100	110
NTPC Sipat	Sipat, Bilaspur	1000	120
CSEB Hasdeo Thermal Power Station (Korba West)	Korba	840	26
CSEB Korba (East)	Korba	2 x 250	37.5
CSEB, Dr. SPM Thermal Power Station	Korba	500	50
Vandana Vidyut Pvt Ltd	Korba	540 MW	18.4
Lanco Amarkantak	Pathadi, Korba	2 x 300	18.3
CSEB Madwa Power Plant	Madwa, Janjgir-Champa	1000	31.1
Swastik Sponge and Power	Korba	2 x 25	0.33
Aryan Coal Benefication Pvt Ltd	Korba	30	-
			Total Water requirement = 412

There are captive thermal plants also in the Hasdeo basin. BALCO and Prakash Industries are the two industries that have large captive thermal power plants. BALCO which is situated in Korba district has a captive thermal plant having a capacity of 1200 MW, and the Prakash Industries Ltd (PIL). plant having a captive thermal power plant of 77 MW is located in Hathnewra in Janjgir-Champa district.

Aluminum, iron and sponge and paper industries:

Other than the thermal power industry there are a few other large scale industries in the Hasdeo basin. These are mainly the aluminum, iron and sponge and paper industries. These are summarised in Table 7.6.

Table 7.6: Other major industries in the Hasdeo basin

Name of Company	Location	Production Capacity	Water Requirement (MCM)
Bharat Aluminum Co. Ltd	Korba	345 KTPA*	28.2
Prakash Industries Ltd	Hathnewra	1.8 MTPA**	18.25
Madhya Bharat Paper Mill	Champa	12 KTPA*	-

*KTPA- kilo tones per annum, **MTPA – million tonnes per annum

All the above industries listed in Table 7.4 and 7.5 are withdrawing water from the Hasdeo. The NTPC Korba and CSEB plants withdraw water from the Hasdeo reservoir. BALCO receives its water from the left bank canal. Vandana Vidyut Pvt Ltd. withdraws water directly from the Hasdeo reservoir. Lanco Amarkantak has built an anicut near Kudurmal on Hasdeo to provide water for their plant at Pathadi. Similarly (PIL) Prakash Industries Ltd. also is withdrawing water from the upstream of the anicut built on the Hasdeo near Hathnewra. These industries also release their effluents into the Hasdeo and its tributaries. The most polluted sections of the river are where the Dhengur naala and the Ahiran river meet Hasdeo. The detailed analysis of the water quality is discussed in Chapter 9.

Chapter 8

Hydrological analysis in the Lower Hasdeo basin

Hydrological Analysis

To assess the environmental flows in the Hasdeo river it was important to quantify the flows and the water availability in the river. To understand the historical flows in the river, gauge-discharge data for the Bamnidih gauging station was analysed. The Bamnidih gauging station is located on the upstream side on the Hasdeo river before it meets the Mahanadi. Hydrological parameters that are measured and recorded at this site are the gauge discharge, sediment load and the water quality. The station was set up on 29th January 1971. The gauge discharge data at this site is available from 18th February 1971. Water quality monitoring began in September 1972 and the sediment load monitoring began in May 1973. The barrage was built in the year 1968 to provide water for surface irrigation. The Minimata Bango dam was built in 1990. The discharge data from 1971 to 2010 was used to determine the following:

- The mean annual and mean seasonal runoffs
- 10- yearly average annual runoff to understand the effect of the change in the flows before and after the construction of the dam.
- Change in the mean seasonal runoffs before and after the construction of the dam

Table 8.1 shows the 10-yearly average annual runoff while Table 8.2 shows the 10-yearly mean seasonal runoff. Three seasons - monsoon, post-monsoon and lean season were considered. The monsoon season is from mid-June to October, post-monsoon season is from November to February and the lean season is from March to mid- June. Figure 8.1 and 8.2 represent this data graphically.

Table 8.1: 10-year annual average and Mean annual runoff

Period	10-year average	Mean annual runoff (BCM)
1971-1980	184.1	5.8
1981-1990	132.4	4.2
1991-2000	138.2	4.4
2001-2010	115.4	3.6

Table 8.2: Mean seasonal discharges and runoffs

Season	Year	Average seasonal discharge (cumecs)	Mean seasonal runoff (BCM)
Monsoon	**1971- 1980**	456.4	5.4
	1981-1990	324.2	3.9
	1991-2000	257.8	3.1
	2001-2010	224.4	2.7
Post-monsoon	**1971-1980**	19.0	0.2
	1981-1990	24.7	0.3
	1991-2000	84.2	0.9
	2001-2010	53.6	0.6
Lean season	**1971-1980**	14.9	0.1
	1981-1990	6.9	0.1
	1991-2000	45.9	0.4
	2001-2010	56.9	0.5

Flow duration curves

A flow duration curve is a plot of discharge or flow versus the time or frequency of occurrence. It indicates the flow in a stream or river that is likely to be equal to or more (exeedance) than the specific value. Therefore the time axis is plotted as a percent indicating the percent of times the flow is equal to or exceeds any particular value. For example, if the flow on the time scale of 50% is 80 cumecs, then one can say that for 50% of the time the flow in the stream is equal to or greater than 80 cumecs. Flow duration calculations were done for each month from 1971 to 2010 to observe typically occurrence of different flows in the river. Table 8.3 shows the availability of water in the Hasdeo at 50%, 75% and 90% dependability in monsoon, post-monsoon and lean season.

Table 8.3: Total runoff at the Bamnidih gauging station at 50%, 75% and 90% dependability

Percent dependability	Monsoon	Post-monsoon	Lean Season
50%	2.7 BCM	0.3 BCM	0.08 BCM
75%	1.4 BCM	0.18 BCM	0.03 BCM
90%	1 BCM	0.09 BCM	0.02 BCM

Figure 8.1: Comparison of the mean annual runoff before and after the construction of the dam

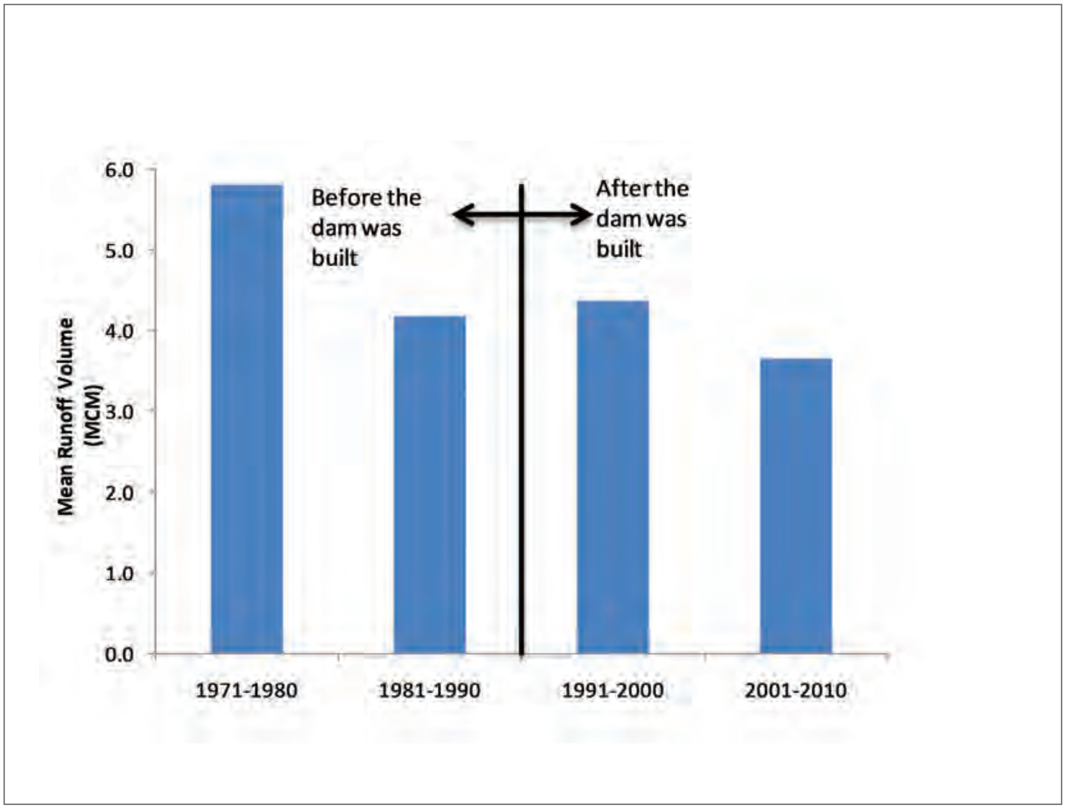


Figure 8.2: Comparison of the mean seasonal runoff before and after the construction of the dam

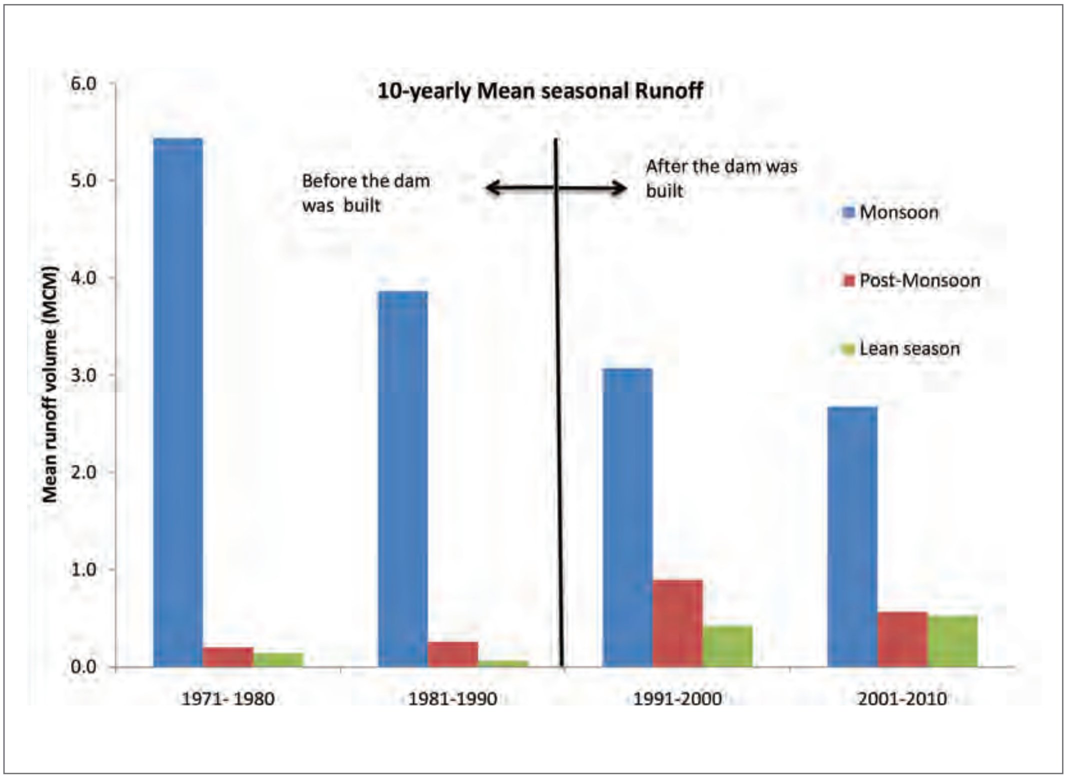
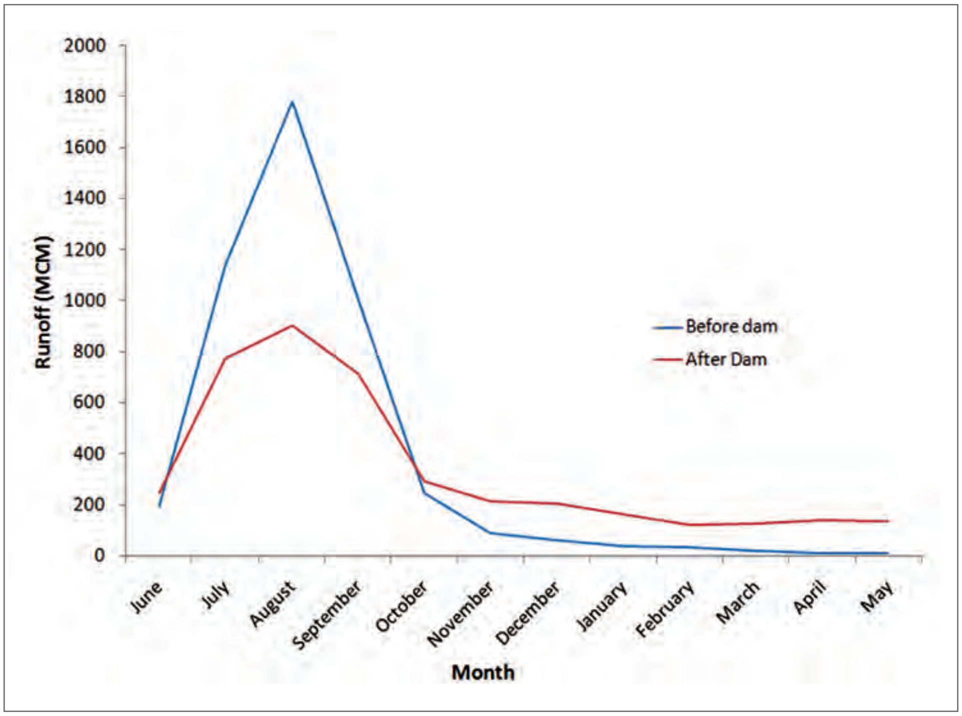


Figure 8.3: Comparison of average monthly hydrographs before and after construction of the dam.



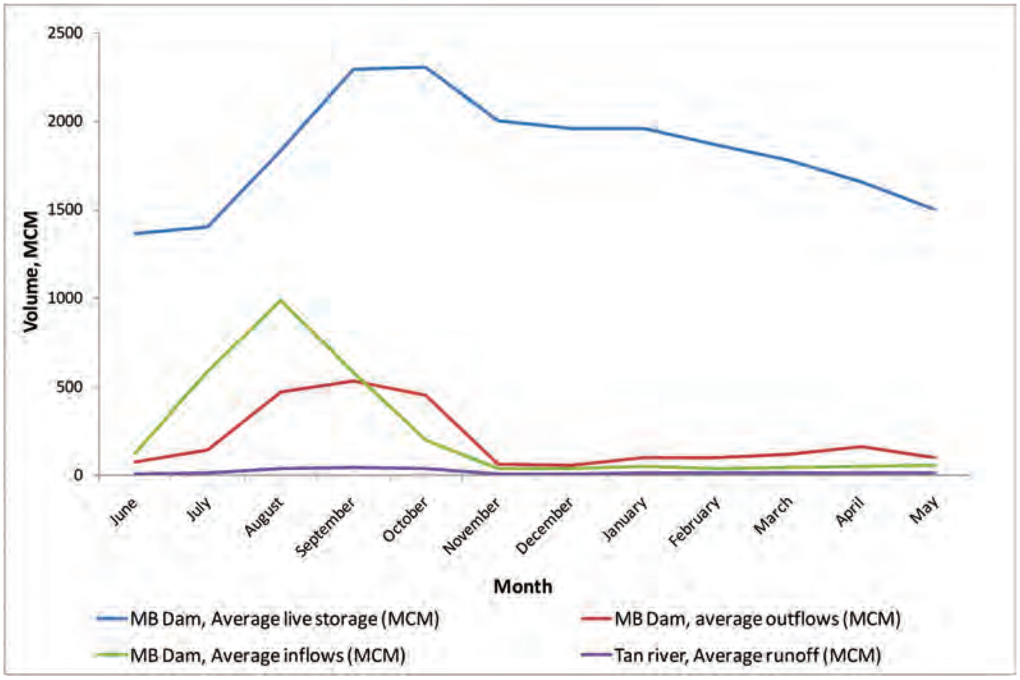
From Figure 8.1 it can be seen that the average annual runoff over each decade has decreased. This can be attributed to increased usage (diversion) of water on the upstream. Post construction period of the dam has seen decrease in the monsoon flows. There has been a flattening of the seasonal flow distribution indicating that after the Minimata Bango dam was commissioned, it has been storing the monsoon flows and releasing them in the post-monsoon and lean seasons. A preliminary estimate reveals that over the period from 1971 to 2010, there has been a 38% reduction in the runoff and corresponding discharge rate. Also, as shown in Figure 8.3, the average monthly hydrograph shows a decrease in the monsoon flows and increase in the post-monsoon and lean season flows.

Additionally, daily data of the inflows, outflows and live storage of the Minimata Bango dam and the flows in the Tan river, for a 10-year period from 2005 to 2010 was analysed to understand the dam operations. Table 8.4 shows the average monthly inflows, outflows and live storage levels in the dam and also the average flows in the Tan river. Figure 8.4 graphically represents this data. From Table 8.4 it can be seen that the average inflows are 2793 MCM. According to the Detailed Project Report (DPR), the Minimata Bango dam was designed to take care of a total water allocation of 3262 MCM which includes that for Kharif, Rabi and summer crop irrigation, as well as the industrial and domestic water requirements. However currently water is not being released for Rabi and summer crop irrigation. Analysis of the dam data showed that on an average the total volume of water released annually from the dam is 2332 MCM. The average annual runoff contributed by the Tan to Hasdeo is about 200 MCM. The flows of the Tan are not regulated. Therefore on an average volume of water available at the Hasdeo barrage is about 2532 MCM. Out of this volume of water 1954 MCM is allocated for Kharif irrigation (1450 MCM), for all the industries (including downstream industries) (488 MCM) and for domestic purposes (16 MCM). Currently, after all the releases and allocations are made at the start of the hydrological year in June on an average about 1368 MCM of water storage is present in the reservoir. Therefore at the end of the hydrological year, on an average the live storage in the dam is nearly 50%.

Table 8.4: Average inflows, outflows and live storage in Minimata Bango dam and average flows in Tan river (2005-2010)

Month	Current average live storage capacity (MCM)	Average inflows into dam (MCM)	Average releases from dam (MCM)	Average flows in Tan (MCM)
June	1368	126	72	6
July	1405	586	137	10
August	1836	988	471	39
September	2291	578	533	45
October	2306	196	455	41
November	2001	38	57	5
December	1960	40	51	5
January	1958	51	93	8
February	1868	40	93	9
March	1779	46	116	11
April	1661	48	159	14
May	1505	56	96	9
Total		**2793**	**2332**	**200**

Figure 8.4: Average inflows, outflows and live storage in Minimata Bango dam and average flows in Tan river (2005-2010)



Chapter 9
The water quality of the Hasdeo river

Background

The Korba district was identified as the 5th critically polluted industrial cluster in India on the basis of Comprehensive Environment Pollution Index (CEPI) computed by Central Pollution Control Board (CPCB) in 2009 (CPCB, 2009). The CEPI is based on the toxicity of pollutants, the scale of impact and traversal path. The CEPI indicated that all these mines and industries are impacting the air, water and noise quality. Based on ten years monitoring data (in the 2001-2010 period) obtained from the Champa monitoring station, the Central Water Commission (CWC) identified contaminants in the Hasdeo to be iron (up to 1.8 mg/L) fluoride (2.72 mg/L), very low levels of dissolved oxygen (DO) (0.3 mg/L), and very high levels of biochemical oxygen demand (BOD) (276 mg/L) (CWC, 2011). Likewise, based on the monitoring stations data in the 1995-2012 period, the CPCB also identified the increasing trend of untreated industrial and domestic waste water being discharged into the Hasdeo and its tributaries. The major point-sources of pollution in the river are stated to be TPPs, BALCO, coal mining operations and other allied industries (CPCB, 2012). Hence CPCB and the Chhattisgarh Environment Conservation Board (CECB) came up with the Korba Action Plan in 2009 to curb the effects of industrialisation. The plan was put into effect from January 2011. As a result, the CEPI for Korba district reduced from 83 to 69 with water quality improving from the severe to normal category. Based on this assessment, the Ministry of Environment and Forest (MoEF) decided to lift the ban on developmental projects in the Korba region (CSE, 2015).

Another independent assessment of CEPI was published by the CECB and Indian Institute of Technology (IIT) Kharagpur in 2015 to strengthen the effect of the Korba Action Plan and to ease the expansion of the industries in the Korba region. Based on the study and data collected in the Critically Polluted Areas (CPA) of Korba during May 2014 to December 2014, it was been found that the overall CEPI value in these CPAs had significantly improved and the present CEPI is 74.5 and the industrial area of Korba is ranked quite low in the list of most polluted industrial areas in the country. This may be due to overall awareness and the implementation of the Korba Action Plan taken by the CECB and actions by individual industries to upgrade pollution control devices, better environmental management and planning and installation of Effluent Treatment Plants (ETPs) and/or improvement of the efficiency of existing ETPs (Meikap, 2015). But this expert report was completely disapproved by intellectuals, environmentalists and the civil society. Their criticism was that the report was mainly meant for facilitating clearances for more new industries and expansion of existing new industries. Moreover this report was criticised for its technical lacunae (Das, 2015). Major parameters like trace and toxic elements (except Arsenic) were not considered for water quality assessment even though these industries are major polluters which discharge toxic elements into the river. In the latest report of CWC in 2014, Hasdeo was reported to be high in more than two trace and toxic elements like Nickel (Ni), Iron (Fe), Chromium (Cr) and Lead (Pb) both in the upper coal mine areas as well as the lower heavily industrialised region (CWC, 2014). MoEF listed Korba into the Critically Polluted Area-MoEF (CPA-MoEF) with respect to Volatile Organic Compounds (VOCs) in 2014-15.

Within the basin, the main focus of water quality monitoring has always been in Korba and Champa. Recently since 2011, the Water Quality Assessment Authority (WQAA) has also started measuring the water quality in Manendragarh region. For three consecutive years, river was found to be contaminated with two or more metals among Chromium (Cr), Iron (Fe), Lead (Pb), Nickel (Ni) in the monsoon season. (CWC, 2014)

Many educational institutes have reported the water quality deterioration at various stretches of Hasdeo in the period between 2006 and 2015. There are several studies which have published the assessment of physio-chemical parameters in the Korba region. Based on the pre-monsoon 2005 study, water in Korba was found very high in Total Dissolved Solids (TDS), Chloride, Nitrate, and Fluoride. It can be classified as "not fit for human use and not suitable for aquatic life" (Vaishnav & Sahu, 2006). Other studies by reputed institutes in 2013 and 2015 found water in Korba to be contaminated with heavy metal. During the monsoon season in 2013, the water samples collected around Manikpur coal mines and National Thermal Power Corporation's (NTPC) flyash pond was found to have Iron (Fe), Manganese (Mn) and Lead (Pb) above permissible limits. Additionally, water samples collected around Manikpur coal mines were found to have Chromium (Cr), Nickel, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and hardness higher than permissible limits (Bhaskar & Dixit, 2013). Tests conducted between October 2012 and March 2013 have indicated that the surface water at Champa was found to be moderately high in EC, hardness, turbidity, sulphate, Chemical Oxygen Demand (COD), Copper (Cu), Manganese (Mn), and phenols at downstream of Madhya Bharat Paper Limited (MBPL). The main reason stated was the untreated effluents released from MBPL (Vaishnav et.al, 2014) The monsoon data at the same location in Champa showed that some of the parameters like EC, Calcium (Ca), Iron (Fe), Manganese (Mn) etc. were slightly higher than their values observed in the post-monsoon season (Vaishnav et al., 2014) indicating the release of more effluents during monsoon season.

Most of the academic reports state the reasons for the pollution are the industries located in the aforementioned areas. They have established this by conducting water quality assessment studies at various locations along the Hasdeo river and correlated the information to the effluent or flyash discharge at respective locations. In spite of this research, the academic institutes did not have any say in the decision making process regarding the corrective measures to be employed. The CPCB has disregarded academic reports and stated that they would autonomously carry out their own studies for the affected areas (Upadhyay and Gupta 2016).

Water quality testing in Hasdeo sub-basin

Based on the literature review and secondary information on the water quality status of the Hasdeo river, but most importantly because of the request from the stakeholders to conduct water quality tests in the Hasdeo basin, water quality assessment studies were taken up by the Forum in the Hasdeo sub-basin below the Hasdeo barrage. The assessments were carried out in pre-monsoon (June) and post monsoon (November) season in Korba and Champa. We would like to specifically mention that these water quality tests carried out were not for academic research. These tests are indicative and comprehensive tests will have to be carried out to determine the correlation between water quality and flow regulations from the dam. The detailed discussion on the water quality tests and inferences are presented in the following sections.

Study area for water quality tests

Water quality samples were collected at the environmental flow assessment sites in Korba and Champa as described in Chapter 1. List of the sites selected for sampling are shown in Table 9.1 and their subsequent representation with the corresponding number of samples collected has been displayed in Figures 9.1 and 9.2.

Table 9.1: Sites selected for sampling in Korba and Champa

Korba region	
Surface Water	**Groundwater**
Bhavani Mandir pond (BM)	Handpump near BALCO's ash dyke (HP-BA)
Dhengur naala (DN)	Bore-well in Vaishali nagar, Korba
Downstream of confluence of Dhengur naala and Hasdeo river, near pump house (DDH)	Open well in Udiya Basti (OP-UB), Korba which is near a closed ash dyke
Downstream of confluence of Ahiran river and Hasdeo river, near power house roads (e-flow site) (DAH)	An additional groundwater sample at Lotlota near NTPC flyash ash pond near Churri (only post-monsoon)
Champa region	
Surface Water	**Groundwater**
Pithampur, towards the bank where Prakash Industry Ltd's (PIL) effluents are released (PTM-PIL)	Hand-pump from Kukaricholi village (HP-KC)
Upstream of anicut in Pithampur, opposite of above location and near Shiv Mandir (PTM-SM)	Bore-well from Pisaud village (BW-Pisaud), Korba
Downstream of anicut in Pithampur (PTM-DA)	

Figure 9.1: Surface water and groundwater testing locations in Korba

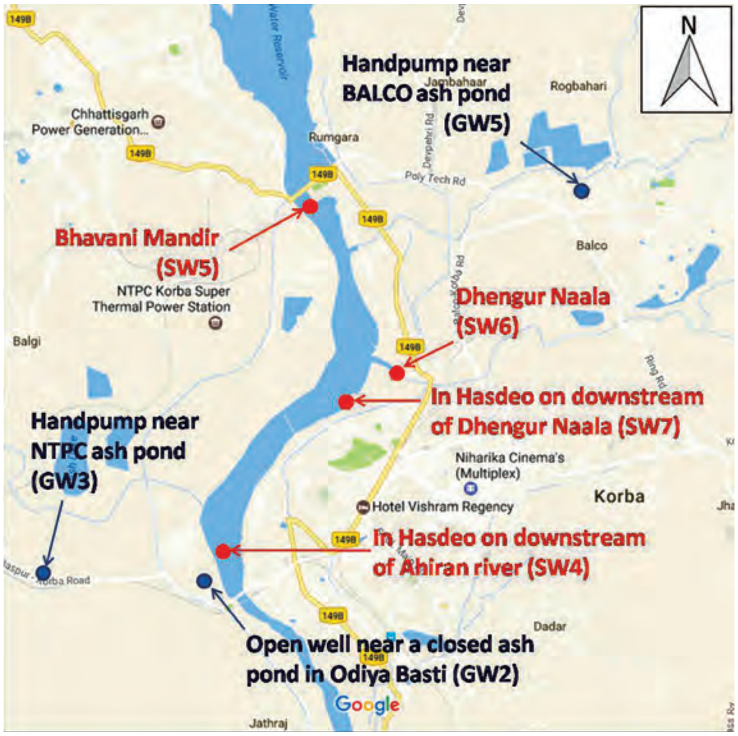
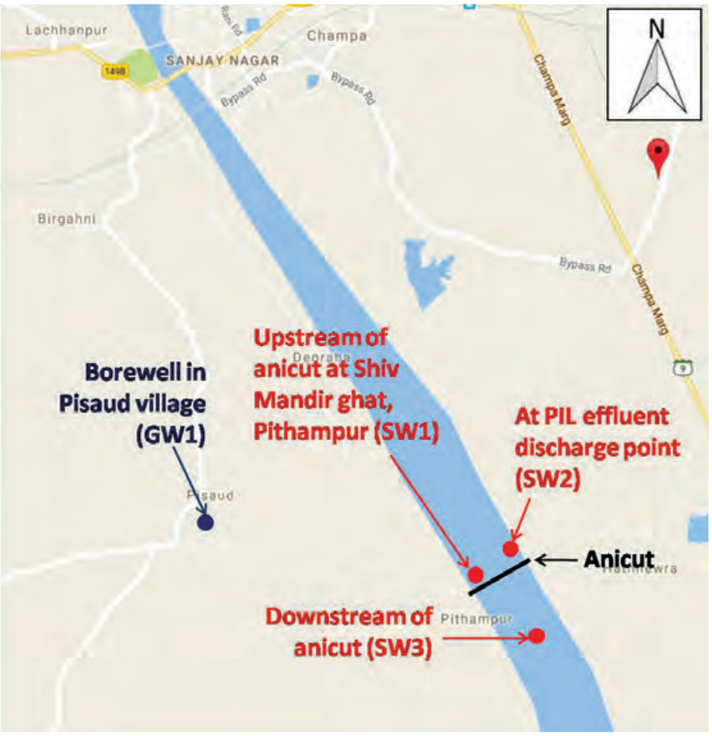


Figure. 9.2: Surface water and groundwater testing locations in Champa



Testing methodology and parameters tested

Sample collection and preservation

The samples were collected as per the American Public Health Association guidelines (APHA, 2005), i.e. representative samples were collected. Two litres of samples were collected from each site. One litre of the sample was used for the in-situ testing whereas another one litre sample was preserved. A total of 7 surface water samples and 5 groundwater samples were collected from Korba and Champa region, respectively. Unfiltered samples were preserved by adding 3 to 5ml of concentrated 70% nitric acid (to bring down the pH <2), which is required for preserving heavy metals. (EPA,2009).

Testing protocol

In-situ water testing

The *Jal-TARA* water testing kit designed by Environment Systems branch of Development Alternatives, New Delhi was used for the in-situ water quality testing. The parameters tested using this kit were - pH, temperature, DO, Residual chlorine (RC), turbidity, chloride, nitrate, fluoride, phosphorous, iron, hardness, ammonia, faecal and benthos. Additionally, EC and TDS were measured by an instrument called "Tracer", which also gave more accurate readings for temperature and pH.

The test results for EC, turbidity, nitrate, fluoride, phosphorous, iron and ammonia were found within the indicative range with the help of *Jal-TARA*. The tests provided by *Jal-TARA* are based on basic, reliable, and simple water quality analysis.

Heavy metal testing

The parameters – Zinc (Zn), Lead (Pb), Cadmium (Cd), Chromium (Cr) and Manganese (Mn) were tested for all the samples in the Water and Soil lab of ATREE, Bangalore. A total 7 surface water samples and 5 groundwater samples were tested for the presence of heavy metals. Additionally all groundwater samples were tested for Arsenic (As).

All the parameters were compared to the IS 10500: 2012 Drinking Water Standards (BIS, 2012).

Results and discussion

Surface water

Pre monsoon and post - monsoon results were compared for most of the water quality parameters. The figures displaying the pertinent surface water quality results are shown in Figure 9.3 and Figure 9.4, respectively. The abbreviations of the surface water testing sites and their corresponding locations are given in Table 9.2.

Table 9.2: Legend of the surface water samples

Name	Location
SW-1	Shiv Mandir ghat
SW-2	PIL Upstream of anicut (Pithampur, Champa)
SW-3	Downstream of anicut (Pithampur, Champa)
SW-4	Downstream of Ahiran river (DAH)
SW-5	Bhavani Mandir pond
SW-6	Dhengur Naala
SW-7	Downstream of confluence of Dhengur naala and Hasdeo (DDH)

pH

The pH of the drinking water must be in the range of 6.5 and 8.5 with no relaxation, according to IS 10500:2012 drinking water quality standards (BIS, 2012). During the pre-monsoon season samples collected at three locations, SW-1, SW-3 and SW-4 showed a pH higher than 8.5. Four out of seven locations had pH within the acceptable, post monsoon. The pH level at three sites SW-1, SW-6 and SW-7 was below 6.5, post monsoon. Long term intake of water that is acidic in nature can cause gastrointestinal trouble. Moreover acidic water can dissolve heavy metal, which can have chronic health impacts including cancer.

Temperature

The temperature of the samples in almost all the locations was 1 to 2 degrees higher than the ambient temperature. Temperature recorded post monsoon was almost 5 to 10 degrees less than the temperature recorded during the pre-monsoon season.

Turbidity

Flyash can be seen flowing through Dhengur naala (SW-6) throughout the year. This clearly reflected in the turbidity measurements of the samples collected at Dhengur naala (SW-6) and downstream where Dhengur naala joined into the Hasdeo (SW-7). At both these locations the recorded turbidity was higher than 100 NTU, which is much higher than the acceptable range of 1-5 NTU (BIS,2012). Table 9.3 summarises the results for turbidity in both the seasons.

Table 9.3: Pre and post monsoon turbidity test results

Location	Pre-monsoon Turbidity (NTU)	Post monsoon Turbidity (NTU)	Desirable Turbidity (NTU)	Permissible Turbidity (NTU)
SW-1	<10	10 – 25	1	5
SW-2	<10	10 – 25	1	5
SW-3	<10	<10	1	5
SW-4	Not measured	25 – 50	1	5
SW-5	<10	10 – 25	1	5
SW-6	>100	>100	1	5
SW-7	>100	50 – 100	1	5

Higher turbidity indicates higher concentration of suspended solids which makes the water unsuitable for drinking due to its aesthetic appearance.

Dissolved Oxygen (DO)

During the pre-monsoon season the DO was lower than the permissible limit i.e. lower than 5mg/L at two places –Dhengur naala (SW6) and at the point of effluent discharge of PIL (SW2), which directly correlates to the pollution load carried by Dhengur naala and possible omission of effluents by PIL. During the post monsoon season all the samples recorded good levels of DO. After monsoon the levels in the river were good and there was ample flow in the river, therefore the DO levels were high. If DO in the surface water sample is lower than 3 mg/L, the water is not suitable even for the survival of strongest fish species. No aquatic life will be found in such surface waters. Dhengur naala is one stream of the Hasdeo where aquatic species are not found anymore.

Electric conductivity

Even though the EC recorded was within the permissible limit of 500 μS/cm. but it was 375 μS/cm for the sample collected at Dhengur naala and 385 μS/cm near PIL indicating a possible higher load of inorganic compounds.

Hardness

The hardness recorded at all the sites during pre-monsoon and post monsoon well below the maximum acceptable level of 200 mg/L.

Iron (Indicative)

Except for the pre-monsoon samples collected at SW-1, SW-2 and SW-3, iron was found to be higher than permissible limit of 0.3 mg/L in all the surface water samples in both pre- and post monsoon tests. Long term consumption of drinking water having iron higher than the acceptable limit can cause vomiting, diarrhoea, nausea and stomach upset.

Fluoride

During the pre-monsoon season, sample collected at Bhavani Mandir (SW-5) had the highest levels of fluoride (in range of 1.5 to 3 mg/L) in comparison to other samples. The high presence of fluoride can be attributed to the effluent from BALCO, as aluminium plants are the major source of fluoride in surface water. The groundwater in the area upstream of Hasdeo barrage was found to be high in fluoride by the ACWADAM organisation in separate tests conducted by them during their field visit. Fluoride can be endogenic to the geology found in the deep core or can be exogenic i.e. from a process like aluminum smelting. The flow of endogenic fluoride from groundwater to surface water is possible only if water has been pumped out and released into surface water. But there is no such possibility here at the Bhavani Mandir pond. The other possibility is that if BALCO is pumping out groundwater for its use and later this water is released as effluent in the surface water then fluoride contamination can occur in the Bhavani Mandir pond. Post monsoon, all the levels of fluoride fell below the acceptable level. Excess of fluorides in the water can lead to the health conditions called 'fluorosis'. Fluorosis can cause mottled appearance of teeth and also weaken bones leading to osteoporosis.

Heavy metals

- **Chromium (Cr)**: The acceptable limit of Chromium is 0.05 mg/L with no relaxation (BIS, 2012). Except in the sample collected from Dhengur naala (SW-6), for the post monsoon season, the concentration of Chromium in all other surface water samples was found to be well below the acceptable limit.
- **Lead (Pb):** The acceptable limit for Lead in drinking water is 0.01 mg/L with no relaxation (BIS, 2012). For the surface water samples collected in the pre-monsoon season, all the samples, except for the sample collected from Dhengur naala, had concentration of Lead well within the acceptable limit. However, all the surface water samples for the post-monsoon season recorded significantly high concentration of Lead. The concentration of Lead was at least two magnitudes greater in comparison with the pre-monsoon concentrations in all the surface water samples. Detection of high quantities of Lead in the post monsoon samples could be correlated to release of higher amount of effluents by the industries due to the availability of water and flow in the river. However, this needs to be validated through further comprehensive water quality tests. Lead is a known neurotoxin and also is carcinogenic. Therefore long term uptake of drinking water containing Lead can lead to cancer.
- **Cadmium (Cd):** The acceptable limit of Cadmium in drinking water is 0.003 mg/L with no relaxation. Cadmium in all the surface water samples in the post monsoon season was significantly higher than the permissible limit and was greater by an order of magnitude in comparison with the concentration measured in the pre monsoon samples. These results are similar to that of Lead and also can be attributed to more effluent load released during the monsoon and post monsoon season. However, as mention earlier, this correlation needs validation.
- **Manganese (Mn):** The concentration of Manganese in pre-monsoon season was found to be higher than the acceptable limit 0f 0.1 mg/L at two sites SW-2 and SW-6. However, these were within the permissible limit of 0.3 mg/L, in case of absence of an alternate source of drinking water. However during the post-monsoon test results reveal that they were higher than even the permissible limit at SW-6. The concentration measured at this site in the post-monsoon season was 1.73 mg/L.

Faecal Coliforms

All the samples had faecal contamination due to domestic use of water by humans as well as livestock. All other parameters are within desirable limits of BIS standards prescribed for drinking water.

Figure 9.3: Surface water quality graphs for pH, temperature, Fluoride and Iron

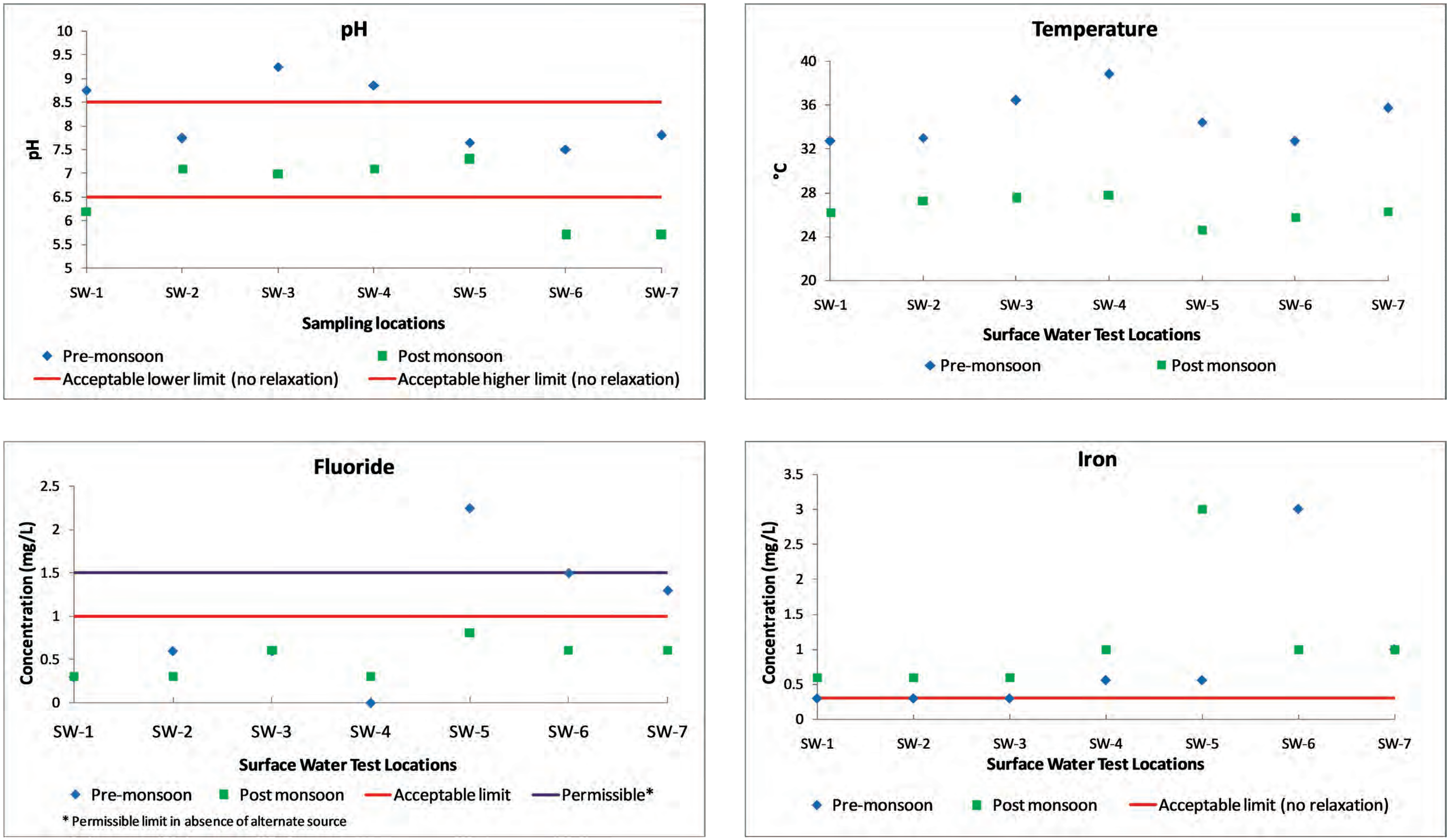
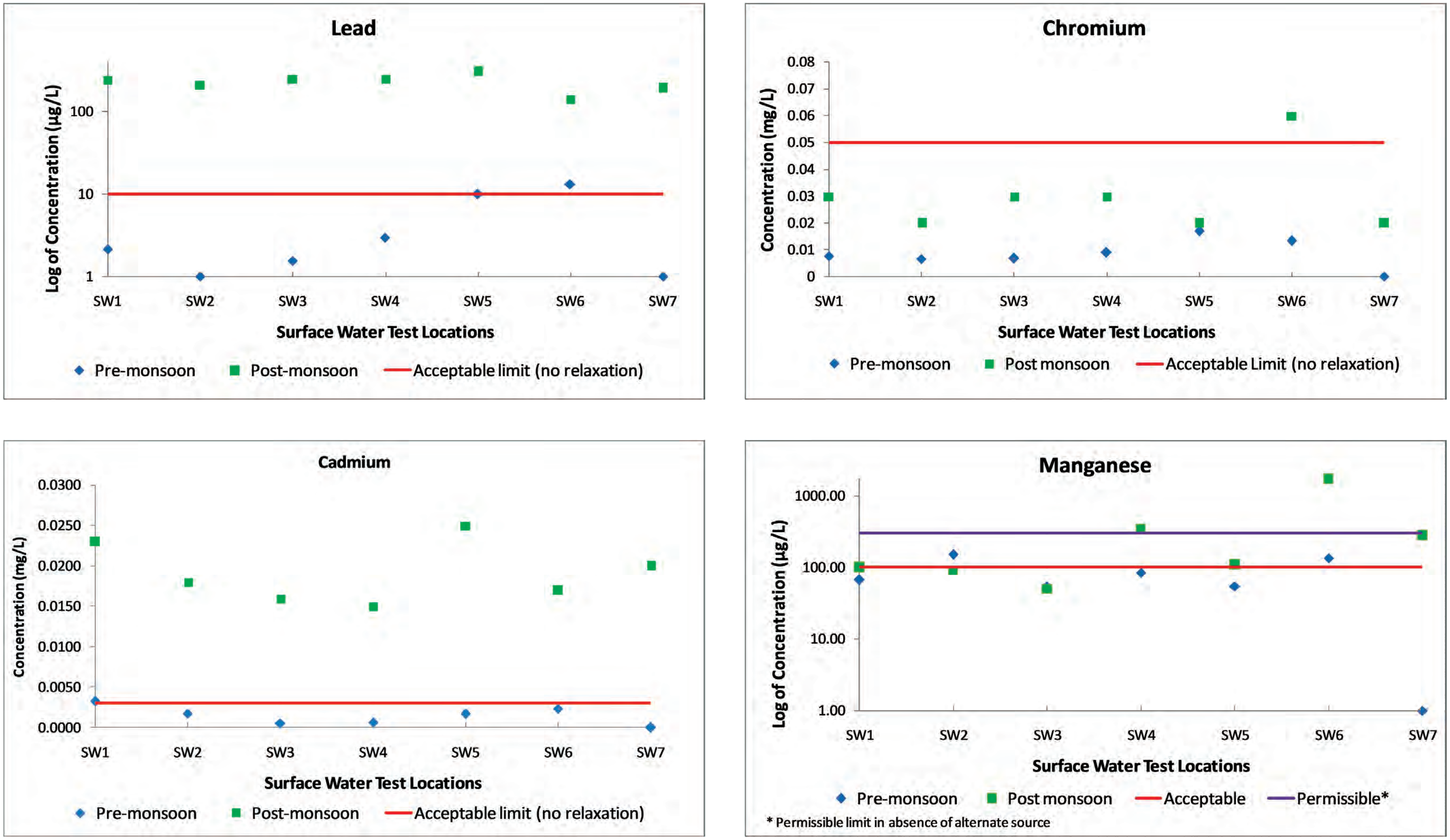


Figure 9.4: Surface water quality graphs showing the heavy metals Lead, Chromium , Cadmium and Manganese



Groundwater

From the water quality testing results it was evident that groundwater is more polluted than surface as three out of five samples showed traces of chloride, nitrates, hardness, high TDS, EC and Cadmium (Cd) above acceptable limits. The pertinent groundwater results have been displayed in Figures 9.5, 9.6 and 9.7 respectively. The important parameters for groundwater are listed in the following Table 9.4. The abbreviations of the groundwater testing sites and their corresponding locations are given in Table 9.5.

Table 9.4: Important parameters for groundwater quality analysis

Parameter	Drinking water standards (BIS,2012)		
	Requirement (Acceptable limit)	Permissible in absence of an alternate source	Unit
Chloride	250	1000	mg/L
Nitrate	45	100	mg/L
Fe	0.3	No Relaxation	mg/L
Hardness	200	600	mg/L
TDS	500	2000	mg/L
EC	150	500	µS cm-1
Cd	0.003	No relaxation	mg/L
Pb	0.01	No relaxation	mg/L
Mn	0.1	0.3	mg/L
Cr	0.05	No relaxation	mg/L
As	0.01	0.05	mg/L

Table 9.5: Samplings locations for groundwater testing

Name	Location
GW-1	BW Pisaud village
GW-2	OW-Udiya Basti, Korba
GW-3	BW- NTPC ash dyke
GW-5	HP- Balco colony
GW-6	HP-KC

Important pre-monsoon and post monsoon results have been discussed below.

pH

During the pre-monsoon season the pH levels of all the groundwater samples ranged between 4 and 7.3 and that for the majority were lower than the acceptable level. The sample collected from a bore well near the NTPC ash dyke or site GW-3, had comparatively the lowest pH levels recorded for both seasons. Unlike the surface water samples, acceptable pH levels weren't achieved even during the post monsoon season. In fact the pH levels fell further.

Temperature

During the pre-monsoon season, temperature did not exceed 31ºC, except for GW-3 during the pre-monsoon season it was recorded to be 31.7ºC. There wasn't much of difference in temperatures recorded for both pre-monsoon and post monsoon season.

Turbidity

During the pre-monsoon season turbidity recorded for the sample collected from an open well in Udiya Basti (GW-2) site was the highest with a range of 25 to 50 NTU. High turbidity means that there are a lot of particles suspended in the water and light cannot get through. For the other samples the turbidity was higher than the permissible limit of 5 NTU.

Hardness

The hardness component of the samples increased in the post monsoon season, yet majority fell within the permissible limit of 600mg/L. The sample collected at site GW-1 had the highest hardness concentration of 1081 mg/L during the pre-monsoon season which fell down to 800 mg/L in the post monsoon season.

Chloride

Except for the groundwater sample collected at the open well in Udiya Basti, the chloride concentrations were above the acceptable level of 250 mg/L. The highest concentration of chloride was recorded in the sample collected at hand pump near BALCO colony (GW-5) for both season. During the pre-monsoon season the chloride concentration was 1758 mg/L and during the post monsoon the concentration fell to 1152 mg/L but both were higher than the permissible limit of 1000 mg/L.

Fluoride

The concentration of fluoride recorded, for both the seasons, in all the groundwater samples were well below the acceptable level of 1 mg/L of water. The highest fluoride concentration was recorded during the pre-monsoon season in the sample collected from a hand pump in Kukaricholi (GW-6) at 1 mg/L, which was still within the desirable limit of fluoride concentrations.

Nitrate

Except for the sample collected at GW-2 site, the concentration of nitrate recorded for both the seasons, was higher than the acceptable level of 45 mg/L of water. During the pre-monsoon season, the highest concentration of nitrate was 100 mg/L which was recorded at site GW-1, GW-5 and GW-6 respectively

Iron

During the pre-monsoon and the post monsoon season, the iron concentration recorded in the samples at GW-5 and GW-6 remained the same at 2 mg/L of water. This was higher than the acceptable level of 0.3 mg/L. Whereas the highest iron concentration of 3 mg/L was recorded at GW-2 site which was the open well in Udiya basti. This level fell down to 0.3 mg/L during the post monsoon season.

Total dissolved Solids (TDS)

During the pre monsoon season the TDS remained above the acceptable level of 500 mg/L for the all the samples except the sample collected at GW-3 Post monsoon the TDS fell below the acceptable limit only at site GW-2 and GW-3. The highest TDS of 1600 mg/L was recorded in the sample collected from site GW-1.

Heavy metals

- **Chromium (Cr):** The acceptable limit for Chromium in drinking water with no relaxation is 0.05 mg/L (BIS, 2012). During the pre-monsoon season Chromium was below the maximum allowable limit and they were detected in trace amounts. The highest level detected was 0.0085 mg/L. Post monsoon Chromium was not detected in any of the samples collected in the post-monsoon season.
- **Lead (Pb):** The acceptable limit for Lead in the drinking water with no relaxation is 0.01 mg/L (BIS, 2012). For the pre-monsoon season, Lead was found in very small quantities below the highest acceptable limit of 0.01 mg/L in all the groundwater samples, except for the sample collected at the hand pump in Kukaricholi village. The concentration of Lead here was 0.014 mg/L which was slightly above the acceptable limit. For post monsoon season, Lead was not detected in any of the groundwater samples.
- **Zinc (Zn):** The acceptable of required limit of Zinc in drinking water is 5 mg/L. In case of absence of an alternate source the permissible limit is 15 mg/L. The concentrations of zinc recorded in both pre monsoon and post monsoon were well within the acceptable limit.
- **Manganese (Mn):** The acceptable limit of Manganese in drinking water is 0.1 mg/L. In absence of an alternate source the permissible limit is 0.3 mg/L. For the pre-monsoon season, except for sample collected at GW-3 location, Manganese was found in all the other groundwater samples. At GW-5 it was below 0.3 mg/L, but in case there is another source of water it should be used. At all other locations (GW-1, GW-2 and GW-6) it was higher than the permissible limit as well. At GW-2 concentration of Manganese was found to be 3.810 mg/L which is 10 times higher than the permissible limit. However, for the post-monsoon season, the concentration of Manganese at GW-2 was below the acceptable limit. At GW-5 the concentration was higher than the permissible limit of 0.3 mg/L for the post-monsoon season. For the same location, the Manganese concentration was higher than acceptable limit of 0.1 mg/L during the pre-monsoon season. The concentration of Manganese at GW-1 was above the permissible limit in both the seasons and an alternate source of water should be used for drinking purpose. Though Manganese does not have acute health impacts it imparts bad taste, colour and odour to the water.
- **Cadmium (Cd):** Acceptable concentration of Cadmium in drinking water is 0.003 mg/L with no relaxation. Except for GW-3 and GW-2 only during the pre-monsoon season, Cadmium was found to be above the acceptable limit in all the other groundwater samples, for both the seasons. The concentration of Cadmium at GW-5, which is closer to the BALCO ash pond, was 4 times and 10 times higher than the acceptable limit in the pre-monsoon and post monsoon seasons respectively. Cadmium is a trace element found in flyash and its significantly high in both the seasons could be indicative that Cadmium is leaching into the groundwater from one of the ash ponds in the vicinity. Though there are no significant acute impacts of Cadmium, long term intake can cause kidney failure, hypertension and also reproductive and developmental problems (WHO, 2011).
- **Arsenic (As):** Arsenic was also detected in a number a majority of the groundwater samples collected. The acceptable limit of Arsenic in the drinking water is 0.01 mg/L. In absence of an alternate source of water, the limit of 0.05 mg/L is allowed. At GW-1 and GW-5 and GW-6, the concentration of arsenic measured in both the seasons was much higher the permissible limit of 0.05 mg/L. At GW-2, the concentration was higher than the permissible limit in the pre-monsoon season; however it was well within the acceptable limit during the post-monsoon season. Only at GW-3, the arsenic concentration was well within the acceptable limit. Long term intake of arsenic can cause cancer of skin, lungs, bladder and kidney. Generally, arsenic is found in groundwater if naturally occurs in the aquifers. However, the types of aquifers found in the Hasdeo basin do not have arsenic occurring naturally in them. Therefore, the detection of arsenic in the groundwater higher than the permissible limits may be due to leaching from the ash ponds.

Figure 9.5: Graphs showing the pH, hardness, Chloride and nitrate in groundwater samples

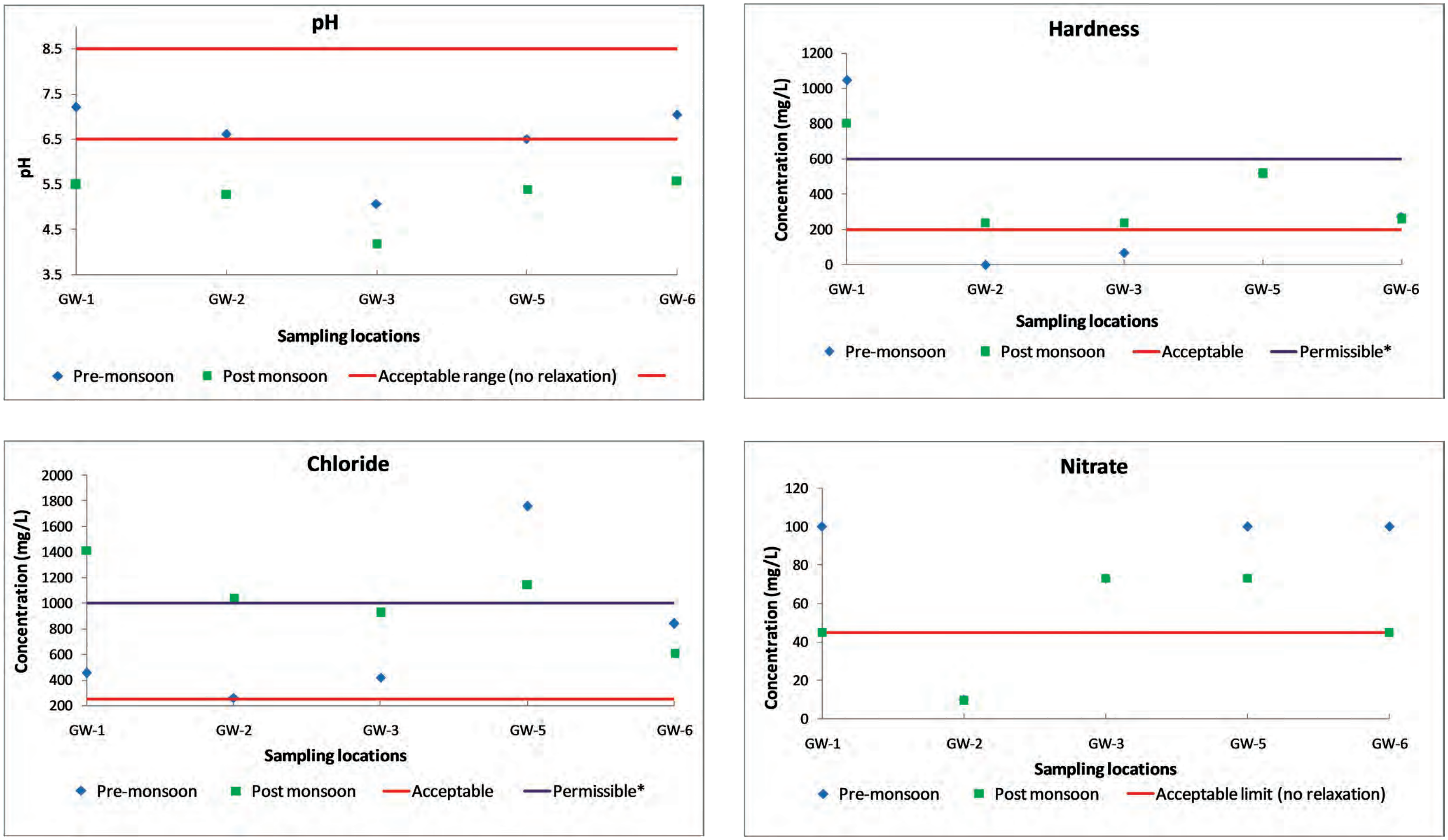


Figure 9.6: Graphs showing turbidity, TDS, Fluoride and Iron in groundwater samples

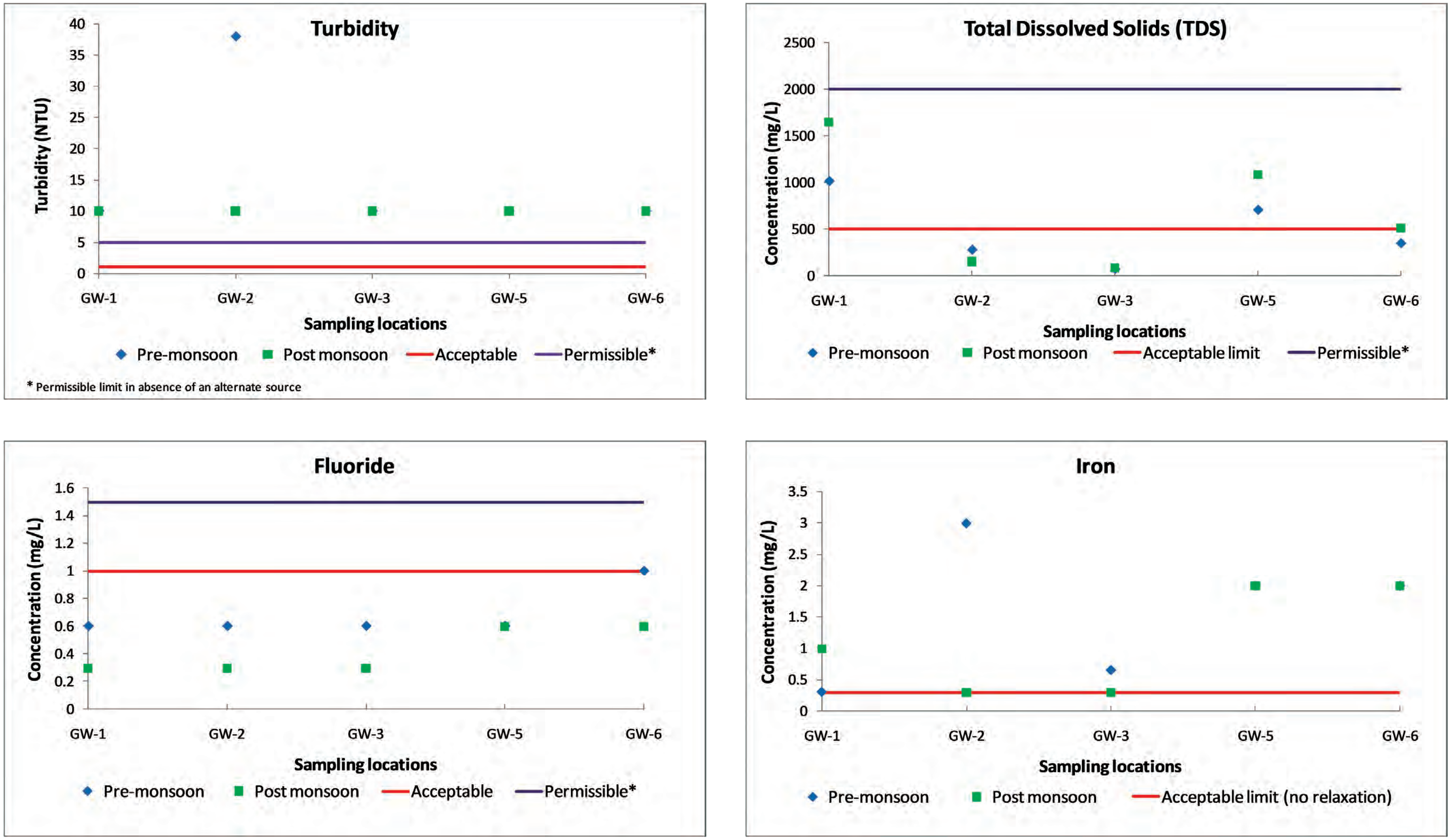
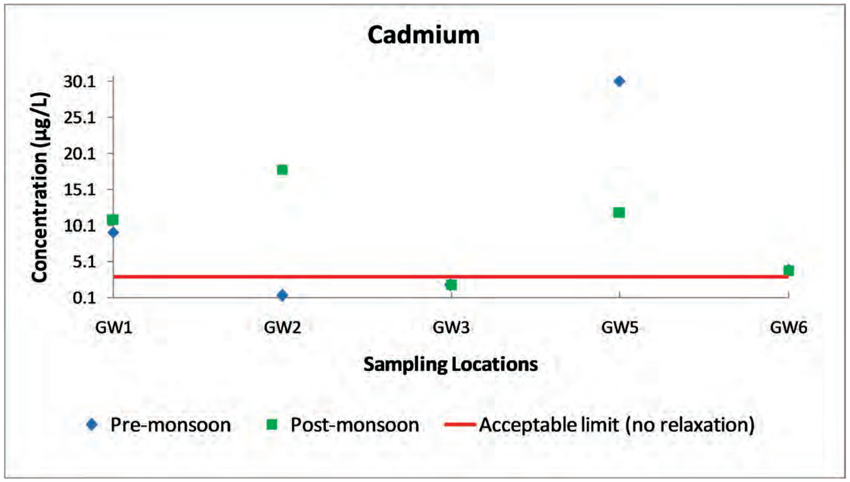
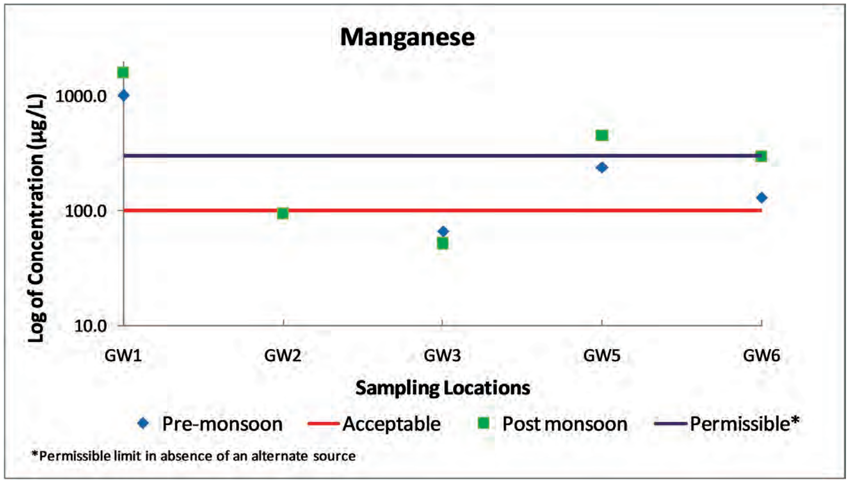
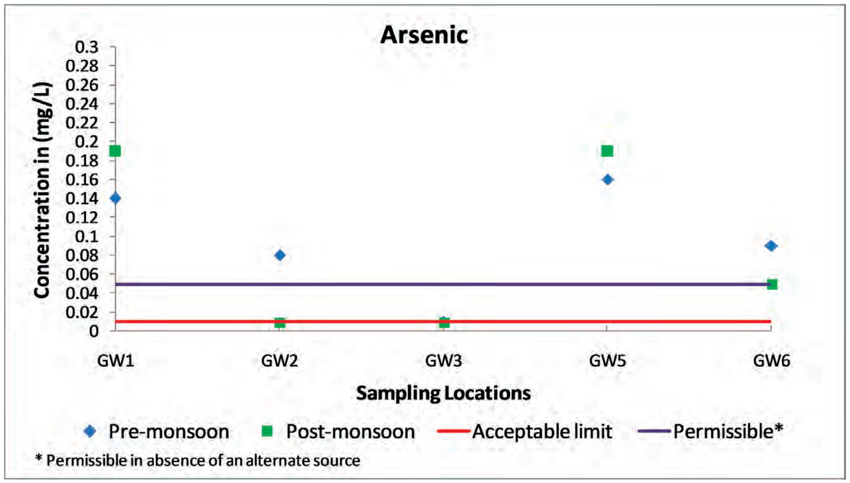


Figure 9.7: Graphs showing Cadmium, Manganese and Arsenic in groundwater samples.







Discussion

The pre-monsoon and post-monsoon water quality show that the water quality of both surface and groundwater are of serious concern in the Hasdeo sub-basin. Heavy metals namely Lead, Cadmium and Manganese that were found above permissible limits were found predominantly in samples from Dhengur naala and in Ahiran river. Both these tributaries of Hasdeo are polluted with flyash as mentioned earlier and these trace metals are found in flyash. Iron also has been found to be above the acceptable limits in many of the surface and groundwater samples which again maybe correlated with the industrial pollution. Considering the hydro geological strata of the Hasdeo basin, arsenic should be detected in extremely negligible amounts, however detection of arsenic in many groundwater samples above permissible limits suggests the probability of arsenic leaching into the groundwater from the ash ponds in the vicinity.

The pre-monsoon and post-monsoon tests conducted have been grab sampling tests. Especially with the surface water quality testing, ideally it would be necessary to conduct tests in pre-monsoon, monsoon and post-monsoon tests over 24 hours to get representative data of the water quality of the Hasdeo and also understand the fate of the pollutants in different seasons. However, owing to the time and the resources on this project, such comprehensive tests could not be conducted during the last phase. Having said that, the water quality tests conducted in the two seasons are still indicative of the pollution and the long term health implications it could have. They have been helpful in providing the preliminary insights regarding the status of both surface and groundwater in the basin. They will be helpful to build on a much more comprehensive study to establish correlations of the impacts of regulated flows on water quality.

Chapter 10

Impacts of poor water quality and human interventions on livelihoods and aquatic habitat

Impacts of coal mines

A field visit was conducted in Hasdeo Arand forest and a number of field interviews were conducted in an attempt to understand the impact of coal mines on the people living in the region. The Hasdeo Arand forests are located in the catchment area of the Minimata Bango dam. There are currently three coal blocks that have been allocated in Parsa, Kete-Basan villages in the Hasdeo Arand forests for coal mining.

Figure 10.1: Water from collieries being discharged into Barra naala

People from Basan village said that the Pathaita naala used to pass through their village and contained water throughout the year but due to the mining activity, the naala has disappeared. This naala earlier joined the Hasdeo but at present does not contribute to it. Drinking water is now obtained from the tube well. The drying up of the naala has wreaked havoc on the animals who are now left with no source of water. Due to the complete diversion of their village and forest land, people have lost access to the common forest resources like mahua. Earlier they used to collect two to three quintal but now there is none, due to which their source of income has been destroyed. At least 3500 ha of forest land has been was diverted for the mines. Birds like vultures and peacock have also disappeared. The drinking water source which was just 5 minutes away is now 15 to 30 minutes away. People from Ghatbarra village said that about 5000 to 6000 trees were cut down and about 20 to 25 acres of forest land was cleared for setting up the Parsa and Kete-Basan coal mines. The collieries or 'coal washeries' directly release water into the local naalas. The villagers have observed death of their cattle after they drank water from these naalas. A picture of the water released from the colliery into one such naala called Barra naala can be seen in Figure 10.1. The flow of the water in the naala has been blocked on all sides by a barricade of sand and a narrow diversion has been made for the passage of the naala water. Since the last three years there are no fish in the stream. Pollution from the effluents have also affected the groundwater in a radius of 1 to 2 km in the region.

Figure 10.2: Effluents from colliery released into Salhi naala

In Salhi village which is situated right on the outskirts of Parsa coal block, the situation is no different. The villagers dread that they will be displaced soon if their block gets allocated for mining. The groundwater tables in a radius of about 5 to 6 km around the Parsa Kete-Basan coal blocks are falling rapidly. With at least 700 trucks passing by every day the number of deaths due to accidents has gone up. The fertility of the land has decreased significantly. The land which once yielded 2000-3000 kg of paddy, now yields 30% less. Also they are unable to grow two crops a year which they would take earlier.

Different villages in the Hasdeo Arand have now formed a Hasdeo Aranya Bachao Andolan Samiti. Their main motto is 'Jal Jungle aur Jameen' which mean 'Water, Forest and Land'. The samiti is uniting different gram panchayats to form a larger group to save their lands, forest and water from the perils of the coal mining activities in the region. Till date, they have 32 gram panchayats from the entire state that have passed resolutions against the new mines and expansion of the existing mines.

Figure 10.3: Farms in Parsa village which have become uncultivable because of flyash pollution.

Figure 10.4: Overburden in the coal block near Parsa village

Impacts of industries

Major thermal power plants are located in Korba. These have been guzzling water leaving very little behind for of the river and the ecosystems dependent on it. Moreover, they have been discharging their effluents into the river polluting it. The thermal power plants discharge their flyash into the ash ponds located close to the plants. However, many of these ash ponds discharge this excess flyash into the nearby streams as discussed in Chapter 9. One such example is the Dhengur naala which is highly polluted from the flyash as can be seen from Figure 10.5

Apart from Dhengur naala, flyash is also discharged into Ahiran from the ash ponds on the right bank. The immediate impact of the pollution is that fish have completely disappeared in this stretch of the river. The population of fish that are left in the river is also dwindling and this has affected the livelihoods of the fishermen. Apart from discharging effluents into the river, the thermal power plants also release hot water into the river causing 'thermal pollution'.

Figure 10.5: Critically polluted Dhengur naala in Korba

Temperature increase reduces the oxygen diffusion capacity of the water and therefore, fish cannot survive for too long in waters with high temperature. Fishermen near the Bhavani Mandir below the Hasdeo barrage in an interview said that they have experienced the impact of thermal pollution where the fish they caught immediately died and began to rot. Downstream at the second site near Pithampur, the PIL iron and steel plant also releases its effluents into the water. Since the river flows as a fork here dividing into two distinct streams, the water on the right bank side of the river is relatively clean. People practicing flood plain riverbed cultivation on the left bank have complained about acidified water destroying their crop. The Madhya Bharat Paper Mill in Champa used to also release its effluents into the water. According to the field interviews conducted with the local people from Pithampur, the effluents released by the mill used to turn the water completely black making it unfit for consumption, fishing and even other daily activities like bathing, washing clothes and bathing cattle.

Impact of dams

The construction of the Bango dam and the Hasdeo barrage has definitely reduced the flows in the river. The river below the Hasdeo barrage does not flow at all. The biggest impact it has created is on the migration of fish due to which fish population in the Hasdeo river is dwindling thus impacting the livelihoods of the fishermen. The perennial river now forms a small stagnant pond immediately below the Hasdeo barrage where very few variety of fish species are found. On interviewing the fishermen dependent on the river fishing at Bhavani Mandir it was evident that the construction of the Bango dam impacted their livelihoods the most. According to the eldest fisherman in the settlement, who used to fish in the river even before the Bango dam was built, they used to catch 25 to 30 kg of fish every day. However they are now able to catch only 1 to 2 kg of fish every day. The time required to catch the fish has also gone up considerably. The fishermen now have to spend on an average 4 to 6 hours a day to catch on an average 1 to 2 kg fish everyday. The average flows in the river used to be “bank full” and the river was perennial. Fishermen at the Bhavani Mandir site observe flows in the river only when the barrage gates are opened. Generally the gates are opened only when there is excess rainfall. This can be attributed to lesser flows in the river. Industries are releasing their effluents without treatment and the flows in the river have also decreased increasing the concentration of the pollutants. Since the average yield of the fish has significantly reduced, they cannot depend on just fishing for their subsistence. Most of the fishermen at Bhavani Mandir are working in power plants in Korba or as daily labourers to make ends meet.

The fishermen at Hathnewra also have similar experiences due to reduced flows in the river. In fact the depth of the river is low and therefore they cannot take their boats in the river for fishing and thus they cannot cover longer distances. Fishermen at Hathnewra also spend on an average 4 to 6 hours for fishing and get just an average yield of 1 kg. According to Dilchand Kevat, the head of the fishermen community at Hathnewra, the Government of Chhattisgarh has been promoting aquaculture and trying to curb river fishing. There are a number of fish species that have been introduced from Andhra Pradesh which are causing the local species to disappear. The low flows have also caused huge decline in the fish population. At both sites that is Bhavani Mandir and Pithampur, one common thing that was observed was the complete disappearance of the Sirangi, Pacheri and Revcha fishes. These fish prefer flowing rivers as their habitat and due to loss of flows are no longer found in the Hasdeo.

The sediment flows and the frequency of the floods have also reduced in the Hasdeo. This has impacted the livelihoods of the riverbed/ flood plain farmers. Riverbed/ flood plain farming is an important source of income for the landless people. They use the fertile land on the banks and the beds when the flood waters of the river recedes after the monsoons. Riverbed/flood plain farming is practiced in a few places at the environmental flow assessment sites. From interviews with the farmers it was found that they typically farm on land available, anywhere between 2 to 4 acres. Cultivation is carried out from October to January. Crops grown are mostly vegetables like cabbage, cauliflower, spring onion, tomato, cucumber, gourd, bitter gourd, brinjal and ladies finger. The farmers said that during monsoon, the banks and flood plains would remain submerged for an average of 2 to 3 days. However for the past few years the flows have reduced due to flow regulation at the Hasdeo barrage for industrial and agricultural use. At the first e-flow site (Gerva Ghat) where flood plain farming is practiced, farmers have dug bore wells for farming and are no more dependent on traditional riverbed/ floodplain farming. They have observed that even the groundwater tables are falling. Sediment flows in the river has reduced due to which they are forced to use artificial fertilisers like urea and potash. Therefore return flows and farm runoffs into river are adding to the chemical nutrient load. The floodplain farms at the first e-flow site (Gerva Ghat) are located right below the CSEB flyash pond. Flyash dust gets blown on to the farms sometimes destroying their crops. Most farmers are growing crops for subsistence. Some of them have to work outside in industries in Korba so as to enable them to make ends meet. Riverbed farmers at the second e-flows site (Hathnewra) said that the flows effluents from the PIL iron and sponge plant have occasionally destroyed their crops. However, the sediment flows have considerably reduced and they have been buying soil to apply to the sand beds. This can change the original geomorphological characteristics of the river and also have certain impacts on the riparian flora and fauna.

Chapter 11
Insights conclusions and future work

Insights

We wish to highlight in this context that the villagers, the fishing communities, the activists and departments and institutions we interacted with were very co-operative and ready to share the available information and their experiences. However, the biggest impediment was the lack of secondary data on the different aspects and parameters which would have enabled a robust assessment of e-flows. Within the limits placed by the data, we have tried to place our insights on how flow regulation, water extraction for coal mines, thermal power plants and industries and pollution in a flow regulated river has affected the river, fishes and livelihoods. The linkages between impact on river ecology and biodiversity and water quality with respect to the change in flows has not been possible due to lack of proper data.

Our insights from the study done in the Hasdeo sub-basin are summarized as below:

- The major water infrastructure projects on the Hasdeo river which are the Bango dam and the Hasdeo barrage have regulated the seasonal flows and also reduced the flows in the river considerably
- There is a decreasing trend in the monsoon flows in the river since the construction of the Bango dam as can be seen from the hydrological analysis.
- At the end of the hydrological season there is about 50% storage left in the dam which is not being utlitized. Actually there is potential for releasing part of this atleast as minimum flows if not environmental flows on trial basis and observe the extent of improvement in the overall flows and the fishes, fisheries and flood plain – riverbed farming. It is understood that the Government sees this as drought reserve. Hence, atleast in good monsoon years, minimum flow releases can be tried.
- Water quality is a serious concern in the Hasdeo basin. Contamination due to flyash can be visibly seen in the Hasdeo below Dhengur naala. Surface water and groundwater have both shown presence of heavy metals above the required acceptable limit. Arsenic has also been detected in all the groundwater samples. Both surface and groundwater in the Korba region is not fit for consumption as it could have chronic health impacts.
- Regulated flows and water quality has also affected the aquatic species in the Hasdeo.
- According to the field interviews conducted, fish populations have reduced. Fish that prefer flowing water and have tendencies to migrate have completely disappeared from the river. Effect of thermal pollution has also been observed by the fishermen at Bhavani Mandir below the Hasdeo barrage. Thermal pollution has occasionally caused fish kills according to them.
- Decline in fish populations due to the flow regulations and river pollution has impacted the livelihoods of fishermen. The total population of the fishermen dependent on the river fishing has also declined and many of them have resorted to other means of earning a livelihood, mostly taking up menial jobs in thermal power plants in Korba.

- Regulated flows from the dam have reduced the sediment flows in the Hasdeo. The period and frequency of flooding has also reduced which has adversely impacted the livelihoods of people dependent on riverbed and flood plain cultivation. Due to reduction of river flows and sediment, farmers are now using fertilisers and pesticides which pollute the river through the return flows from their farms.
- The coal blocks that have been allocated for mining are posing a threat to the river catchment and consequently the streams that originate from the forests in the catchment. There are a number of streams that feed into the Hasdeo in this region. Some of these streams have disappeared or have been clogged by waste from mines and coal washeries. The availability of water for irrigation and power generation and downstream flows at the dam site will reduce if the catchment area of the dam is deforested at the present rapid rate for mining.
- Tribal rights have been violated while assigning land for coal mining in the Hasdeo Arand area. Many tribes have lost their ancestral lands, farming areas along the river, drinking water sources, crop varieties, cattle and overall health.
- The water requirement for the coal mines, thermal power plants and industries in the Hasdeo sub-basin has been indicated in the relevant tables. Cumulatively it would amount to a huge quantity of water extraction. Moreover there would be more water extraction than on records. The amount of water intake versus the amount going back to the river after use and treatment needs to be assessed. This would give the true picture of the contribution of coal mines, thermal power plants and industries on flow reduction and water quality.

Data Gaps and Challenges

From the research study done in the Hasdeo sub-basin, it is evident that the flows in the river have reduced and that the quality of the water has also degraded to a point that it is unfit for human consumption and aquatic life. To determine the quantum of water that will have to released as e-flows to restore some of the functions of the river a complete water balance study will have to be done. There are a number of data gaps in trying to solve the water balance which are as below

- Actual water used by the 13 main industries in the Hasdeo basin
- Mapping of streams (naalas) that have been lost due to coal mines
- Discharge data from streams that are ungauged
- Historical data of water released from barrage and the anicuts on the river
- Comprehensive list and ecosystem information on the fish and other riparian plants which are indicative of the degraded flows and water quality of the Hasdeo
- The linkages between inflows, outflows, flow changes and fish
- The linkages between how hydrological changes are affecting the river ecosystem and biodiversity (at least the fish and riparian flora)

Way forward

Looking at the existing situation in the Hasdeo basin as presented in this report, there is a need for allocating e-flows from the Minimata Bango dam to improve the health of the river and its ecosystems and enhance the livelihoods of the riparian communities. Taking the case of the Hasdeo basin and the lessons learnt from its the situation analysis, important indicators and criteria will be developed based on a stakeholder process. A framework will be developed based on a participatory, bottom-up approach to river basin planning with dams and environmental flows in focus.

We plan to recommend to the concerned authorities to sit together and jointly identify the data gaps in all sectors at least for the Hasdeo sub-basin i.e., fish and fisheries, flood plain farming, industrial water uptake and discharge into the river, type of pollution, effluent discharge, coal mine discharges, forest land actually lost to mining, impact on wild life, streams lost to mines and industries, traditional livelihoods displaced by deforestation, mining and industries to name a few. This would enable a more accurate assessment of e-flows for the sub-basin.

There is a need to involve all the concerned technical institutions and University faculty and research students in Chhattisgarh to generate the above data on a war footing basis. The communities dependent on the river and activists groups working for river protection will also have to be involved in this process.

E-flows assessment is the need of the times if we plan to keep our rivers flowing or in other words maintain the life of our rivers. From our observations, studies and interactions within just one sub-basin it has been proven beyond doubt that Hasdeo is in a very bad condition. At a larger scale, the future of the Mahanadi river depends on the extent to which both Chattisgarh and Odisha come together to assess the flows left in their commonly shared river and arrive at a realistic allocation of water for the different needs with a limits to supply and demand approach rather than assuming unlimited availability of water. E-flows assessment is the pivotal factor to meet this goal.

References

APHA (American Public Health Association guideline). (2005). *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association (APHA), American Water Work Association (AWWA) and Water Environment Federation (WEF)

BIS (Bureau of Indian Standards) (2012). *Indian Standards- Drinking Water- Specification* (Second Revision) Retrieved from http://cgwb.gov.in/Documents/WQ-standards.pdf

Bhaskar.M, Dixit.A.K (2013). *Water Quality Appraisal of Hasdeo River at Korba in Chhattisgarh, India*. Internation Journal of Science and Research

Census of India (2011). *District Census Handbook, Chhattisgarh.* Retrieved from http://www.censusindia.gov.in/2011census/dchb/DCHB.html

Central Mine Planning and Design Institute Ltd. (2013a). *Application for Form I and EIA & EMP for Peak Capacity of Existing Gevra Opencast Project. SECL, Bilaspur.* Retrieved from http://www.environmentclearance.nic.in/writereaddata/EIA/18112014T1V5B4NKEIAgevra.pdf

Central Mine Planning and Design Institute Ltd. (2013b). *Environment Impact Assessment & Environmental Management Plan: Nawapara Underground Project.* Retrieved from http://environmentclearance.nic.in/writereaddata/EIA/8111127121112013_7_29_Jul_2013_133237570_1A1A_123-2009-EC.pdf

CBD (Convention on Biological Diversity) (2010). *Global Outlook 3, Biodiversity in 2010*. Retrieved from https://www.cbd.int/gbo3/?pub=6667&section=6708

Choubey.K; Qureshi. Y. (2013). *Study of Ichthyofaunal Biodiversity of Rajnandgaon town, CG, India*. International Research Journal of Biological Sciences. Vol 2. (2), 21-24, ISSN 2278-3202

CPCB (Central Pollution Control Board) (2009). *Comprehensive Environmental Assessment of Industrial Clusters*. Retrieved from http://cpcb.nic.in/divisionsofheadoffice/ess/NewItem_152_Final-Book_2.pdf

CPCB (Central Pollution Control Board) (2012). *Status of Water Quality in India- 2012*. Retrieved from http://cpcb.nic.in/WQ_Status_Report2012.pdf

CPCB (Central Pollution Control Board) (2013). *Guidelines for loading, unloading and nuisance free transportation of all types of fly-ash, including bottom ash generated by thermal power stations*. Retrieved from http://cpcb.nic.in/divisionsofheadoffice/pci2/FinalReport_Flyash_Ttrans.pdf

CSE (Centre of Science and Environment) (2015): *Polluters Under MoEF Scanner*. Retrieved from http://www.downtoearth.org.in/news/polluters-under-moef-scanner-42304

Central Water Commission (2014). *Status of Trace and Toxic Metals in Indian Rivers*. Ministry of Water Resources, Government of India

CWC and NRSC (2014). *Mahanadi Basin*. A report jointly published by Central Water Commission, Ministry of Water Resources and National Remote Sensing Centre, Indian Space Research Organization (ISRO), Hyderabad.

CWC (Central Water Commission) (2016). *National Register of Large Dams*. Retrieved from, http://www.cwc.nic.in/main/downloads/New%20NRLD.pdf

Dandekar, P. (2012). *Damaged Rivers, Collapsing Fisheries: Impacts of Dams on Riverine Fisheries in India*. South Asia Network on Dams, Rivers and People (SANDRP). Retrieved from, http://sandrp.in/dams/Impacts_of_Dams_on_Riverine_Fisheries_in_India_ParineetaDandekar_Sept2012.pdf

Das, R K. (2015). *Expert reports on Korba pollution under scanner*. Retrieved from http://www.business-standard.com/article/current-affairs/expert-reports-on-korba-pollution-under-scanner-115103000854_1.html

Das.R.K (2016). *Centre Seeks Clarification on Community Forest Rights*. Business Standard. Retrieved from http://www.business-standard.com/article/economy-policy/centre-seeks-chhattisgarh-s-clarification-on-cancellation-of-community-forest-rights-116061400661_1.html

Dhiman, S.C., Verma, J.R., Sahoo, B.K., Naik, K.C., Kumar, S., Sinha, S.K., Chakraborty, D. and Swaroop, S.K. (2012). *Aquifers Systems of Chhattisgarh*. Central Groundwater Board, North Central Chhattisgarh Region, Ministries of Water Resources, Government of India. Retrieved from http://cgwb.gov.in/AQM/Chhattisgarh.pdf

Directorate of Geology and Mining, Chhattisgarh (2011). *Coal Deposits in Chhattisgarh*. Retrieved from http://chhattisgarhmines.gov.in/coal.htm

Dyson, M. (2003). *Flow-The Essentials of Environmental Flows*. IUCN Publications Services Unit, 219c Huntingdon Road, Cambridge CB3 ODL, United Kingdom, ISBN: 2-8317-0725-0

Ecomen Laboratories Pvt. Ltd (2014). *EIA/EMP of Chirmiri OC of SECL*. Retrieved from http://environmentclearance.nic.in/writereaddata/EIA/281020142T3L58OKEIAEXESUMMERY.pdf

Environmental Protection Agency (2009). *Environment Protection (Industrial Waste Resource) Regulations 2009*. Publication IWRG701, June 2009

Fish Base (2016). Retrieved from http://www.fishbase.org/search.php

Forest Department, Government of Chhattisgarh (2015). *Chhattisgarh Biodiversity Strategy and Action Plan*. Retrieved from http://chtenvis.nic.in/pdf/bio%20diversity.pdf

Geological Survey of India (2004). *Coal Resource of India*. Retrieved from http://www.portal.gsi.gov.in/gsiDoc/pub/IndiaCoalResources2004.pdf

Groombridge, B. and Jenkins, M. (1998). *Freshwater Biodiversity: A Preliminary Global Assessment*. Cambridge, United Nations Environment Programme-World Conservation Monitoring Centre, World Conservation Press.

India-WRIS (2012). *Minimata Bango (Hasdeo) Dam D01063*. Retrieved from, http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Minimata(Hasdeo)_Bango_Dam_D01063

India-WRIS (2013). *Hasdeo Bango Major Irrigation Project JI0322*. Retrieved from http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Hasdeo_Bango_Major_Irrigation_Project_JI03221

India –WRIS (2014). *Hasdeo Barrage B00071*. Retrieved from http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Hasdeo_Barrage_B00071

International Water Centre (2007). *Brisbane Declaration*. Retrieved from http://www.watercentre.org/news/declaration

IUCN (2016). *The IUCN Red List of Threatened Species*. Retrieved from http://www.iucnredlist.org/

Iyer, R. (2005). *The Notion of Environmental Flows: A Caution*. NIE/IWMI Workshop on Environmental Flows, New Delhi, March 23-24, 2005

Meikap.B.C. (2015). *Final Technical Report on - Monitoring in Critically Polluted Area (CPA) Korba for Assessment of Comprehensive Environmental Pollution Index*. Raipur, Chhattisgarh

MoEF (Minsitry of Environment and Forest) (2008). *Letter granting Term of Reference for Parsa East and Kanta Besan Opencast mine*. Retrieved from http://environmentclearance.nic.in/writereaddata/Form-1A/TOR/parsator.pdf

MoEF (Minsitry of Environment and Forest) (2009). *Letter granting Term of Reference for Kusmunda OCP Expansion*. Ministry of Environment and Forest, Government of India. Retrieved from http://secl.gov.in/writereaddata/Environment/15.pdf

MoEF (Minsitry of Environment and Forest) (2013). *Letter granting Term of Reference for Expansion of Dipka Opencast Project*. Ministry of Environment and Forest, Government of India. Retrieved from http://environmentclearance.nic.in/writereaddata/Form-1A/EC/1401843623_DipkaErevised2.pdf

Nilsson, C., Reidy, C. A., Dynesius, M., and Revenga, C. (2005). *Fragmentation and Flow Regulation of the World's Largest River Systems*. Science, Vol. 308, pp: 405-408

O'Keeffe, J. and Le Quesne, T. (2009). *Keeping rivers alive, A Primer on Environmental Flows and their Assessment*. WWF Water Security Series, 2.

Ramky Enviro Engineers Ltd (2010). *Executive Summary of Environmental impact Assessment and Environmental Management Plan for Proposed Expansion of Rehar UG Coal mining Project at Getra village, Surguja district*. A report submitted by South Eastern Coalfield Ltd, Retrieved from, http://www.enviscecb.org/117/ExeSummary_ReharUG_English.pdf

Ramky Enviro Engineers Ltd (2013). *An EIA report for Proposed Expansion Manikpur Coal Project at Korba*. Retrieved from, http://environmentclearance.nic.in/writereaddata/EIA/1111291220121211129-2007.pdf

Singh. A.K. and. Singh, S.S (2010). Upper Hasdeo Sub Watershed Status in Hasdeo River Basin at Chhattisgarh. FIG Congress 2010 Facing the Challenges – Building the Capacity Sydney, Australia, 11-16 April 2010

Singh, A.K. (2013). *Watershed Management and Fire Monitoring by using Remote Sensing and GIS in Hasdeo River Basin Area of Chhattisgarh*. Retrieved from http://shodhganga.inflibnet.ac.in/handle/10603/9725

Singh. T.K.(2014). *Fish Diversity in Selected Stretch of the River Mahanadi in Odisha and the Livelihood of Inhabiting Fisher Community*. International Research Journal of Biological Sciences, Vol 3(8), 98-104, ISSN 2278-3202

South Eastern Coalfields Limited (2014). *28th Annual Report*. Retrieved from https://www.coalindia.in/DesktopModules/DocumentList/documents/SECL_08082014.pdf

Tharme, R. E. (2003). *A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers*. River research and applications, Vol. 19(5-6), pp: 397-441

The Brisbane Declaration (2007). *Environmental flows are Essential for Freshwater Ecosystem Health and Human Well-Being*. Retrieved from https://www.conservationgateway.org/Documents/Brisbane-Declaration-English.pdf

The Economic Times (2015). *Chhattisgarh Power Generation Capacity Touches 160,000 MW*. Retrieved from http://economictimes.indiatimes.com/industry/energy/power/chhattisgarh-power-generation-capacity-touches-16000-mw/articleshow/47962305.cms

Upadhyay, M. and Gupta, V.L. (2016). *Studies on variation of some parameters of Hasdeo River*. Lambert Academic Publishing (2016-02-17).

Vaishnav.M.M, Sahu.D (2006). *Study of Physio-chemical characteristics of Hasdeo river water at Korba*. Journal of Environment Research and Development.

Vaishnav, M.M., Hait, M., and Rahangdale, P.K. (2014). *Assessment of Water Pollution of Hasdeo River and its Surrounding Areas at Janjgir-Champa District (CG) India*. International Journal, Vol. 2(8), pp: 721-727.

WHO (World Health Organization) (2011). *Cadmium in Drinking Water*. Retrieved from http://www.who.int/water_sanitation_health/dwq/chemicals/cadmium.pdf

Forum Publications

Books and Reports

- Water Conflicts in India: A Million Revolts in the Making (Routledge)
- Life, Livelihoods, Ecosystems, Culture, Entitlements and Allocations of Water for Competing Uses
- Water Conflicts on India: Towards a New Legal and Institutional Framework
- Linking Lives-Reviving Flows: Towards Resolving Upstream Downstream Conflicts in Chalakudy River Basin.
- Water Conflicts in Odisha: A Compendium of Case Studies
- Floods, Fields and Factories: Towards Resolving Conflicts around Hirakud Dam
- Agony of Floods: Floods Induced water Conflicts in India
- Water Conflicts in Northeast India: A Compendium of Case Studies
- Conflicts around Domestic Water and Sanitation: Cases, Issues and Prospects
- Drinking Water and Sanitation in Kerala: A Situation Analysis
- Reform Initiatives in Domestic Water and Sanitation in India
- Right to Water in India: Privileging Water for Basic Needs
- Right to Sanitation in India: Nature, Scope and Voices from the Margins
- Mahanadi River Basin- A Situation Analysis
- Groundwater Resource and Governance in Kerala: Status, Issues and Prospects

Policy Briefs

- Water Entitlements and Allocations for Basic Needs, Environment, Livelihoods and Socio-cultural Needs: a Framework for Preventing and Managing Water Conflicts
- Towards a New Legal and Institutional Framework around Water: Resolving Water Conflicts in Equitable, Sustainable and Democratic Manner
- Resolving Upstream-Downstream Conflicts in River Basins
- Right to Sanitation: Position Paper of Right to Sanitation Campaign in India
- City Makers and WASH: Towards a Caring city
- Sanitation Rights and Needs of Persons with Disabilities
- Adivasis and Right to Sanitation
- Right to Sanitation: A Gender Perspective
- Dalits and Right to Sanitation

The Forum and Its Work

The Forum (Forum for Policy Dialogue on Water Conflicts in India) is a dynamic initiative of individuals and institutions that has been in existence for the last ten years. Initiated by a handful of organisations that had come together to document conflicts and supported by World Wide Fund for Nature (WWF), it has now more than 250 individuals and organisations attached to it. The Forum has completed two phases of its work, the first centring on documentation, which also saw the publication of 'Water Conflicts in India: A Million Revolts in the Making', and a second phase where conflict documentation, conflict resolution and prevention were the core activities. Presently, the Forum is in its third phase where the emphasis of on backstopping conflict resolution. Apart from the core activities like documentation, capacity building, dissemination and outreach, the Forum would be intensively involved in right to water and sanitation, agriculture and industrial water use, environmental flows in the context of river basin management and groundwater as part of its thematic work. The Right to water and sanitation component is funded by WaterAid India. Arghyam Trust, Bangalore, which also funded the second phase, continues its funding for the Forums work in its third phase.

The Forum's Vision

The Forum believes that it is important to safeguard ecology and environment in general and water resources in particular while ensuring that the poor and the disadvantaged population in our country is assured of the water it needs for its basic living and livelihood needs. The Forum is committed to the core values of equity, environmental sustainability, efficiency, livelihood assurance for the poor and democratisation.

The Forum's Mission

The Forum's mission is to influence policies and actions at all levels and work towards resolving, and preventing water conflicts in an environmentally and socially just manner, and creating awareness for achieving participatory, equitable, and sustainable water use. The Forum aims to carry out these through stakeholder interactions, knowledge creation, policy advocacy, training, networking and outreach.

Contact

Forum for Policy Dialogue on Water Conflicts in India
c/o SOPPECOM, 16 Kale Park, Someshwarwadi Road,
Pashan, Pune 411008, Maharashtra, India
Phone: 0091-20-2025 1168, 2588 6542
Fax: 0091-20-2588 6542
URL: www.waterconflictforum.org; www.conflicts.indiawaterportal.org