2022

ACTION PLAN FOR REDUCING PERSISTENT ORGANIC POLLUTANTS FOR GUJARAT

INDIA-NORWAY COOPERATION PROJECT ON CAPACITY BUILDING FOR REDUCING PLASTIC AND CHEMICAL POLLUTION IN INDIA (INOPOL)

INOPOL

Norwegian Embassy
New Delhi

NIVA

mμ gamma

SRM
INSTITUTE OF SCIENCE & TECHNOLOGY
Deemed to be University u/s 3 of UGC Act, 1956

Toxics Link

INOPOL (2022) Action Plan for Reducing Persistent Organic Pollutants (POPs) in Gujarat

Acknowledgements

Action Plan for Reducing Persistent Organic Pollutants in Gujarat is a joint effort by the **Norwegian Institute for Water Research (NIVA)**, Norway's leading institute for fundamental and applied research on marine and freshwaters; **Mu Gamma Consultants Pvt Ltd (MGC)**, a research and consultancy organization working towards environmental-friendly solutions in promoting green development across India; **SRM Institute of Science & Technology (SRMIST)**, a private deemed university at the forefront of breakthrough research and innovation in environmental sciences and other areas; **Toxics Link (TL)**, an NGO dedicated to bringing toxic-related information into the public domain with unique expertise in the areas of hazardous, medical and municipal wastes; **The Energy and Resources Institute (TERI)**, a not-for-profit, multi-dimensional, policy research organization working in the fields of energy, environment, and sustainable development, and **Central Institute of Petrochemicals Engineering & Technology (CIPET)**, a premier academic institution working on developing plastics recycling technology and cost-effective recycled plastics. The research for the Action Plan for Reducing Persistent Organic Pollutants in Gujarat was carried out under the scope of the India-Norway cooperation project on capacity building for reducing plastic and chemical pollution in India (INOPOL), under the Marine Pollution Initiative developed by the two governments, and funded through the Norwegian Development Program to Combat Marine Litter and Microplastics. The INOPOL group would like to thank the project owner, the Royal Norwegian Embassy in New Delhi, and the Norwegian Ministry of Foreign Affairs (MFA), for funding and supporting the project.

Suggested Citation

INOPOL (2022) Action Plan for Reducing Persistent Organic Pollutants (POPs) in Gujarat. India-Norway Cooperation Project on Capacity Building for Reducing Plastic and Chemical Pollution in India.

Designed by

Paper Play, Delhi. E: care.paperplay@gmail.com

Foreword

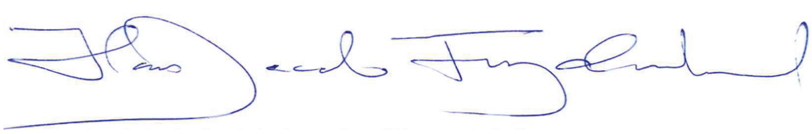
HANS JACOB FRYDENLUND

Ambassador, The Royal Norwegian Embassy in New Delhi

Over three years have passed since India and Norway established a Joint Marine Pollution Initiative to tackle and prevent pollution from both land-based and offshore activities in India, in line with SDG 14 – Life Below Water. This bilateral cooperation blossoms by taking advantage of our nations' respective strengths in marine research, waste management, technology, environmental pollution and human health, to learn from one another and implement best practices for sustainable development. The Royal Norwegian Embassy in New Delhi is pleased to support the publication of the INOPOL project's Action Plan for Reducing Persistent Organic Pollutants in Gujarat state in India.

The Action Plan highlights the important cooperation between India and Norway towards a sustainable blue economy; a joint effort which is continuously expanding in the fields of climate change, environmental research and ocean health. The common challenges of marine litter and pollution demands global solutions and local actions. Through high quality research and capacity building the two countries collaboratively accelerate the implementation of common responsibilities under multilateral platforms such as the Stockholm Convention on POPs. The close bilateral dialogue and transdisciplinary relationships developed as part of the INOPOL project will also be key when we continue to explore the feasibility of establishing a new global agreement to combat plastic pollution.

At the Embassy, we are delighted to read the State Action Plan published under the INOPOL project, which is a repository of knowledge for state level action. The report bridges important knowledge gaps on POPs pollution in the State of Gujarat and contributes to strengthen capacity to prevent and mitigate associated environmental threats, which in turn will benefit both policy makers and the wider public.



Hans Jacob Frydenlund
Ambassador, The Royal Norwegian Embassy in New Delhi

Foreword

DR. THORJØRN LARSSEN

DEPUTY MANAGING DIRECTOR, NORWEGIAN INSTITUTE FOR WATER RESEARCH

Plastic and chemical pollution are key threats to the sustainability of our societies and environment. The interlinked challenge of plastic pollution and persistent organic pollution requires diverse solutions that are local, national and global in scope. One important measure is to identify and tackle the sources of plastic waste and chemical pollution. This is particularly important in countries lacking efficient monitoring systems, waste management infrastructure and capacity to manage plastic waste at pollution hotspots.

The INOPOL project is part of the India-Norway Marine Pollution Initiative, which is a bilateral collaboration aimed at combatting marine pollution. An important component in this strategy is to improve societal wellbeing as part of achieving the sustainable development goals (SDGs), in addition to preventing and significantly reducing marine pollution from land-based activities (SDG target 14.1).

At NIVA, we are privileged to be working with leading Indian partner organizations and stakeholders to co-produce this important knowledge base. NIVAs strategy towards 2030 aims to use our expertise in multidisciplinary water research to find solutions to environmental challenges at the local and national levels. International cooperation projects such as INOPOL are important elements in this strategy.

We are delighted to share INOPOL project's Action Plan for Reducing Persistent Organic Pollutants in Gujarat state, India which provides a starting point to reduce plastic and chemical pollution in Gujarat State, India, the region and beyond. The Action Plan provides important insights for the Indian policy environment, on pollution levels, existing monitoring practices, related health and environmental impacts, best practices and ways forward. This science-based knowledge forms the foundation of developing future actions to strengthen local and regional capacity towards significantly reducing the environmental and human threats posed by plastic and chemical pollution. The preparation of this report would not have been possible without the contributions from many highly committed people.

On behalf of NIVA, I want to thank the Royal Norwegian Embassy in New Delhi for support, the Government of India and Gujarat State for excellent co-operation, and the entire project team for their great efforts.

Dr. Thorjørn Larssen
Deputy Managing Director, Norwegian Institute for Water Research

Table of CONTENTS

List of FIGURES

List of **TABLES**

List of ABBREVIATIONS AND ACRONYMS

ABS	Acrylonitrile-butadienestyrene
AMD	Acid Mine Drainage
ATIRA	Ahmedabad Textile Industry's Research Association
BAT	Best Available Technologies
BDL	Below Detectable Limit
BEP	Best Environmental Practices
BIS	Bureau of Indian Standards
BMF	Bio magnification Factor
BRS (Convention)	Basel, Rotterdam and Stockholm (Convention)
BRSR	Business Responsive Sustainability Report
CAS	Chemical Abstracts Service
CETP	Common Effluent Treatment Plant
CIB&RC	Central Insecticides Board and Registration Committee
CMSR	Chemicals (Management and Safety) Rules
COP	Conference of Parties
CPCB	Central Pollution Control Board
CPRI	Central Power Research Institute
CSIR	Council of Scientific & Industrial Research
DCM	Dichloromethane
DDT	Dichlorodiphenyltrichloroethane
decaBDE	Decabromodiphenyl ether
EC	European Community
ECHA	European Chemicals Agency
EI	Electron Ionization
EPA	Environment Protection Act
EPI	Emerging Policy Issues
EQS	Environmental Quality Standards
ESI	Electro Spray Ionization
ESM	Environmentally Sound Management
EU	European Union
E-waste	Electronic waste
FDI	Foreign Direct Investment
FAO	Food and Agriculture Organization of the United Nations
GATT	General Agreement on Tariffs and Trade
GC-ECD	Gas Chromatography – Electron Capture Detector
GC-MS	Gas chromatography Mass Spectrometry
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHCL	Gujarat Heavy Chemicals Limited
GIDC	Gujarat Industrial Development Corporation
GoG	Government of Gujarat
GPCB	Gujarat Pollution Control Board
GSPC	Gujarat State Petroleum Corporation
HBB	Hexabromobiphenyl
HBCDs	Hexabromocyclododecanes
HCB	Hexachlorobenzene
HCBD	Hexachlorobutadiene
HCH	Hexachlorobenzene
HIL	Hindustan Insecticide Limited
HIPS	High-impact polystyrene
ICS	International Chemical Secretariat

IEC	Information, Education, Communication
IIT	Indian Institute of Technology
INOPOL	India-Norway cooperation project on capacity building for reducing plastic and chemical pollution in India
IPM	Integrated Pest Management
KGE	Kling–Gupta Efficiency
KPIs	Key Performance Indicators
LCMS	Liquid Chromatography Mass Spectrometer
LOD	Limit of Detection
LOQ	Limit of Quantification
MEA	Multilateral Environmental Agreements
MEE	Ministry of Ecology and Environment
MIS	Management Information Systems
MoAFW	Ministry of Agriculture and Farmers Welfare
MoCF	Ministry of Chemicals and Fertilizers
MoEFCC	Ministry of Environment, Forest and Climate Change
MoHFW	Ministry of Health & Family Welfare
MST	Ministry of Science & Environment
MT	Metric Tonne
NCC	National Coordination Committee
ND	Not Detectable
NEERI	National Environmental Engineering Research Institute
NGO	Non-governmental organization
NGT	National Green Tribunal
NIP	National Implementation Plan
NIST	National Institute for Interdisciplinary Science and Technology
NSE	Nash–Sutcliffe Efficiency
NVBDCP	National Vector Borne Disease Control Programme
OCPs	Organochlorine pesticides
Octa-BDE	Octabromodiphenyl ether
PBDEs	Polybrominated Diphenyls Ethers
PBT	Persistent, Bio-accumulative and Toxic
PCB	Polychlorinated Biphenyl
PCD	Personal Compound Database
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dibenzo-p-furans
PCNs	Polychlorinated Naphthalenes
PCU	Project Coordination Unit
PE	Polyethylene
PeCB	Pentachlorobenzene
Penta-BDE	Pentabromodiphenyl ether
PERSiST	Precipitation, Evapotranspiration and Runoff Simulator for Solute Transport (hydrology model)
PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane Sulfonic Acid
PIB	Press Information Bureau
PIC	Prior Informed Consent
POPS	Persistent Organic Pollutants
PP	Polypropylene Plastic
PPB	Parts Per Billion
PSU	Public Sector Undertakings
PUF-PAS	Passive Air Samplers equipped with Polyurethane Foam
PUR	Polyurethanes
PVC	Polyvinyl Chloride
PwC	PricewaterhouseCoopers
QA/QC	Quality Assurance/Quality Control
R&D	Research and Development
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SAICM	Strategic Approach for International Chemicals Management
SC	Stockholm Convention on Persistent Organic Pollutants
SCCP	Short-chained Chlorinated Paraffins
SCRC	Stockholm Convention Regional Centre
SDGs	Sustainable Development Goals

SHD	State Health Department
SOM	System-on-Module
SPCBs	State Pollution Control Boards
SPE	Solid Phase Extraction
SPM	Suspended Particulate Matter
SPMU	State Programme Management Unit
SRCC	Spearman's Rank Correlation Coefficient
SUDA	Surat Urban Development Authority
SVOC	Semi-Volatile Organic Compounds
SWMR	Solid Waste Management Rules
TBBPA	Tetrabromobisphenol A
TBBPs	Tetrabromobisphenols
TBT	Technical Barriers to Trade
TCmX	2,4,5,6-tetrachloro-m-xylene
TCPP	Tris (1-chloro-2-propyl) Phosphate
TDCPP	Tris(1,3-dichloroisopropyl) Phosphate
TOC	Total Organic Carbon
TSDF	Treatment, storage, and disposal facility
ULBs	Urban Local Bodies
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
USA	United States of America
USEPA	US Environmental Protection Agency
WEEE	Waste of Electrical and Electronic Equipment
WFD	Water Framework Directive
WP	Wettable Powder
WTO	World Trade Organization

Executive SUMMARY

The INOPOL project

The India-Norway cooperation project on capacity building for reducing plastic and chemical pollution in India (INOPOL) is a collaboration project between Indian and Norwegian institutions with the objective to build knowledge and capacity to reduce plastic and chemical pollution from major sources within industry, public sector, and civil society in India. The INOPOL project is led by the Norwegian Institute for Water Research (NIVA), in close collaboration with Mu Gamma Consultants Pvt. Ltd. (MGC), Central Institute of Petrochemicals Engineering and Technology (CIPET), The Energy and Resources Institute (TERI), SRM Institute of Science and Technology (SRMIST) and Toxics Link (TL). The project aims to address the highly interlinked challenges of marine litter, microplastics and Persistent Organic Pollutants (POPs), with the overarching goals of enhancing capacity to reduce marine litter and microplastic pollution in Gujarat State, and building capacity to reduce releases of plastic wastes and POPs in India by supporting the implementation of the Stockholm Convention on Persistent Organic Pollutants (henceforth, Stockholm Convention (SC). The POPs Action Plan for Gujarat focuses on INOPOL's work in the latter domain.

POPs monitoring and inventorization in Gujarat

The INOPOL project was predominantly conducted in Gujarat state in two catchment areas of the Tapi river, with the city of Surat as an urban industrial centre, and the Daman Ganga catchment, that has the city of Vapi as its industrial hub. The sampling sites were determined based on the catchment area covering upstream, midstream, and downstream of the two riverine systems, and hotspots along urban and suburban transects including industrial discharges, open dumpsites, and wetlands. A control site was selected >20 km away from the hotspot region. Passive air sampling in the plastic manufacturing belts at Vapi in Gujarat was included. Secondary research has revealed that a few industries in Gujarat have been identified in producing new POPs and/or use them to produce secondary chemicals and Acid Mine Drainage (AMD) products, most of which are industrial chemicals. Industries have been mapped in Gujarat that produce POPs such as hexabromobiphenyl, hexachlorobutadiene, and decabromodiphenyl ether.

About this report

The POPs Action Plan discusses the releases and emissions of POPs related to anthropogenic activities **(source categories)** and categorizes them as intentional and unintentional use and release of chemicals. The intentional chemicals are actively added through industrial processes, agricultural applications, and consumer products, whereas POPs produced as by-products in industrial processes or combustion processes, or waste and leachate thereof, are referred to as 'unintentional' releases.

It has been identified that the seven newly banned POPs in India in 2021 are still **used for various purposes** including fungicides and pesticides to control specific pests in agriculture; solvents, greasing agents and in abatement technology in industrial processes; and in plastic materials and products. All these chemicals can also be found unused or leftover in stockpiles and/or specific waste fractions, potentially leaching into the local environment.

In a review of the SC guidance documents with relevance for India's implementation, a selection of the listed alternatives to POPs was assessed towards the status under the EU Chemical regulation. Several of the promoted alternatives are now firmly regulated and controlled under the EU law, due to their hazardous nature. The findings highlight one significant drawback of the opt-in ratification approach chosen by India, as many of the supporting guidelines developed under the convention are outdated and not relevant when needed. It was however, out of scope of this report to comprehensively assess the safety and potential hazard of each of the alternatives listed under the SC. Hence, India needs to adopt a careful approach, applying state-of-the-art science to critically evaluate the alternatives listed in the SC documents (in which some are outdated), to ensure that new harmful chemical alternatives are not put into circulation.

Outline

The aims, objectives, and context of INOPOL are outlined in **Chapter 1** of this POPs Action Plan. **Chapter 2** details the approach and methodology of the study. It also specifies the study locations, catchment areas, and sampling sites as well as the socio-economic context, policy environment/management capacity, and the industrial and potential source of POPs in these locations. **Chapter 3** presents an overview of the situation analysis (baseline) indicating the history of POPs in Indian environment, human exposure of POPs, source categories, common uses, and its alternatives. This chapter also covers the global and national legislative framework as well as the status of existing regulations for POPs management in India. **Chapter 4** presents an outline of POPs concentrations in selected catchments of Gujarat, and establishes sampling and monitoring guidelines as well as recommends a POPs monitoring program for Gujarat. **Chapter 5** emphasizes on modelling and management considerations for the catchment areas, identification of hotspots, and the crucial aspects related to the interlinkages between POPs and plastics. **Chapter 6** presents the Action Plan on POPs for Gujarat and lays out the goals, objectives, key actions (for handling POPs in Gujarat), implementation plan, defines the roles and responsibilities of stakeholders, and lists the key performance indicators for POPs Action plan. **Chapter 7** presents the key challenges and opportunities including pollution issues, trade issues, science and research, education, and outreach, and leveraging financial and human resources. It also touches upon the challenges related to compliance and accountability and commitment to POPs management as well as its integration with regional/global activities and efforts.

About the Action Plan

The **POPs action plan** report is developed to identify key actions to reduce the use and release of legacy and new POPs, which in turn will minimize the exposure to human health and environment in Gujarat. The aim of the POPs Action Plan is also to support and help strengthen regulations, cooperation, and awareness among stakeholders in management of POPs in Gujarat. The **key action areas** for handling POPs in Gujarat are:

a) Strengthen regulation, management, and control of unintentional releases of POPs in accordance with Annex C of the Stockholm Convention (Unintentional production) as well as institutional capacity building through enhancing chemical analyses capacity/ labs/equipment/skills,

b) Manage the production and use of chemicals listed on Annex A (Elimination) - unless there are specific exemptions - and Annex B (Restriction); of the Stockholm Convention

c) Identify and manage POPs stockpiles, articles in use and wastes (Annexes A, B and C of the Stockholm Convention),

d) Identify and manage POPs contaminated sites,

e) Knowledge management

f) Reporting of credible data

g) Monitoring and Evaluation

h) Research and Development

i) Technical and financial assistance and

j) Coordination and Sustainability of efforts in this regard

The proposed actions in the POPs Action Plan are directly linked to the goals and strategies of the Basel, Rotterdam, and Stockholm Conventions, Rotterdam Convention and Stockholm (BRS) Convention and will make contribution towards achieving the UN Sustainable Development Goals (SDGs) related to chemicals and wastes, including 2.1, 3.9, 6.3, 11.6, 12.4, 12.5 and 14.1, thereby contributing to improved environment, public health, well-being.

Chapter 1
AIMS AND OBJECTIVES

1.1 Project Context

The India-Norway cooperation project on capacity building for reducing plastic and chemical pollution in India (INOPOL) is a collaboration project between Indian and Norwegian institutions with the objective to build knowledge and capacity to reduce plastic and chemical pollution from major sources within industry, public sector, and civil society in India. The INOPOL project is led by the Norwegian Institute for Water Research (NIVA), in close collaboration with Mu Gamma Consultants Pvt. Ltd. (MGC), in cooperation with contributing partners including the Central Institute of Petrochemicals Engineering and Technology (CIPET), the SRM Institute of Science and Technology (SRMIST), The Energy and Resources Institute (TERI) and Toxics Link (TL). The INOPOL project aims to address the highly interlinked challenges of marine litter, microplastics and Persistent Organic Pollutants (POPs), with the overarching goals of enhancing capacity to reduce marine litter and microplastic pollution in Gujarat State, and building capacity to reduce releases of POPs in India by supporting the implementation of the Stockholm Convention. This report focuses on INOPOLs work in the latter domain.

A stronger scientific knowledge base will support India's ambitious targets to reduce plastic releases from land-based sources and enhance its efforts to achieve international commitments, such as the UN Clean Seas, the Basel Convention on hazardous waste and the implementation of the Stockholm Convention on Persistent Organic Pollutants (POPs). To combat marine litter and microplastics, the Norwegian government launched a development program "the Norwegian development program to combat marine litter and microplastics" in 2018. The main objective of the program is to "prevent and greatly reduce the extent of marine litter from large sources in developing countries", with a focus on populous and economically fast-growing countries in Asia. INOPOL was granted funding under the program in 2019 to develop coherent systems for data collection and analysis in India. The INOPOL project was formally launched by the Norwegian Minister of Climate and the Environment, Mr. Sveinung Rotevatn, at the Sabarmati Riverfront, Ahmedabad, in February 17, 2020. Project preparations and inception work commenced in 2019 and the project will wrap up in 2022. Building on the project teams' strong experience within environmental monitoring and management of POPs, micro and macro plastics, the key goals include to establish baselines on use and release, to strengthen monitoring capacity and standardization techniques, to assess social drivers and impacts, and identify sustainable solutions, and to develop sound monitoring and management tools. As one of the final combined products of these efforts, this report offers an *action plan for Gujarat state to improve implementation of regulations on POPs and reduce it presence and negative impacts on environments and human health*.

1.2 Report outline

Chapter 1 presents the aims, objectives, and context of Project INOPOL, and presents an outline of the Action Plan for Reducing Persistent Organic Pollutants in Gujarat. **Chapter 2** of the report introduces the methodological context, including the case study area, socio-economic and regulatory contexts, as well as the waste generation and pollution data. **Chapter 3** presents an overview of the situation analysis indicating the history of POPs in Indian environment, human exposure of POPs, source categories, common uses, and its alternatives. This chapter also covers the global and national legislative framework as well as the status of existing regulations for POPs management in India. **Chapter 4** presents a hydrodynamic modelling approach for identifying zones that are likely to generate more waste than others.

Chapter 5 presents an analysis of recent policy development with regard to phasing out plastic pollution, specifically in Gujarat State, and more broadly in India, along with state-of-the-art data on the role of the informal sector in preventing plastic leakage using survey and mapping methodologies. It also reviews health implications and interlinkages related to plastic and POPs exposure. **Chapter 6** reviews relevant international and national best available practices (BAP) and assesses their relevance for India and opportunities for enhancing local-level initiatives. **Chapter 7** summarizes recommendations from the previous sections and outlines the way forward, including impediments and opportunities for strengthening science-policy-society interphases towards reducing pollution and broader sustainable development.

Chapter 2
APPROACH AND METHODOLOGY

2.1 Case Study Location, Catchment, Sampling Sites

The study was conducted in Gujarat state in two catchment areas of the Tapi river, with the city of Surat as an urban industrial centre, and the Daman Ganga catchment, that has Vapi as its industrial hub. The following section details the location, catchment, and sampling sites.

Case Study Location

While the overarching goal of INOPOL is to build capacity to reduce pollution at the national level, the geographical focus of the study is Gujarat State (Figure 2.1.1). With a land area of 196,244 km^2 and a population projected to be almost 70 million in 2021, Gujarat is one of India's leading industrialized states, experiencing rapid industrial growth. A large number of pharmaceutical, chemical, petrochemical, textiles, pesticide and fertilizer industries dominate the economic landscape. The two catchment areas selected in Gujarat are the Tapi and Daman Ganga rivers which have Surat and Vapi respectively as their urban-industrial hubs (Figure 2.1.2). Based on socio-economic, geographical, and ecological factors, these catchments are likely to be contributing to plastic and chemical waste in the marine ecosystem.

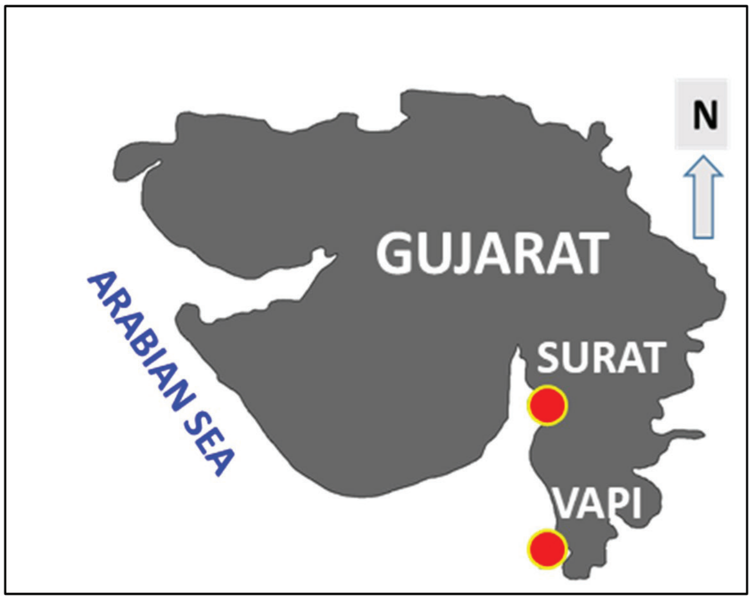
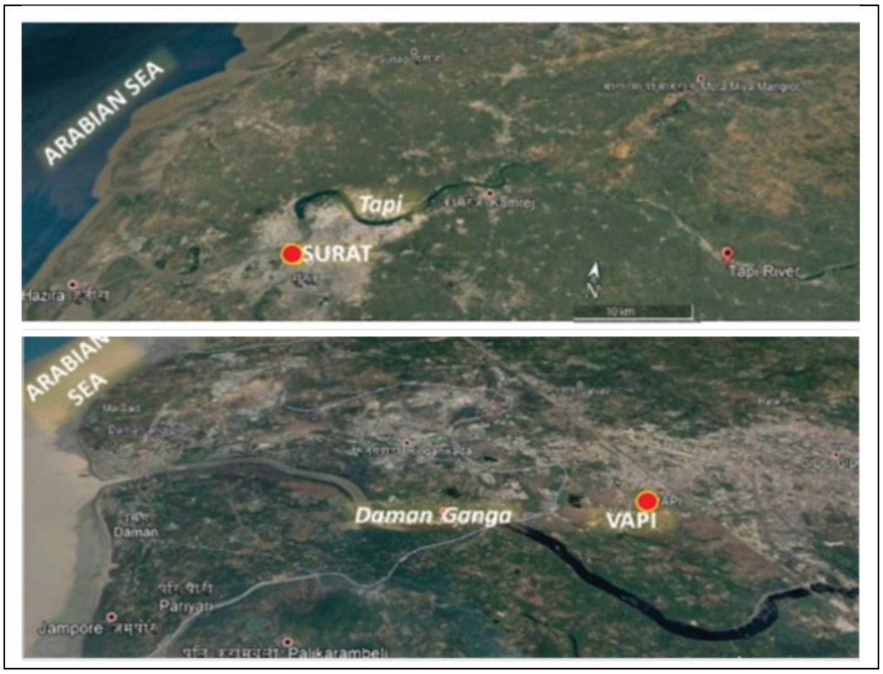


Figure 2.1.1: Case study locations of Surat and Vapi



Tapi Catchment
Urban Centre – Surat
Population (Million): 4.4 (2011)
7.1 million (2021 estimated)
Total Area: 474.2 km
Waste Generation: 2200 TPD

Daman Ganga Catchment
Urban Centre – Vapi
Population (Million): 0.16 (2011)
0.19 million (2021 estimated)
Total Area: 22 km
Waste Generation: 50 TPD

Figure 2.1.2: Catchment areas of Tapi and Daman Ganga rivers

Catchment

The Tapi River is the second-largest westward draining inter-state river basin in India, with the total elongated catchment being approx. 326.515 km^2. At the mouth of River Tapi, the industrial city Surat is located at 21.1702° N latitude and 72.8311° E longitude, which is also India's ninth-largest urban agglomeration and one of the world's fastest urbanizing cities. Surat has the highest composition of municipal plastic waste generation among 60 Indian cities, while it is also ranked as the second cleanest city in the country for the past three consecutive years (2020, 2021 and 2022).

The Daman Ganga River, which originates from the Sahyadri hills in Maharashtra and drains into the Arabian sea, is 131.30 km long and has a total catchment area of 2318 km^2. The industrial town of Vapi is located at the north bank of the river, at 20.3893° N latitude and 72.9106° E longitude. Vapi city houses Asia's largest industrial area and hosts small-scale, chemical-based industries as well as plastic recycling units. The Vapi Industrial Estate, started by Gujarat Industrial Development Corporation (GIDC) in 1967, stretches over 11.4 km^2 and houses more than 1400 industries, mostly small and medium sized enterprises which largely manufacture chemicals and paper. The Common Effluent Treatment Plant (CETP) in Vapi treats effluents before they are released into the river and is one of the largest of its kind in India.

Selection of sampling sites

The sampling sites were determined based on the catchment area covering upstream, midstream, and downstream of the two river systems (of Daman Ganga & Tapi) in the cities of Surat and Vapi in Gujarat, and hotspots along urban and suburban transects including industrial discharges, open dumpsites, and healthy wetlands. A control site was selected >20 km away from the hotspot region. Passive air sampling in the plastic manufacturing belts at Vapi in Gujarat was included. The collected samples included different environmental matrices for POPs analysis, namely surface water, sediment, soil, air samples (using polyurethane foam disk passive air samplers), and bovine milk. The samples were collected during two sampling campaigns in December 2020 and September 2021. In all, 73 samples were collected in December 2020 and 50 samples were collected in September 2021. Annexure I details the sampling locations.

2.2 Socio-economic context, policy environment and management capacity

Over the past few decades, efforts to manage the production and release of toxic chemicals including persistent organic pollutants (POPs) into the environment have been placed on the international development agenda, particularly evident through regulatory frameworks such as the Stockholm Convention on Persistent Organic Pollutants (SC). In response to the growing concern of managing these chemicals globally, India needs to develop systems for improving compliance by standardization of sampling and analytical protocols to manage these hazardous chemicals and POPs pollution.

POPs are chemicals which persist in the environment for years and can be highly toxic even when released in small quantities. Due to the emerging concern pertaining to chemical safety, the SC was adopted with the aim to eliminate or restrict the production and use of POPs globally. India ratified the SC in 2006 and submitted the National Implementation Plan (NIP) in 2011 to act on the twelve listed POPs. Thereafter, eighteen (18) new POPs were listed in the SC. In 2018, the MoEFCC promulgated regulations on seven (7) new POPs and subsequently ratified these in 2020 (PIB, 2020). As of date, India has ratified nineteen (19) POPs.

The POPs are used in day-to-day products and play an important role in the everyday life of people around the world. Products containing POPs provide protection for crops and increase yields, prevent and cure diseases, and provide other benefits that make life better and easier for people. However, after the scientific evidence on the harmful effects of POPs surfaced, there was a pressing need for its sound management to avoid risks to human health and the environment. The paradigm of risk assessment covers four main phases: hazard identification; examination of the relationship between harmful chemicals and environment and its adverse effects; exposure assessment and finally, risk characterization.

Prudent economic analyses of regulatory measures for harmful substances require consideration of external damages and associated socio-economic costs in decision making processes, including all stakeholders affected by the chemicals of concern. Socio-economic analysis is an important and necessary part of this process, and it is of great importance to perform in the right time, taking into account all relevant factors of POPs. The socio-economic analysis provides a standard framework for comparing the costs and benefits of policies, programs and projects that entail health and environmental impacts of POPs. However, for substances that are persistent, bio-accumulative and toxic (PBT), the cost-benefit assessments face some challenges. Persistence and bioaccumulation can occur far away (in terms of space and time) from their source, and therefore it is extremely difficult to predict and quantify the public health and environmental impacts of these substances. There are a few aspects that have triggered specific research efforts, such as:

- Deterioration of public health
- Loss or increase of means of living
- Changes in costs of living
- The level of child labour
- Changes in the degree of balanced distribution of social wealth
- Changes in demand for public services, such as health care, education and infrastructure
- Impact on vulnerable segments of society

All these aspects have been the focus of specific research efforts, but the strongest emphasis is on the assessment of the impact of POPs on public health particularly in the workplace. The Stockholm Convention mandates a global program to routinely monitor the concentrations of POPs in various environmental compartments (biota and human). Numerous research studies have focused on the effects of these chemicals on the ecosystem and somewhat lower number of research studies on their economic development impact (Zvonko et al., 2015).

The policy and legal frameworks for monitoring and managing POPs in India are currently under the control of the Ministry of the Environment, Forests and Climate Change, Central Pollution Control Board, Ministry of Chemicals and Fertilizers, Ministry of Health and the State Pollution Control Boards.

To meet the increasing global efforts on environmental monitoring of chemical contamination, India can enhance efforts to establish nationwide monitoring of chemical contamination in human population and standardize sampling and analytical protocols. While actively participating in various international treaties and conventions related to pollution control, India has a comprehensive set of environmental laws and policies. These include the National Implementation Plan, newly enacted legislation on the control of seven new POPs (2018), Draft Chemicals (Management and Safety) Rules, 20xx and the development of a set of National Environmental Standards. In addition to imparting environmental education, these new policy measures will further enhance the control of POPs and facilitate increasingly effective law enforcement.

2.3 Industry and potential sources of POPs

The chemical industry is a critical and integral part of the growing Indian economy. POPs are intentionally being used and unintentionally generated through various processes. Considering the environmental challenges, the industry needs to act by putting better system to mitigate and shift to better alternatives.

With respect to market size, India ranks 6th in the world and 4th in Asia in the chemicals and petrochemicals sector (PwC, 2021). The country ranks 14th in export and 8th in import of chemicals (excluding pharmaceuticals products) globally. The Department of Chemicals and Petrochemicals, Government of India, has anticipated that the demand for chemical products will grow at 9% per annum between 2020 and 2025, and is pegged at 1.2 X GDP (gross domestic product) growth. The Indian chemical industry is estimated to be valued at $163 Bn in 2017 (against the global estimate of $4.7 Tn) and contributes 3.4% to the worldwide chemical industry. The state of Gujarat on the western coast of India, with a coastline of 1,600 km, is the primary contributing state accounting for 51% of the production of significant chemicals in India (including organic and inorganic chemicals, alkali, pesticides, and dyes and dyestuffs).

Chemical production is the highest in the states of Gujarat and Maharashtra. The major chemical hubs of Gujarat are Ahmedabad, Vadodara, Bharuch, Vapi, Valsad, Dahej, Hazira (Surat), and Jamnagar. Gujarat accounts for over 50% of India's polymer production. The world's largest ship breaking yard is also located in Bhavnagar in Alang. As per the Government of Gujarat, there are about 500 large- and medium-scale industrial units of chemical and petrochemical industries, nearly 16,000 small-scale industry units, and other factory units. The State has promoted environment-friendly practices for effluent treatment of industrial plants, 28 of which are operational plants, and six are proposed (Government of Gujarat, 2016-2017). It has developed industrial estates in clusters, with South Gujarat alone having 132 clusters.

Secondary research has revealed that a few industries have been identified in producing new POPs and/or use them to produce secondary chemicals & Acid Mine Drainage (AMD) products, most of which are industrial chemicals. Industries have been mapped in Gujarat that produce POPs such as hexabromobiphenyl, hexachlorobutadiene, and decabromodiphenyl ether. AMD is the largest source of environmental problems caused by the mining industry (Geller et al., 2009).

The waste of electrical and electronic equipment (WEEE) generated in India and many other parts of the world have been related to the high concentration of polychlorinated biphenyls (PCBs) and polybrominated diphenyls ethers (PBDEs) in various environmental compartments (Brigden et al., 2005; Eguchi et al., 2012). In India, POPs, especially dichlorodiphenyltrichloroethane (DDT), hexachlorocyclohexane (HCH), and hexachlorobenzene (HCB) have been measured in all environmental compartments (Chakraborty et al., 2022). A recent review found terrestrial anthropogenic-based pollution to be a key source of POPs in the Indian Ocean ecosystem (Miraji et al., 2021). Bioaccumulation, bioconcentration, biomagnification, and long-range mobility of POPs, even beyond common human vicinity, support the global need for its effective management.

Chapter 3
SITUATION ANALYSIS

3.1 History of POPs in Indian environments and human exposure

In India, various research studies have reported the environmental occurrences, source identification, fate, and behavior of POPs in different environmental matrices (Chakraborty & Snow, 2022).

India is one of the most densely populated countries in the world and agriculture with its allied sectors is the largest source of livelihoods. The country has gained a rapid boost in industrial development in recent years, adversely affecting the environment quality and human health (Galli et al., 2012; Parikh, 2012; World Bank, n.d.). POPs, particularly organochlorine pesticides (OCPs), have unquestionably played an important role in India's development, with the country ranking as one of the world's most important producers of technical DDT and hexachlorobenzene (HCH) in the past. Rapidly developing agricultural and industrial sectors have been accompanied by the widespread application of OCPs including DDTs and HCHs (Awasthi et al 2016) .

Although the use of POPs in India has been banned or restricted during the last decade, much later than most western countries, derived products such as DDT containing dicofol and anti-fouling paints and lindane still constitute active primary sources of contamination. Organometals that bind to protein, especially organomercurials; lipophilic pollutants including dioxins, PCBs, PBDEs, and chlorinated insecticides; and persistent non-lipophilic chemicals like per fluorinated compounds as repellents are all sources of concern for human health. DDT and its derivatives have been discovered in almost all environmental media and are the most common OCPs detected in human tissues, particularly adipose tissue.

Research studies in India have shown potential for exposure of organisms, as relatively high levels of POPs have been detected in drinking water, food products, and even human breast milk (Shrivastava et al., 2018). For example, a study conducted by Someya et al. (2009) measured concentrations of POPs, including dioxins (PCDDs), furans (PCDFs), PCBs, and OCPs, in human breast milk from lactating mothers residing near an open dumping site in the Indian city of Kolkata. These studies investigate the inter-media transfer and remobilization of emerging POPs that are persistent and undergo biomagnification.

Multiple studies have established that POPs contaminate the Indian ecosystem even though there are few studies that document their direct impact on human health. (Toxics Link India, 2006; Sharma et al., 2014).

3.2. Source Categories and common uses

To manage, control and reduce the use, emissions, and release of POPs, it is essential to understand for what purposes the chemicals are used, as well as how they are applied and produced. A better understanding of such contextual factors will help us understand the different source categories and make a basis for identifying alternatives. This section reviews the common uses and potential source categories of POPs for Gujarat in particular, and India in general. The review is based on the guidance provided by UNEP and the Basel, Rotterdam, and Stockholm (BRS) Secretariat to assess its relevance to the Indian situation.

Source categories

Due to the favorable chemical properties, low cost of production in large volumes, high efficiency in low concentrations, and ease of use, many POPs have been used in the industry, agriculture, and consumer products. It is commonly distinguished between anthropogenic and natural releases of chemicals, and remobilization of the two former ones. This section will focus on the releases and emissions related to anthropogenic activities that subsequently may be divided into two categories: intentional and unintentional use/release of chemicals. The term 'intentional' use is applied when chemicals are intentionally and actively added to products or industrial processes, whereas POPs produced as by-products in industrial processes or combustion processes, or waste and leachate thereof, are referred to as 'unintentional' releases. An overview of the different source categories is provided in Figure 3.2.1.

Understanding the different source categories is essential for deciding which control measures to develop and implement. The active application of POPs in products, agriculture or industrial processes may be avoided and phased out through replacing harmful, hazardous chemicals with safer, non-harmful alternative chemicals. The unintentional releases must be reduced through abatement technology, best management practices and integrated systems approaches to avoid problem shifting to other environmental compartments.

Common uses

An overview of the active, intentional, and common uses of the seven new POPs ratified by India in 2018 are presented in Table 3.2.1. It must be noted that these categories are extracted from the Stockholm Convention guidance documents

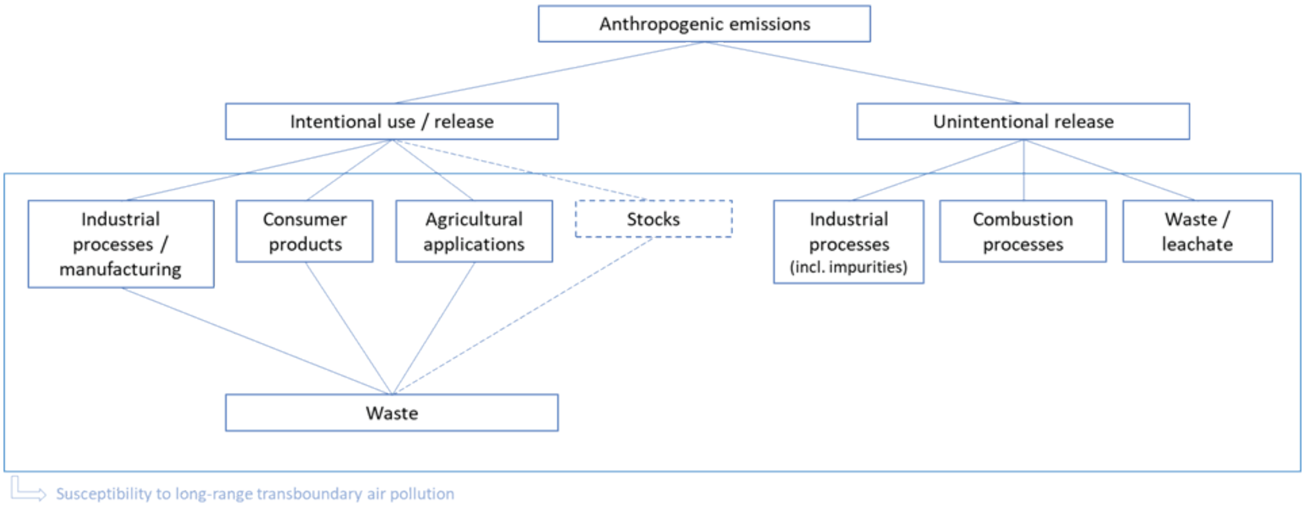


Figure 3.2.1. Key emission and release sources categories of POPs.

and the BRS webpages. It is important to note that these documents were developed mostly by North American and European experts and funded by the same countries. Our analysis has shown that throughout consultative hearings, very few developing countries have provided input and data. Hence, it is likely that different types of common uses of these POPs in developing countries may have been missed out in these overviews. In the case of India, improved public reporting schemes that require the industry to report the production, import and use of all hazardous chemicals, including their purpose of use, may significantly improve the knowledge basis for effective and proper management throughout the chemical life cycle. The implementation of the new scheme, the India Chemical Management and Safety Rules (CMSR), may provide such an opportunity. However, in its most recent draft, not all POPs are listed or addressed (Table 3.2.2). Furthermore, it is not sufficient to systematically collect the data; it is also essential to analyze it, to understand the flows, changes, and trends for effective decision making. It is still not clear how the Indian Government will deal with such matters once the CMSR is adopted.

The seven new POPs, as mentioned above, are used for various purposes (Table 3.2.1), including fungicides and pesticides to control specific pests in agriculture; solvents, greasing agents and in abatement technology in industrial processes; and in plastic materials (e.g., polystyrene, polyurethane foam, etc.) and products (e.g., furniture, upholstery, cables, electronics, etc.). An important feature with four of the seven chemicals/groups is their attractive flame-retardant properties, reducing risk and impact of fire. Moreover, all these chemicals can be found unused or leftover in stockpiles and/or specific waste fractions, potentially leaching into the local environment. A more detailed overview of common uses can be found in a dedicated Factsheet on the seven POPs, developed by Toxics Link under the INOPOL project (Toxics Link, 2018).

Table 3.2.1. Information of substances, use, and sources.

Substance / trade names (CAS/EC-No.)	Use	Source(s)	Alternatives
Chlordecone / Kepone / Merex (CAS no: 143-50-0; EC / List no: 205-601-3)	Pesticide (wide range of pests, e.g., banana root borer, tobacco wireworms, ants and/or cockroaches).	Agriculture, pest alleviation: Believed to be produced and used in some developing countries. Stockpiles. Detected in soil, water sediment, biota, and air. Prone to long-range transboundary air transport.	Alternatives to chlordecone exist and can be implemented inexpensively. Information on alternative pesticides has been reported from Canada and USA. Several of the alternative compounds are not concluded as safe or recommended by the POP Review Committee in the SC.

Substance / trade names (CAS/EC-No.)	Use	Source(s)	Alternatives
Hexachlorobutadiene / HCBD / Dolen-pur (CAS no: 87-68-3; EC / List no.: 201-765-5)	By-product from chemical synthesis of other chemicals. Used as a solvent for other chlorine-containing compounds. Industry uses; intermediate in chemical industry, as a product, solvent, scrubber to recover/ remove chlorine compounds from gas, as hydraulic, heat transfer, transformer fluid, and production of aluminum, magnesium, and graphite rods.	Industries that produce or use chlorinated aliphatic compounds (especially carbon tetrachloride and tetrachloroethene). Aluminum and magnesium production. Waste dumps and wastewater. Limited potential for long-range transboundary air transport.	Indication of no longer intentionally production and use in the UNECE region. Indication that substitution in the UNECE region, including Canada and USA have taken place. Specific information on alternatives have not been provided for the COP.
Hexabromobiphenyl / HBB / FireMaster (CAS no: 36355-01-8; EC / List no.: 252-994-2)	Used as a flame retardant in acrylonitrile-butadienestyrene (ABS) thermoplastics for constructing business machine housings, in industrial (e.g., motor housing), and electrical (e.g., radio and TV parts), in coatings and lacquers, and in polyurethane foam for auto upholstery.	Production of the thermoplastic polymer ABS. Cable coatings and lacquers. Polyurethane foam for auto upholstery. Waste dumps and leaching. Prone to long-range transboundary air transport.	Alternatives are available for all uses of hexabromobiphenyl, so prohibiting its use and production is deemed feasible and inexpensive. Several organic phosphorus compounds which are available as halogenated or non-halogenated substances can serve as alternatives for use in ABS plastics. Unfortunately, several of the substances have later been regulated and should not be recommended (e.g., TBBPA, TCPP, and TDCPP) and listed in the SC as alternatives.

Substance / trade names (CAS/EC-No.)	Use	Source(s)	Alternatives
Penta-BDE (TETRABROMODIPHENYL ETHER and PENTABROMODIPHENYL ETHER) (CAS no: 5436-43-1 and 60348-60-9)	Flame retardant in polyurethane (PUR) foam in furniture, automotive, and aviation industry.	In production, use and disposal/waste of material containing PUR foam. Waste dumps, landfills, and stockpiles.	Alternatives are available and used to replace these substances in many countries, although these may also have adverse effects on human health and the environment.
Octa-BDE HEXABROMODIPHENYL ETHER & HEPTABROMODIPHENYL ETHER Polybromodiphenyl ethers/ PBDEs (CAS no: 68631-49-2, 207122-15-4, 446255-22-7 and 207122-16-5)	Flame retardant additive, in polystyrene foam, plastic industry (ABS, high impact polystyrene, polybutylene terephthalate (insulator in electric industry), certain use in textile applications and electric equipment.	In production, use and disposal/waste of material containing ABS, electric industry, and textiles. Waste dumps, landfills, and stockpiles.	Alternatives generally exist. However, it is reported that many articles in use still contain these chemicals. In ABS, substances like TBBPs (tetrabromobisphenols) have been suggested as alternatives in the SC, but there are several health and environmental concern related to these substances.
HEXABROMOCYCLODODECANE / HBCD / HBCDD (CAS no: 25637-99-4, 3194-55-6, 134237-50-6, 134237-51-7, 134237-52-8; EC / List no.: 247-148-4)	Flame retardant additive, in polystyrene foam (insulation boards), and certain use in textile applications (back-coating of cotton/synthetic textiles) and electric equipment (polystyrene).	Direct emissions to air, to wastewater and to surface water / sediment from industry using HBCD.Waste dumps and landfills. Prone to long-range transboundary air transport.	The production of HBCD has decreased in the last years and chemical alternatives are available on the market to replace HBCD in high-impact polystyrene (HIPS) and textile back-coating. For polystyrene foam no 'drop in' replacement chemicals are commercially available at present. Alternative materials and product redesign techniques are suggested in the SC.

Substance / trade names (CAS/EC-No.)	Use	Source(s)	Alternatives
PENTACHLOROBENZENE / PeCB / PeCB (CAS no: 608-93-5; EC / List no.: 210-172-0)	Past uses in the risk profile concern PeCB as a component in PCB (polychlorinated biphenyl) products, dyestuff carriers, as fungicide, a flame retardant, chemical intermediate (production of quintozene), produced unintentionally during combustion and present as impurities (for example in pesticides).	Unintentionally production during incineration. Impurities in solvents and pesticides. Prone to long-range transboundary air transport.	The production of PeCB ceased some decades ago in the main producer countries as efficient and cost-effective alternatives are available. For the production of quintozene, an alternative process using the chlorination of nitrobenzene is available. Applying best available techniques and best environmental practices would significantly reduce the unintentional production of PeCB.

Table 3.2.2. Stockholm Convention POPs and their incorporation in CMSR. Number in brackets is the list number in the draft CMSR.

POP	CMSR Part II (n=13)	CMSR Schedule II (n=5)	Not listed (n=15)
Aldrin	√ (15)		
Chlordane	√ (116)		
Chlordecone			√
Commercial mixture, c-decaBDE		√ (162 + 449)	
Dicofol			√
Dieldrin	√ (189)		
Endrin	√ (236)		
Heptachlor	√ (291)		
Hexabromobiphenyl			√
Hexabromocyclododecane		√ (264 + 266)	
Commercial octabromodiphenyl ether)			√
Hexachlorobenzene (HCB)	√ (293)		
Hexachlorobutadiene (HCBD)			√
Alpha hexachlorocyclohexane			√
Beta hexachlorocyclohexane			√
Lindane (gamma-hexachlorocyclohexane)	√ (294)		
Mirex			√
Pentachlorobenzene (PeCB)			√
Pentachlorophenol and its salts and esters (PCP)		√ (722-723 + 725)	
Polychlorinated biphenyls (PCB)			√
Polychlorinated naphthalenes (PCNs)			√
Perfluorooctanoic acid (PFOA)		√ (101)	
Short-chained chlorinated paraffins (SCCP)		√ (277)	
Endosulfan and its related isomers	√ (234)		
Commercial pentabromodiphenyl ether)			√
Toxaphene	√ (103)		
DDT	√ (169)		
Perfluorooctane sulfonic acid (PFOS)			√
Hexachlorobenzene (HCB)	√ (293)		
Hexachlorobutadiene (HCBD)			√
Pentachlorobenzene (PeCB)			√
Polychlorinated dibenzo-p-dioxins (PCDD)	√ (296 + 591)		
Polychlorinated dibenzofurans (PCDF)	√ (108)		

CMSR-Chemical Management and Safety Rules (India)

3.3 Alternatives

An evident source of information on less/not-harmful chemical alternatives to the POPs is the Stockholm Convention's (SC) website. According to our review, several of the alternatives listed are harmful to the environment and to human health. The main explanation is that countries follow a very different trajectory when it comes to the implementation of the SC, whereas most countries automatically ratify amendments to the SC (i.e., new substances listed), others have an opt-in clause in their ratification, which imply that they must ratify each amendment actively. Often, this practice results in significant delays in implementation. Hence, the guidance material developed under the SC, becomes outdated and irrelevant. This has been the case for several of the guidance documents developed under the SC.

During the development of this report, a few of the listed alternatives (in SC guidance documents) were reviewed along with their status under the EU Chemical Regulation. Several of those listed are firmly regulated and controlled under the EU law, due to their hazardous nature. However, it has been out of scope of this report to assess the safety and potential hazard of each of the alternatives listed under the SC. Hence, the central and state government bodies in India needs to adopt a more careful approach, with critical evaluation of the alternatives listed in the SC documents (in which some are outdated), to ensure that new harmful chemicals are not put into circulation. Such a potential regulatory detour may cause a high economic burden on both industries and government bodies when new regulatory actions are put in place at a later stage. To assess the suitability of the alternatives, the resources provided by the EU and its European Chemicals Agency (ECHA) to its member states (and others, open accessible), including the listing of problematic chemicals (www.echa.europa.eu) needs to be considered (see Table 3.3.1). Another very useful resource is the search engine of the International Chemical Secretariat (ICS), which provides a comprehensive overview of hazardous and regulated chemicals, as well as a market space for safe alternatives (www.chemsec.org).

Table 3.3.1 ECHA Regulation of specific POPs (ECHA, n.d.)

Specific (New) POPs	Chlordecone	Hexabromo-biphenyl	Pentachloro-benzene	Hexachloro-butadiene	Hexabromo-cyclododecane
Date of inclusion in the ECHA POPs Regulation & POPs Regulation Annex	29/04/2004 Annex I, part A Annex IV	29/04/2004 Annex I, part A Annex IV	24/08/2010 Annex I, part A Annex III, part B Annex IV	19/06/2012 Annex I, part A Annex III, part B Annex IV	01/03/2016 Annex I, part A Annex IV
No harmonized classification or regulatory inclusion in ECHA		Penta-BDE (TETRABROMODIPHENYL ETHER and PENTABROMODIPHENYL ETHER)		Octa-BDE HEXABROMODIPHENYL ETHER and HEPTABROMODIPHENYL ETHER	

Note: Annex I to the regulation are subject to prohibition (with specific exemptions) on manufacturing, placing on the market and use; Annex II to the regulation is subject to restriction on manufacturing, placing on the market and use; Annex III to the regulation is subject to release reduction provisions; and Annex IV to the regulation is subject to waste management provisions.

3.4 International and national policy and legislation

Stockholm Convention: In May 2001, the Stockholm Convention on POPs was adopted, and it went into effect on May 17, 2004. The Convention's provisions mandate each of the 185 countries to prohibit, restrict, diminish, and eliminate specific POPs enumerated in various Annexes. The Convention currently regulates 31 POPs on its list. The Convention maintains a POPs Review Committee that examines the properties of POPs before deciding whether it should be recommended for listing.

EU developments on management of POPs: On November 16, 2004, the European Commission (EC) ratified the Stockholm Convention, expressing its support for the Convention's goals. On June 25, 2019, the EU recasted the POPs Regulation and the new regulation took effect on July 15, 2019, and the original (EC) No 850/2004, was repealed. The European Chemicals Agency (ECHA) of the European Union (EU) is in charge of the technical and administrative aspects of implementation of the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Recently, the EU published several amendments (EU) 2019/1021 to the POPs regulation (EU) 2019/1021 in its official journal to revise requirements for regulated substances and related provisions. (EU, 2019)

China: China signed the UN Stockholm Convention in May 2001, ratified it with an opt-in clause in June 2004, and issued the NIP in April 2007 (UNEP-POPS- NIP-China, 2007) for the initial group of 12 POPs. The NIP set objectives in stages and by region and industry for Convention implementation, developed implementation measures and specific action plans, and made action objectives in detail for the first stage (by 2010), the second stage (2010-2015) and the long-term future**.** The country submitted its second NIP in 2018. By December 2017, the number of POPs restricted and controlled in China according to the Convention and its amendments increased from 12 to 23.

China's Ministry of Ecology and Environment on June 4, 2021, issued a circular on operations to implement a ban on the production and use of hexabromocyclododecane (HBCD) under the Stockholm Convention on POPs. The circular describes implementation actions to take for the period until December 2021 (MEE China, 2021).

India's regulatory framework on POPs. The Stockholm Convention was ratified by India on January 13, 2006, and it entered into force on April 12, 2006. The Environmental Protection Act-1986 (EPA) is the overarching act to protect the environment.The EPA has specific regulations for managing industrial chemicals and POPs. The Rules under the EPA Act are: The Manufacture, Storage, and Import of Hazardous Chemical Rules, 1989; The Chemical Accidents (Emergency Planning, Preparedness, and Response) Rules, 1996; Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016; The Solid Waste Management Rules 2016, The Biomedical Waste Management Rules 2016, and The Regulation of Persistent Organic Pollutants (POPs) Rules 2018. Besides these, the Insecticide Act, 1968 has specific important provisions for managing the POPs - pesticides in India.

As mentioned earlier, the Government of India developed the NIP in 2011 to deal with 12 old POPs and measures have been taken to reduce and minimize their use and release. Yet, there are multiple prevailing gaps and challenges to managing those POPs. Subsequently, the Government of India also ratified seven new POPs and paved the way for updating the NIP.

3.5 Current Status of existing regulations

Current status of old POPs in India

As per the National Implementation Plan (NIP), about 9837.662 tons of PCB containing oil including retro-fillings are identified in India. The Government of India issued an order to manage the PCBs in an environmentally sound manner in 2016 and is currently implementing a Global Environment Facility (GEF) project to manage the PCBs. The old POPs-pesticides are completely banned for use in India. However, the NIP has also found the stockpiles of pesticides like dieldrin and aldrin in various states of the country various states of the country. Many of the POPs (pesticides like mirex, chlordane, heptachlor, etc.) are either never registered or used in India or have been banned for a long time. Further, there are reports of availability of some of these banned pesticides in India.

The NIP has also estimated the release of unintentional POPs like dioxins (PCDD) and furans (PCDF) (Bharat, 2018). The major source of the unintentional release of dioxins and furans are waste incineration (67%), ferrous/non-ferrous metal production categories, followed by the heat and power generation sector. Besides, landfill disposal facilities and sewage treatment facilities are also the sources of dioxins and furans release. Table 3.5.1 illustrates some of the regulations promulgated by the Government of India for the management of these POPs.

India has not yet updated the NIP for the new POPs. Many of these chemicals are not in the public domain. However, actions have been initiated to restrict the use of some of these chemicals through Court orders, and some regulations have been put in place (Toxics Link, 2018). The most special order was the ban on the use, sale, import, and export of endosulfan by the Hon'ble Supreme Court of India on May 13, 2011. Further, the E-waste rules of India restrict the use of hazardous chemicals like decaBDE etc. The Cabinet ratified "Regulation of Persistent Organic Pollutants Rules, 2018", which has put a complete ban on the manufacture, sale, and use of the seven new POPs, as an important step forward, to accelerate the phase out of these new POPs.

There is a need for the development of chemical analytical methods, instrumentation facility, capacity building, and skills to capture reliable data for the environmental and biological occurrences, and to investigate the distribution, temporal and spatial trends, environment fates, and potential sources of new POPs. Such quantitative analysis-based monitoring helps stakeholders to share responsibilities and provide vital information required by regulators.

Table 3.5.1. Regulatory actions against POPs.

Types of POPs	Name of the POPs	Regulatory Action
Pesticides	Aldrin, chlordane, endrin, heptachlor, hexachlorobenzene (HCB), mirex, toxaphene	Banned under the insecticides act 1986 and the rules
Industrial	Hexachlorobenzene (HCB), polychlorinated biphenyls (PCB)	Order on PCBs by the MoEFCC in 2016
Unintentional	Hexachlorobenzene (HCB), polychlorinated biphenyls (PCB), polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated-dibenzofurans (PCDF)	The Solid Waste Management Rules 2016 The Biomedical Waste Management Rules 2016 The Hazardous and other Wastes (Management and Transboundary Movement) Rules 2016

Chapter 4
SAMPLING AND MONITORING OF POPS

4.1. Sampling of POPs in selected matrices and locations in the Daman Ganga and Tapi river basins

The river basins of Daman Ganga and Tapi were selected for studies of POPs in INOPOL. Both river basins are located in the state of Gujarat and represent areas with urban and industrial contamination. For further information about the river basins see Chapter 2.1. Concentrations of PBDE (polybrominated diphenyl ethers) and HBCD (hexabromocyclododecane) were determined in water, river surface sediments, soil, air, and milk (manuscripts under preparation).

4.1.1 Daman Ganga sampling sites

Daman Ganga samples were collected in two phases from 2020 to 2021 covering upstream, midstream, and downstream areas, where the river empties into the Arabian Sea (Figure 4.1.1). The sampling stations were selected in such a way that they cover significant pollution hotspots within the industrial belt of Vapi, which includes numerous plastic processing and allied industries, chemical industries along as well as religious and tourist destinations. Station 1 and 2 are located in the upper stretch of Dadra & Nagar Haveli. Station 3 and 4 are located in the middle stretch. Station 5 is located in the estuarine region where the Daman Ganga meets the Arabian Sea. From each station surface water and sediment samples were collected. From the middle stretch particularly from the hotspot areas, air, soil, and bovine milk samples were collected. Phase 1 samples were collected during December 2020 while phase 2 samples were collected during 20th & 22nd September 2021 in the locations as shown in Figure 4.1.1.

4.1.2 Tapi sampling sites

Sample collection sites in the Tapi river basin are shown in Figure 4.1.2. Phase 1 samples were collected during December 2020 while Phase 2 samples were collected during 23rd & 24th September 2021. The sampling stations were located in such a way that they cover key pollution hotspots and covering hotspots of Surat city and its industrial belt which houses petrochemical refineries along with a major port. Station 1 is located in the upper stretch of Tapi river. Stations 2, 3 and 4 are located along the middle stretch, while Station 5 is located along the estuarine regions where the Tapi River meets the Arabian Sea. Figure 4.1.3, illustrates photographs from the sampling campaigns.

4.1.3 Sample collection techniques for air, soil, sediment, surface water, bovine milk, and biota

A brief description of sampling techniques used for sampling air, soil, surface sediments, and surface water is shown in Figure 4.1.4. Bovine milk

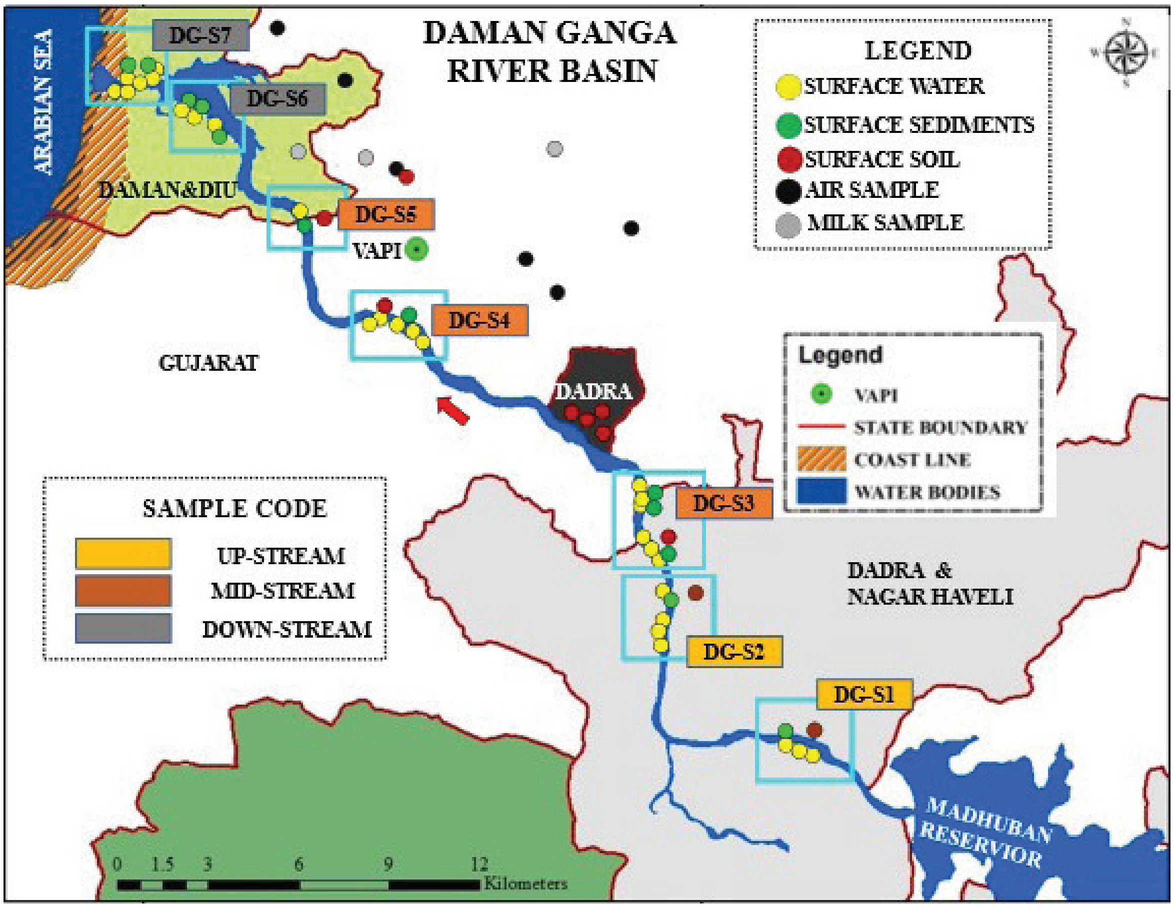


Figure 4.1.1. Sample collection sites of the Daman Ganga river basin.

samples were collected from cowsheds along the riverbanks of Daman Ganga (Vapi) from both cows and buffaloes. Samples were collected only from cows in the case of Tapi (Surat). Care was taken not to mix the milk from different cows. All bovine milk samples were thawed and homogenized by shaking them. Biota samples (fish and mussels) were only available in limited quantitites (Mussels – 1 no. from Daman Ganga & Fish – 2 nos. from Tapi). These were freshly captured/collected from the site live. In order to minimise the effect of temperature, samples were transported in ice boxes and stored in a -20°C refrigerator when they arrived.

4.2 Chemical analyses of PBDE and HBCD

A description of analytical method used to analyze the POPs PBDE and HBCD is provided below.

4.2.1 Extraction and cleanup process for PBDE and HBCD in the different matrices

Various extraction methods were used to prepare the samples for extraction after they were collected from sites and stored at -20°C refrigeration. Prior to extraction, 20 ng of 2,4,5,6-tetrachloro-m-xylene (TCmX), decachlorobiphenyl (PCB209), and 2,2′,3,4,4′,5,6-heptabromodiphenyl ether (BDE 181), α, β and γ HBCD 13C – mass-labelled standards were added to each sample as surrogates. Specific extraction protocols are discussed in the following sections. Quality control/assurance (QA/QC) of PBDEs was maintained at the range of LOD at 2-10 PPB and LOQ at 5-25 PPB.

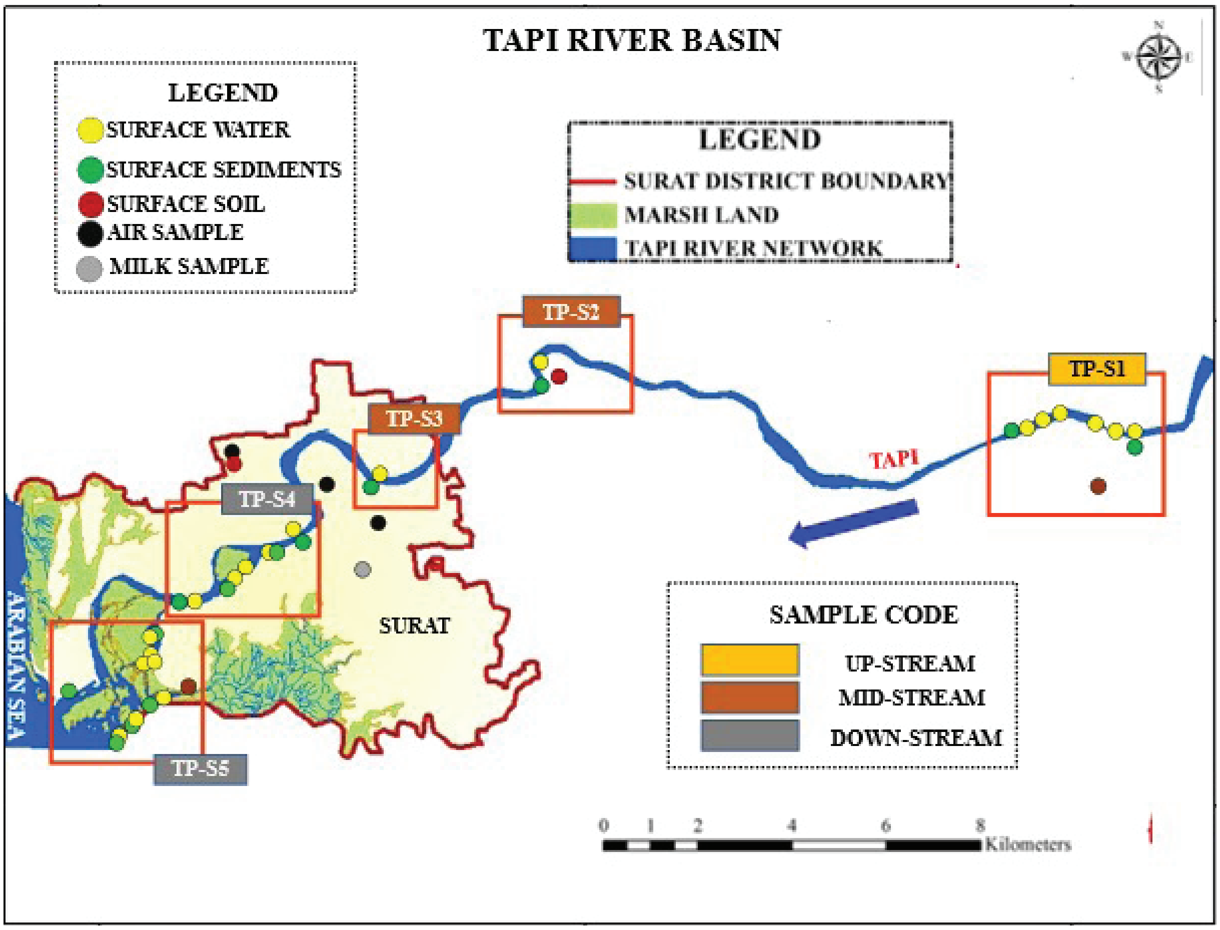


Figure 4.1.2. Sample collection sites of Tapi river basin.

Air

The PUF-PAS samplers were disassembled, and the PUF-PAS foam disks folded into previously cleaned paper thimbles to fit them into Soxhlet extractors. Then the PUF-PAS foam disks were subjected to Soxhlet extraction with dichloromethane (DCM) for 18 hours as suggested elsewhere (Chakraborty et al., 2010). The extracts were concentrated using a rotary evaporator (Buchi) and solvent-exchanged to hexane.

Soil and sediment

Samples of soil and sediment were extracted according to Chakraborty et al. (2015). Briefly air-dried soil and sediment samples were pulverised and sieved through a stainless-steel mesh of 1 mm. 20 g of the homogenized samples were Soxhlet extracted with DCM for 18 hours. The extracts were concentrated using a rotary evaporator (Buchi) and solvent-exchanged to hexane.

Surface water

1 L water sample was filtered using 0.45 m filter paper and extracted using method given elsewhere (Khuman and Chakraborty., 2019). Briefly, extraction was done using solid phase extraction (SPE) unit with 500 mg C18 SPE cartridge (Fig 4 and 5). The cartridges were conditioned by passing 6 mL methanol, 6 mL ethyl acetate: DCM (dichloromethane) (1:1, v/v). 6 mL methanol and 6 mL water further passed through to cartridge to avoid dryness. After loading the water sample, cartridges were washed with 3 mL water. The cartridges were then air-dried using vacuum for 15 minutes and eluted with 5 mL ethyl acetate: DCM

Figure 4.1.3. Onsite sample collection.

(1:1, v/v). The collected extracts were reduced to dryness under a gentle nitrogen stream and re-dissolved in 0.5mL hexane.

Bovine milk

Milk samples were extracted based on method adopted from Battu et al. (2004). 5 g milk samples were taken and samples were spiked with surrogate standards (2,4,5,6-tetrachlorom- xylene (TCmX). $^{13}C_{12}$ isotope labeled standard containing 7 PBDEs (MBDE-MXFS) and 3 HBCDs (MHBCD-MXA) were used for surrogate recovery, whereas 2,2′,3,4,4′,5,6-Heptabromodiphenyl ether (BDE 181) was used as internal standard. The samples were mixed with baked silica gel (20 g) and anhydrous sodium sulphate (20 g) and transferred to a column containing 40 mL Dichloromethane (DCM). The columns were kept at rest for 90 minutes and DCM eluted drop by drop from the column. The columns were eluted with 150 mL DCM: Acetone mixture (1:2, v/v). Anhydrous sodium sulphate was added to remove turbidity. The elutes were then concentrated using the rotary evaporator to dryness and the final volume was re-dissolved in hexane.

Biota

Biota samples (fish and mussels) were thawed, homogenized in a blender, frozen at -20°C, and freeze dried with an SP-Scientific Benchtop Pro Lyophilizers to remove moisture. 20 g of freeze-dried sample was then Soxhlet extracted using 150 ml of DCM, as mentioned for air samples.

The extracted samples were cleaned to get rid of matrix interferences using 15 mm i.d. alumina/silica columns, which were filled from bottom to top with neutral alumina (3 cm), neutral silica gel (3 cm), and acid silica (50%) (2 cm), and anhydrous sodium

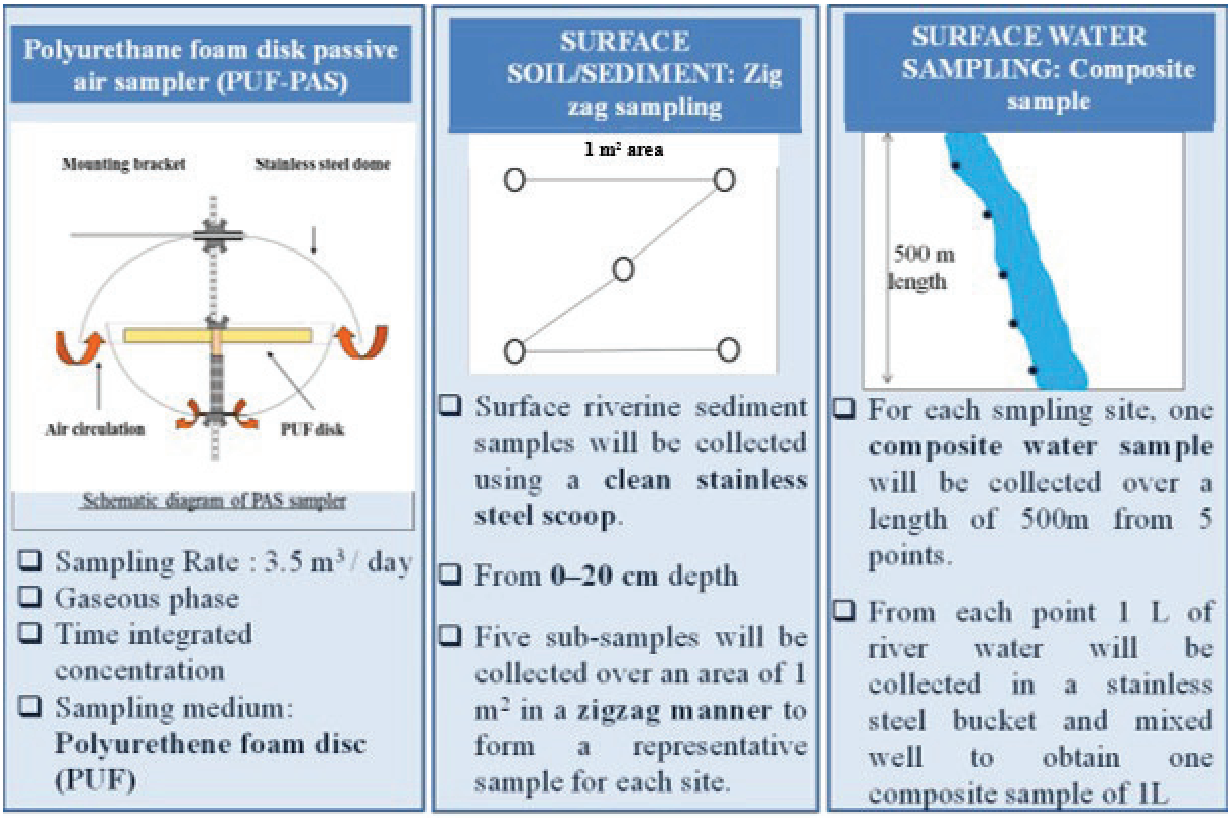


Figure 4.1.4. Brief sample collection protocol for air, soil, sediments, and water.

sulphate (1 cm). The columns were eluted with a dichloromethane/hexane (1:1) mixture. Isotope labelled BDE standards were added as internal standards prior to Gas Chromatography – Electron Capture Detector (GC-ECD) analysis. Samples were further cross-checked using GC-MS/MS for confirmation.

4.2.2. Instrumental Quantitation details (GC-MS/MS)

a. Polybrominated diphenyl ethers (PBDEs)

All the collected samples were analysed using an Agilent Gas chromatography-7890B/7000D mass spectrometry-Triple Quadrupole. An Agilent 19091S-433: 789.56862 HP-5MS 5% Phenyl Methyl Silox column (30 m x 250 m x 0.25 m) with helium as the carrier gas (99.9% purity) and total flow of 104.48 mL/min, temperature range of 60˚C—325˚C (350˚C), septum purge flow of 3 mL/min, and purge Flow of 100 mL/min at 0.75 min. The column temperature program was initiated at 100˚C for 2 mins. and increased to 290˚C at 20˚C/min, followed by increased to 315˚C and held for 28 mins. The MS source temperature was set at 300˚C and in electron ionization (EI) mode.

b. Hexabromocyclododecanes (HBCDs)

HBCDs was analyzed using Liquid chromatography mass spectrometer (LC-MS-MS) Triple quadrupole with AJS ESI ion source. Mobile phase A: water and B: Methanol were used for the separation. The program was: mobile phase B (100%) from 0 to 17 min, followed by mobile phase A (65%) and B (35%) from 17 to 18 min. Flow rate of 0.3 mL min−1 was maintained. Compounds were identified based on mass and spectrum compared with Mass Hunter METLIN PCD library.

QA/QC: Surrogate recoveries for PBDEs in different matrices ranged between 87-118% and for HBCDs ranged between 76% - 123%. Signal to noise ratio was > 3 for all samples analysed.

4.2.3. Total Organic Carbon (TOC)

For sediment and soil samples TOC was measured following the method of Salehi et al., (2011). The soil and sediment samples were air dried and sieved through a 2-mm sieve. The samples were then oven-dried at 105°C overnight, cooled in a desiccator, and weighed before they were combusted at 300, 360, 400, 500 and 550°C for 2 h in a muffle furnace (Model Exation 1200-30 L). After combustion, the samples were cooled in a desiccator and weighed. An estimation of soil organic matter (SOM) percentage from the loss-on-ignition method (SOMLOI) was calculated by the following equation:

SOM_{LOI} = [(soil weight after combustion - oven-dry soil weight) /oven-dry soil weight] X 100.

Water samples were analysed using Schimadzu-Total Organic Carbon Analyser (TOC).

4.3 Statistical Analysis

Statistical analyses were undertaken to assess the variability in the obtained dataset and create figures using SPSS version 22 (www.ibm.com). The dataset was found to be not normally distributed. Concentrations in some individual samples were considerably higher than average concentrations. In this document, maximum and minimum results refer to the highest and lowest concentration measured. The reason for high variation in measured concentration is unknown. Log scale is used for ease of representation.

4.4 Concentrations of PBDE and HBCD in selected matrices in the river basins of Daman Ganga and Tapi

During the project, water, surface sediments, soil, biota, air, and bovine wilk were sampled, and concentrations of PBDE (polybrominated diphenyl ethers) and HBCD (hexabromocyclododecane) were

Table 4.4.1. List of PBDE homologs analysed along with the respective PBDE congeners (Bold italics indicate the congeners analysed in air).

S. No	PBDE Homolog	PBDE Congener	S. No	PBDE Homolog	PBDE Congener
1	Mono BDE	BDE 3	16	Hexa BDE	BDE 138
2	Di BDE	BDE 7	17		***BDE 153***
3		BDE 15	18		***BDE 154***
4	Tri BDE	BDE 17	19		BDE 156
5		***BDE 28***	20	Hepta BDE	***BDE 183***
6	Tetra BDE	***BDE 47***	21		BDE 184
7		BDE 49	22		BDE 191
8		***BDE 66***	23	Octa BDE	BDE 196
9		BDE 71	24		BDE 197
10		BDE 77	25	Nona BDE	BDE 206
11	Penta BDE	***BDE 85***	26		BDE 207
12		***BDE 99***	27	Deca BDE	BDE 209
13		***BDE 100***			
14		BDE 119			
15		BDE 126			

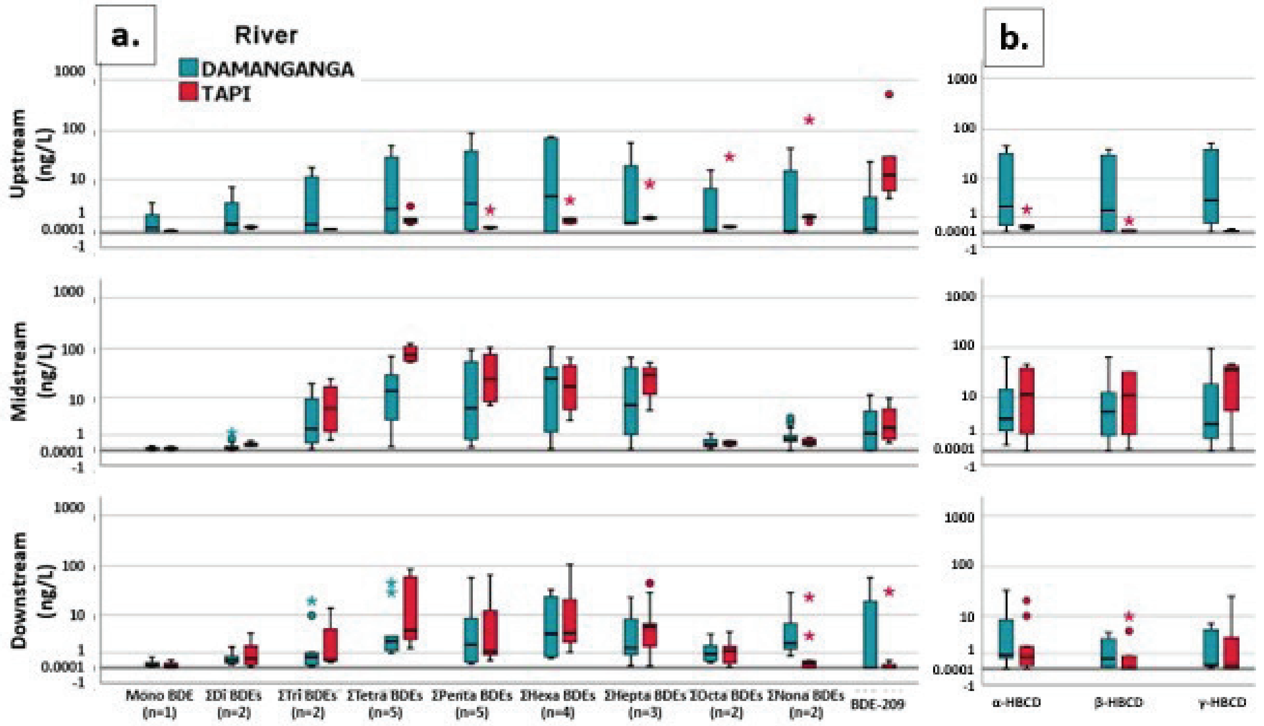


Figure 4.4.1. Box whiskers plot showing individual concentration range in log scale (Unit: ng/L). The central box represents the concentration values from the 25th to 75th percentile. The bold line represents the median. The horizontal line extends from the minimum to the maximum value. Outliers which display the high/low concentrations values are marked as dots and asterisks. (a) sum of PBDE homologs ("n" is the no. of congeners) and (b) HBCD isomers along the Daman Ganga and Tapi rivers in Gujarat. Manuscript under preparation (Chakraborty et al., 2023, "New POPs along the Damanganga and Tapi rivers of Gujarat, India)

determined. Details of PBDE congeners in each homolog are listed in Table 4.4.1.

4.4.1 Water samples in Daman Ganga and Tapi

Twenty-seven polybrominated diphenyl ethers (PBDE) congeners and three hexabromocyclododecane (HBCD) isomers were analyzed in water samples from Daman Ganga and Tapi. Sampling was undertaken at three major locations: upstream, midstream, and downstream of both rivers. Results are presented in Figure 4.4.1 a and b. Manuscript under preparation (Chakraborty et al., 2023, "New POPs along the Damanganga and Tapi rivers of Gujarat, India).

Total Σ_{27}PBDEs appear to be higher in midstream water samples followed by upstream and downstream in both Daman Ganga and Tapi rivers. Surface water samples affected by industrial wastewater discharges in Silvassa industrial area showed elevated PBDEs and HBCDs, and especially in station 2 in the upstream of Daman Ganga. Several hotspots including open dumps and industrial discharge points may explain the high levels of these flame retardants in the midstream stations. The deca BDE congener BDE-209 concentration (525 ng/L) was highest in Tapi (maximum value), and hexa BDE congener (BDE-153) (102 ng/L) contributed the maximum concentration in midstream waters of Daman Ganga. The BDE-153 appear higher downstream of Tapi river compared to upper and midstream. The presence of BDE-153 in midstream and downstream waters was possibly due to the discharges from commercial octa-BDE products and the debromination of deca-BDE (Liang et al., 2019). Deterioration of wastes dumped in certain hotspot sites could also be the reason for increased level of BDEs (Daso et al., 2013).

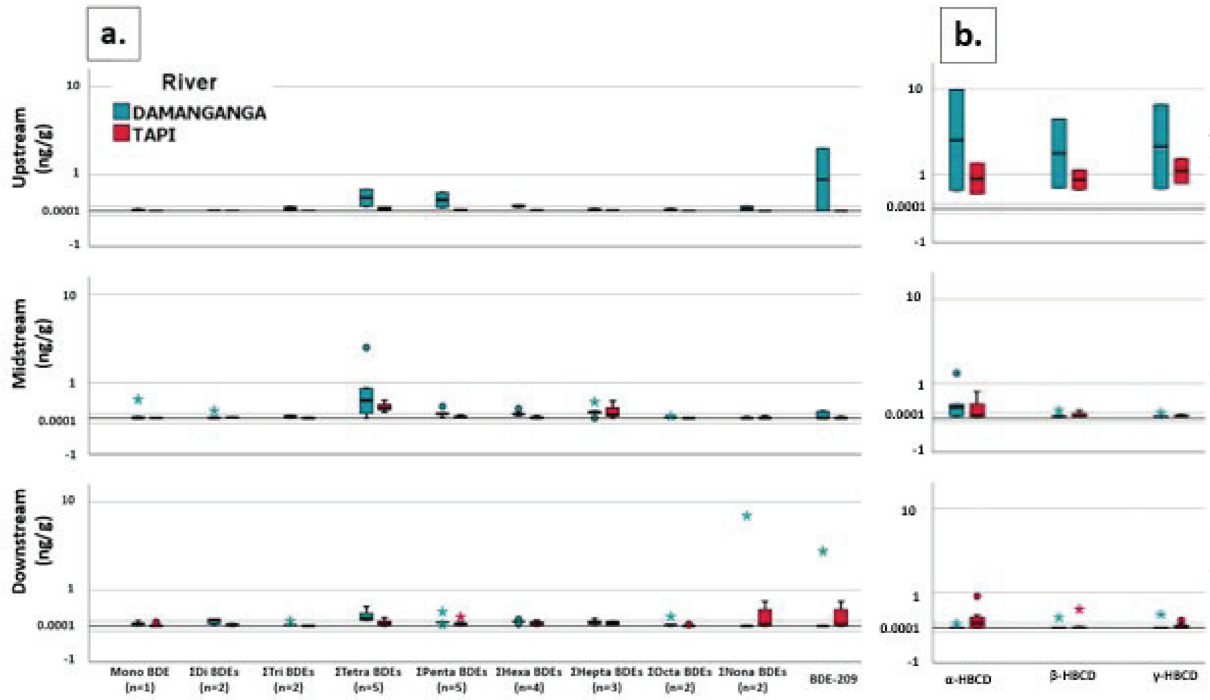


Figure 4.4.2. Box whiskers plot showing individual concentration range in log scale (Unit: ng/g dry weight). The central box represents the concentration values from the 25th to 75th percentile. The bold line represents the median. The horizontal line extends from the minimum to the maximum value. Outliers which display the high/low concentrations values are marked as dots and asterisks. (a) sum of PBDE homologs ("n" is the no. of congeners) and (b) HBCD isomers in the riverine sediments of upstream, midstream and downstream sections of Daman Ganga and Tapi rivers.

Σ_3HBCDs in the surface waters of Daman Ganga River ranged between below detectable limit (BDL) to 230 ng/L while in Tapi river it ranged between below detectable limit – 107 ng/L (Figure 4.4.1 b). Σ_3HBCDs in the midstream section (S2, S3, S4 & S5) of Daman Ganga and downstream section (S3 & S4) of Tapi river were found to be comparable to levels found in another study conducted in a highly industrialized region in South China (He et al., 2013). Levels of HBCDs observed in the current study were two orders of magnitude lower than in studies conducted nearby a HBCD production plant in China (Zhang et al., 2018). HBCD levels in the upstream and downstream sections of the Daman Ganga and Tapi were found to be comparable to levels found in the Yangtze river, China (Zhang et al., 2022), Taihu Lake, China (Xu et al., 2013), South Korea (Jeon et al., 2019) and several orders of magnitude higher than in surface waters of English lakes (Harrad et al., 2009).

4.4.2. Surface sediments in Daman Ganga and Tapi

Sediments can be considered historical archives for the emission history of PBDEs and HBCDs into the aquatic ecosystems because PBDEs regularly accumulate over time (Zhu & Hites 2004).

In Figure 4.4.2 concentrations of PBDE and HBCD in Daman Ganga and Tapi riverine sediment are shown.

PBDE levels in Daman Ganga riverine sediment (Figure 4.4.2 a) showed similar trend to the water samples with elevated levels of tetra-, penta- and deca-BDEs in the upper stretch of the Daman Ganga River. Interestingly, there is a considerable spike in the tetra BDEs in the midstream section of Daman Ganga River which was found to be marked with dumped plastic waste from religious activities undertaken on the riverbanks. Unlike the

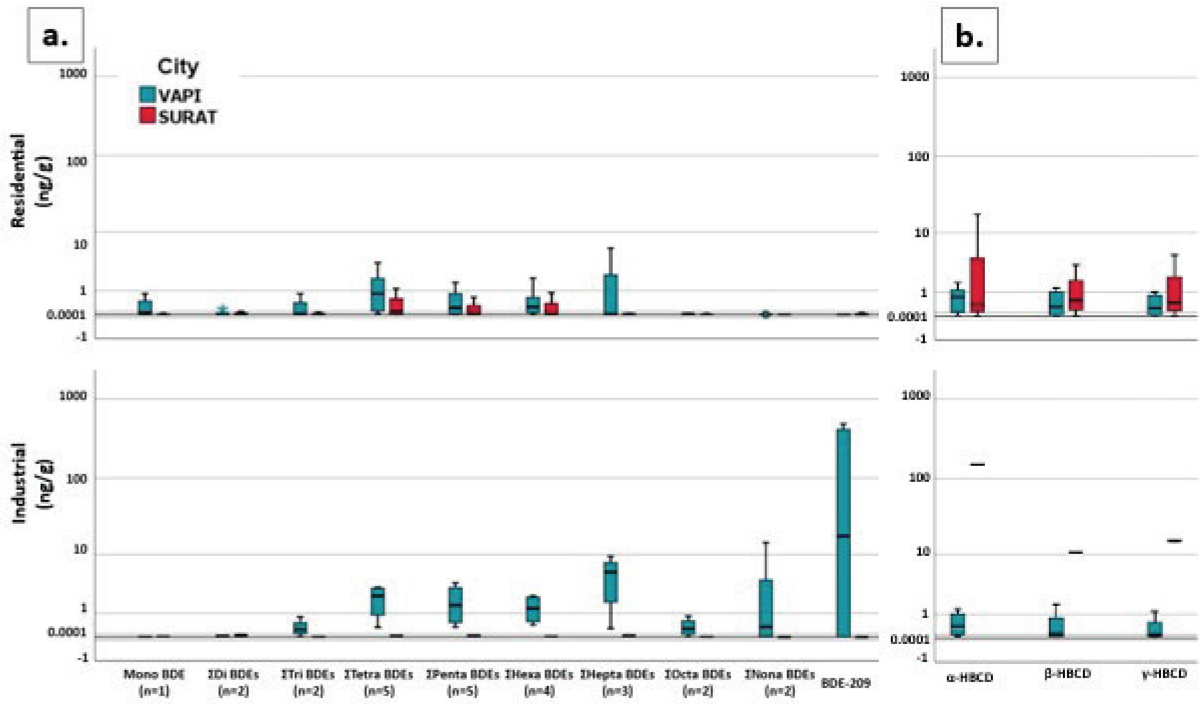


Figure 4.4.3 Box whiskers plot showing individual concentration range in log scale (Unit: ng/g dry weight). The central box represents the concentration values from the 25th to 75th percentile. The bold line represents the median. The horizontal line extends from the minimum to the maximum value. Outliers which display the high/low concentrations values are marked as dots and asterisks. (a) sum of PBDE homologs ("n" is the no. of congeners) and (b) HBCD isomers in the soils from residential and industrial transects of Vapi and Surat. (Single dash indicate concentrations for only one industrial site in Surat).

water samples, BDE concentrations were higher in downstream riverine sediment compared to the upstream and midstream sections (especially nona- & deca-BDEs) of both Daman Ganga and Tapi. These results indicate that the PBDEs found in water could have partitioned into the sediment in the mouth of the river where velocity of the flow is considerably reduced compared to upstream, an important factor for the BDEs to settle in sediments. Industrial waste, waste dumping sites, and spillage from fishing vehicles could also be the source of PBDEs in sediments. The PBDE concentrations found in the sample sites are comparable with concentrations found elsewhere in the world. For example, the Prédecelle River in France (Labadie et al., 2010), Jukskei River in South Africa (Olukunle et al., 2012), primary watersheds in Shanghai, China (Wu et al., 2013), and Niagra River, North America (Richman et al., 2013) have respectively displayed mean concentrations of 27.2, 23.9, 29.7, and 23.9 ng/g dw. The BDE levels found in Tapi riverine sediments were lower than those found in the Daman Ganga river.

Σ_3HBCDs in the sediment of Daman Ganga River ranged from 0.08 – 0.4 ng/g dw and 0.11 – 1.65 ng/g dw in the Tapi river (Figure 4.1.2 b). Levels observed in both the riverine sediments in all three sections were found to be comparable with sediments from Tokyo Bay, Japan (Minh et al., 2007) and South China (Li et al., 2021), and much lower than levels observed in Scheldt estuary, Netherlands (Verslycke et al., 2005), Sydney estuary (Drage et al., 2015), from near a HBCD production plant in China (Zhang et al., 2018) and Hyung-san river and Pearl river delta in China (Feng et al., 2012; Jo et al., 2017).

4.4.3. Soil

Concentrations of PBDE and HBCD in soil from

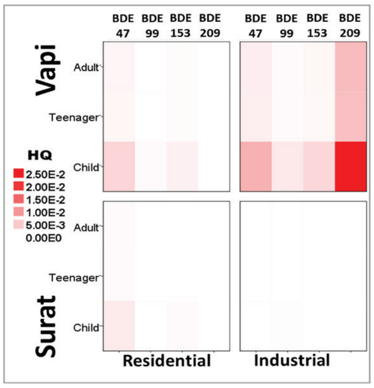


Figure 4.4.4: Heat map of hazard quotients calculated for soil samples in the residential and industrial transects of Vapi and Surat.

the catchment close to Daman Ganga and Tapi are shown in Figure 4.4.3. The result showed clear distinction of PBDE concentrations between industrial activity-oriented soil (Daman Ganga) and residential soil (Tapi).

Excluding the highest concentration of BDE-209, it was found that residential soils of Vapi exhibited higher levels of BDEs in comparison to residential soils from Surat. It is to be noted that the residential areas in Vapi are located within or at close proximity from the industrial belt. High PBDE concentrations were found in industrial manufacturing areas of Vapi. The results were similar to concentrations of higher brominated PBDEs in soils from a closed deca-BDE manufacturing factory in Jiangsu Province, China (Li et al., 2018). The highest value was for the BDE-209 congener accounting for up to 486 ng/g in a sample from an industrial site of Vapi. Around 95% of BDE-209 was found in the industrial sites. Similar results were reported by Xu et al. 2019. In this study, 99% of the detected BDEs was found to be BDE-209 of total 13 congeners analysed in soil along the Yangtze River in China. BDE-209 is a deca-BDE congener often used as the main component of flame retardants, and added to polyethylene (PE), polypropylene (PP), polyvinyl chloride, ABS resin, epoxy resin and other products (Xu et al., 2019). The results indicate the BDE-209 is the most dominant congener in soil from the core industrial site where plastic recycling is prevalent. Non-carcinogenic risk is assessed in terms of hazard quotient for dermal contact and ingestion. A hazard quotient is the ratio of potential exposure to a substance and the level at which no adverse effects are expected. If the hazard quotient is calculated to be less than 1, then no adverse health effects are expected as a result of exposure. Hazard quotient values for dermal contact and ingestion of BDE-47, -99, -153 and -209 in soil for adults, teenagers and children revealed low risk with all values being < 1 (Xu et al., 2019). However, children were found to be more susceptible. Σ_3HBCDs in soils from Vapi and Surat ranged from 0.01 – 3.3 ng/g and below the detectable limit – 176 ng/g in their respective residential areas (Figure 4.4.4). The maximum level of HBCD was observed in the industrial soil of Surat. Levels observed in the current study were found to be between one and two orders lower than the concentrations found in soil along the Hyung-san river in South Korea (Jo et al., 2017), near a HBCD production plant in China (Zhang et al., 2018) and in the Ningbo (Tang et al., 2014) and Chongqing regions (Lu et al., 2018) in China.

4.4.4 Bovine milk

Analysed bovine milk samples from Vapi and Surat showed detectable concentrations of PBDEs. The results showed that average levels of PBDEs in buffalo milk from Vapi were comparable to cow milk samples collected from Vapi. Σ_9PBDEs levels between Vapi and Surat cow milk samples were comparable (Figure 4.4.5). However, the individual levels of hexa-BDE (particularly BDE-153) were higher in cow milk samples of Surat, compared to other congeners. Overall results showed that BDE-153 was the dominant congener in all the milk samples. Manuscript under preparation (Chakraborty et al., 2023, "New POPs in the bovine milk of Vapi and Surat districts of Gujarat, India")

The highest level of hexa-BDE with the dominance of BDE-153 was found in a buffalo milk sample from Vapi. Generally, the lipid content in buffalo milk is higher than in cow milk (Abd El-Salam & El-Shibiny, 2011) and PBDEs and HBCDs are highly lipophilic in nature. The higher level of lipid content in buffalo

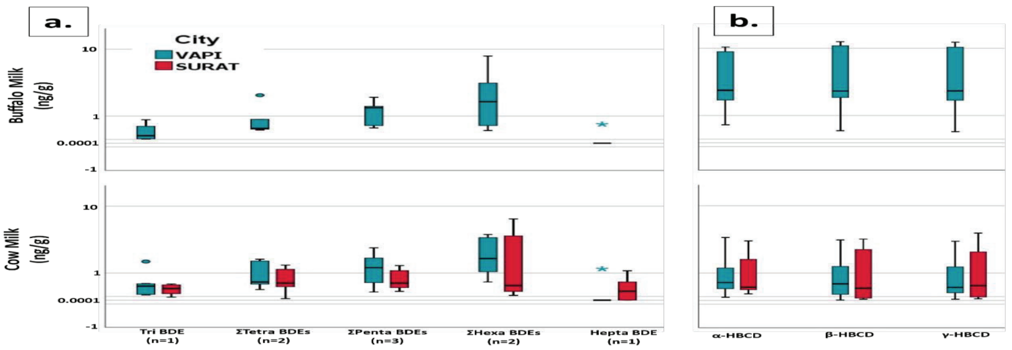


Figure.4.4.5: Box whiskers plot showing individual concentration range in log scale (Unit: ng/g). The central box represents the concentration values from the 25th to 75th percentile. The bold line represents the median. The horizontal line extends from the minimum to the maximum value. Measurements which display the high/low concentrations values are marked as dots and asterisks. (a) sum of PBDE homologs ("n" is the no. of congeners) and (b) HBCD isomers in bovine milk (buffalo and cow) of Vapi and Surat (cow). Manuscript under preparation (Chakraborty et al., 2023, "New POPs in the bovine milk of Vapi and Surat districts of Gujarat, India").

milk can favor increased accumulation of these compounds (Tanabe 2007, Asante et al, 2010, Kim et al, 2013). As a result of this lipophilicity, buffalo milk had higher HBCD concentrations compared to cow milk. Compared to a previous study in the US (Schecter et al., 2010), where no HBCD was detected in the milk samples, substantial levels have been found in the current study.

4.4.5 Air

Concentrations of PBDE and HBCD in the air are shown in Figure 4.4.6.

Air samples showed higher concentrations in industrial corridors of Vapi and Surat (Figure 4.4.6). Similar results were observed by Cincinelli et al. (2012) that recorded higher concentrations of PBDEs in industrial sites than in urban areas. However, considerable amounts of heavier penta-, hexa- and hepta-BDEs were also noted in the residential area of Surat. The presence of PBDE emissions from urban areas were previously documented by Saini et al, (2019). PBDEs are physically mixed with other chemicals in the plastic production process which allows them to leach from consumer products into the air, leading to their release into the environment (Watanabe I., 2003). However, it is noteworthy that incomplete combustion-oriented processes such as open burning of dumped waste including plastics can be a possible reason for the higher levels of heavier PBDEs in the air of Vapi and Surat.

Σ_3HBCDs in air samples showed higher concentrations in Surat compared to Vapi (Figure 4.4.6). The results were comparable to the soil sample with higher HBCDs in few individual sites in Surat. β-HBCD was found in maximum level in Vapi and γ-HBCD showed higher range in Surat. However, levels observed in the current study were found to be lower than the concentrations reported in Sweden by Covaci et al., (2006).

4.4.6 Biota

Given the low number of biota analysed, high uncertainty of the results is to be anticipated. While drawing definitive conclusions might not be possible, the results are still presented for reference. Biota contaminated with PBDEs showed a predominant presence of tetra-BDE congeners, unlike bovine milk. PBDEs being lipophilic in nature are more likely to accumulate in the fatty tissue of fish and get biomagnified at higher trophic levels.

PBDEs and HBCDs were detected only in one fish sample collected from upstream of the Tapi river (Figure 4.4.7). Mussels showed minimal amounts of contamination compared to fish. In contrast to the upstream pristine site fishing activity was

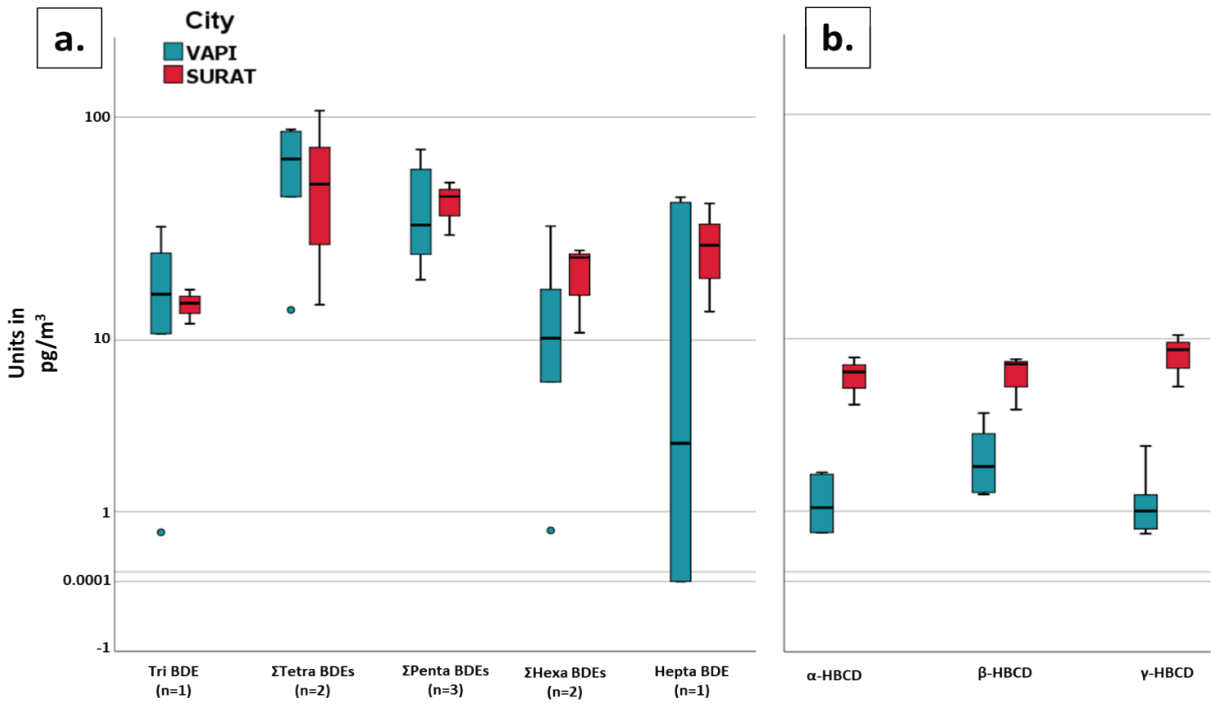


Figure 4.4.6: Box whiskers plot showing concentration range (in pg/m³). The central box represents the concentration values from the 25th to 75th percentile. The bold line represents the median. The horizontal line extends from the minimum to the maximum value. Outliers which display the high/low concentrations values are marked as dots and asterisks. (a) sum of PBDE homologs ("n" is the no. of congeners) and (b) HBCD isomers in the air of Vapi and Surat.

more prevalent in the second fish sampling site downstream. It is to be noted that this site had a discharge point from the community dwellers and plastic wastes were found to be floating. Water samples taken from this site also showed a similar profile of PBDEs with an elevated level of heavier congeners compared with the upstream site. PBDE and HBCD levels in the fish were found to be lower than the FAO stipulated values. It was found that the fish samples exceeded the limit for PBDEs as per Directive 2013/39/EU of the European Union and were also lower than the limits for HBCD (Eljarrat & Barcelo, 2018).

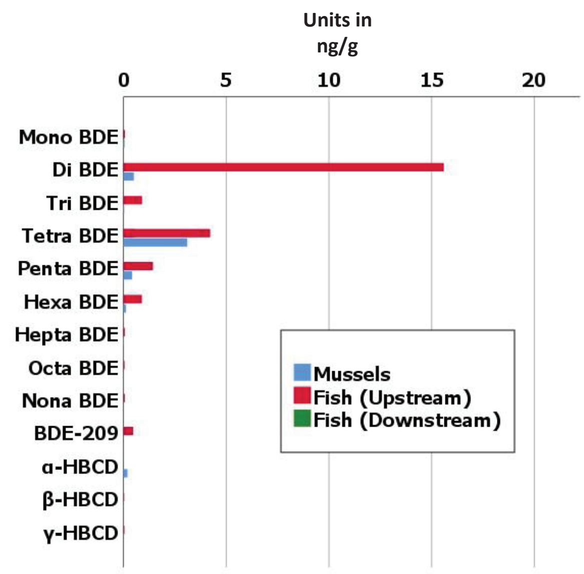


Figure 4.4.7: Box whiskers plot showing range (in ng/g) sum of PBDE homologs and HBCD isomers in biota from Daman Ganga and Tapi rivers

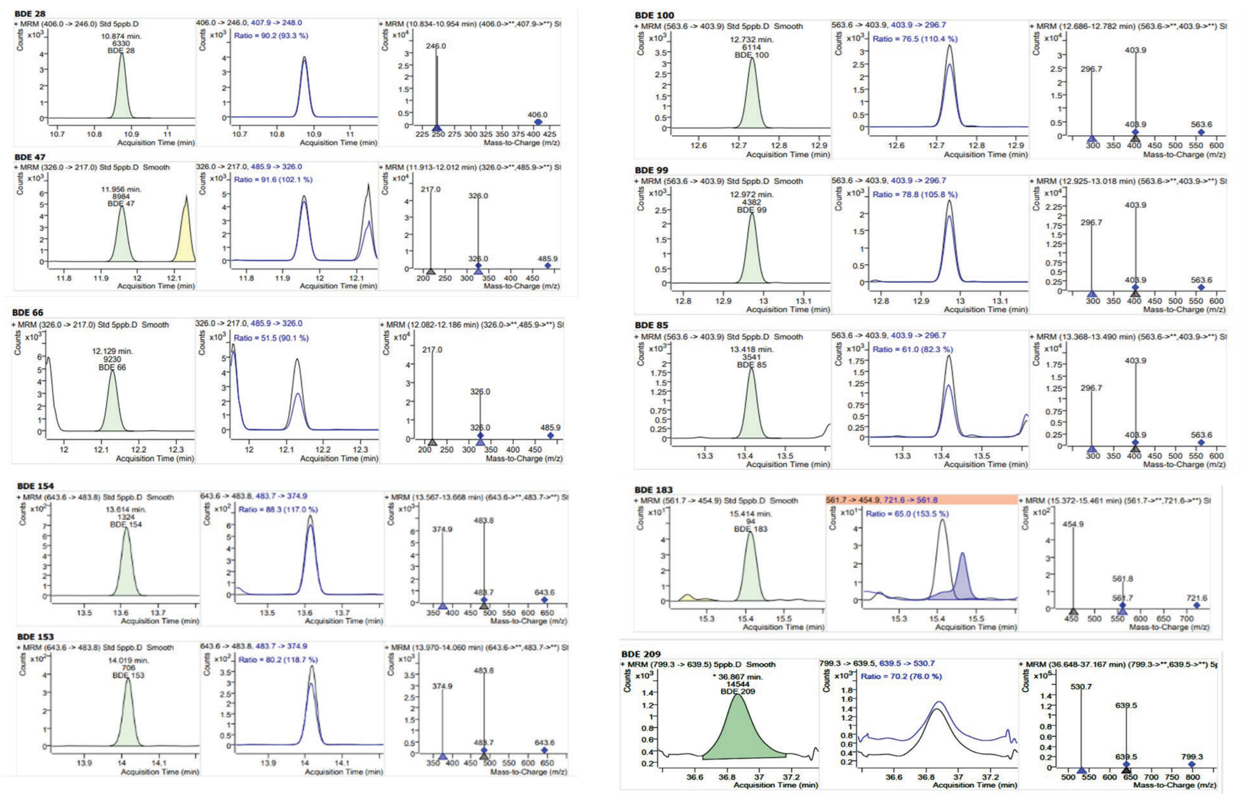


Figure 4.4.8 Chromatograms showing the multiple reaction monitoring in GC-MS of most abundant PBDE congeners.

4.5 Recommended POPs monitoring program for Gujarat

Sampling and analysis of POPs in different environmental compartments during the INOPOL project has provided critical information for the establishment of a POPs monitoring program for Gujarat. Information gathered has provided insight into levels of POPs in air, water, soil, sediments, bovine milk, and biota. The identified levels of POPs may pose a threat to human health and the environment. While the INOPOL sampling campaigns were undertaken at a limited number of locations and does not reflect seasonal variations, the results provides an insight into the state of POPs pollution across environments in Gujarat state. A further strengthening of sampling capacities, laboratory analyses, supporting parameters for POPs, and a holistic interpretation of the gathered environmental data is needed.

A monitoring program for all environmental matrices should be designed according to site specific premises at each location. In order to establish a sound and efficient monitoring program with respect to costs and capturing the environmental status of the POPs, local knowledge is needed. Knowledge of previous and present industrial emissions and discharges, weather and climate conditions, catchment properties, water flow, biota, and soil properties etc. are needed to establish a well-organized monitoring program. Based on the information gathered, an overview of monitoring programs for air, soil, the aquatic environment, and bovine milk are provided.

- **Spatio-temporal variations of atmospheric POPs** by polyurethane foam disks passive air sampling can be conducted annually to understand the trend of POPs. Further, detailed insights on the spatiotemporal variability of these POPs in various parts of Gujarat can help in identifying the hotspots to take further actions. Apart from existing levels of these POPs in the atmosphere, the effect of direct emissions such as industrial and open burning related emissions of these compounds can be effectively identified through inexpensive passive air sampling techniques. At certain pockets, diurnal variations of POPs in both particulate and gaseous phases should be conducted by using a high volume or active air sampling devices.
- **Soil and dust from the industrial zones need regular monitoring** to determine and assess the health risks posed by POPs to workers. Especially children of workers playing within the industrial premises are at higher risk owing to the increased inhalation of dust closer to the ground, dermal exposure and ingestion of soil containing POPs. Hence heavily contaminated areas such as ship breaking yards in Alang and Sosiya where higher loadings of industrial POPs can be expected should be monitored and necessary clean-up processes should be initiated (Demaria, 2010). Accidental cases in industrial areas of Ankleshwar need frequent monitoring, given the persistent nature of these organic compounds. Workers within the industrial zones need to be assessed for their exposure to various POPs throughout the course of their workday.
- **Seasonal monitoring of POPs in riverine networks is needed to understand the fate of these organic toxicants.** Direct discharge points, especially in industrial belts need immediate attention. It is suggested that seasonal monitoring of water, riverine sediment, and fish in the Daman Ganga and Tapi rivers is sufficient to assess the levels of contamination and associated impact on the ecosystem. Monitoring of aquatic biota on the top of the aquatic food chain should be preferred, since all the POPs bioaccumulate, and the highest concentrations will be detected in these organisms. Special attention should also be given to shrimp and other aquaculture areas near Dumas and Abhaya. Monitoring of biota, which is used for human consumption is of utmost importance.
- **Exposure of humans through consumption of POPs contaminated bovine milk.** High levels of POPs may be found in bovine milk, due to the lipophilic properties of the POPs. As Gujarat is home to a mostly vegetarian population, bovine milk and dairy products may provide a dietary source of POPs. Furthermore, cows and buffaloes graze in a wide variety of urbanised regions, including industrial activity zones as well as open dumps of garbage. There is a higher risk of POPs intake in these cows and buffaloes, which is higher than other animals which graze in cleaner regions. An annual bovine milk monitoring program in coordination with the local cowshed owners would be beneficial in safeguarding public health and assessing the intake of these POPs through diet.

Chapter 5
MODELLING AND MANAGEMENT CONSIDERATIONS

5.1 Modelling of the catchments

5.1.1 Model description and set up

A hydrological catchment model was set up for the Tapi and Daman Ganga River catchment systems, including a contaminant module to simulate the concentrations of three organic contaminants. The catchment model is composed of two modules, the hydrology model PERSiST (Futter et al., 2014) catchment-specific representations of perceptual models of the runoff generation process. Here, we present a flexible, semi-distributed landscape-scale rainfall-runoff modelling toolkit suitable for simulating a broad range of user-specified perceptual models of runoff generation and stream flow occurring in different climatic regions and landscape types. PERSiST (the Precipitation, Evapotranspiration and Runoff Simulator for Solute Transport) which was coupled to the Mobius version of the INCA-Tox model (Mobius, 2019/2022) which is another version of INCA-Contaminants (Nizzetto et al., 2016). PERSiST model parameters include site-specific information on soil water and groundwater retention, evapotranspiration, river size, width, depth, slope, and catchment characteristics. Within INCA-Tox, pollutants deposited on the soil are dynamically partitioned between solid and aqueous phases in the soil, groundwater and river, and transported along surface, river and groundwater flows. Pollutant degradation is computed in all phases as well as compartments and depends on temperature through a temperature coefficient (Q10). In the river, pollutants are partitioned between suspended sediment (solid) and water (aqueous). Hence, prior to running the INCA-Tox model for pollutants, suspended sediment in the river must be simulated.

Daily time steps were used over a period of 3000 days to allow for concentrations in the soil to stabilize, only the mean concentrations in the last half of the run were considered in the results. The input data for PERSiST, i.e., daily air temperature and total precipitation, were downscaled over the entire catchment from the ERA5 gridded dataset (Hersbach et al., 2020)2020. Instead, the values of the most sensitive parameters were varied within ranges reported in the literature (or estimated from expert knowledge) to estimate uncertainty. Input data for INCA-Tox include pollutant atmospheric concentration as well as point discharge, when available.

Both Tapi and Daman Ganga rivers experience a high degree of regulation with the presence of large reservoirs and some water abstraction mainly for irrigation purposes (Gupta et al., 2022). This was a major limitation in developing skillful daily river flow simulations since data on water regulation and abstraction is limited. Constant abstraction rates were applied to both reservoirs, i.e., Ukai and Madhuban, to reach an average annual runoff that was consistent with those reported by Gupta et al.

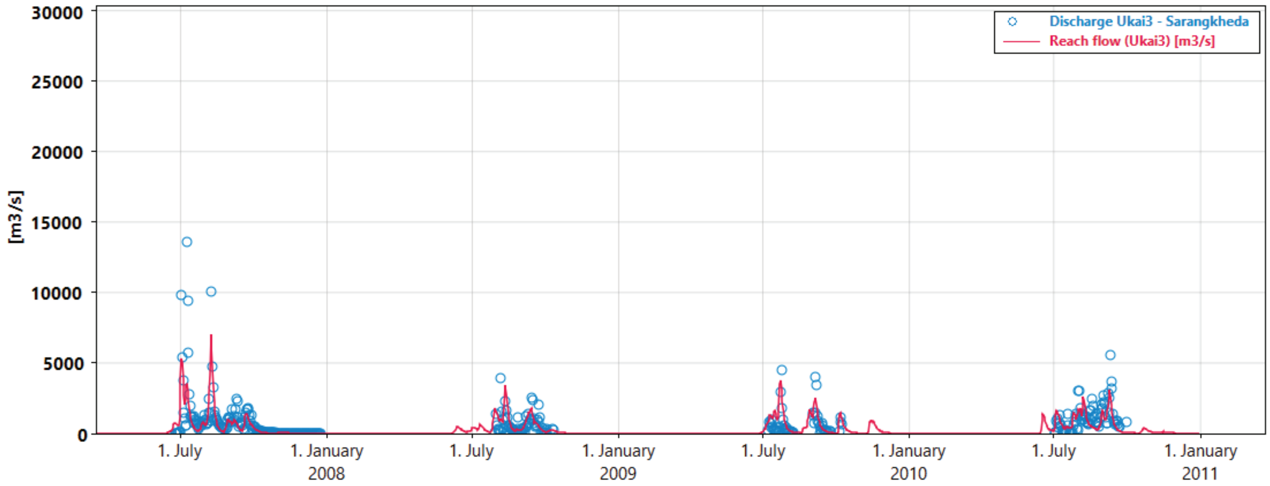


Figure 5.1.1. Comparison between observed (blue dots) and modeled (pink line) river discharge in Tapi river at Sarangkheda station

(2022). Discharge data for calibration and validation was available from two stations in Tapi catchment, at Sarangkheda (21.42830, 74.52720) and Motinaroli (21.26484, 72.91103), and one station in Daman Ganga catchment, at Silvassa (20.26805, 72.98555). Both Motinaroli and Silvassa discharge stations are located downstream of the main reservoirs. Their data was bias corrected to yield annual runoff consistent with those reported by Gupta et al. (2022). Discharge data from Sarangkheda located upstream of Ukai reservoir was consistent with Gupta et al. (2022) without any bias correction. Simulated river flow was associated with good statistics in Tapi river when evaluated against Sarangkheda data (Nash–Sutcliffe efficiency-NSE of 0.61; Kling–Gupta efficiency-KGE of 0.68; Spearman's rank correlation coefficient-SRCC of 0.76 as given in Figure 5.1.1). When compared to discharge data located downstream of the reservoirs, The simulated river flow was associated with less good statistics (NSE < 0 to 0.15; KGE of 0.40–0.42; SRCC of 0.66–0.67), although the seasonal variations and overall amplitude of the high flow events were captured. This decrease in model performance downstream can be attributed to the large degree of regulation of the two rivers as well as our lack of knowledge and data on the management of these water resources.

Suspended sediments were calibrated to give levels within the range of the observed levels, but since the concentrations in the model are driven by stream flow and precipitation-based erosion, the modeled signal is much more seasonal, and cannot be matched well to the observed signal (Figure 5.1.2). This could underestimate in-stream concentrations in low-flow periods (assuming the observed values are correct).

Only three contaminants have been modelled: BDE-47, BDE-99, and BDE-153 since these are the only ones where both physiochemical properties (to some degree) and observed data from the studied catchments were available. The observations are from December 2020. Given that water concentrations fluctuate a lot over time, as described in section 4.2, composite sampling over time is highly recommended to obtain realistic and representative samples. This is particularly relevant to a country like India where there are sharp contrasts between the dry and wet seasons. Given that water concentrations were only available from December 2020, these were not considered for model validation.

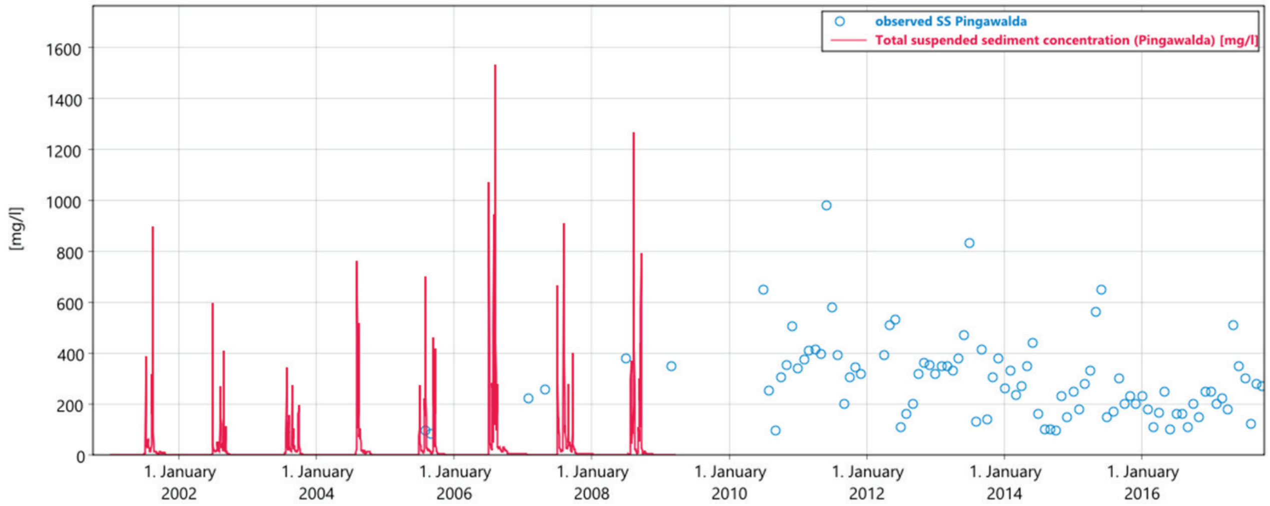


Figure 5.1.2 Modelled and observed suspended sediment concentrations in the Vapi catchment.

Table 5.1.1. Physiochemical properties of the contaminants with uncertain ranges.

	Henry's constant	Octanol-water partitioning coefficient (log10)	Atmospheric concentration (observed range)
BDE-47	0.5-1.2	6-01-6.81	11.94e-3 – 17.19e-3
BDE-99	0.49-2.1	6.51-7.66	16.04e-3 – 29.49e-3
BDE-153	0.067-0.34	6.85-8.55	2.63e-3 – 20.5e-3

Sources: (Chakraborty et al., 2022; Wang et al., 2021; Wania et al., 2002; Yue & Li, 2013)

Table 5.1.2. Physiochemical properties of the contaminants not included in the uncertainty analysis (constant)

	Molar mass	Molecular volume	Enthalpy air-water	Enthalpy octanol-water	Enthalpy octanol-air	Soil half-life	Octanol-air partitioning coefficient (log10)
BDE-47	485.8	287.7	94.6	97	90.1	90	10.34
BDE-99	564.7	311	108	91.1	98.5	90	11.28
BDE-153	643.6	334.3	110	98.2	105.7	90	11.61

Given the lack of information on point sources of contaminants within the catchments, contaminants were assumed to originate only from wet and dry deposition from the atmosphere. These are computed using partitioning between precipitation and air based on Henry's constant (wet) and a dry deposition velocity (dry) using the given atmospheric concentration (Table 5.1.1, Table 5.1.2). Since some physiochemical properties of the contaminants and atmospheric concentrations were uncertain, a Monte Carlo run was performed, sampling each parameter set 100 times, giving a distribution of possible outcomes from the model. Additional uncertainty ranges were included in the Monte Carlo run for other parameters influencing deposition, and thus contaminant input (Table 5.1.3).

Table 5.1.3. Ranges for other uncertain input parameters

Overall air-soil mass transfer coefficient	Dry deposition velocity	Q10 for degradation rates
1-100	5-20	1-1.5

5.1.2 Model results

The predicted contaminant concentrations in soils and surface sediments are usually slightly lower than the observed values (Table 5.1.4). Also, it should be noted that the observed values often range from below the detection limit (BDL) to levels higher than the modelled concentrations. There may be significant spatial variations linked to localized point sources.

It may be noted that the modeled values for soil and surface sediments are concentrations in carbon, while the observed values are total dry concentrations. This means that the modeled values could be decreased by some factor (the soil carbon content) to give a proper comparison.

Considering the lack of data on industrial sources, we have not tried to further divide the landscape into different land use classes, even though some of the observed data have different values for residential and industrial (Chakraborty et al., 2017). Similarly, more care could be taken to take degradation, sediments, soil carbon and other factors into the uncertainty analysis allowing more time.

Table5.1.4. Comparison between modeled and observed concentrations of contaminants in various compartments.

	Surface water	Soil*	Surface sediments
Tapi			
BDE-47	$6.77 \times 10^{-6} – 4.83 \times 10^{-5}$	3.28 – 6.10 (BDL‡–1040)†	3.04 – 5.21 (310 – n = 1) (BDL – n = 12)
BDE-99	$1.18 \times 10^{-6} – 2.98 \times 10^{-5}$	38.94 – 78.92 (BDL–40)	4.31 – 8.87 (50 – n = 1) (BDL – n = 12)
BDE-153	$5.78e \times 10^{-8} – 1.03 \times 10^{-5}$	15.67 – 113.87 (BDL–540)	0.93 – 6.83 (BDL–60)
Daman Ganga			
BDE-47	$2.24 \times 10^{-6} – 6.63 \times 10^{-6}$	5.12 – 8.77 (BDL–1710)	2.62 – 4.66 (BDL–290)
BDE-99	$6.91 \times 10^{-7} – 1.63 \times 10^{-5}$	60.21 – 118.28 (BDL–160)	6.44 – 13.05 (BDL–310)
BDE-153	$4.29 \times 10^{-8} – 6.36 \times 10^{-7}$	20.26 – 182.27 (10–1740)	1.63 – 15.84 (20–140)

*†Observations are in parentheses. ‡BDL stands for “below detection limit”. *Note that observed soil concentrations are only from residential areas.*

As noted, some uncertainty can originate from the suspended sediment model, but since the modelled water concentrations do not show large variations between low and high flow, i.e., during high and low sediment load periods, respectively, suspended sediments are unlikely to have a large effect on contaminant concentrations.

5.1.3 Discussion and future recommendations

The deposition model should be improved to take into account "scavenging" (precipitation sweeping POPs that are particle-bound to the ground). This could yield more realistic modelled concentrations in the system.

Sources of BDEs in the system need to be properly quantified. The model shows that they can only be explained by atmospheric deposition if it is local in space or time and is not detected by the existing measurements of atmospheric concentrations

The model also shows that contamination is probably not only a result of effluent emissions directly into the river, but that they can also be transported through the soil. This is because the modeled levels in the soil are underestimated compared to the observed ones and are not affected by effluent emissions since effluents are directly discharged into the river.

According to literature, an influential source of BDEs in India is flame retardant material in polymers, often used in furniture and electronics. A major source is probably weathering litter and uncontrolled burning of waste. The resulting deposition from uncontrolled burning of waste could be very local and can happen fast (while the rest is dispersed). It may be noted that one of the atmospheric measurements in Surat was from an open burning site, but still, it did not provide high enough levels for the model to explain the observed soil concentrations. It would be beneficial to quantify the abundance of illegal dumping and burning sites and the amount of waste processed in them. Another source could be from the polymer producing/processing industry.

It could also be useful to have time series of concentrations, especially in the atmosphere and surface waters since these are expected to significantly vary over time. Just a one-time measurement may not be representative for the ecosystem.

As an input to the deposition process in the model, for instance, we have only provided the range of probable concentrations based on one single measurement, but the seasonal variation could theoretically explain a much higher variation. However, passive sampling from other locations in India shows that the variation is not big enough to account for the discrepancy found here. Therefore, the main missing sources are industrial and waste processing.

In addition, modelling can be improved by direct measurement of deposition, such as measuring concentrations in precipitation as well as local measurements of other contaminants (such as PCBs) are also needed to be able to model them with meaningful quantification.

5.2 Identification of hotspots

Two catchment areas of Daman Ganga and Tapi rivers in Gujarat were chosen as case-studies to carry out project activities and establish a knowledge base for POPs and plastic pollution issues (Figure 5.2.1). The locations were selected both due to their socio-economic, physical, and ecological features, and because these cities are among the most industrialized areas of Gujarat:

- Tapi river catchment with the city of Surat as the main urban industrial centre
- Daman Ganga catchment with Vapi as the leading industrial centre

Surat is known as the industrial hub of India and is located on the bank of the Tapi River, there are over 41,300 small and medium industries functioning in the district. Some of the leading industries are textiles, chemicals, dying & printing, diamond

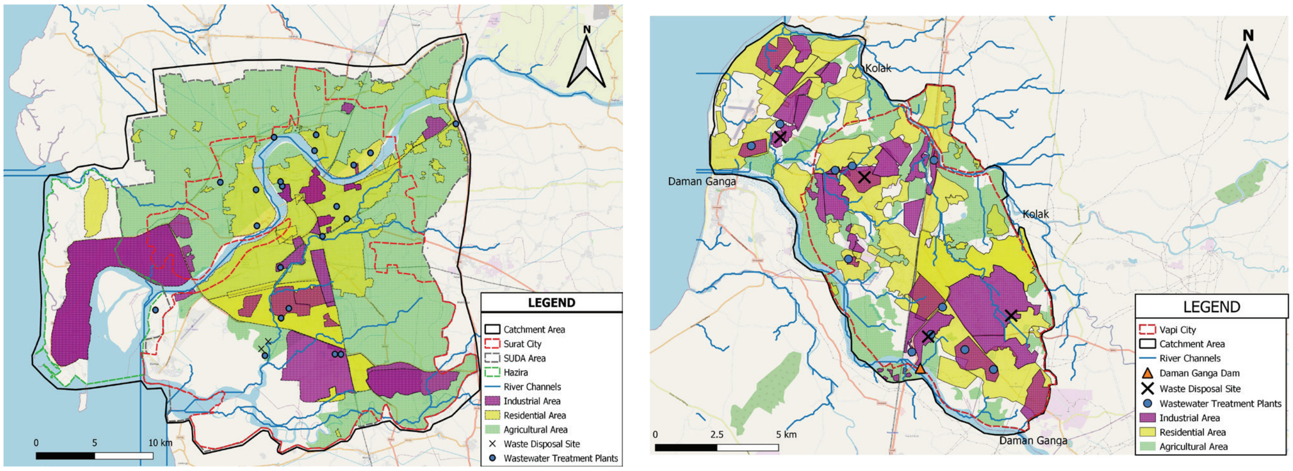


Figure 5.2.1. Land use map and catchment of (A). Surat & (B). Vapi (Map developed on QGIS 3.18) *(INOPOL, 2021)*

processing, *zari* (silver) making, and engineering and related activities (including manufacturing machines and equipment). Most of them are small-scale industries located in Choryasi (Western Surat), Mangrol and Olpad (Northern Surat), Mandvi (Central Surat), and Palsana (Southern Surat).

However, release of untreated water and waste into Tapi by over 150 industrial units, located in the jurisdiction of Surat Urban Development Authority (SUDA), is a major source of pollution to the river (The Indian Express, 2022). One study concluded that "the biological oxygen demand, chemical oxygen demand, turbidity, and ammonia levels were also high due to industrial effluents and sewage disposal into the Tapi River (Gujarat)" (Ujjania et al., 2020). Similarly, a study conducted by Ahmedabad Textile Industry's Research Association (ATIRA) in 2021 reported industrial effluent discharged into the water bodies near the vicinity of the Hazira plant (The Indian Express, 2022).

The city of Vapi, situated near the banks of the Daman Ganga River, is another pollution hotspot. It is known as the 'City of Chemicals' as it is the largest industrial area in Gujarat in terms of small-scale industries, dominated by the chemical industry. The "Vapi Industrial Estate" was set up in 1967 by Gujarat Industrial Development Corporation, a government agency supporting and facilitating the establishment of almost 2100 industries. About 70% of the total industries in Vapi are chemical plants, mainly for chemical distillation and the production of pesticides, dyes, dye intermediaries and paints. Other major industries include paper, packaging, pharmaceuticals, plastics, rubber, textiles, wood, computer hardware and software, engineering workshops, glass, and food products.

Proximity to the larger cities of Mumbai, Surat, Vadodara, and Ahmedabad, coupled with liberal Government policy, has helped Vapi and surrounding areas attain their current level of industrial activity. In 2010, Vapi Action Plan was implemented by Gujarat Pollution Control Board which had various management and mitigation measures like the safe disposal of treated water, strengthening air quality monitoring and measuring impact on health within surrounding populations. However, the pollution level on the Daman Ganga at Vapi is very high due to the staggering rate of industries discharging effluents into the river (Earth5r, 2020). The Action Plan for Daman Ganga was submitted by Administration of Daman and Diu in 2019 that reported the Common Effluent Treatment Plant (CETP) of the GIDC, Vapi and Gujarat Heavy Chemicals Limited (GHCL), Bhilad were major source for industrial effluents discharged into river and its estuary. It also mentioned that the river water downstream of CETP, Vapi (at the discharge location) was highly coloured that persists till the confluence of the river with Arabian sea (Administration of Daman and Diu, 2019).

5.3 POPs and Plastics

Around 0.8-2.7 million tonnes of plastic waste are released into the oceans each year (Meijer et al., 2021). The sources of plastic pollution are predominantly associated with land-based anthropogenic activities. Studies now report that plastic pollution is globally pervasive, even reaching remote regions (Allen et al., 2019). Adding to the scale and impact of plastic pollution, significant concern has been raised in recent years about how plastics interact or relate to chemicals especially the persistent organic pollutants (POPs), regulated under the Stockholm Convention since 2004.

Plastics are used in a myriad of ways and inevitably crossing paths with POPs during the course of their lifecycle. Some of the chemical additives added to plastics during production are POPs themselves e.g., brominated flame retardants like polybrominated diphenyl ethers (PBDEs), polyfluorinated alkyl substances (PFAS/PFOS) etc. contributing to unintentional POPs release. During their usage, plastics can also come in contact with POPs and adsorb onto their surface, acting as a vector (Koelmans et al., 2016; Mato et al., 2001; Teuten et al., 2009). Figure 5.3.1 provides and overview of the interlinkages between POPs and plastic pollution.

Riverine/marine litter also gives rise to the generation and spread of microplastics. Microplastics (less size than 5 mm) have become prevalent even in the most remote regions of the planet, transported over long ranges by atmospheric and oceanic circulation (Allen et al., 2019; Imhof et al., 2017; Kelly et al., 2020; Tan et al., 2020; Zhang et al., 2016). As such, riverine/marine plastic litter is a cause for concern, given the potential for the transfer and bioaccumulation of POPs in a range of species upon ingestion, which may incur a range of negative effects (Abdolahpur Monikh et al., 2021; Seltenrich, 2015). Much of the concern around microplastics are associated with their potential role as vectors of POPs into terrestrial and marine ecosystems (Cole et al., 2011; Ivar do Sul & Costa, 2014). Studies have documented ingestion of microplastic by a range of organisms (Boerger et al., 2010; Thompson et al., 2004),

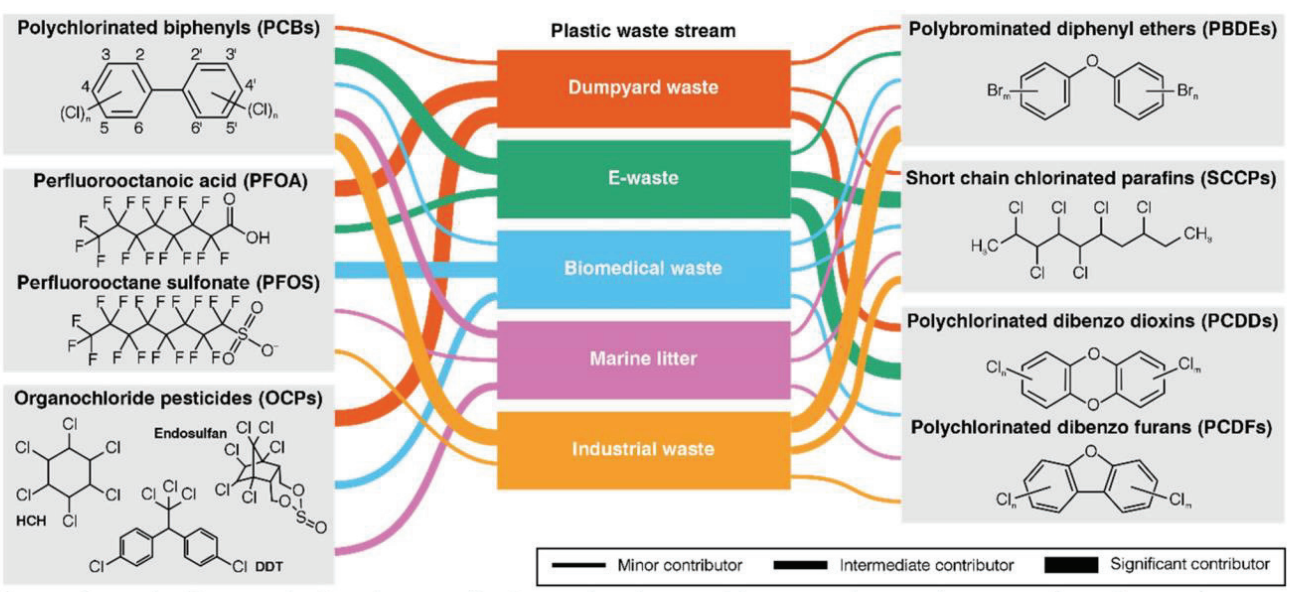


Figure 5.3.1. Interlinkages between POPs and plastic pollution(Chakraborty et al., 2022)

including several species that represents critical trophic links in many oceanic ecosystems (Davison & Asch, 2011). Consequently, there is concern that POPs may transfer to organisms following ingestion. The potential health and environmental risks and uncertainties associated with microplastics acting as vectors for chemicals in aquatic environments represents a key concern and area for further research (Koelmans et al., 2016).

India generates around 6.5 to 8.5 million tons of recyclable plastic waste every year (Nandy et al., 2015). Over 60% of the plastics consumed have a service life of less than 3 years and contribute to waste generation from households, industries and other establishments (Mutha et al., 2006). Polypropylene plastic (PP) is the most consumed polymer type in Indian cities (25%) closely followed by polyvinyl chloride (PVC) (20%) (Singh et al., 2019). With the sharp increase in the use of plastic products in India, in a business-as-usual scenario, India is predicted to become the largest generator of mismanaged plastic waste by 2035 (Lebreton & Andrady, 2019).

Plastics in the dump yard waste stream originate primarily from households, institutions, and other establishments and may interact with and accumulate POPs at any stage of production, usage, or disposal. Open burning is a major source of POPs emission, in both gaseous and sometimes particulate form. Incomplete or complete combustion of polymeric materials resulted in release of dioxins (PCDD/Fs) and dioxin like (dl)-POPs in Indian cities (Chakraborty et al., 2018; Rajan et al., 2021).

The informal plastic recycling sector in India handles a vast amount of waste every year. Estimates provided by the Government of India suggest that 15600 tons (58%) of the 26000 tons of total plastic waste generated each day are handled and recycled by the informal sector. As the informal recycling processes do not have the facilities necessary for a "closed" recycling process, POPs are released via air and run-off from recycling activities such as smelting, shredding, dedusting, and scrubbing. Temperatures in combustion processes associated with informal recycling can exceed the threshold for generation of POPs and may give rise to significant dioxin and furan emissions. Consequently, the informal sector, and its associated activities, represents a potential major POPs source.

Electronic waste includes any unused or discarded electrical or electronic item intended for resource recovery, recycling or disposal (Makkar Panwar et al., 2018). Improper handling likely causes the release of harmful POPs that are associated within e-waste components (Chakraborty et al., 2016). Low temperature combustion of e-waste components, acid leaching for precious metal recovery, and improper waste management are the primary contributors to POPs release from e-waste plastics by the informal e-waste recycling sector (Chakraborty et al., 2018).

Industries represent some of the major users of packaging, insulation, and products augmented with various additives, many of them POPs or POPs precursors, to safeguard and improve durability (Breivik et al., 2004). Due to a need for plastic with these various properties in the industry, plastic waste from the industry may contain higher concentrations POPs, compared to common plastic waste. The most obvious industrial waste stream that contains POPs is the wastes from the chemical production of established POPs like pesticides, flame retardants, and surfactant chemicals (Chakraborty et al., 2015; Chakraborty et al., 2010; Hong et al., 2010; Shan et al., 2014).

Enhanced understanding of these processes may aid policy decisions to combat the release of POPs from different waste types and processes in India. Presently, there is no mandate or incentive for plastic producers to re-procure much of the recycled plastic and close the loop on plastic wastage. Channelization of recyclables to recyclers is urged in the legislation. Moreover, measures must be put in place to avoid producers using POPs or POPs contaminated raw materials in manufacturing. Adoption of labelling systems on the final product to indicate the number of times the plastic feed has been recycled could prove beneficial in tracking recycled and virgin plastic consumption. Provisions can also be made in the regulations to test residual POPs levels in recycled plastics and to set limits on their maximum POPs content. India can implement the scrutiny of flammability standards to reduce the use of hazardous flame retardants which appears to be the increasing purview of European Union regulations (Charbonnet et al., 2020). India should promote POPs disposal techniques that will destroy them irreversibly to eliminate their presence in the environment and avoid giving rise to toxic byproducts or metabolites. In collaboration with the international community and guided by the recommendations developed under the Basel and Stockholm Conventions, best available technologies should be adapted to the Indian situation to prevent serious contamination and impacts on human health and the environment.

Chapter 6
AN ACTION PLAN ON POPS FOR GUJARAT

6.1 Goals and objectives

The goal of the POPs action plan is to identify key actions and stakeholders to reduce the use and release of legacy and new POPs, which in turn will minimize the exposure to human health and environment in Gujarat.

Objectives

- Strengthening regulations, cooperation, and awareness among stakeholders in the management of POPs in Gujarat
- Managing POPs in all relevant sectors
- Increase monitoring data on POPs and make it publicly available
- Increase research and knowledge about chemical analyses of POPs, including fate and effects in the environment and human health
- Identify available funding sources outside governmental resources
- Identify the gaps in environmental monitoring systems as well as implementation of regulatory mechanisms to help reduce the use and release of POPs in Gujarat.
- Identify the challenges in implementation of Best Environmental Practices (BEP) and Best Available Technologies (BAT) for managing POPs.
- Equip the regulatory authorities in Gujarat with science-informed recommendations for safe management of POPs, thereby leading to reduced exposure to human health and environment.
- Build capacities of key stakeholders involved in the regulatory, institutional, technological aspects of managing POPs in Gujarat and generate awareness about the long-term human and environmental health caused due to inaction.

The Government of India is in the process of reviewing and updating its National Implementation Plan (NIP) by implementing control measures for POPs, developing, and implementing action plans for unintentionally produced chemicals, and developing inventories of the chemicals' stockpiles, amongst others. This action plan on POPs for Gujarat represents an attempt to acknowledge and address the intent of the Government of India and contribute to the revised National Integrated Plan.

Safe management of POPs is also dependent on the cross-sectoral coordination between different state government departments such as Industries & Petrochemicals, Forest & Environment, Agriculture & Farmers Welfare, Water Resources, and Health. The roles and responsibilities of these stakeholders are vital for concerted action and implementation of the regulations for reduced emissions of POPs. There is an increased need for enhancing the knowledge base and know-how of these stakeholders about safe alternatives to POPs.

The community needs to be aware of the health and environmental impacts of POPs. A comprehensive communication strategy should be co-created to ensure the smooth and continuous flow of information among all stakeholders. Such efforts, as indicated in this action plan on POPs could be customized and replicated in other Indian States.

6.2 Key actions for handling POPs in Gujarat

Based on the status of the use and regulation of POPs, specific actions for the state of Gujarat have been identified and specified to support the efficient management of POPs in an environmentally sound manner. The key action areas for handling POPs in Gujarat are:

a) Strengthen regulation, management and control of unintentional releases of POPs & contaminated land/sites as well as institutional capacity building through enhancing chemical analyses capacity/ labs/ equipment/skills,

b) Managing the production and use of chemicals listed in Annex A (Elimination) unless there are specific exemptions; Annex B (Restriction); and Annex C (Unintentional Production)

c) Identification and management of POPs stockpiles, articles in use and wastes (Annexes A, B and C),

d) Identification and management of POPs contaminated sites,

e) Knowledge management,

f) Reporting,

g) Monitoring and Evaluation,

h) Research and Development,

i) Technical and financial assistance, and

j) Coordination & Sustainability

6.2.1 Key actions for handling POPs in Gujarat

In this section, we will summarize the key actions for handling POPs in the state of Gujarat (Table 6.2.1). It is crucial to identify and assess pollution levels and contaminant sources of POPs for which monitoring systems, analysis and inventorization play a vital role.

Based on the NIP of India (NIP India, 2011) and the Baseline Report on POPs Pollution (developed under the project INOPOL (INOPOL, 2021), various action points are presented here for further consideration to assist the state of Gujarat to be able to effectively implement the Stockholm Convention to eliminate and manage all forms of POPs emissions, products and wastes. The proposed actions are as follows:

Table 6.2.1: Key actions for POPs management in Gujarat

Nr	Implementation plan	Key players
1	**Manage the production and use of chemicals listed on Annex A (Elimination) unless there are specific exemptions; Annex B (Restriction); and Annex C (Unintentional Production)**	
	■ Update POPs inventory ■ Ensure that all POPs are integrated in the upcoming Chemical Safety and Management Rules and registration system ■ Analyse active ingredient content in the stocks for verification ■ Safe and sound transport and temporary storage of stocks for disposal ■ Environmentally sound disposal of all POPs ■ Explore environmentally sound alternatives to the listed POPs ■ Evaluate institutional capacity for environmentally sound management (ESM) of POPs containing equipment and wastes. ■ Plan and organize phase out/down and treatment methods of banned/ restricted POPs. ■ Follow and develop occupational safety occupational safety guidelines and protocols (e.g., use of personal protective gear) for formal and informal workers ■ Identify and label equipment ■ Establish accredited laboratories	MoEFCC, GPCB, GIDC, SPMU, GSPC, NEERI, Gujarat State Government Departments (Energy & Petrochemical; Industries & Mines)

Nr	Implementation plan	Key players
2	**Strengthen regulation, management and control of unintentional releases of POPs and contaminated land/sites**	
	■ Develop and apply regulations & guidelines on managing/monitoring of POPs (use and disposal) including contaminated materials. ■ Monitor POPs, Research and Development (R&D) promotion, technology transfer, facilitating data collection, enforcement, and evaluation capabilities on POPs. ■ Industries to take measures in the production/treatment of air/water before emissions/discharges, to stop by-product formation/unintentional production ■ Institutional capacity building (government and others)	MoEFCC, MoES, CPCB, NEERI, GPCB, GIDC, GSPC, ULBs*, State Relevant Departments of Government of Gujarat**
3	**Identify and manage POPs stockpiles, articles in use, and wastes (Annexes A, B and C)**	
	■ Develop capacity within the Government of Gujarat to map and manage POPs stockpiles ■ Develop capacity for environmentally sound storage and disposal of POPs stocks/wastes ■ Ensure the environmentally sound disposal of POPs wastes.	GPCB, GIDC, SPMU, GSPC, NEERI, GOG Departments (Energy & Petrochemical; Industries & Mines)
4	**Identify and manage POPs contaminated sites**	
	■ Collect information to estimate the likelihood of POPs contamination (desk review, site visits, interviews) ■ Develop a prioritization system for mitigation ■ Develop a conceptual site model & a sampling plan ■ Sample relevant environmental media ■ Laboratory analysis of samples and selected environmental media for substances that may cause contamination ■ Develop a stepwise plan for mitigation and/or clean-up, including clarifying legal and financial responsibilities	GPCB, GIDC, SPMU, GSPC, Gujarat State Government Departments (Energy & Petrochemical; Industries & Mines), NEERI
5	**Knowledge management, strengthened knowledge (on POPs pollution), information access and exchange, awareness, and outreach**	
	■ Generate public awareness ■ Ensure free access to available and up-to-date information on POPs ■ Develop publications for different target audiences (policy briefs, scientific commentaries etc.) ■ Ensure that Indian institutions and knowledge providers take part in multilateral processes to collect best practices and share research and experiences from India and on the Indian situation	NEERI, GPCB, ULBs*, State Relevant Departments of GoG**, industry associations, specific enterprises, IIT Gandhinagar, CERC, research institutions Universities, private laboratories, NGOs, informal workers
6	**Reporting**	
	■ Set up system for Annual State-level Reporting on POPs to the National Government	MoEFCC, (GPCB, CPCB)

Nr	Implementation plan	Key players
7	**Monitoring and Evaluation**	
	• Develop and implement strategies for data collection, sampling & analysis • Strengthen monitoring protocols, guidelines, and analytical methodologies • Evaluate POPs monitoring data in blood, breast milk, food, air, soil & water	CPCB, NEERI, GPCB, ULBs*, industry associations, IIT Gandhinagar, research institutes, Universities, private laboratories, NGOs
8	**Research and Development**	
	• Draw on best available national and international scientific knowledge • Carry out India-specific research on usage, production, storage, waste management, industry data, effects, risk assessment, environmental fate of POPs, eco-toxic effects, transport and transfer processes, degradation mechanisms, bioaccumulation and biomagnification, and destruction. • Mother-child cohort studies. • Research and development of non-hazardous and safe POPs alternatives. • Strengthen public laboratory monitoring capacities (technical/human).	IIT Gandhinagar, research institutes, Universities, private laboratories, the industry
9	**Technical and financial assistance**	
	• Promote funds/technical assistance besides government resources • Adapt best available technologies (BAT), adopt best environmental practices (BEP), and promote technology transfer to manage POPs. • Solicit funding through international mechanisms (e.g., GEF) to support and strengthen research, management and institutional capacity in India to tackle POPs.	MoEFCC, CPCB, GPCB
10	**Coordination for implementation & Sustainability of actions**	
	• Strengthen cooperation and collaboration among stakeholders towards the common goal of sound POPs management. • Improve coordination and co-production of ideas and activities aiding the smooth implementation of the POPs action plan in Gujarat. • Effective data management and free sharing of information among key stakeholders.	GPCB, ULBs*, GIDC, SPMU, GSPC, State Relevant Departments of Government of Gujarat**, public & private sector organizations

**ULBs - Surat Municipal Corporation, Ahmedabad Municipal Corporation, Vapi Municipal Corporation; ** Relevant Departments of Government of Gujarat - Energy & Petrochemical; Industries & Mines; Narmada, Water Resources, Water Supply & Kalpsar; Science & Technology; Women & Child Development; Forests & Environment.*

Figure 6.2.1 Contribution to UN Sustainable Development Goals (SDGs) in relation to chemicals

From the above-mentioned actions listed in the plan, the researchers have identified the core actions for effective management of POPs, such as the following:

- Strengthening regulations, cooperation, and awareness among stakeholders
- Establish a system for inspection, control and monitoring of implementation and compliance
- Managing of POPs in all sectors
- Increase data on POPs and make it public available
- Increase research and knowledge about chemical analyses of POPs and faith and effects
- Identify funds outside governmental resources

Summarily, the proposed actions are directly linked to the goals and strategies of the Basel, Rotterdam, and Stockholm (BRS) Conventions. The synergistic approach to implementation of the BRS Conventions in India helps to strengthen the implementation of all three Conventions at the national level by providing policy guidance, enhancing efficiency in providing support, reducing the administrative/management load, and maximizing the effective use of resources at all levels. Further, these actions will contribute towards achieving the UN Sustainable Development Goals (SDGs) related to chemicals and wastes, including 2.1, 3.9, 6.3, 11.6, 12.4, 12.5, and 14.1 (Figure 6.2.1). The achievement of these SDGs can provide an integrated framework for a cross-sectoral approach for sound chemicals management for Gujarat, to support environmental and public health and wellbeing.

6.3 Implementation plan – key steps

New compounds are regularly added to the Stockholm Convention (SC). Hence, the NIP must be updated on a regular basis and the seven newly ratified POPs are in the process of being updated. In accordance with the SC (Art. 7, para 1.c.), all parties are required to submit its implementation plan to the Conference of the Parties (COP) within two years after the treaty enters into force (for it)(http://chm.pops.int/). This implies that India was three years late with its first NIP, and lags behind with the NIP for all POPs (20) that have been added after the 'dirty dozen'. According to the guidance developed by the SC Secretariat, the older versions of the NIP should also be updated on a regular manner and whenever any new amendment is ratified (NIP India, 2011).

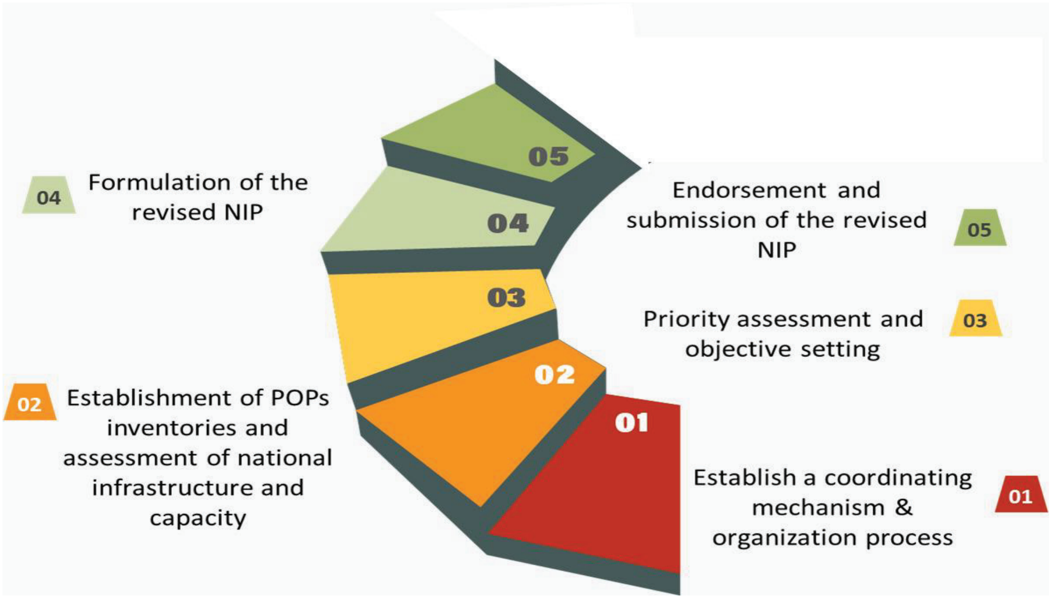


Figure 6.3.1 Major activities of NIP update divided into five phases.

In 2020, the Government of India ratified seven more POPs and POP groups for elimination. Hence, the NIP should be updated to accommodate the implementation in national law, within the year of 2022. India could either develop a *new* NIP for these seven POPs and revise the 2011 NIP or *expand* and *update* the latter to also include the seven new POPs. The responsibility of developing and updating the NIP lies with the Ministry of Environment - Forest and Climate Change of India (MoEFCC).

Currently, numerous research studies on POPs are being conducted by several research institutions in India. A review of the ongoing research activities of POPs across India have been conducted, and major challenges with respect to the regulation of POPs have been identified (Sharma et al., 2014; Bharat, 2018). Coordination between key stakeholders, fragmentary and insufficient regulatory and management framework, lack of analytical chemical laboratory skills and equipment, lack of existing data from India, and low awareness and knowledge level among stakeholders are some of the key aspects disclosed through the stakeholder interviews conducted in February 2022, as part of the implementation of Project INOPOL.

Since 2011, when India's NIP was first published, a considerable number of guidance documents have been revised and published by the SC. In addition, specific documents directly linked to the seven new POPs to be included in India's NIP are provided. During the revision of the last updated NIP, it was recommended to evaluate the efficiency of the previously adopted action plans, strategies, and measures. It is common to focus on a reassessment of priorities due to new POPs, updating and reconsidering earlier action plans, and development of separate new action plans for newly listed POPs, as appropriate.

The levels of details in the NIP should be in accordance with needs, priorities, and resources available. First and foremost, the NIP is intended to be a tool for the Party to plan the national implementation of the SC. CSIR-NEERI is the lead agency that has been entrusted by MoEFCC under the GEF funding to develop the structure and the process of updating the NIP. It has established a multi-stakeholder coordinating committee and an executing body representing policy-makers, environmental protection practitioners, stakeholders from agriculture, public health, industry and the private sector, the public, and various interest groups. A coordination mechanism between the national and state levels has also been part of this activity, considering the interdependence, both in terms of understanding the existing situation, the specific requirements and the local context, and making plans suited to the wide diversity of situations and challenges that exist in India's states and union territories. The expected timeline of NIP-II is 2025.

The process of updating a NIP can be broadly categorised into five phases as illustrated in Figure 6.3.1 and Figure 6.3.2.

1. **Establishment of a coordinating mechanism and organization process**
   - Establish an effective project planning and management structure
   - Produce a detailed project plan
   - Raise awareness and secure commitment among the multi-stakeholders committee
2. **Establishment of POPs inventories and assessment of national infrastructure and capacity**
   - Attain information on the sources, use, and production of the new POPs
   - Identify gaps in resources, capacity, and knowledge, and the need for financial assistance

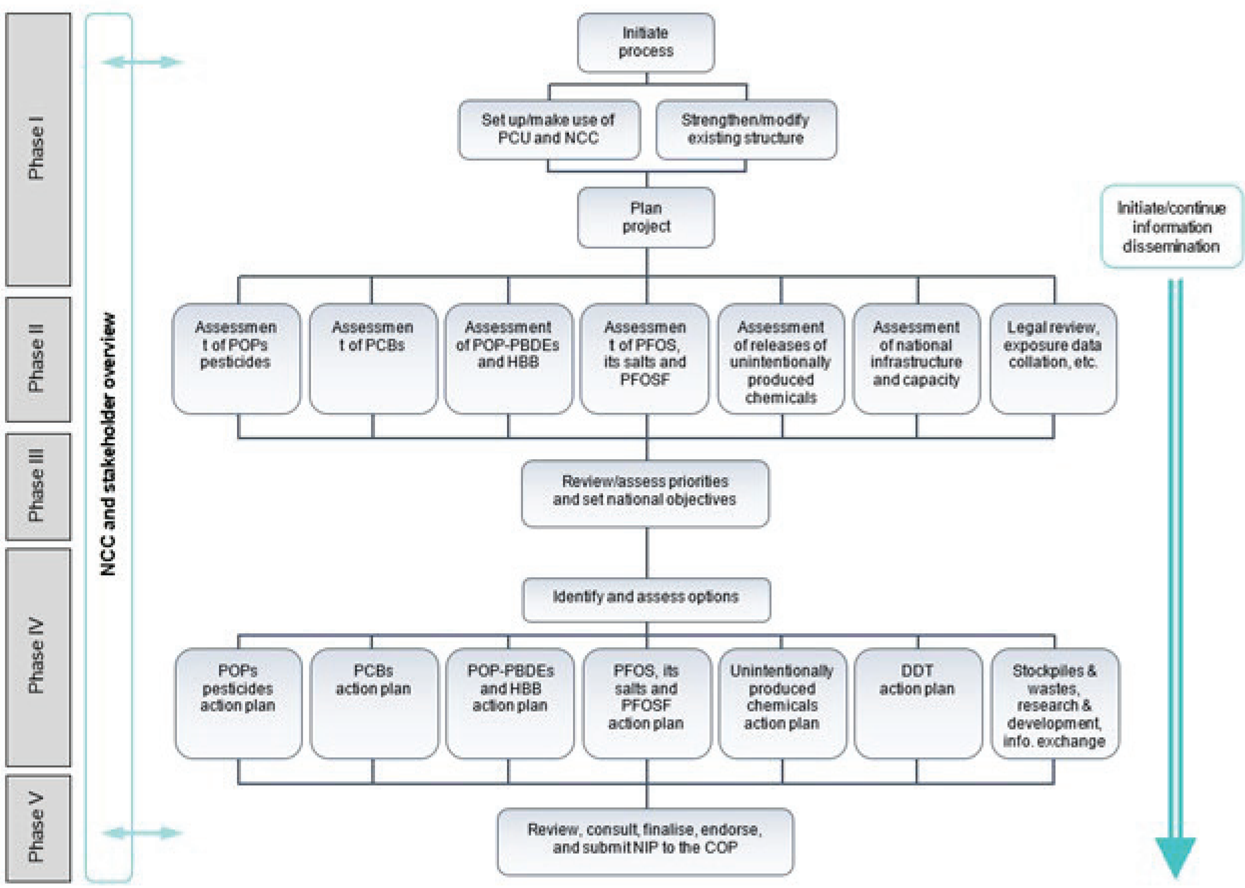


Figure 6.3.2. A process flow chart describing the five phases of an action plan with main activities. PCU (project coordination unit), responsible for planning and implementation of the NIP. NCC (national coordination committee), a multi-stakeholder body responsible for stakeholder involvement, NIP development, review, and updating. Figure is taken from BRS, 2017.

- Facilitate the coordination of activities related to national and international pollution control policies

3. **Priority assessment and objective setting**
    - Identify the Indian criteria for prioritizing the health and environmental impacts of the new POPs
    - Retrieve information and gaps from priority areas identified in phase 2
    - Define a set of appropriate short- and long-term objectives, goals, and measurable indicators for the management of POPs in compliance with the SC and other conventions (e.g., The Rotterdam and Basel Conventions).
4. **Formulation of the revised NIP**
    - Identify and gather information on possible options for management of POPs in India to meet the obligations under the SC.
    - Prioritize the options available, and indicate the scope of application, limitations, requirement for assistance, costs, and benefits of each.
    - Draw up an updated draft of the NIP suitable for the country to meet the needs of the SC with India's specific objectives and priorities, coordinated with national activities on sustainable development and related goals.
5. **Endorsement and submission of the revised NIP**
    - Communicate clearly the scope, need for, purpose, and value of the NIP to all stakeholders and secure political support.
    - Finalize the NIP, and transmit an agreed NIP to the COP of the SC.
    - Establish and put into practice a mechanism for periodic updating, review and reporting to the COP.
    - Put in place the mechanism for implementation of the NIP.

6.4 Defining roles and responsibilities

India has a federal structure of governance and there is a division of power between the central and state government. The Constitution of India has not earmarked any provisions specifically on environmental issues. Thus, the legislative power of environmental protection lies with the central government. However, the State governments have an important role to play in implementing the rules and regulations. The MoEFCC is one of the focal agencies to deal with environmental protection in India including on international environmental treaties and conventions, such as the Stockholm Convention on POPs.

In India, there are a number of regulations in place to manage chemicals and to minimize their adverse impact on environment and human health. However, these chemicals are categorized based on the nature of their usage, such as industrial chemicals and pesticidal chemicals. Regulations of industrial chemicals are within the purview of the Environment Protection Act (EPA), 1986 and fall under the auspices of the MoEFCC. The regulation of chemical pesticides is under the purview of the Insecticides Act, 1968 and is managed by the Ministry of Agriculture and Farmers Welfare (MoA&FW). Such differentiation in regulatory responsibilities between ministries creates challenges in implementing chemical regulations and regulatory gaps. There is no exclusive authority to monitor and harmonize the implementation of the Stockholm Convention in the country. The MoA&FW is the sole authority to draft rules for the management of pesticides and environmental contamination caused by pesticidal POPs. Similarly, though there are other agencies like the Central Insecticides Board and Registration Committee with certain specific responsibilities (CIB&RC), it is the State agencies that have key responsibility for the overall management of pesticidal POPs in the respective States. There are also peripheral roles for several other bodies across the country. These include the Ministry of Chemicals and Fertilizers, Ministry of Power, Food Safety and Standards Authority of India, under Ministry of Health and Family Welfare etc. The Government of India recognizes enhanced coordination is needed regarding the overall management of POPs in the country.

The MoEFCC has developed the National Implementation Plan (NIP) to manage the POPs that have been ratified so far. Most central government agencies who are executing the NIP are the Central Pollution Control Board (CPCB), Central Power Research Institute, National Environmental Engineering Research Institute (NEERI, Nagpur) and National Institute for Interdisciplinary Science and Technology (NIST), Trivandrum. The CSIR-NEERI has been acting as the regional centre for the Stockholm Convention in the Asian region. The CPCB is constituted to function at the national level for the control of water and air pollution, and to provide technical advice to the MoEFCC on the various aspects of environmental pollution including POPs. Furthermore, along with the CPCB, the State Pollution Control Boards have been bestowed with the responsibility for monitoring the emission levels and enforcement of the regulations on POPs at various levels.

Powers and Functions of CPCB regarding POPs management (CPCB, n.d.)

- The CPCB has issued stringent emission standards for Dioxins and Furans and certain regulations to monitor the POPs. The State Pollution Control Boards are the key implementing agencies in POPs management.
- In 2016, the Government of India issued the Solid Waste Management Rules (SWMR), which granted municipalities the authority to manage solid waste. As a result of improper waste management, dioxin and furan emissions are directly linked to waste burning.

At the State / Union Territory levels, the State Pollution Control Boards (SPCBs) / Pollution Control Committee (PCCs) are regulatory agencies for pollution control, as differentiated below:

Government Agencies

1. Central Government

- Ministry of Environment, Forests and Climate Change
- Central Pollution Control Board
- National Green Tribunal (NGT)

2. State Governments / Union Territories

- State Department of Environment
- State Pollution Control Boards / Pollution Control Committees
- Urban Local Bodies (ULBs)

6.5 Key performance indicators for POPs Action plan

Key Performance Indicators (KPIs) for management of POPs pollution can potentially play an important role in measuring the impacts of the POPs action plan of Gujarat. A total of 23 KPIs have been categorized into seven components: Regulatory, Institutional, Financial, Technological, Management and Information Systems (MIS), Capacity building and Information, Education and Communication (IEC).

KPIs are quantifiable metrics that reflect the performance of actions in the context of achieving its broader goals and objectives. It would help to implement strategies by linking various levels of the POPs action plan with clearly defined targets and benchmarks, and hence measure and adequately capture the impact. **Table 6.5.1** lists 23 KPIs that are deemed to be significant for the POPs Action Plan of Gujarat and also be a useful tool for the Government of India's ongoing initiative of updating the NIP, with GEF support.

Table 6.5.1: Key performance indicators for POPs Action plan

Sl. No.	Key performance indicator	Details of the Performance Indicators	Description of the Indicators	Benchmark	Sources of verification
I.	**REGULATORY**				
	Implementation of policies and processes	1. Number of industries monitored 2. Regularity of monitoring (each year) 3. No. of industries producing export-oriented products that are monitored 4. All POPs are added to the CMSR and amendments to the SC are added once ratified	Industries regularly monitored for violations (banned POPs being manufactured, used or stored)	Zero # of defaulting cases reported	GPCB Report on defaulting industries
	Coordination between National and state governments and regulatory institutions	No. of meetings with relevant departments of Centre and State government	Number of close coordination meetings with relevant departments of Centre and State Governments and other regulatory institutions	Once a year	Minutes of the meetings
3.	Stakeholder participation in implementation of regulation	1. Forum for participation of / consultation with stakeholders in developing regulations 2. Participation of stakeholders in decision making	Coordination between regulatory authorities and other relevant stakeholders	Involvement of: 1. Relevant Central/ State Government Departments 2. Local Governments 3. Large industries and corporates	1. Participant list of meetings 2. (Minutes of meetings)

Sl. No.	Key performance indicator	Details of the Performance Indicators	Description of the Indicators	Benchmark	Sources of verification
		3. Established process for regulatory decisions 4. Established process for communication between stakeholders 5. Review of regulatory decisions		4. Medium and small-scale industries / associations 5. Academia/Scientists 6. Civil society 7. Farmers Associations 8. Informal market groups 9. Women Self-help Groups	3. Database for communication 4. Public accessible registry of consultations
4.	Consultative Channels for communications	1. No. of formal or informal channels for communication 2. Use of vernacular languages 3. Adequate time in communicating notices	Direct communication to relevant industries by authorities on every new ban order on POPs	Notice issued every time a new legal order is passed	Copy of notice to industries/industry association
II	**INSTITUTIONAL**				
5.	Institutional development	1. Existence of Institutional compliances of relevant POPs regulations 2. No. of public and private institutions focused on POPs	Institutions (structures, entities, frameworks, and norms organizing society) with a focus on the regulation of POPs.	Institutional Framework	Report on defaulting enterprises

Sl. No.	Key performance indicator	Details of the Performance Indicators	Description of the Indicators	Benchmark	Sources of verification
6.	Institutional governance	1. Democratic processes of functioning of main regulatory institutions 2. Adoption of the process of Law with regard to POPs	Institutional governance infrastructure across scales with effective inter-institutional communication and coordination	Governance Framework	Details on Websites
7.	Capacity enhancement of Regulatory Institutions	1. Funds allocated for capacity enhancement / institutional support 2. No. of trainings/workshops conducted 3. No. of persons attended	Training of institutional staff and funds for instrumentation and consumables	Meetings/training workshops on POPs to be quantified and impact of these programs assesses	Training /Workshop reports
III	**FINANCIAL**				
8.	Funds utilization	1. Transparency of funds collected and utilized 2. Funds allocated and utilized for research, capacity building, awareness generation and management of POPs	Revenue collected by the government from industries (e.g. with chemical registration through the CMSR) needs to be re-invested in environmental improvement and environmental management	100% of funds are used for environmental protection, monitoring and inspections, etc.	Audit Statements Financial Reports
9.	Economic Instruments for better management	Review of Economic instruments such as taxes, subsidies, grants etc.	Strengthening and reviewing economic instruments for better management	Review process	Review documents

Sl. No.	Key performance indicator	Details of the Performance Indicators	Description of the Indicators	Benchmark	Sources of verification
10	Co-financing models for implementation and regulation	1. Corporate Funds 2. No. of corporates in co-finance	Supporting and strengthening co-finance enhances the responsibility and participation of stakeholders in the regulation	Co-finance Plans through the upcoming CMSR under which industry must pay levies for chemical registration and reporting.	Plans Co-Finance Reports
IV	**TECHNOLOGICAL**				
11	Invest and support innovation & technology advancement	1. Budget allocation for innovation and technology advancement 2. No. of industries/institutions supported for technology advancement 3. Investment and support for laboratory equipment, resources, adequate technically qualified personnel	Incentives (and disincentives) for corporates	A set target of corporates reporting about incentives in either Business Responsive Sustainability Report (BRSR) or through the upcoming CMSR	Proof of incentives as per the BRSR scores / Management control of the CMSR scheme
12	Process and Standards for testing of relevant POPs	Development of processes and standards for testing. Accreditation of laboratories.	Need for validation process for testing	A public registry of accredited labs. Requirement of relevant accreditation in public procurement processes?	A state or national registry. Protocol / templates for public procurement.
V	**MANAGEMENT AND INFORMATION SYSTEMS (MIS)**				
13	Monitoring and testing	1. Monitoring of POPs in organisms, humans, environment, products, and at enterprises (pipes and stacks) 2. Testing of biological effects (prior to listing under the SC with reference to special Indian situation, exposure, metabolism, different climatic regime and profile. 3. Testing the presence of POPs in waste, imports, and products 4. No. of Labs with testing facilities	Process and systems in place for monitoring, testing, and reporting Inventorization of the POPs data in MIS Platform	Regular annual reporting of monitoring and testing CMSR to be updated with new information	Monitoring and testing reports

Sl. No.	Key performance indicator	Details of the Performance Indicators	Description of the Indicators	Benchmark	Sources of verification
14	Review of National level implementations	1. New Policy Draft Document / Update of 2011-document 2. Stakeholder consultations for review	Revised Policy with the inclusion of 15 new POPs *(Stockholm Convention currently regulates 31 POPs out of which India regulates only 19 POPs)*	Revised NIP; National Implementation Policy for the new POPs	Policy Draft Document
15	Knowledge management – POPs data	No. of districts having high-quality data reported for POPs samples and regularly quantifying of various classes of POPs in different matrices	Levels of different POPs (Legacy and emerging) in: 1. Air 2. Water 3. Soil 4. Sediments 5. Biota	Scientific publications Study reports Policy Briefs	GPCB consolidated report from all districts
16	Implementation of policies and process	1. No. of Industries monitored 2. No. of Micro, Small & Medium Enterprises (MSMEs) producing export-oriented products monitored	Industries regularly monitored for violations of banned POPs	Zero # of defaulting cases reported	GPCB Reports on defaulters
17	Management and disposal of stockpiles	1. Monitoring activities conducted to identify, manage and appropriately dispose stockpiles 2. No. of stockpiles identified according to CPCB guidelines 3. No. of stockpiles managed off as	The need for enhancing the efficiency of TSDF where stockpiles are disposed	Annual report on management / destruction of POPs stockpiles (incineration, co-processing, TSDF)	Annual reported data on management of POPs stockpiles

Sl. No.	Key performance indicator	Details of the Performance Indicators	Description of the Indicators	Benchmark	Sources of verification
		4. per CPCB guidelines 5. No. of Treatment Storage and Disposal Facilities (TSDF) with capacities to dispose stockpiles as per CPCB guidelines 6. Training and Capacity building to TSDF For adequate disposal of stockpiles			
V	**CAPACITY BUILDING AND EDUCATION**				
18	Capacities to implement regulations related to POPs	1. Fund allocation for Capacity building and education activities 2. Regular capacity building activities i) Regulations ii) Testing, Accreditation iii) Safer Alternatives 3. No. of people reached for capacity building activities 4. Regular publications that are easily available to all stakeholders	Regular capacity building activities and publications that are easily available to all stakeholders	Meetings/training workshops on POPs	Proceedings of the Workshop at GPCB website
19	Collaborations with academia and scientific institutions for capacity building	1. No. of Academic /Scientific organizations for capacity building 2. Scientific Research on reducing and replacing POPs and the health impacts of POPs 3. Publications made accessible freely on the State website	Need to improve collaboration of industry and academic institutes as lack of capacity is a major constraint.	Collaboration Plans At least two other Publications for different target audiences	Reports Workshop/ Capacity building conducted by Academia/Scientific organizations Policy briefs, scientific commentaries

Sl. No.	Key performance indicator	Details of the Performance Indicators	Description of the Indicators	Benchmark	Sources of verification
V	**INFORMATION AND COMMUNICATION**				
20	Effective Communication	1. Communication plan in consultation with Industry 2. No. of Industry communication meetings held 3. Number of industry stakeholder participation 4. No. of notice mailers sent to industries 5. No. of public notice issued 6. Notices issued with adequate time for action 7. Effectiveness of communication strategy	Development of an active and an effective communication plan in consultation with the industry to ensure the following: i. Crucial information and regulations are understood and implemented, ii. Public notice issued on every new ban order on POPs, iii. Adequate time provided while issuing public notices iv. Stakeholders' easy access to communication	Communication Plan for orientation, hand-holding, capacity building in place	Communication Plan

Sl. No.	Key performance indicator	Details of the Performance Indicators	Description of the Indicators	Benchmark	Sources of verification
21	Outreach and Awareness Generation	1. Number of outreach/awareness campaigns 2. Outreach to relevant stakeholders i) State Government ii) Local Governments iii) large industries and corporates iv) medium and small-scale industries v) Civil societies vi) farmers Associations v) Informal market groups vi) Women's Groups	# of close coordination meetings with industries on safe storage and disposal of specific POPs	A fixed number of meetings with industries/ associations	Minutes of the meetings
22	Inclusion of small and medium industries specifically for information & communication	1. Specific communication Plan for industries, MSMEs 2. No. of small and medium industries reached	Despite several publications and circulars, newsletters already in place with vital information, several small industries are unaware of the compliances and bans	Communication Plan for small and medium industries	Communication Plan
23	Knowledge and capacity enhancement for safer alternatives	1. Allocation of funds for knowledge and capacity enhancement for safer alternatives 2. No. of capacity enhancement programs on safer alternatives	Alternatives and technologies identified for new POPs	List of alternatives/ technologies for new POPs	List of feasible alternatives and technologies available, and progress report

Chapter 7
KEY CHALLENGES AND OPPORTUNITIES

7.1. Pollution Issues

As a result of the industrial revolution, technology, society, and the provision of multiple services developed, but it also resulted in huge quantities of pollutants being emitted into the atmosphere that are harmful to human health (Manisalidis et al., 2020). Global environmental pollution is without a doubt a major public health issue with significant social, economic, and environmental implications. Anthropogenic pollution is one of the largest public health hazards worldwide, given that it accounts for about 9 million deaths per year (WHO, 2018). Persistent Organic Pollutants (POPs) are one of the most hazardous pollutants that are toxic, bioaccumulative, and persistent.

The environmental challenges caused by POPs are of growing concern, as the production, release, and treatment of these chemicals remain inadequately managed. Raising awareness of these environmental concerns amongst the public and key stakeholders, and taking mitigation measures to restore our air, water and soil is vital. Toxins released by factories, combustion of fossil fuels, oil spills, and industrial waste continue to cause damage to the environment, ecosystems and public health (Mininni, 2007; Thacker, 2013). Many of these emissions contribute to global warming, which amplifies climate pressures, including rising sea levels, polar ice melting, flash floods, and desertification.

Researchers are continuously trying to find solutions for the sustainable mitigation of the environmental pollution imposed mainly by anthropogenic activities. Conventional methods, such as the physical removal of contaminants from a polluted site or the chemical treatment methods applied for removal of various contaminants, may affect the area's flora and fauna in both positive and negative direction, depending on the methods used and the context of application. Moreover, some of these techniques may help change, adsorb or convert the pollutant from one form to another rather than completely degrading or removing it from the site (Noel and Rajan, 2014).

As discussed earlier in this report, PBDEs have been detected in the Daman Ganga and Tapi river catchments. Concentrations of PBDEs have been detected in water, soil, surface sediments, bovine milk, biota, and air samples. Air samples collected during the first phase of sampling in the Daman Ganga and Tapi catchments indicated extensive PBDE contamination, most likely due to industrial and open burning activities. The subsequent deposition of PBDEs from the atmosphere back into the soil and water further adds to the problem of PBDEs being detected in the riverine environment.

Effluent emissions from industries and runoffs from urban areas have contributed towards riverine pollution of POPs (USEPA, n.d.). In the first phase of sampling in Tapi and Daman Ganga rivers, dominance of the BDE-47, -99, 100, -153 and -154 congeners was observed in water samples, which is reminiscent of commercial penta-BDE formulations which contain these specific homologs in varying percentages (as depicted in Section 4.1).

The riverine sediment collected during both phases of sampling was also found to contain a myriad of PBDE congeners. There were sporadic spikes in certain congeners along the length of the river, indicative of point source emissions along the riverine belt of rivers Daman Ganga and Tapi.

Soil samples collected from the polymer manufacturing industrial premises during the first phase of sampling was found to be abundant in BDE-209 and BDE-183, which are heavier congeners used in heavy duty applications. Especially BDE-209, which is the most abundantly produced and used PBDE congener to date (Chakraborty et.al, 2021).

Milk samples collected during the first phase of sampling indicated the presence of PBDEs, highlighting a potential pathway of human exposure to these flame retardants. Although levels were moderate / low at least 7 out of the 9 PBDE congeners tested were detected in all the milk samples pointing to an widespread presence of these flame retardants in the environment, leading to their consequent bioaccumulation in bovine milk.

7.2 Trade issues

The Draft Chemicals (Management and Safety) Rules (CMSR) included recommendations on the development of an inventory registration scheme for chemicals and outlined plans for adoption of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). The GHS is an internationally harmonized approach to classification and labelling of chemicals, which aims to ensure that countries have consistent and appropriate information on the chemicals they produce domestically, import and export (UNECE, n.d.).

India's chemical industry accounts for about 14% of production in Indian industries. The Indian chemical industry stood at $178 billion in 2020 and is projected to reach $300 billion by 2025. Approximately 70% of India's chemical production is consumed in the country. India imported $56 billion and exported $41 billion worth of chemicals and petrochemicals in the year 2020 (IBEF, 2022).

In 2020, India was among the top exporters of pesticides with trade of $2.75 billion. During the financial year 2020, nearly 100 thousand metric tons of insecticides was exported from India to other countries, a significant increase from the previous year. India produces some of the POPs like DDT (Dichlorodiphenyltrichloroethane). Hindustan Insecticide Limited (HIL), a PSU under the Ministry of Chemicals and Fertilizers has supplied 20.60 Metric tons of DDT 75% WP (wettable powder) to South Africa for their Malaria control program in July 2020. The Company supplied DDT 75% WP to Zimbabwe (128 MT), Zambia (113 MT) and 25 MT of a different chemical, Malathion Technical 95%, to Iran in FY 2020-2021. HIL (India) is the sole manufacturer of DDT globally. HIL (India) also exported Agrochemical-fungicide (32 MT) to Latin American region. (PIB, MoCF, 2020).

As one of the fastest growing economies in the world, India is assuming an important role in international trade. Since 2018, the Government of India, through the Bureau of Indian Standards (BIS), proposed to make mandatory a suite of voluntary domestic standards for chemicals. It has since then notified 25 proposed mandatory standards for specific chemicals to the World Trade Organization (WTO) Committee on Technical Barriers to Trade (TBT Committee) (The Dollar Business. 2018). There are environmental exceptions in the WTO General Agreement on Tariffs and Trade (GATT) rules. Article XX (20) sets out the conditions for restricting international trade in the interest of human, animal, or plant life or health (GATT, 2012). These restrictions are allowed if performed in a non-discriminating manner with no less trade-intrusive alternatives available, as environmental concerns could otherwise be used as disguised protectionism (Jaspers, N and Falkner, R, 2013). India is party to WTO GATT and being the sole producer of some POPs, like DDT, it is imperative for the Government of India (GoI) to ratify more POPs and adopt sustainable alternatives at the earliest.

The government has been proactive in announcing several measures to improve the global competitiveness of the Indian chemical industry. Industrial licensing has also been abolished in most chemical sub-sectors, except a small list of hazardous chemicals. Extending the same spirit, foreign direct investment (FDI) up to 100% in the chemical sector has also been approved (GPCA, 2021). Trade of chemicals is deregulated in India and technical barriers to trade (TBTs) are increasing day by day. Indian companies are facing TBT in international export, for example, in cases where contaminant levels in their products exceeds the limits of importing countries. It is imperative for the GoI to adopt the necessary regulations on Chemical Trade.

India has not officially adopted GHS for chemicals yet. However, standard 16-section GHS compliant safety data sheets in English seem to be acceptable in India. The Draft Chemicals (Management and Safety) Rules (CMSR) published in 2020 also intends to implement GHS in India (ChemSafetyPro, 2018). The draft CMSR included recommendations on the development of an inventory registration scheme for chemicals and outlined plans for GHS adoption. The timings for implementation are yet to be defined. India should adopt the GHS to ensure that information on the hazardous properties of chemicals is available throughout the world to enhance the protection of human health and the environment during the handling, transport, and use of chemicals. Enhancing the harmonization of rules and regulations of chemicals on the nationa, regional, and global level is essential for facilitating trade and obtaining access to markets with stringent environmental regulation and protection.

7.3 Science and Research

Many synthetic chemicals were introduced widely for commercial use during the boom in industrial production after World War II. Some of these chemicals were used for pest and disease control and crop production and were later categorized as Persistent Organic Pollutants (POPs). The persistent, bioaccumulative, toxic and transboundary nature of POPs make them a class of chemicals posing global threat (Fitzgerald & Wikoff, 2014; Kodavanti et al., 2014; Miniero & Iamiceli, 2008).

The affinity of POPs for lipid-rich tissue allows it to accumulate, persist, due to their resistance to biological degradation, and biomagnify in the human/animal body. Consequently, even though the level of exposure may be low, POPs can eventually reach toxicologically relevant concentrations. POPs exposure could be through dermal contact, ingestion or inhalation. Research has shown that exposure to POPs in humans can cause several negative health effects, including cancer (Park et. al, 2020), developmental abnormalities, damage to the central and peripheral nervous systems (Berghuis et.al, 2015), and disruption of the endocrine, reproductive, and immune systems (Schug et al. 2016).

There are correlations between POPs exposure and increased incidence of diseases and/or anomalies in animal species, including fish, birds, and mammals, according to the US Environmental Protection Agency (USEPA). Changes in reef community structure, such as decreased live coral cover and increased algae and sponges, as well as herbicide damage to seagrass beds and other aquatic vegetation, are all harmful consequences of pesticides in the marine and coastal settings (Damstra, 2002; Qing Li et al., 2006).

A densely populated and developing country like India is exposed to environmental contamination of POPs from several sources and activities. This leads to significant exposure of all organisms to relatively high levels of POPs, which have been detected in all quarters of the environment, drinking water, food products (Sharma et.al, 2021), and even human breast milk (Shinsuke Tanabe and Tatsuya Kunisue, 2007). The identified sources of POPs in India include production units, illegal imports as well as stockpiles of obsolete pesticide stocks. Except for DDT, which continues to be used in vector control, several other pesticide POPs listed in the Stockholm Convention are banned for manufacture and use in the country. However, stockpiles of unused POPs remain unidentified causes of concern. Emission of dioxins and furans due to open burning of plastic wastes poses a serious risk to public health and the environment (Velis and Cook 2021). In addition, unregulated e-waste recycling is also a major source of dioxins like-PCBs, dioxins, and furans (Chakraborty et.al, 2018).

The National Implementation Plan (NIP) is still in the first phase of phasing out the initial twelve POPs. The Union Cabinet has approved ratification of the seven new POPs on October 7, 2020. At present, the information on the seven new POPs is limited as India has not created any inventory on these chemicals, most of which are industrial chemicals. NIP for the second phase is work-in-progress by CSIR-NEERI under GEF support.

One of the essential aims of Stockholm Convention is to support the transition to safer alternatives. Although it is difficult to estimate the potential risk of alternatives, the replacement of these POPs should not result in creating another problem such as mutagenicity, carcinogenicity, or adverse effect on the product to developmental, endocrine, or immune or nervous system. While the debate over the benefits and drawbacks of pesticide use continues, the Integrated Pest Management (IPM) platform is being viewed in terms of environmental sustainability by promoting the use of biological pesticides over chemical pesticides. Electronic pest repellents are another viable option to reduce use of POPs pesticides. In India, the alternative pesticides, and methods (such as IPM) have not been successful due to higher costs as compared to chemicals. There is limited awareness on the issue and requirement of additional investment in research and creating awareness about biological and organic alternatives to synthetic chemicals (Toxics Link India, 2006). In tropical climate contexts like India, rapid dissipation of the semi-volatile organic compounds (SVOCs) can occur. Hence, more research is needed in the fate and transport of POPs and long-range atmospheric transport of POPs.

7.4 Education and Outreach

The key goals of developing a robust education and outreach program for the POPs Action Plan for Gujarat are to improve learning, promote public engagement, and strengthen the knowledge and capacity of stakeholders to enable effective implementation of the Stockholm Convention on POPs at the State and national levels. The key objectives are to:

- Enhance the capacity and knowledge of relevant stakeholders in the state of Gujarat, such as industries manufacturing chemicals, some of which are POPs, farmer associations, agricultural scientists, water resources department officials, State Pollution Control Board officials, and academic and institutions engaged in research within the fields of environment, toxicology, and ecology.
- Enhance the skills and knowledge of research and academic institutions in Gujarat to strengthen capacity to analyse sampling and analysis techniques in the implementation process of the Stockholm Convention.
- Contribute to establish inter-agency coordination in support of long-term efforts to achieve chemical safety.
- Generate awareness around phasing out POPs in Gujarat amongst key stakeholders.

Key components of education and outreach program for the POPs Action Plan (Figure 7.4.1)

1. *Generation of public awareness:*

- It is imperative to develop awareness and knowledge amongst the general public and key stakeholder groups on the risks caused by POPs to human health and environment.
- Public participation must be encouraged, and specific roles of the public and other stakeholders needs to be defined in the management of POPs.
- A public awareness raising program on POPs should be conducted at the state level and could include the development and distribution of targeted IEC

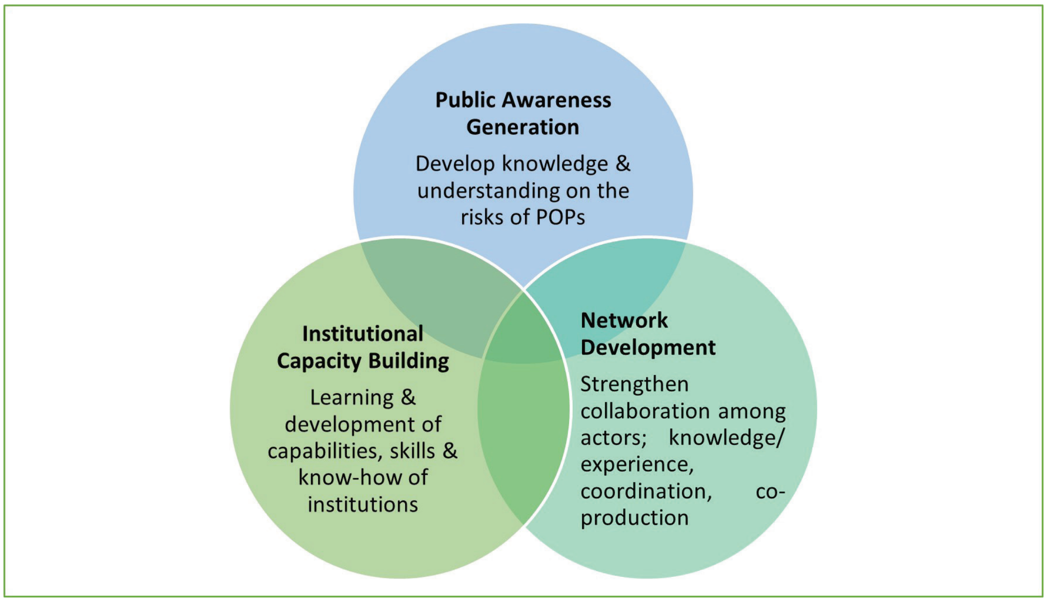


Figure 7.4.1: Key components of Education & Outreach Program of POPs Action Plan for Gujarat

(information education communication) materials (like leaflets) on POPs amongst various stakeholders.

- A podcast on the health and environmental effects of POPs could contribute to reach a wider audience with facility for a two-way exchange of knowledge on POPs and its health impacts.
- All popular social media platforms (Twitter, Facebook, Instagram etc.) of stakeholder organizations should be utilized to raise public awareness on POPs.

2. *Institutional capacity building:*

- Capacities of governmental officials and other relevant stakeholders should be strengthened to effectively implement national (and international) regulatory requirements related to environmentally sound POPs management.
- Knowledge building and development of capabilities, skills & know-how of key stakeholders should facilitate for enhanced independent application and use by respective institutions (including government agencies)
- A series of state-level workshops should be conducted for stakeholders from government institutions, NGOs, industry, private and informal sectors have the opportunity to learn more about the issues and challenges of POPs management in the state. The workshop could serve as a platform to bring out the concerns of each stakeholder group on POPs.
- Knowledge about POPs need to be taught at higher education (e.g., chemistry, biology, toxicology, environmental studies, ecology, medicine etc.). An effort should be made to ensure that POPs and hazardous chemicals are a theme in relevant studies and students and research scholars are engaged in deep learning.

3. *Network development*

- It is important to develop and strengthen cooperation and close collaboration among governmental institutions, public, private sector, and other relevant stakeholders towards reaching common goals of sound POPs management.
- Key analyzed information (both time series data and newly generated information on POPs) must be shared among stakeholders through easily accessible knowledge platforms.
- High-schools, colleges and universities should be involved in the network, with students engaging in outreach activities to the public, including through social media platforms and outlet formats such as Twitter, Facebook, Instagram, video creation and podcasts.
- Sharing of knowledge and experience should be

seamlessly done so that it leads to better coordination and co-production of ideas and activities for smooth implementation of the POPs action plan in Gujarat.

7.5 Leveraging resources - Financial & Human resources

Several institutions in India have varied roles for the overall chemical management in the country. Depending on the nature of the substances, their use and release, these institutions have different roles in managing the chemicals, including POPs at different levels.

In India, the Ministry of Environment, Forests, and Climate Change (MoEFCC) is the nodal ministry to deal with the international environmental treaties and conventions (such as the Stockholm Convention), to frame the rules and regulations, as well as to coordinate with the Central Pollution Control Board (CPCB), the State Pollution Control Boards (SPCBs) and the Department of Environment and Forest in the respective States, to implement the rules. The Central Government, through MOEFCC, has derived its power to negotiate and ratify new chemicals to the Stockholm Convention. However, this only concerns chemicals that already are regulated in some way or another under domestic regulation. The national interests were considered by the Government of India while making the rules and regulations on issues related to the global Conventions (such as the SC or Minamata Convention). Evidently, POPs are listed in various Annexes to the Stockholm Convention after thorough scientific research, deliberations, and negotiations among member countries. As part of the listing process to include and regulate new POPs in India, different stakeholders including government agencies are consulted several times through sector-wise coordination meetings, responses to specific questionnaires, and capacity building workshops. Despite the specific roles and responsibilities of various ministries and government agencies, knowledge inputs from all stakeholders to address the various cross-cutting issues of POPs management, is considered.

For the development of the National Implementation Plan (NIP), the MoEF worked closely with the CPCB, the Ministry of Agriculture & Farmer's Welfare (MoAFW)) for dealing with pesticides, the Ministry of Chemicals and Fertilizers (MoCF) for policy, planning, development and regulation of the chemical, petrochemical and pharmaceutical industries, the Ministry of Power dealing with the power sector, the Ministry of Health and Family Welfare (MoHFW) for risk management from chemicals in consumer products and foods; State Health Departments (SHD) for protecting public health, and with the Ministry of Science & Technology (MST) through their research institutions.

Led by the MoEFCC, the government agencies who are executing the NIP for POPs management are the CPCB, Central Power Research Institute (CPRI), National Environmental Engineering Research Institute (NEERI, Nagpur) and National Institute for Interdisciplinary Science and Technology (NIST, Trivandrum). The other concerned ministries with specific roles involved in implementation of NIP are MoCF, MoHFW and MoAFW. NEERI is the Stockholm Convention Regional Centre (SCRC) for POPs, a knowledge resource center for Asia. The SCRC conducts research and development on POPs focusing to promote their environmentally sound management, capacity building and awareness raising campaigns in the region. However, the institute has no exclusive authority to overview and harmonize the implementation of the Stockholm Convention in the country. The Central Pollution Board, the State Pollution Control Boards have been bestowed with the responsibilities for monitoring the emission levels and enforcement of the regulations on POPs at various levels.. Further, the CPRI, and the urban local bodies have been provided with responsibilities for some critical POPs like PCBs and Dioxins /Furans. Figure 7.5.1 presents an overview of the institutional arrangements for POPs management in India.

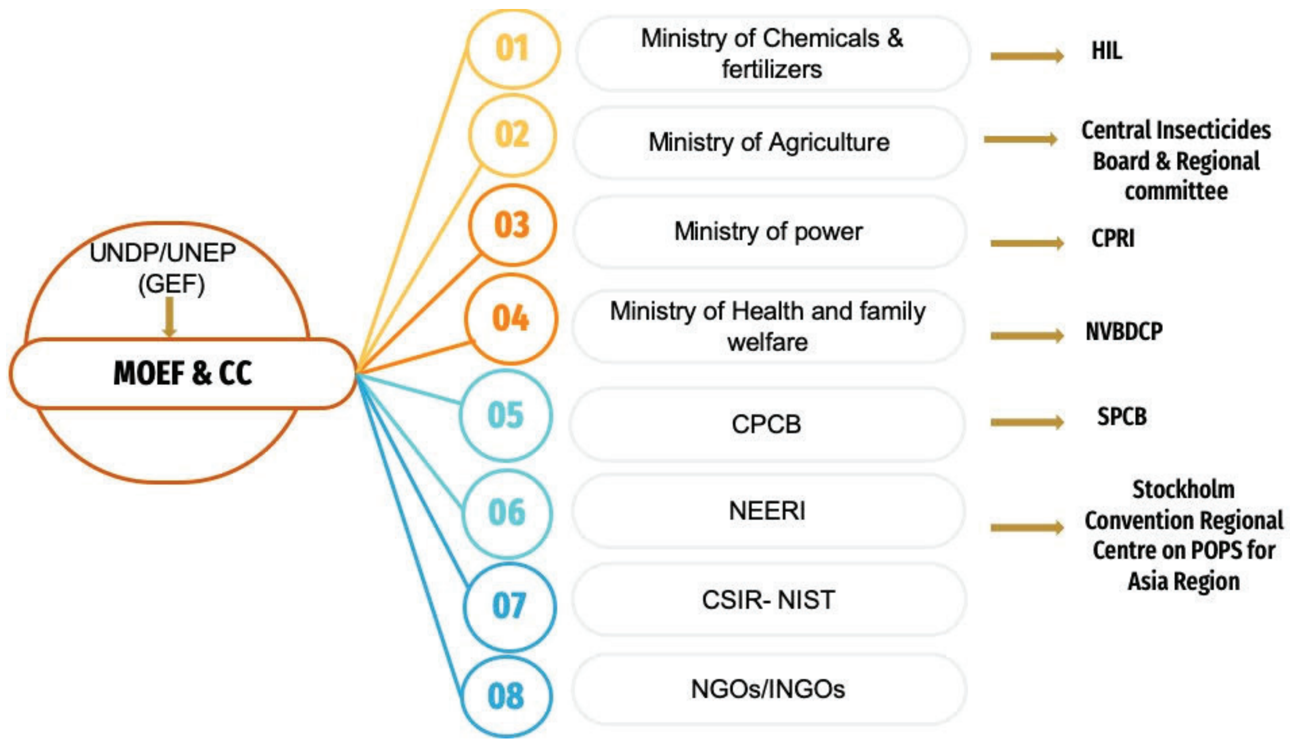


Figure 7.5.1: Institutional Arrangements for POPs management in India

HIL - Hindustan Insecticides Limited; CPRI - Central Power Research Institute; NVBDCP - National Vector Borne Disease Control Programme; CPCB – Central Pollution Control Board; SPCB – State Pollution Control Board; NEERI – National Environmental Engineering Research Institute; CSIR-NIST - CSIR – National Institute for Interdisciplinary Science and Technology (NIIST); NGO - Non-governmental organization

(Toxics Link, 2018)

In India, efforts are being made to leverage the human resources for POPs and management of other chemicals. There are only a few research and academic institutions in India that are equipped with the analytical and instrumentation facilities and capacity for POPs and contaminants of emerging concern.

The Government of India also allocates resources towards management of pollution which also includes management of chemicals. In the budget speech of 2021-2022, the Central government had allocated Rs 3,030 crore to the MoEFCC for the financial year 2022-2023, of which Rs 460 crore was allotted towards pollution control (Union Budget of India, 2022-2023). The Government of India is also able to leverage resources through Global Environment Facility (GEF) fund to carry out the activities towards the management of POPs. Research studies undertaken through bilateral agreements such as the INOPOL project also contributes to bridging some of the financial gaps towards monitoring, knowledge support and management of POPs.

However, there are challenges as new POPs are being added to the Stockholm convention, which are far more complex to manage. Therefore, there is specific need for prioritization on management of POPs in India by enhancing human and financial resources to control the growing environmental and health challenges associated with POPs. There is huge need for awareness generation among policy makers, research community etc. to bring attention to the adverse impacts of POPs on environmental/ human health impact.

7.6 Challenges with regard to compliance and accountability and commitment to POPs management

In order to facilitate monitoring and compliance mechanisms on POPs in Gujarat, significant financial investment is needed in the capacity of monitoring systems, laboratory infrastructure and technical personnel. This would provide confidence that prescribed quality standards are being met regarding POPs emission into all the environmental matrices such as: water bodies, soil, biota and air. In order to successfully implement the Stockholm Convention on POPs in Gujarat, it is essential to institutionalize compliance mechanisms. The implementation of the POPs Action Plan may face several challenges including:

Compliance with standards: The persistence and toxic effects of POPs in food have been a major concern for food safety and human health. Significant efforts will be needed to ensure prevailing food safety and quality standards are met, thus reducing risks to public health and the environment. There are a number of steps to be taken, including improving the financing and capacity of compliance institutions, incorporating transparent self-monitoring systems into business models with sufficient checks and balances, and engaging stakeholders in the process. Food safety is of paramount importance for national public health and for export trade. There have been numerous instances where non-compliance with food safety and quality standards has resulted in a loss of export potential in the past. Additionally, the development of national norms for planning and managing water safety risks will also be important.

Public awareness: Awareness generation programs focusing on the point and non-point sources of POPs pollution and the negative impacts of POPs on human health and environment should be conducted for public health safety. Such programmes should entail consistent and targeted messaging for end users and the public for effective communication on food and water safety. Discharges of industrial effluents or spills of POPs from old stockpiles into water bodies should be immediately reported to the local communities. Their health should be monitored to target resources and provide trained medical personnel.

Financing and viability: Successful implementation of POPs Action Plan would require an alignment of interests and incentives amongst the key stakeholders and designing support programmes that are efficient in time and resources. The regulations allowing economic incentives for businesses to integrate best available technologies (BAT) and best environmental practices (BEP) into their production processes and reducing emissions of POPs, must be taken into consideration. This would require an enabling regulatory and pricing environment that provides incentives for compliance and managing the transition.

7.7 Integration with Regional/ Global activities

POPs, as pesticides and industrial chemicals, so hastily adopted in the middle of the last century, are posing grave danger today. Global contaminants such as POPs or mercury are regulated by Multilateral Environmental Agreements (MEAs), namely the Stockholm and Minamata Conventions. Other multilateral environmental agreements like Basel and Rotterdam share the common objective of protecting human health and environment from hazardous chemicals and wastes. In addition, several additional 'Emerging Policy Issues' (EPIs) have been nominated for voluntary, cooperative risk reduction actions by countries through the Strategic Approach for International Chemicals Management (SAICM).

The inclusion of chemicals under the Rotterdam

Convention does not ban the chemical. However, importing countries need to follow the Prior Informed Consent (PIC) procedure. But in the public interest, the listing of chemicals under the Stockholm convention bans/restricts the chemicals for trade, import, export, and use and minimizes the unintentional release of POPs. While the Basel Convention discuss the control of transboundary movements of hazardous wastes and their disposal, the Rotterdam Convention deliberates on the prior informed consent procedure for certain hazardous chemicals and pesticides in international trade. These have, however, been addressed on an ongoing basis through legislation, rules, and inspections by the regulatory authorities in India.

India is committed towards its obligations of BRS and Minamata conventions as well as the SAICM. It is also important, at the same time, to safeguard the country's interest. In this context, the Ministry of Environment, Forests and Climate Change is playing an instrumental role in environmentally sound management of hazardous chemicals and wastes, keeping in view the overall objectives of sustainable development and growth.

India should actively ratify more POPs to take the lead in the Asia region and access the capacity building and technical assistance that is available, including technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment; technical guidelines for environmentally sound management of wastes consisting of, containing, or contaminated with low POPs.

The Government of India is engaging with intergovernmental organisations like UNIDO (United Nations Industrial Development Organization), UNEP (United Nations Environment Programme) and implementing various projects on POPs management, and by involving various Indian institutions like, CSIR- National Environmental Engineering Research Institute, Central Power Research Institute, National Botanical Research Institute, HIL Limited and NGOs to manage POPs and adopt safer alternatives. CSIR-NEERI is the Stockholm Convention Regional Centre for Capacity-building and Transfer of Technology, India (SCRC India), and serves different countries in the Asia region to aid in capacity building and transfer of technologies related to POPs. CSIR-NEERI has evolved as a knowledge hub to impart knowledge and information on POPs in the Asia region. The Indo-Norwegian project INOPOL (2019-2022) addresses the highly interlinked challenges of POPs in India, and facilitates cross learning across the spectrum.

Chapter 8
CONCLUSION AND WAY FORWARD

India has been actively involved in the management of POPs as a party to the Stockholm Convention, and needs to continue its endeavor through prohibiting or restricting the production and use of POPs, reducing its environmental release formed as industrial by-products, safely managing the stockpiles of restricted POPs, and ensuring the environmentally sound disposal of waste consisting of, or contaminated by POPs. It is crucial to strengthen the existing regulation, management, and control of POP releases. Minimising the environmental release of such POPs with specific control measures will help protect human health and the environment.

The SC calls for each member state to develop a national implementation plan (NIP) for the implementation of its obligations under the Convention. India has developed a NIP for the first 12 POPs, but has since lagged behind. Unlike most countries, India ratified the SC with an opt-in clause, meaning that it does not automatically ratify all new listings under the Convention. In 2021, India ratified additional 7 POPs, mostly brominated flame retardants. In India, the process of developing, reviewing, and updating a NIP requires an action plan or a strategy for POPs management. To support the process of updating the NIP and provide knowledge-based support to ongoing efforts by government and other stakeholder institutions, the present POPs Action Plan for Gujarat identifies key actions and specifies the roles and responsibilities of key stakeholders to reduce the use and release of legacy and emerging POPs. The POPs Action Plan entails a list of resources, including human resources, infrastructure facilities, equipment, services, materials, etc., needed for its implementation. The Action Plan also lists the Key Performance Indicators (KPIs) for management of POPs pollution, a management tool that can play a crucial role in measuring the impacts of the proposed actions. The 23 respective KPIs aligned under 7 categories are quantifiable metrics that would reflect the performance of actions in the context of achieving its broader goals and objectives, with clearly defined targets and benchmarks to measure and capture the impact(s). Hence, they will be useful resources for the Government of India's ongoing initiative of updating the NIP.

The INOPOL project has also contributed to research related to the prevention and reduction of marine litter from land-based sources in the catchment areas of rivers Tapi and Daman Ganga in Gujarat, which are highly affected by various industrial processes, wastes from manufacturing chemicals, and POPs pollution from riverine transport. The knowledge and capacity of stakeholders, experts, and civil society has been enhanced for the reduction of releases and impacts of POPs pollution (related to the chemicals listed under the SC). The INOPOL project has been able to sucessfully address some of the gaps and challenges of POPs management by providing state-of-the-art and science-based research approaches, knowledge exchange between key actors, training and capacity building, and policy inputs, to strengthen local and national capacity to

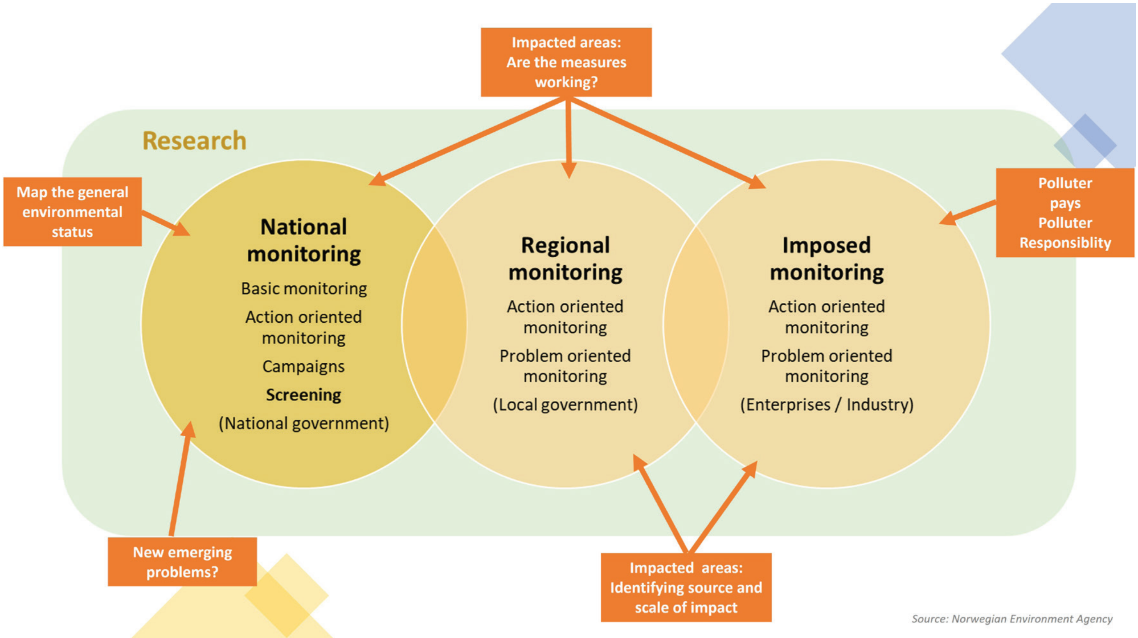


Figure 8.1: Inter-relationship between National Monitoring, Regional Monitoring and Imposed Monitoring and the purposes they fill.

Source: the INOPOL team, adapted from an overview of different monitoring purposes by the Norwegian Environment Agency.

ultimately mitigate the environmental threats posed by chemical and POPs pollution.

The extensive research, capacity building, advocacy and outreach programs conducted under INOPOL (Phase I) have provided many valuable lessons on monitoring of POPs, modelling, policy perspectives, social impacts, and the areas for capacity building needs in India with a special focus on Gujarat. India's commitment to SC, the upcoming Chemical Management and Safety Rules (CMSR), the NIP on new POPs, and the remaining SC POPs that are still not addressed by India (#11), provide a fertile environment for further research in the domain of pollution by POPs. The inter-relationship between National Monitoring, Regional Monitoring, and Imposed Monitoring and the science-informed policy processes that the INOPOL project has tried to impact is encapsulated in Figure 8.1.

By preventing and reducing marine pollution and hazardous waste in India, the INOPOL project will in its next phase continue to contribute towards improving management systems for POPs from land-based sources; recommend measures to manage waste from reaching the riverine and marine environment; and ensure sustainable production, use, and waste management within the private sector; thereby strengthening the national and regional instruments to prevent POPs pollution. The INOPOL team is keen to develop targeted, efficient, mitigative, and solution-oriented measures for control and reduction of plastic and POPs pollution in India through a multidisciplinary, cross-sectorial, and integrated approach in other States of India. Figure 8.2 outlines the mapping, assessment, solutions, and resilience, as well as the key deliverables.

In adopting the 17 Goals of the 2030 Agenda for Sustainable Development, chemicals and POPs management are directly or indirectly related to achieving every aspect of this framework. Sound management of chemicals and waste reinforces the

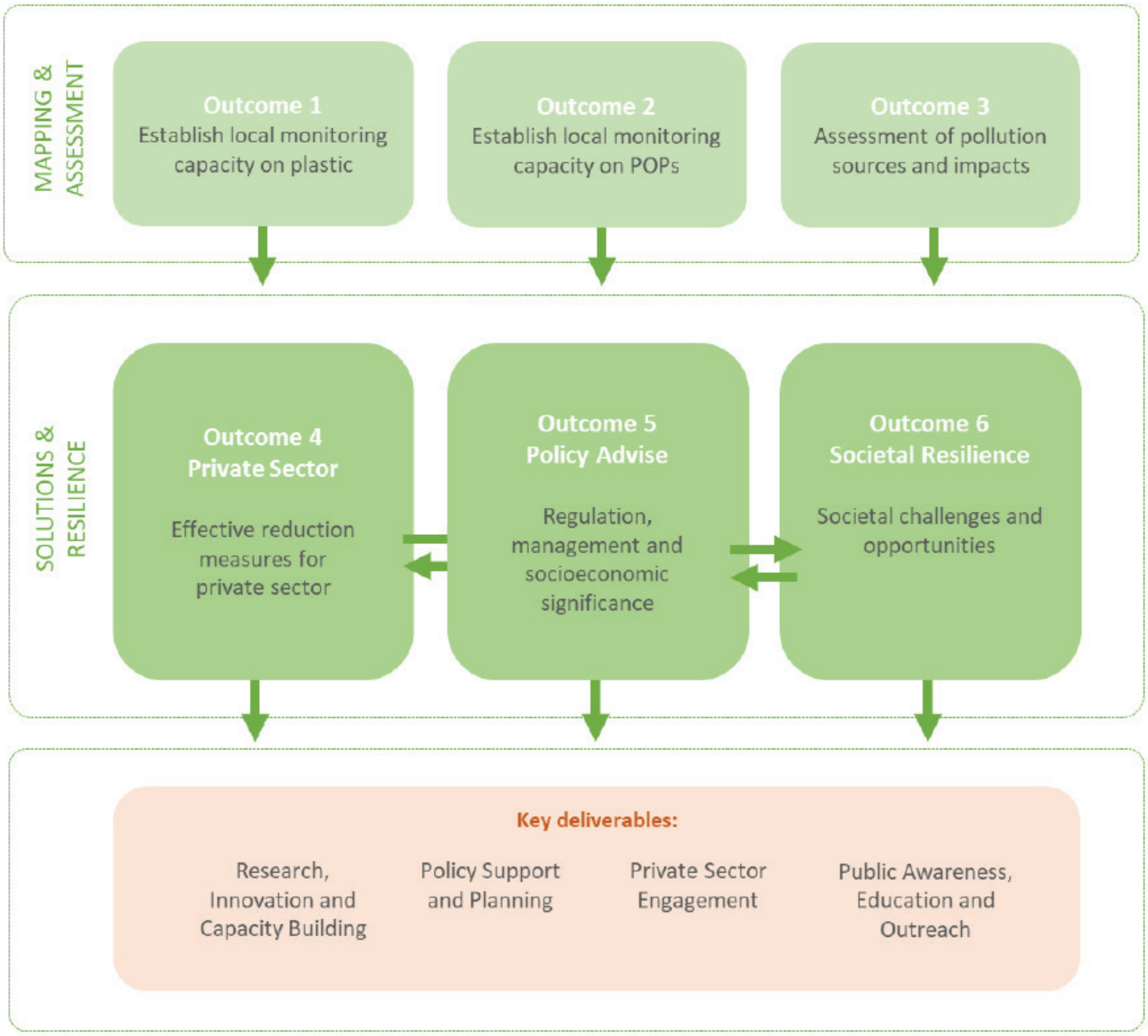


Figure 8.2: Mapping, Assessment, Solutions and Resilience of POPs pollution in India

Source: Author's contribution

effective achievement of the SDGs at the national level. Through scientific and policy research efforts, the POPs Action Plan under the INOPOL project has addressed the targets associated with several of the Sustainable Development Goals (SDGs) related to chemicals and wastes: Targets 2.1, 3.9, 6.3, 11.6, 12.4, 12.5, and 14.1. These targets also correspond directly to the strategies and work plans of the Basel Convention (1988), Rotterdam Convention (1998) and Stockholm Convention (2004), as well as their implementation targets and goals. The achievement of these SDGs can therefore provide an integrated framework for a cross-sectoral approach towards the sound management of chemicals to achieve improved environment, public health, and well-being.

ANNEXURE

Annexure I - Sampling location details

Phase-I Sampling-December 2020			
S.NO	**Sample ID**	**Latitude**	**Longitude**
Matrix	**Surface water**		
1	DG-U-1A	20.263458	72.990382
2	DG-U-1B	20.263458	72.990382
3	DG-U-2	20.268229	72.988571
4	DG-U-3A	20.275632	72.983993
5	DG-U-3B	20.275632	72.983993
6	DG-U-4	20.276158	72.983047
7	DG-M-1	20.340157	72.911734
8	DG-M-2	20.339713	72.910998
9	DG-M-3	20.339914	72.910249
10	DG-M-4A	20.339910	72.909590
11	DG-M-4B	20.371480	72.881397
12	DG-M-5	20.371480	72.881397
13	DG-D-1	20.410910	72.834249
14	DG-D-2	20.411445	72.832091
15	DG-D-3	20.411723	72.832034
16	DG-D-4	20.411369	72.828365
17	DG-DS-GW	20.410381	72.834314
18	TP-U-1	21.284529	72.951519
19	TP-M-1	21.221273	72.866489
20	TP-M-2	21.178804	72.792199
21	TP-M-3	21.145330	72.746384
22	TP-D-1	21.130732	72.708321
23	TP-D-2A	21.105825	72.703320
24	TP-D-2B	21.105825	72.703320
25	TP-D-2C	21.105825	72.703320

Phase-I Sampling-December 2020			
Matrix	Sediment		
1	DG-USED-1	20.263458	72.990382
2	DG-USED-2A	20.268229	72.988571
3	DG-USED-2B	20.268229	72.988571
4	DG-MSED-1	20.371480	72.881397
5	DG-MSED-2	20.339914	72.910249
6	DG-DSED-1	20.411445	72.832091
7	TP-USED-1	21.284529	72.951519
8	TP-MSED-1	21.178804	72.792199
9	TP-MSED-2	21.14533	72.746384
10	TP-DSED-1	21.130732	72.708321
11	TP-DSED-2	21.105825	72.70332
Matrix	Soil		
1	DG-S-1	20.263458	72.990382
2	DG-S-2	20.37148	72.881397
3	DG-S-3	20.339914	72.910249
4	DG-S-4	20.386255	72.896398
5	DADRA EDPC 1	19.38047	72.82413
6	DADRA EDPC 2	19.38047	72.82413
7	DADRA Maitry Plastics 1	20.27169	73.00382
8	DADRA Maitry Plastics 2	20.27169	73.00382
9	TP-S-1	21.284529	72.951519
10	TP-S-2	21.212272	72.736612
Matrix	Air		
1	VAP-1	20.386624	72.896559
2	VAP-2	20.37803	72.942594
3	VAP-3	20.367313	72.921179
4	VAP-4	20.408888	72.88315
5	VAP-5	20.422554	72.865023
6	VAP-6	20.361925	72.924396
7	SUR-1	21.229283	72.837162
8	SUR-2	21.212272	72.736612
9	SUR-3	21.220409	72.865135
Matrix	Milk		
1	DG-BMC-1	20.387327	72.89096
2	DG-BMC-2	20.387327	72.89096
3	DG-CMC-1	20.387327	72.89096
4	DG-CMC-2	20.387327	72.89096
5	DG-BMD-1	20.397088	72.867943
6	DG-BMD-2	20.397088	72.867943
7	DG-CMD-1	20.397088	72.867943

Phase-I Sampling-December 2020			
8	DG-CMD-2	20.397088	72.867943
9	DG-CMD-3	20.397088	72.867943
10	DG-CMD-4	20.397088	72.867943
11	DG-BMG-1	20.397079	72.926526
12	DG-CMG-1	20.397079	72.926526
13	TP-CM-1	21.221002	72.864614
14	TP-CM-2	21.221002	72.864614
15	TP-CM-3	21.221002	72.864614
16	TP-CM-4	21.221002	72.864614
17	TP-CM-5	21.221002	72.864614
18	TP-CM-6	21.221002	72.864614
Total no. of samples: 73			

Phase-II Sampling-September 2021		
S.NO	**Sample ID**	**Location**
Matrix: Surface water		**Latitude & Longitude**
1	DG- UW-S1-01	20.216667, 73.026667
2	DG-UW-S1-02	20.21671, 73.02631
3	DG - UW-S1-03	20.21665, 73.02712
4	DG - UW-S2-01	20.25641, 72.99072
5	DG - UW-S2-02	20.25621, 72.99103
6	DG - UW-S2-03	20.25666, 72.99083
7	DG - UW-S2-04	20.25821, 72.99028
8	DG - DW-S1-01	20.41083, 72.83416
9	DG - DW-S1-2A	20.41027, 72.83611
10	DG - DW-S1-2B	20.41055, 72.83611
11	DG - DW-S2-01	20.41222, 72.83138
12	DG - DW-S2-02	20.41222, 72.83166
13	TP- UW-S1-01	21.2701, 73.50536
14	TP-UW-S1-02	21.27095, 73.50564
15	TP - UW-S1-03	21.27052, 73.50344
16	TP - UW-S2-01	21.26934, 73.49989
17	TP - UW-S2-02	21.26913, 73.50004
18	TP- UW-S2-03	21.26934, 73.49907
19	TP - DW-S1-01	21.07937, 72.70686
20	TP - DW-S1-02	21.07857, 72.70787
21	TP - DW-S1-03	21.07744, 72.70951

Phase-II Sampling-September 2021		
22	TP - DW-S2-01	21.16075, 72.76721
23	TP - DW-S2-02	21.16104, 72.76723
24	TP - DW-S3-01	21.17911, 72.79216
Matrix	Ground water	
1	DG- UGW -01	20.25944, 72.99083
2	TP- UGW -01	21.26964, 73.50563
3	TP- DGW -01	21.17573, 72.72849
Matrix	Sediment	
1	DG- Used -S1-01	20.21674, 73.02634
2	DG- Used -S1-02	20.25822, 72.99032
3	DG- Dsed -S1-2A	20.41027, 72.8361
4	DG- Dsed -S1-2B	20.41055, 72.8361
5	DG- Dsed -S2-01	20.41277, 72.82972
6	DG-Dsed-S1-01	20.41083, 72.83416
7	TP- Used -S1-01	21.27023, 73.50537
8	TP- Used -S2-02	21.26934, 73.49989
9	TP- Dsed -S1-01	21.0793, 72.70656
10	TP- Dsed -S1-02	21.0788, 72.70784
11	TP- Dsed -S1-03	21.07768, 72.70967
12	TP- Dsed -S2-01	21.16069, 72.7672
13	TP- Dsed -S3-01	21.17903, 72.79196
14	TP- Dsed -S4-01	21.16493, 72.619
Matrix	Soil	
1	DG- Usoil -S1-01	20.21727, 73.02622
2	DG- Usoil -S2-01	20.25943, 72.99083
3	TP-Usoil -S1-01	21.26961, 73.50556
4	TP- Usoil -S2-01	21.26624, 73.5031
5	TP-Dsoil -S1-01	21.08176, 72.71247
Matrix	Fish	
1	DG- Dmussels -S1-01	20.41083, 72.83416
2	TP-Ufish S1-01	21.2695, 73.49969
3	TP-Dfish S1-01	21.07937, 72.70686
Matrix	Debris	
1	DG- Ddeb -S1-01	20.41089, 72.83407
Total no. of samples: 50		

Bibliography

1. El-Salam, A., Mohamed, H., & El-Shibiny, S. (2011). A comprehensive review on the composition and properties of buffalo milk. Dairy science & technology, 91(6), 663-699.
2. Abdolahpur Monikh, F., Chupani, L., Vijver, M. G., & Peijnenburg, W. J. G. M. (2021). Parental and trophic transfer of nanoscale plastic debris in an assembled aquatic food chain as a function of particle size. Environmental Pollution, 269, 116066-116066. https://doi.org/10.1016/j.envpol.2020.116066.
3. Administration of Daman & Diu. 2019. Action Plan on Damanganga River. U.T. Administration of Daman & Diu. 3rd March 2019. Accessed on Sep 14, 2022: https://daman.nic.in/websites/Pollution-Control-Committee/2019/Action-Plan-on-Damanganga-River-03-04-2019.pdf last accessed on June 16, 2022.
4. Allen, S., Allen, D., Phoenix, V. R., Le Roux, G., Durántez Jiménez, P., Simonneau, A., Binet, S., & Galop, D. (2019). Atmospheric transport and deposition of microplastics in a remote mountain catchment. Nature Geoscience 2019 12:5, 12(5), 339-344. https://doi.org/10.1038/s41561-019-0335-5.
5. Asante, K. A., Sudaryanto, A., Devanathan, G., Bello, M., Takahashi, S., Isobe, T., & Tanabe, S. (2010). Polybrominated diphenyl ethers and polychlorinated biphenyls in cow milk samples from Ghana. Interdiscipl Studies Environ Chem, 191-8.
6. Awasthi AK, Zeng X, Li J. Relationship between e-waste recycling and human health risk in India: a critical review. Environ Sci Pollut Res Int. 2016 Jun;23(12):11509-32. doi: 10.1007/s11356-016-6085-7. Epub 2016 Feb 16. PMID: 26880523.
7. Battu, R., Singh, B., & Kang, B. (2004). Contamination of liquid milk and butter with pesticide residues in the Ludhiana district of Punjab state, India, Ecotoxicology and environmental safety, 59(3), 324-331.
8. Berghuis SA, Bos AF, Sauer PJ, Roze E. Developmental neurotoxicity of persistent organic pollutants: an update on childhood outcome. Arch Toxicol. 2015 May;89(5):687-709. doi: 10.1007/s00204-015-1463-3. Epub 2015 Jan 25. PMID: 25618547.
9. Bharat GK. 2018. POPs in Indian environment: a wake-up call for concerted action - Policy Brief. The Energy and Resources Institute (TERI). January 2018. Accessed on Sep 14, 2022: https://www.teriin.org/sites/default/files/2018-02/Policy%20Brief%20on%20PoP.pdf
10. Boerger, C. M., Lattin, G. L., Moore, S. L., & Moore, C. J. (2010). Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Marine Pollution Bulletin, 60(12), 2275-2278. https://doi.org/10.1016/j.marpolbul.2010.08.007.
11. Breivik, K., Alcock, R., Li, Y.-F., Bailey, R. E., Fiedler, H., & Pacyna, J. M. (2004). Primary sources of selected POPs: regional and global scale emission inventories. Environmental Pollution, 128(1-2), 3-16. https://doi.org/10.1016/j.envpol.2003.08.031.
12. Brigden K, Labunska I, Santillo D, et al (2005) Recycling of electronic wastes in China and India: workplace and environmental contamination
13. Chakraborty, P. & Snow D. Eds. (2022). Legacy and Emerging Contaminants in Water and Wastewater: Monitoring, Risk Assessment and Remediation Techniques - Hardback Emerging Contaminants and Associated Treatment Technologies. Springer Nature Switzerland AG. ISBN10 3030954420
14. Chakraborty, P., Chandra, S., Dimmen, M. V., Hurley, R., Mohanty, S., Bharat, G. K., Steindal, E. H., Olsen, M., & Nizzetto, L. (2022). Interlinkage Between Persistent Organic Pollutants and Plastic in the Waste Management System of India: An Overview. Bulletin of Environmental Contamination and Toxicology. https://doi.org/10.1007/s00128-022-03466-x
15. Chakraborty, P., Gadhavi, H., Prithiviraj, B., Mukhopadhyay, M., Khuman, S. N., Nakamura, M., & Spak, S. N. (2021). Passive Air Sampling of PCDD/Fs, PCBs, PAEs, DEHA, and PAHs from

Informal Electronic Waste Recycling and Allied Sectors in Indian Megacities. Environmental Science & Technology, 55(14), 9469-9478. https://doi.org/10.1021/acs.est.1c01460

16. Chakraborty, P., Selvaraj, S., Nakamura, M., Prithiviraj, B., Cincinelli, A., & Bang, J. J. (2018). PCBs and PCDD/Fs in soil from informal e-waste recycling sites and open dumpsites in India: Levels, congener profiles and health risk assessment. 621, 930-938. https://pubmed.ncbi.nlm.nih.gov/29223911.

17. Chakraborty, P., Selvaraj, S., Nakamura, M., Prithiviraj, B., Ko, S., & Loganathan, B. (2016). E-Waste and Associated Environmental Contamination in the Asia/Pacific Region (Part 2): A Case Study of Dioxins and Furans in E-Waste Recycling/Dump Sites in India. In ACS Symposium Series (Vol. 1243, pp. 139-154). American Chemical Society. https://doi.org/10.1021/bk-2016-1243.ch007.

18. Chakraborty, P., Zhang, G., Cheng, H., Balasubramanian, P., Li, J., & Jones, K. C. (2017). Passive air sampling of polybrominated diphenyl ethers in New Delhi, Kolkata, Mumbai and Chennai: Levels, homologous profiling and source apportionment. Environmental Pollution (Barking, Essex: 1987), 231(Pt 1), 1181–1187. https://doi.org/10.1016/j.envpol.2017.08.044

19. Chakraborty, P., Zhang, G., Li, J., Sivakumar, A., & Jones, K. C. (2015). Occurrence and sources of selected organochlorine pesticides in the soil of seven major Indian cities: Assessment of air–soil exchange. Environmental Pollution, 204, 74-80. https://doi.org/https://doi.org/10.1016/j.envpol.2015.04.006.

20. Chakraborty, P., Zhang, G., Li, J., Xu, Y., Liu, X., Tanabe, S., & Jones, K. C. (2010). Selected organochlorine pesticides in the atmosphere of major Indian Cities: Levels, regional versus local variations, and sources. Environmental Science and Technology, 44(21), 8038-8043. https://doi.org/10.1021/es102029t.

21. Charbonnet JA, Weber R, Blum A (2020) Flammability standards for furniture, building insulation and electronics: Benefit and risk. Emerging Contaminants 6:432–441. https://doi.org/10.1016/j.emcon.2020.05.002.

22. ChemSafetyPro. 2018. GHS in India. Accessed on Sep 14, 2022: https://www.chemsafetypro.com/Topics/India/GHS_India_SDS_Requirements.html

23. Cincinelli, A., Martellini, T., Misuri, L., Lanciotti, E., Sweetman, A., Laschi, S., & Palchetti, I. (2012). PBDEs in Italian sewage sludge and environmental risk of using sewage sludge for land application. Environmental Pollution (Barking, Essex : 1987), 161, 229–234.

24. Cincinelli, A., Pieri, F., Martellini, T., Passaponti, M., Del Bubba, M., Del Vento, S., & Katsoyiannis, A. A. (2014). Atmospheric occurrence and gas-particle partitioning of PBDEs in an industrialised and urban area of Florence, Italy. Aerosol and Air Quality Research, 14(4), 1121-1130.

25. Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. (2011). Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin, 62(12), 2588-2597. https://doi.org/10.1016/j.marpolbul.2011.09.025.

26. Covaci A, Gerecke AC, Law RJ, Voorspoels S, Kohler M, Heeb NV, et al. Hexabromocyclododecanes (HBCDs) in the environment and humans: a review. Environ Sci Technol. 2006;40:3679–3688.

27. CPCB. (n.d.). CPCB | Central Pollution Control Board. Retrieved June 1, 2022, from https://cpcb.nic.in/Introduction/

28. Damstra, T. (2002). Persistent organic pollutants: potential health effects. Journal of Epidemiology & Community Health, 56(11), 824–825. https://doi.org/10.1136/jech.56.11.824

29. Daso, A. P., Fatoki, O.S., & Odendaal, J. P. (20130. Occurrence of polybrominated diphenyl ethers (PBDEs) and 2,2',4,4',5,5'-hexabromobiphenyl (BB-153) in water samples from the Diep River, Cape Town, South Africa. Environmental Science and Pollution Research, 20, 5168–5176.

30. Daso, A. P., Fatoki, O. S., Odendaal, J. P., & Olujimi, O. O. (2013). Polybrominated

diphenyl ethers (PBDEs) and 2, 2′, 4, 4′, 5, 5′-hexabromobiphenyl (BB-153) in landfill leachate in Cape Town, South Africa. Environmental monitoring and assessment, 185(1), 431-439.

31. Davison, P., & Asch, R. G. (2011). Plastic ingestion by mesopelagic fishes in the North Pacific Subtropical Gyre. Marine Ecology Progress Series, 432, 173-180. https://doi.org/10.3354/meps09142.

32. Demaria, F. 2010. Shipbreaking at Alang–Sosiya (India): An ecological distribution conflict, Ecological Economics, Volume 70, Issue 2, 2010, Pages 250-260.

33. Drage, Daniel, JF Mueller, G Birch, G Eaglesham, LK Hearn, and Stuart Harrad. 2015. 'Historical trends of PBDEs and HBCDs in sediment cores from Sydney estuary, Australia', Science of The Total Environment, 512: 177-84.

34. Earth5r. 2020. Damanganga: Restoration of the River Choked by Toxins. https://earth5r.org/. July 8, 2020. Uncategorized. Web-link: https://earth5r.org/damanganga-restoration-river-choked-toxins/#:□:text=The%20pollution%20level%20on%20the,which%20supports%20almost%201800%20industries last accessed on June 16, 2022.

35. Eguchi A, Nomiyama K, Devanathan G, Subramanian A, Bulbule KA, Parthasarathy P, Takahashi S, Tanabe S. Different profiles of anthropogenic and naturally produced organohalogen compounds in serum from residents living near a coastal area and e-waste recycling workers in India. Environ Int. 2012 Oct 15;47:8-16. doi: 10.1016/j.envint.2012.05.003. Epub 2012 Jun 18. PMID: 22717641.

36. El-Salam, A., Mohamed, H., & El-Shibiny, S. (2011). A comprehensive review on the composition and properties of buffalo milk. Dairy science & technology, 91(6), 663-699.

37. Eljarrat, E., & Barceló, D. (2018). How do measured PBDE and HCBD levels in river fish compare to the European Environmental Quality Standards?. Environmental research, 160, 203-211.

38. European Chemicals Agency (ECHA). N.d. List of substances subject to POPs Regulation. Last accessed on Sep 15, 2022: https://echa.europa.eu/list-of-substances-subject-to-pops-regulation

39. European Commission. (2010). Common implementation strategy for the water framework directive (2000/60/EC). Guidance document No. 25 on chemical monitoring of sediment and biota under the water framework directive. http://www.aquaref.fr/system/files/u124/_-_Chemical_Monitoring_of_Sediment_and_Biota.pdf

40. European Union (EU). 2019. Regulation (EU) 2019/1021 of the European Parliament and the Council of 20 June 2019 on persistent organic pollutants. Accessed on Sep 14, 2022: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1021&rid=3

41. Feng, A. H., Chen, S. J., Chen, M. Y., He, M. J., Luo, X. J., & Mai, B. X. (2012). Hexabromocyclododecane (HBCD) and tetrabromobisphenol A (TBBPA) in riverine and estuarine sediments of the Pearl River Delta in southern China, with emphasis on spatial variability in diastereoisomer-and enantiomer-specific distribution of HBCD. Marine Pollution Bulletin, 64(5), 919-925.

42. Fitzgerald, L., & Wikoff, D. S. (2014). Persistent Organic Pollutants. In Encyclopedia of Toxicology (pp. 820–825). Elsevier. https://doi.org/10.1016/B978-0-12-386454-3.00211-6

43. Futter, M. N., Erlandsson, M. A., Butterfield, D., Whitehead, P. G., Oni, S. K., & Wade, A. J. (2014). PERSiST: A flexible rainfall-runoff modelling toolkit for use with the INCA family of models. Hydrology and Earth System Sciences, 18(2), 855–873. https://doi.org/10.5194/hess-18-855-2014

44. Galli A, Kitzes J, Niccolucci V, Wackernagel M, Wada Y, Marchettini N. Assessing the global environmental consequences of economic growth through the ecological footprint: a focus on China and India. Ecol Indic 2012;17:99–107.

45. Geller, W., Koschorreck, M., Schultze, M., Wendt-Potthoff, K. (2009). Restoration of acid drainage.

In: Likens, G.E. (ed.) Encyclopedia of inland Waters. Vol. 1. Elsevier, Amsterdam, p. 342 - 358

46. Government of Gujarat. 2016-2017. Development Programme. General Administrative Department, Planning Division, Gandhinagar. February. 2016. Last accessed on Sep 14, 2022: https://openbudgetsindia.org/dataset/316a3edf-5a46-41f6-bbbc-ac7242ffa208/resource/24a6d943-9cf0-4793-9c63-2ef8dd8028c3/download/35.-development-programme-2016-17.pdf
47. Government of India. (2011, April). National Implementation Plan (NIP) Stockholm Convention on Persistent Organic Pollutants.
48. Gulf Petrochemicals and Chemicals Association (GPCA). 2021. India's restrictive trade and regulatory actions can harm its industry and damage investment. (2021, June 7). Accessed on Sep 14, 2022: https://www.gpca.org.ae/2021/06/07/indias-restrictive-trade-and-regulatory-actions-can-harm-its-industry-and-damage-investment/
49. Gupta, H., Reddy, K. K., Gandla, V., Paridula, L., Chiluka, M., & Vashisth, B. (2022). Freshwater discharge from the large and coastal peninsular rivers of India: A reassessment for sustainable water management. Environmental Science and Pollution Research International, 29(10), 14400–14417. https://doi.org/10.1007/s11356-021-16811-0
50. Harrad S, Abdallah MA, Rose NL, Turner SD, Davidson TA. Current-use brominated flame retardants in water, sediment, and fish from English lakes. Environ Sci Technol. 2009 Dec 15;43(24):9077-83. doi: 10.1021/es902185u. Erratum in: Environ Sci Technol. 2010 Jul 1;44(13):5318. PMID: 19921842.
51. He, M. J., Luo, X. J., Chen, M. Y., Sun, Y. X., Chen, S. J., & Mai, B. X. (2012). Bioaccumulation of polybrominated diphenyl ethers and decabromodiphenyl ethane in fish from a river system in a highly industrialized area, South China. Science of the Total Environment, 419, 109-115.
52. He, Ming-Jing, Xiao-Jun Luo, Le-Huan Yu, Jiang-Ping Wu, She-Jun Chen, and Bi-Xian Mai. 2013. 'Diasteroisomer and enantiomer-specific profiles of hexabromocyclododecane and tetrabromobisphenol A in an aquatic environment in a highly industrialized area, South China: Vertical profile, phase partition, and bioaccumulation', Environmental Pollution, 179: 105-10.
53. Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., … Thépaut, J.-N. (2020). The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society, 146(730), 1999–2049. https://doi.org/10.1002/qj.3803
54. Hong, S. H., Kannan, N., Jin, Y., Won, J. H., Han, G. M., & Shim, W. J. (2010). Temporal trend, spatial distribution, and terrestrial sources of PBDEs and PCBs in Masan Bay, Korea. Marine Pollution Bulletin, 60(10), 1836-1841. https://doi.org/10.1016/j.marpolbul.2010.05.023.
55. Imhof, H. K., Sigl, R., Brauer, E., Feyl, S., Giesemann, P., Klink, S., Leupolz, K., Löder, M. G. J., Löschel, L. A., Missun, J., Muszynski, S., Ramsperger, A. F. R. M., Schrank, I., Speck, S., Steibl, S., Trotter, B., Winter, I., & Laforsch, C. (2017). Spatial and temporal variation of macro-, meso- and microplastic abundance on a remote coral island of the Maldives, Indian Ocean. Marine Pollution Bulletin, 116(1-2), 340-347. https://doi.org/10.1016/j.marpolbul.2017.01.010.
56. India Brand Equity Foundation (IBEF). 2022. Indian Chemicals Industry Analysis. Accessed on Sep 14, 2022: https://www.ibef.org/industry/chemicals-presentation
57. INOPOL (2021) Summary of Baseline Report – POPs Pollution in India. India-Norway Cooperation Project on Capacity Building for Reducing Plastic and Chemical Pollution in India.
58. Ivar do Sul, J. A., & Costa, M. F. (2014). The present and future of microplastic pollution in the marine environment. Environmental Pollution,

185, 352-364. https://doi.org/10.1016/j.envpol.2013.10.036.

59. Jaspers, Nico and Falkner, Robert (2013) International trade, the environment, and climate change. In: Falkner, Robert, (ed.) The Handbook of Global Climate and Environment Policy. Wiley-Blackwell, Chichister, UK, pp. 412-428. ISBN 9780470673249

60. Jeon, Jin-Woo, Chul-Su Kim, Leesun Kim, Sung-Eun Lee, Ho-Joong Kim, Chang-Ho Lee, and Sung-Deuk Choi. 2019. 'Distribution and diastereoisomeric profiles of hexabromocyclododecanes in air, water, soil, and sediment samples in South Korea: Application of an optimized analytical method', Ecotoxicology and Environmental Safety, 181: 321-29.

61. Jo, Hyeyeong, Min-Hui Son, Sung-Hee Seo, and Yoon-Seok Chang. 2017. 'Matrix-specific distribution and diastereomeric profiles of hexabromocyclododecane (HBCD) in a multimedia environment: Air, soil, sludge, sediment, and fish', Environmental Pollution, 226: 515-22.

62. Kelly, A., Lannuzel, D., Rodemann, T., Meiners, K. M., & Auman, H. J. (2020). Microplastic contamination in east Antarctic sea ice. Marine Pollution Bulletin, 154, 111130-111130. https://doi.org/10.1016/j.marpolbul.2020.111130.

63. Khuman, N. S., & Chakraborty,P. (2019). Air-water exchange of pesticidal persistent organic pollutants in the lower stretch of the transboundary river Ganga, India, Chemosphere, 233, 966-974.

64. Kodavanti, P. R. S., Royland, J. E., & Sambasiva Rao, K. R. S. (2014). Toxicology of Persistent Organic Pollutants. In Reference Module in Biomedical Sciences. Elsevier. https://doi.org/10.1016/B978-0-12-801238-3.00211-7

65. Koelmans, A. A., Bakir, A., Allen Burton, G., & Janssen, C. R. (2016). Microplastic as a Vector for Chemicals in the Aquatic Environment: Critical Review and Model-Supported Reinterpretation of Empirical Studies. https://doi.org/10.1021/acs.est.5b06069.

66. Kim, D.-G., Kim, M., Jang, J.-H., Bong, Y. H., & Kim, J.-H. (2013). Monitoring of environmental contaminants in raw bovine milk and estimates of dietary intakes of children in South Korea. Chemosphere, 93(3), 561–566. doi:10.1016/j.chemosphere.2013.06.055

67. Labadie, P., Tlili, K., Alliot, F., Bourges, C., Desportes, A., & Chevreuil, M. (2010). Development of analytical procedures for trace-level determination of polybrominated diphenyl ethers and tetrabromobisphenol A in river water and sediment. Analytical and Bioanalytical Chemistry, 396(2), 865–75.

68. Lebreton, L., & Andrady, A. (2019). Future scenarios of global plastic waste generation and disposal. 5(1), 1-11. https://doi.org/10.1057/s41599-018-0212-7.

69. Li, H., Zhang, Z., Sun, Y., Wang, W., Xie, J., Xie, C., ... & Mai, B. (2021). Tetrabromobisphenol A and hexabromocyclododecanes in sediments and biota from two typical mangrove wetlands of South China: Distribution, bioaccumulation and biomagnification. Science of the Total Environment, 750, 141695.

70. Li, Nankun & Niu, Shan & Wang, Xiaohui & Li, Yuan & Na, Situ & Hai, Reti & Li, Tianwei. (2018). Occurrence and distribution characteristics of polybrominated diphenyl ethers (PBDEs) from a closed deca-BDE manufacturing factory in Jiangsu province, China. Journal of Soils and Sediments. 18. 10.1007/s11368-017-1910-2.

71. Liang, X., Junaid, M., Wang, .Z, Li, T., & Xu N. (2019). Spatiotemporal distribution, source apportionment and ecological risk assessment of PBDEs and PAHs in the Guanlan River from rapidly urbanizing areas of Shenzhen, China. Environmental Pollution, 250, 695–707.

72. Lu, Jun-Feng, Ming-Jing He, Zhi-Hao Yang, and Shi-Qiang Wei. 2018. 'Occurrence of tetrabromobisphenol a (TBBPA) and hexabromocyclododecane (HBCD) in soil and road dust in Chongqing, western China, with emphasis on diastereoisomer profiles, particle size distribution, and human exposure', Environmental Pollution, 242: 219-28.

73. Makkar Panwar, R., Ahmed, S., & Sharma, A. (2018). Briding the gaps between formal and informal e-waste management in India with EPR. http://www.journalijdr.com.

74. Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and Health Impacts of Air Pollution: A Review. Front Public Health. 2020 Feb 20;8:14. doi: 10.3389/fpubh.2020.00014. PMID: 32154200; PMCID: PMC7044178.

75. Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., & Kaminuma, T. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environmental Science & Technology, 35(2), 318-324. https://doi.org/10.1021/es0010498.

76. Meijer, L. J. J., van Emmerik, T., van der Ent, R., Schmidt, C., & Lebreton, L. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. Science Advances, 7(18), eaaz5803-eaaz5803. https://doi.org/10.1126/sciadv.aaz5803.

77. Minh, N. H., T. Isobe, D. Ueno, K. Matsumoto, M. Mine, N. Kajiwara, S. Takahashi, and S. Tanabe. 2007. 'Spatial distribution and vertical profile of polybrominated diphenyl ethers and hexabromocyclododecanes in sediment core from Tokyo Bay, Japan', Environ Pollut, 148: 409-17.

78. Miniero, R., & Iamiceli, A. L. (2008). Persistent Organic Pollutants. In Encyclopedia of Ecology (pp. 2672–2682). Elsevier. https://doi.org/10.1016/B978-008045405-4.00421-3

79. Mininni, G., Sbrilli, A., Braguglia, C. M., Guerriero, E., Marani, D., & Rotatori, M. (2007). Dioxins, furans and polycyclic aromatic hydrocarbons emissions from a hospital and cemetery waste incinerator. Atmospheric Environment, 41(38), 8527-8536. https://doi.org/10.1016/j.atmosenv.2007.07.015

80. Ministry of Ecology and Environment (MEE), China. 2021. Notice on Carrying out the Management of Industrial Solid Waste Discharge Permits. Accessed ion Sep 14, 2022: https://www.mee.gov.cn/xxgk2018/xxgk/xxgk05/202112/t20211224_965175.html

81. Miraji, H., Ripanda, A., & Moto, E. (2021). A review on the occurrences of persistent organic pollutants in corals, sediments, fish and waters of the Western Indian Ocean. The Egyptian Journal of Aquatic Research, 47(4), 373–379. https://doi.org/10.1016/j.ejar.2021.08.003

82. Mobius. (2022). [Jupyter Notebook]. Norsk institutt for vannforskning. Accessed on Set 15, 2022: https://github.com/NIVANorge/Mobius (Original work published 2019)

83. Mutha, N. H., Patel, M., & Premnath, V. (2006). Plastics materials flow analysis for India. Resources, Conservation and Recycling, 47(3), 222-244. https://doi.org/10.1016/j.resconrec.2005.09.003.

84. Nandy, B., Sharma, G., Garg, S., Kumari, S., George, T., Sunanda, Y., & Sinha, B. (2015). Recovery of consumer waste in India – A mass flow analysis for paper, plastic and glass and the contribution of households and the informal sector. Resources, Conservation and Recycling, 101, 167-181. https://doi.org/10.1016/j.resconrec.2015.05.012.

85. Nizzetto, L., Butterfield, D., Futter, M., Lin, Y., Allan, I., & Larssen, T. (2016). Assessment of contaminant fate in catchments using a novel integrated hydrobiogeochemical-multimedia fate model. The Science of the Total Environment, 544, 553–563. https://doi.org/10.1016/j.scitotenv.2015.11.087

86. Noel, D., & Rajan M. (2014). Impact of dyeing industry effluent on groundwater quality by water quality index and correlation analysis. Journal of Pollution Effects & Control, 02,2–5.

87. Olukunle, O., Okonkwo, J., Kefeni, K., & Lupankwa, M. (2012). Concentrations of polybrominated diphenyl ethers in sediments from Jukskei River, Gauteng, South Africa. Bulletin of environmental contamination and toxicology, 88(3), 461-466.

88. Parikh K. Sustainable development and low carbon growth strategy for India. Energy 2012;40:31–8.

89. Park EY, Park E, Kim J, Oh JK, Kim B, Hong YC, Lim MK. Impact of environmental exposure to persistent organic pollutants on lung cancer risk. Environ Int. 2020 Oct;143:105925. doi: 10.1016/j.envint.2020.105925. Epub 2020 Jul 2. PMID: 32623224.

90. Press Information Bureau (PIB). 2020. Press Release - Cabinet approves Ratification of seven Persistent Organic Pollutants listed under Stockholm Convention and delegate its powers for future ratifications for streamlining the procedure. 07 OCT 2020. Delhi. Last accessed on Sep 14, 2022: https://pib.gov.in/PressReleasePage.aspx?PRID=1662335

91. Press Information Bureau (PIB). Ministry of Chemicals and Fertilizers (MoCF). 2020. HIL (India) has supplied 20.60 MT of DDT to South Africa for Malaria control program. Press Release. 21 July 2020 12:12PM by PIB Delhi. Accessed on Sep 14, 2022: https://pib.gov.in/PressReleasePage.aspx?PRID=1640136

92. PricewaterhouseCoopers Private Limited (PwC). 2021. India: A global manufacturing hub for chemicals and petrochemicals March 2021 Knowledge report on Indian chemical and petrochemical industry. Last accessed on Sep 14, 2022: https://ficci.in/spdocument/23452/Knowledge_Report.pdf

93. Qing Li, Q., Loganath, A., Seng Chong, Y., Tan, J., & Philip Obbard, J. (2006). Persistent Organic Pollutants and Adverse Health Effects in Humans. Journal of Toxicology and Environmental Health, Part A, 69(21), 1987–2005. https://doi.org/10.1080/15287390600751447

94. Rajan, S., Rex, K. R., Pasupuleti, M., Muñoz-Arnanz, J., Jiménez, B., & Chakraborty, P. (2021). Soil concentrations, compositional profiles, sources and bioavailability of polychlorinated dibenzo dioxins/furans, polychlorinated biphenyls and polycyclic aromatic hydrocarbons in open municipal dumpsites of Chennai city, India. Waste Management, 131, 331-340. https://doi.org/10.1016/j.wasman.2021.06.015.

95. Richman, L. A., Kolic, T., Macpherson, K., Fayez, L., & Reiner, E. (2013). Polybrominated diphenyl ethers in sediment and caged mussels (Elliptio complanata) deployed in the Niagara River. Chemosphere, 92, 778–786.

96. Saini, A., Clarke, J., Jariyasopit, N., Rauert, C., Schuster, J. K., Halappanavar, S., ... & Harner, T. (2019). Flame retardants in urban air: a case study in Toronto targeting distinct source sectors. Environmental pollution, 247, 89-97.

97. Salehi, M. H., Beni, O. H., Harchegani, H. B., Borujeni, I. E., & Motaghian, H. R. (2011). Refining Soil Organic Matter Determination by Loss-on-Ignition. Pedosphere, 21, 473–482.

98. Schecter, A., Haffner, D., Colacino, J., Patel, K., Päpke, O., Opel, M., & Birnbaum, L. (2010). Polybrominated diphenyl ethers (PBDEs) and hexabromocyclodecane (HBCD) in composite US food samples. Environmental health perspectives, 118(3), 357-362.

99. Schug TT, Johnson AF, Birnbaum LS, Colborn T, Guillette LJ Jr, Crews DP, Collins T, Soto AM, Vom Saal FS, McLachlan JA, Sonnenschein C, Heindel JJ. Minireview: Endocrine Disruptors: Past Lessons and Future Directions. Mol Endocrinol. 2016 Aug;30(8):833-47. doi: 10.1210/me.2016-1096. Epub 2016 Jul 19. PMID: 27477640; PMCID: PMC4965846.

100. Secretariat of the Basel, Rotterdam and Stockholm Conventions (BRS). 2017. Guidance for Developing a National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants. January 2017. Accessed on Sep 15, 2022: http://chm.pops.int/implementation/nips/guidance/guidancefordevelopingnip/tabid/3166/default.aspx

101. Seltenrich, N. (2015). New Link in the Food Chain? Marine Plastic Pollution and Seafood Safety. Environmental Health Perspectives, 123(2), A34-A34. https://doi.org/10.1289/ehp.123-A34.

102. Shan, G., Wei, M., Zhu, L., Liu, Z., & Zhang, Y. (2014). Concentration profiles and spatial

distribution of perfluoroalkyl substances in an industrial center with condensed fluorochemical facilities. Science of The Total Environment, 490, 351-359. https://doi.org/10.1016/j.scitotenv.2014.05.005.

103. Sharma BM, Bharat GK, Chakraborty P, Martiník J, Audy O, Kukučka P, Přibylová P, Kukreti PK, Sharma A, Kalina J, Steindal EH, Nizzetto L. A comprehensive assessment of endocrine-disrupting chemicals in an Indian food basket: Levels, dietary intakes, and comparison with European data. Environ Pollut. 2021 Nov 1;288:117750. doi: 10.1016/j.envpol.2021.117750. Epub 2021 Jul 9. PMID: 34265562.

104. Sharma BM, Bharat GK, Tayal S, Nizzetto L, Cupr P, Larssen T. Environment and human exposure to persistent organic pollutants (POPs) in India: a systematic review of recent and historical data. Environ Int. 2014 May;66:48-64. doi: 10.1016/j.envint.2014.01.022. Epub 2014 Feb 11. PMID: 24525153.

105. Shinsuke Tanabe and Tatsuya Kunisue. Persistent organic pollutants in human breast milk from Asian countries. 2007. Environmental Pollution 146(2):400-13. DOI: 10.1016/j.envpol.2006.07.003

106. Shrivastava, M., Ghosh, A., Bhattacharyya, R., & Singh, S. (2018). Urban Pollution in India. In Urban Pollution: Science and Management (p. 341). https://doi.org/10.1002/9781119260493.ch26

107. Singh P, Singh RP, Srivastava V, et al. Contemporary environmental issues and challenges in era of climate change. In: Singh P, et al., editors. Contemporary environmental issues and challenges in era of climate change. New York: Springer; 2019. pp. 1–293.

108. Someya, M., Ohtake, M., Kunisue, T., Subramanian, A., Takahashi, S., Chakraborty, P., Ramachandran, R., Tanabe, S. (2009). Persistent organic pollutants in breast milk of mothers residing around an open dumpsite in Kolkata, India: specific dioxin-like PCB levels and fish as a potential source. Environmental International, 36 (1): 27-35.

109. Tan, F., Yang, H., Xu, X., Fang, Z., Xu, H., Shi, Q., Zhang, X., Wang, G., Lin, L., Zhou, S., Huang, L., & Li, H. (2020). Microplastic pollution around remote uninhabited coral reefs of Nansha Islands, South China Sea. Science of The Total Environment, 725, 138383-138383. https://doi.org/10.1016/j.scitotenv.2020.138383.

110. Tang, Jianfeng, Jiayong Feng, Xinhu Li, and Gang Li. 2014. 'Levels of flame retardants HBCD, TBBPA and TBC in surface soils from an industrialized region of East China', Environmental Science: Processes & Impacts, 16: 1015-21.

111. Tanabe, S. (2007). Chapter 18 Contamination by Persistent Toxic Substances in the Asia-Pacific Region. Developments in Environmental Science, 773–817. doi:10.1016/s1474-8177(07)07018-0

112. Tang, Z., Huang, Q., Cheng, J., Yang, Y., Yang, J., Guo, W., ... & Jin, L. (2014). Polybrominated diphenyl ethers in soils, sediments, and human hair in a plastic waste recycling area: a neglected heavily polluted area. Environmental science & technology, 48(3), 1508-1516.

113. Teuten EL, Saquing JM, Knappe DR, Barlaz MA, Jonsson S, Björn A, Rowland SJ, Thompson RC, Galloway TS, Yamashita R, Ochi D, Watanuki Y, Moore C, Viet PH, Tana TS, Prudente M, Boonyatumanond R, Zakaria MP, Akkhavong K, Ogata Y, Hirai H, Iwasa S, Mizukawa K, Hagino Y, Imamura A, Saha M, Takada H. Transport and release of chemicals from plastics to the environment and to wildlife. Philos Trans R Soc Lond B Biol Sci. 2009 Jul 27;364(1526):2027-45. doi: 10.1098/rstb.2008.0284. PMID: 19528054; PMCID: PMC2873017.

114. Thacker, N., Sheikh, J., Tamane, S. M., Bhanarkar, A., Majumdar, D., Singh, K., Chavhan, C., & Trivedi, J. (2013). Emissions of polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs), and dioxin-like polychlorinated biphenyls (PCBs) to air from waste incinerators and high thermal processes in India. Environmental Monitoring

and Assessment, 185(1), 425-429. https://doi.org/10.1007/s10661-012-2564-6

115. The Dollar Business. 2018. TBTs are hurting chemical exports. March 2018. Accessed on Sep 14, 2022. https://www.thedollarbusiness.com/magazine/tbts-are-hurting-chemical-exports/46201

116. The Indian Express, 2022. Gujarat HC notice in PIL against effluent discharge into Tapi river. The Indian Express. February 16, 2022. Web link: https://indianexpress.com/article/cities/ahmedabad/hc-notice-in-pil-against-effluent-discharge-into-tapi-river-7775703/ last accessed on June 16, 2022.

117. Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonigle, D., Russell, A.E., 2004. Lost at sea: where is all the plastic? Science, 838.

118. Toxics Link India, (2006). International POPs Elimination Project Fostering Active and Efficient Civil Society Participation in Preparation for Implementation of the Stockholm Convention Country Situation on Persistent Organic Pollutants (POPs) in India. http://www.ipen.org

119. Toxics Link. 2018. Persistent Organic Pollutants (POPs) in India: Country Situation Report. International POPs Elimination Network (IPEN). Accessed on Sep 14, 2022: https://ipen.org/sites/default/files/documents/toxics_link_country_situation_report_new_size.pdf

120. Ujjania, N.C., &. Dubey, M. (2020). Assessment of water pollution in Tapi river, Gujarat (India). In Singh et al. (Eds.) Recent Trends in Indian Limnology and Fishery Science (Chap 11): 143-151. Web link: https://indianexpress.com/article/cities/ahmedabad/hc-notice-in-pil-against-effluent-discharge-into-tapi-river-7775703/ last accessed on June 16, 2022.

121. Union Budget of India. 2022-2023. Rs 3,030 crore allocated to Environment Ministry. (2022, February 1). Accessed on Sep 15, 2022: The Times of India. https://timesofindia.indiatimes.com/business/india-business/union-budget-2022-23-rs-3030-crore-allocated-to-environment-ministry/articleshow/89274489.cms

122. United Nations Economic Commission for Europe (UNECE). N.d. About the GHS - Globally Harmonized System of Classification and Labelling of Chemicals (GHS). Accessed on Sep 14, 2022: https://unece.org/about-ghs

123. United States Environmental Protection Agency (USEPA). n.d. Persistent Organic Pollutants: A Global Issue, A Global Response. USEPA. Retrieved April 18, 2022, https://www.epa.gov/international-cooperation/persistent-organic-pollutants-global-issue-global-response

124. Velis, CA, Cook, E (2021) Mismanagement of plastic waste through open burning with emphasis on the global south: A systematic review of risks to occupational and public health. Environmental Science & Technology 55(11): 7186–7207. Doi: doi.org/10.1021/acs.est.0c08536

125. Verslycke, Tim A., A. Dick Vethaak, Katrien Arijs, and Colin R. Janssen. 2005. 'Flame retardants, surfactants and organotins in sediment and mysid shrimp of the Scheldt estuary (The Netherlands)', Environmental Pollution, 136: 19-31.

126. Vrana, B., Allan, I. J., Greenwood, R., Mills, G. A., Dominiak, E., Svensson, K., Knutsson, J., & Morrison, G. (2005). Passive sampling techniques for monitoring pollutants in water. TrAC Trends in Analytical Chemistry, 24(10), 845–868. https://doi.org/10.1016/j.trac.2005.06.006

127. Wang, G., Jiang, N., Liu, Y., Wang, X., Liu, Y., Jiao, D., & Wang, H. (2021). Competitive microbial degradation among PBDE congeners in anaerobic wetland sediments: Implication by multiple-line evidences including compound-specific stable isotope analysis. Journal of Hazardous Materials, 412, 125233. https://doi.org/10.1016/j.jhazmat.2021.125233

128. Wania, F., Lei, Y. D., & Harner, T. (2002). Estimating Octanol−Air Partition Coefficients of Nonpolar Semivolatile Organic Compounds from Gas Chromatographic Retention Times.

Analytical Chemistry, 74(14), 3476–3483. https://doi.org/10.1021/ac0256033

129. Watanabe, I. (2003). Environmental release and behavior of brominated flame retardants. Environment International, 29(6), 665–682. doi:10.1016/s0160-4120(03)00123-5

130. World Bank, N.d. The World Bank In India. Accessed on Sep 15, 2022: https://www.worldbank.org/en/country/india/overview

131. World Health Organization (WHO). 2018. 9 out of 10 people worldwide breathe polluted air, but more countries are taking action. WHO News release. Retrieved April 18, 2022, https://www.who.int/news/item/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action

132. WTO General Agreement on Tariffs and Trade (GATT) rules. 2012. Article XX. Accessed on Sep 15, 2022: https://www.wto.org/english/res_e/booksp_e/gatt_ai_e/art20_e.pdf

133. Wu, M. H., Tang, L., Xu, G., Ma, J., Liu, N., Wang, L., & Lei, J. Q. (2013). Polybrominated diphenyl ethers in surface sediments from principal watersheds of Shanghai, China: levels, distribution, influencing factors, and risk assessment. Environmental Science and Pollution Research, 20, 2651–2660.

134. Xu, J., Qian, W., Li, J., Zhang, X., He, J., & Kong D. (2019). Polybrominated diphenyl ethers (PBDEs) in soil and dust from plastic production and surrounding areas in eastern of China. Environmental Geochemistry and Health, 41, 2315–2327.

135. Xu, Jian, Yuan Zhang, Changsheng Guo, Yan He, Lei Li, and Wei Meng. 2013. 'Levels and distribution of tetrabromobisphenol A and hexabromocyclododecane in Taihu Lake, China', Environmental Toxicology and Chemistry, 32: 2249-55.

136. Yue, C., & Li, L. Y. (2013). Filling the gap: Estimating physicochemical properties of the full array of polybrominated diphenyl ethers (PBDEs). Environmental Pollution, 180, 312–323. https://doi.org/10.1016/j.envpol.2013.05.029

137. Zhang, K., Su, J., Xiong, X., Wu, X., Wu, C., & Liu, J. (2016). Microplastic pollution of lakeshore sediments from remote lakes in Tibet plateau, China. Environmental Pollution, 219, 450-455. https://doi.org/10.1016/j.envpol.2016.05.048.

138. Zhang, Yueqing, Yonglong Lu, Pei Wang, Qifeng Li, Meng Zhang, and Andrew C. Johnson. 2018. 'Transport of Hexabromocyclododecane (HBCD) into the soil, water and sediment from a large producer in China', Science of The Total Environment, 610-611: 94-100.

139. Zhang, Yueqing, Yvette Baninla, Jia Yu, Juying Li, Yezhi Dou, and Deyang Kong. 2022. 'Occurrence, Spatial Distribution and Health Risk of Hexabromocyclododecane (HBCD) in Source Water in the Lower Yangtze River, China', Bulletin of Environmental Contamination and Toxicology.

140. Zhu, L. Y., & Hites, R. A. (2004). Temporal trends and spatial distributions of brominated flame retardants in archived fishes from the Great Lakes. Environmental science & technology, 38(10), 2779-2784.

141. Zhu, L. Y., & Hites, R. A. (2005). Brominated flame retardants in sediment cores from Lakes Michigan and Erie. Environmental Science and Technology, 39, 3488–3494.

142. Zvonko, B., Marijana, Ć., & Ivan, S. (2015). Assessment of the Socio-economic Impact of the Chemicals Environmental Contamination. International Review, 6.

INOPOL

INDIA-NORWAY COOPERATION
PROJECT ON CAPACITY BUILDING
FOR REDUCING PLASTIC AND CHEMICAL
POLLUTION IN INDIA (INOPOL)

Norwegian Embassy
New Delhi

NIVA

mμ gamma

SRM
INSTITUTE OF SCIENCE & TECHNOLOGY
Deemed to be University u/s 3 of UGC Act, 1956

Toxics Link