Uncovering the Hidden Pollution in the Arkavathi: Emerging Contaminants Impacting Bengaluru & Beyond

Paani.Earth in Collaboration with International Centre for Clean Water
16th of January, 2025

Arkavathi River, Upstream of its Confluence with the Cauvery River
Source: Paani.Earth

Project Team: Madhuri Mandava and Khushbu K Birawat

Primary Data Collection:

International Centre for Clean Water (ICCW) supported the sample collection and analysis of water and sediment samples.

Envirotech, Bengaluru supported the sample collection and on-site analysis.

Acknowledgements:

We thank MGI Distribution Pvt. Ltd. for supporting this study. We are grateful for the inputs provided by Dr. Indumathi M. Nambi, Professor, IIT-Madras, and Dr.Ankur Jamwal from Azim Premji University. We thank Victoria R Belcher, Intern at Paani, for her support during the study. We were also glad to have support from a young volunteer, Nandana, during the study.

Suggested Citation:

Paani.Earth. (2025). *Uncovering the Hidden Pollution in the Arkavathi: Emerging Contaminants Impacting Bengaluru & Beyond.*

Summary

This report summarizes the results of pollution testing along the Arkavathi River conducted by Paani.Earth, in collaboration with the International Centre for Clean Water, in February and March 2024. The study quantifies the risks of emerging pollutants such as pesticides, hazardous industrial pollutants, and heavy metals by evaluating dry season[1] pollution samples from seven sites along the Arkavathi and its tributary, the Vrishabhavathi River. Paani tested samples for 65 unique water and 20 unique sediment pollution parameters. This report then compares testing results to national and international standards and guidelines for freshwater and sediment pollution.

The findings reveal alarming levels of physicochemical pollutants, pesticides, heavy metals, and hazardous organic compounds that exceed both Indian and international standards and guidelines. Every single test site contained multiple pollutants exceeding recommended guidelines, posing major ecosystem and human health risks. Notably high pollutants include:

- **Pesticides:** Harmful substances with health impacts such as Heptachlor and DDT found at levels as high as **25022 times** United States Environmental Protection Agency guidelines.
- **Heavy Metals:** Toxins such as Mercury found in sediment at levels up to **26 times** above Canada's Sediment Quality Guidelines.
- **Industrial Pollutants:** Polycyclic aromatic hydrocarbons (PAHs) from industrial burning such as Dibenz[a,h]anthracene found at **3076 times** United States Environmental Protection Agency guidelines.
- **Nutrients:** Excessive phosphorus levels causing eutrophic conditions at all sites

Using these results, the study identifies critical pollution trends, including inflows from urban Bengaluru and spikes in select harmful pollutants downstream of industrial areas and quarries, among other sources.

Controlling pollution from point sources and enhancing treatment levels are essential to protect the Arkavathi River and revive Bengaluru's local water supply. Without urgent intervention, escalating pollution will further endanger human and aquatic health, forcing the city to increasingly rely on distant water sources - Cauvery, Netravathi, and next, Sharavathi. This pursuit of clean water imposes environmental costs, including damage to the ecologically critical Western Ghats, and heavy economic burdens due to rising infrastructure and energy costs. Is this unsustainable path, both environmentally and economically, the legacy we choose for ourselves?

In addition to this report, a spatial representation of this data, with additional data integrated from public domain studies, is available on Paani's [Arkavathi River Interactive Map].

[1] The dry season refers to a period of the year characterized by little to no rainfall

How to Navigate this Document

Report Structure

Section	Description
Setting the Context	Provides overview of study area and purpose
Testing Methodology	Lists parameters tested, describes sampling process and parameter guidelines
Test Results	Shares parameter measurements and potential sources / risk factors
Analysis	Compares parameter measurements to local and international guidelines
Evidence Through the Years	Provides overview of related studies on pollution in the region
Key Takeaways	Summarizes study results and recommendations

Table of Contents

Due to the large file size, the appendix for this report is included in a separate document linked here.

Setting the Context

The Arkavathi River begins its 170 kilometer journey in the Nandi Hills of Chikkaballapur district, flowing through Bengaluru Rural, Bengaluru Urban, and Ramanagara districts before merging with the Cauvery River, just a few kilometers upstream of the proposed Mekedatu Dam.

Once a lifeline and water source for Bengaluru and the farmlands it nourished, the Arkavathi is now in crisis - choked with pollution and struggling for survival. **It is, in many ways, a river on the brink of death**.

Many signs of distress are visible - floating garbage, untreated sewage, discolored water from industrial discharges (Figures 01 to 04). Yet, hidden beneath the surface is an even greater danger- **emerging contaminants and toxic pollutants that cannot be seen.** These include heavy metals, industrial chemicals, and banned pesticides, which have turned Arkavathi water into a toxic brew that threatens aquatic life and endangers the health of countless people who depend on it.

While the Arkavathi deteriorates, Bengaluru, desperate for water, taps into the pristine Netravathi River[2] from the distant Western Ghats - **only to mix this clean water with the Arkavathi's toxic flow at Tippagondanahalli (TG Halli) Reservoir**. This over-extraction is not only unsustainable but also damages the fragile ecosystems of the Western Ghats, a biodiversity hotspot and a lifeline for countless communities and rivers.

To understand the full scale of the Arkavathi's pollution as Bengaluru evaluates future water sources, Paani.Earth conducted a detailed study of water and sediment at key locations along the river.

This study confirmed the **presence of emerging contaminants and toxic pollutants, many exceeding international standards and guidelines** and posing long-term risks to ecosystems and human health.

These include pesticides, commonly used in agriculture but harmful when they leach into water; phenolic compounds, industrial

Figure 01: Arkavathi River, Foaming Upstream of TG Halli, February 2024

Figure 02: Arkavathi River Channel Infested with Water Hyacinth at Varthur Bridge, February 2024

[2]Yettinahole Integrated Drinking Water Supply Project Details

chemicals that threaten plants, animals, and humans; and polycyclic aromatic hydrocarbons (PAHs), persistent pollutants from burning fuels, plastics and industrial activities.

Additionally, our analysis of **heavy metals and nutrients in surface sediments** uncovers a historical record of pollution, offering valuable context for understanding the scale and persistence of contamination.

In response to a National Green Tribunal directive, the Karnataka State Pollution Control Board (KSPCB) devised a restoration plan[3] for the 55-kilometer stretch from the TG Halli Reservoir to Kanakapura town. However, the plan does not consider emerging contaminants.

Arkavathi is in crisis means our lives are in crisis., though we may not see it.

The toxic pollutants flowing in the river enter the crops irrigated by its waters, eventually finding their way back to our plates[4] and also into the water we drink[5], threatening our health. The contamination affects not just humans but all life[6], depending on the river.

Our comprehensive study identifies hidden threats, providing a deeper understanding of pollution in the Arkavathi River to support more informed and effective restoration plans. Restoring the Arkavathi **can reduce extraction from the fragile Western Ghats, protect this critical ecosystem, and revive a lifeline for Bengaluru,** with numerous environmental benefits as well as significant economic gains.

In addition to this report, a spatial representation of this data, with additional data integrated from public domain studies, is available on Paani's [Arkavathi River Interactive Map](#).

Figure 03: Vrishabhavathi River Downstream of Kumbalgodu Industrial Area, January 2024[7]

Figure 04: Solid Waste Dumped in Vrishabhavathi River at Thagachaguppe Bridge, July 2024

[3] Arkavathi Polluted River Stretch Restoration Plan, Jan 2019
[4] Deccan Herald Article, Oct 2023
[5] Citizen Matters, October 2021
[6] Wildlife London Trust
[7] Unless otherwise stated, photo images were collected by Paani.Earth

Study Area

The Arkavathi River Basin, west of Bengaluru, is impacted by wastewater runoff and solid waste generated within the catchment from industrial, quarrying, agricultural, and urban activities. To understand the extent of pollution, Paani tested seven sites[8]: five on the Arkavathi River and two on its tributary, the Vrishabhavathi River. Site locations were selected based on specific criteria (see Table 1), including their proximity to critical projects and pollution hotspots. To determine the volume of wastewater in the basin, Paani measured river flow at two sites (labeled 1 and 2 in Figure 05) during the lean season in March 2024.

This report organizes test sites from upstream to downstream for better clarity, with the full area map provided in Figure 05. The Arkavathi River flows 170 km southward from Nandi Hills to join the Cauvery at Sangama. Sites A, B, C, D and E are at 76th, 83rd, 130th, 149th, and 171th km from its origin respectively. Sites F and G are located on the Vrishabhavathi, a tributary of the Arkavathi, at the 43rd and 63rd kilometers from its origin. The Vrishabhavathi merges with the Arkavathi between Sites C and D.

The stretch from TG Halli to Kanakapura Town is classified as a Priority-I Polluted River Stretch by the Karnataka State Pollution Control Board (KSPCB) due to BOD levels exceeding 30 mg/L. Marked by red dots in Figure 06, this stretch was included in Paani's testing, which went beyond BOD parameters to identify key contaminants, offering deeper insights for restoration.

Figure 05: Map of the Study Area with Testing locations

[8]Paani prioritized seven sites to address key areas of interest within allocated project budget

Figure 06: KSPCB Polluted River Stretch

An interactive visual representation of these sites available in Paani's [Arkavathi River Interactive Map]

Table 1 shows the order of the pollution test sites based on river flow, and a brief description of each site. Test sites are referred to using their letter code (e.g. A, B, C) for the rest of this report.

Table 1: Overview of Pollution Test Sites

CODE	SITE LOCATION	TEST NO.[9]	TEST DATE	RATIONALE FOR TESTING
A	**Upstream of TG Halli Reservoir, Arkavathi River**	**M0104**	**28 FEB 2024**	• Baseline for evaluating water and sediment quality downstream of agricultural, Peenya Industrial, and urban areas • Critical as TG Halli's downstream water is planned to augment Bengaluru's supply.
B	**Downstream of TG Halli Reservoir, Arkavathi River**	**M0105**	**28 FEB 2024**	• Captures water quality after the confluence of the Arkavathi with the Kumudvathi River and downstream of TG Halli Reservoir.
C	**Upstream of Muduwadi Bridge, Arkavathi River**	**M0101**	**28 FEB 2024**	• Provides control before Vrishabhavathi meets the Arkavathi • Site with limited government monitoring • Downstream of Ramanagara, and its silk industries
D	**T. Bekuppe, Arkavathi River**	**M0107**	**29 FEB 2024**	• Demonstrates the impact of pollution from Vrishabhavathi inflow and Kanakapura town flows on Arkavathi
E	**Sai Spoorthi Hydro Power Plant, Arkavathi River**	**M0108**	**29 FEB 2024**	• Evaluates the river's health at a remote site, away from heavily populated and industrial areas, with limited government monitoring
F	**Shyanumangala Bridge, Vrishabhavathi River**	**M0106**	**29 FEB 2024**	• Hotspot for illegal tanker dumping and downstream of major industrial zones, solid waste plants,informal recyclers and Bengaluru urban area.
G	**Downstream of Rising Sun Anecut, Vrishabhavathi River**	**M0102**	**28 FEB 2024**	• Captures cumulative pollution downstream of Byramangala, Harohalli Industrial Area, and after confluence with the Suvarnamukhi River, Tributary of Vrishabhavathi

*Testing at Site No. M0103 was limited to only BOD and sediment nutrients and is thus excluded from this report

[9] This internal test number is used by Paani and ICCW to track samples

Table 2 demonstrates flow measurements recorded by Paani in March of 2024. These dry season flow measurements primarily comprise partially treated sewage from sewage treatment plants (BWSSB) and raw/partially treated wastewater directly discharged into the river from domestic and industrial clusters.

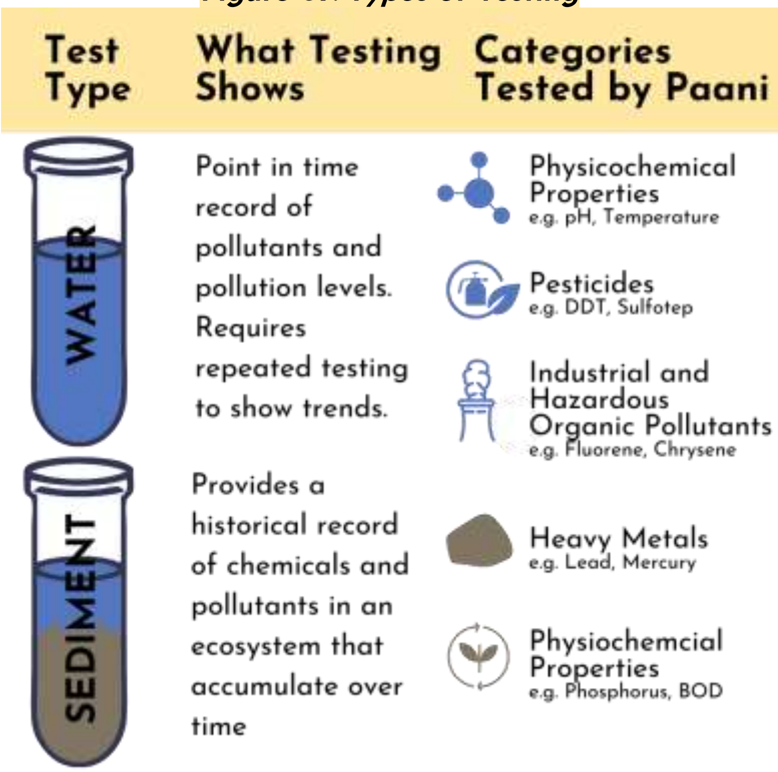
Table 2: Overview of Flow Measurement Locations

CODE	SITE LOCATION	TEST DATE	VOLUME MEASURED	RATIONALE FOR TESTING
1	**Upstream of TG Halli Reservoir, Arkavathi**	**15 MAR 2024**	163 MLD (megaliters per day)	Estimates lean season flow into the reservoir to assess if treatment capacities align with flow and quality.
2	**Behind Provident Sunworth Apartments, Vrishabhavathi**	**11 MAR 2024**	595 MLD (megaliters per day)	Estimates the river's lean-season flow from the BBMP area of the Vrishabhavathi catchment, which houses over 300+ MLD of sewage treatment capacity upstream of Site F

Testing Methodology

Testing both sediment and water quality is essential for a comprehensive assessment of river health, capturing both historical and current conditions. The Paani team tested 65 unique parameters in water samples and 20 unique parameters in soil samples across seven test sites. The analysis focused on three categories for water (Physicochemical Properties, Pesticides, and Industrial and Hazardous Organic Pollutants) and two categories for sediment (Heavy Metals, and Physicochemical Properties) shown in Figure 07.

Figure 07: Types of Testing



Sampling and Analysis Process

The team collaborated with the International Centre for Clean Water (ICCW) for water and sediment testing. See figures 08 and 09 for a visual of the testing process.

Time-sensitive water parameters like Dissolved Oxygen were measured onsite by Envirotech. Sampling followed IS 17614 standards (Part 6 for water, Part 12 for sediment).

Paani collected samples from seven sites over two days in February 2024 (Feb 28 and 29) and ICCW analyzed them in the ICCW lab. One site, Site C, had no active flow so water samples were collected from puddles. Paani used a checklist (see example in Appendix A) to ensure compliance with procedures.

At each site, **three water and soil samples were collected within a 50m radius**, homogenized, and analyzed in triplicate. The report presents the average values for each site. Pollutants not detected were assigned a value of 0 for averaging purposes.

Figure 08: Sediment Sample Collection Process with the Ekman Sampler

Figure 09: Water Sample Collection Process

Parameters Tested

For ease of reporting, the various parameter categories are represented using the symbols shown in Figure 10:

Figure 10: Testing Categories

In India, the Central Pollution Control Board's Water Quality Criteria focus only on physicochemical properties of water. Testing for hazardous pollutants such as pesticides, PAHs, and phthalates - **considered as emerging contaminants** - provides a more comprehensive assessment and enables comparisons with stricter international standards and guidelines discussed in the next section.

See Table 3 for the full list of water parameters tested in each category.

Table 3: Water Parameters Tested in Study

WATER PARAMETERS TESTED		
Physicochemical Properties show the basic requirements to support healthy water and ecosystems. In excess, these parameters can harm the river ecosystem and human health.	**Pesticides** are toxic to other organisms and when used in excess can lead to poisoning and health impacts. Many pesticides remain in soil and water for years[10].	**Industrial and Hazardous Organic Pollutants** include PAHs discharged during industrial burning. PAHs are linked to cancer (carcinogenic)[11]. Additionally other hazardous pollutants like phthalates (plasticizers) were studied.
1. Biochemical Oxygen Demand (BOD) 2. pH 3. Total Dissolved Solids (TDS) 4. Dissolved Oxygen (DO) 5. Temperature 6. Electrical Conductivity (EC) 7. Turbidity 8. Ammonia as NH_3 9. Sulphide as S^{2-} 10. Chloride as Cl^- 11. Total Hardness as $CaCO_3$ 12. Calcium as Ca 13. Magnesium as Mg 14. P-Alkalinity as $CaCO_3$ 15. OH-Alkalinity 16. CO3-Alkalinity 17. HCO3-Alkalinity 18. Total Alkalinity as $CaCO_3$ 19. Nitrate as NO_3 20. Nitrite as NO_2 21. Fluoride as F^- 22. Sulphate as SO_4 23. Total Phosphorus 24. Hexavalent Chromium (Chromium (VI)) 25. Chemical Oxygen Demand (COD) 26. Oil & Grease 27. Total Suspended Solids (TSS)	28. Beta lindane 29. Delta lindane 30. Alpha lindane 31. Gamma lindane 32. Heptachlor 33. Heptachlor epoxide 34. Chlordane 35. Alpha endosulfan 36. Trans chlordane 37. p, p'-DDE 38. Endrin aldehyde 39. Endosulfan sulfate 40. p, p'-DDT 41. Methoxychlor 42. Sulfotep 43. o, o, o-triethyl thiophosphate	44. Naphthalene 45. 2-Chloronaphthalene 46. Acenaphthene 47. Fluorene 48. 9h-fluorene-9methylene 49. Fluoranthene 50. Pyrene 51. Triphenylene 52. Benzo[j] fluoranthene 53. Chrysene 54. Dibenz[a,h]anthracene 55. Benzo[ghi] perylene 56. Dibutylphthalate 57. Benzylbutylphthalate 58. Bis(2-ethylhexyl)phthalate 59. 2,4-Dimethylphenol 60. 2,4-Dichlorophenol 61. 4-Chloro-3-methylphenol 62. Bis(2-chloroethyl) ether 63. Nitrobenzene 64. Isophorone 65. Bis(2-chloroethoxy)methane

[10] Chemical safety: Pesticides
[11] Report of the Working Group on Polycyclic Aromatic Hydrocarbons of the Joint Task Force on the Health Aspects of Air Pollution

Sediment testing provides a historical record of pollution, showing long-term contaminant accumulation. Higher parameter values indicate polluted sediments, which pose risks to aquatic ecosystems and human health. In India, there are no current recommended guidelines for river sediments. Given this, the parameters tested are compared to international guidelines. See the sediment quality parameters tested in Table 4.

Table 4: Sediment Parameters Tested in Study

SEDIMENT PARAMETERS TESTED	
Heavy Metals occur naturally or through pollution in sediments. In excess, these metals can harm aquatic and human health.	**Physicochemical parameters**[12] in sediments are critical indicators of pollution with higher values indicating significant pollution and poor water quality, contaminating sediment and harming aquatic ecosystem health.
66. Antimony (Sb) 67. Arsenic (As) 68. Barium (Ba) 69. Beryllium (Be) 70. Cadmium (Cd) 71. Chromium (Cr) 72. Cobalt (Co) 73. Copper (Cu) 74. Iron (Fe) 75. Lead (Pb) 76. Lithium (Li) 77. Mercury (Hg) 78. Nickel (Ni) 79. Selenium (Se) 80. Sodium (Na) 81. Zinc (Zn) 82. Hexavalent Chromium (Chromium (VI))	83. Total Nitrogen (TN) 84. Biological Oxygen Demand (BOD) 85. Available Phosphorus (P)

Figure 11: Paani Team Onsite Monitoring the Sampling Process

[12]The Paani study included parameters such as Faecal Coliform, Total Coliform, and Faecal Streptococci; however, due to reporting inaccuracies of these 3 parameters by Envirotech, we have excluded them from this report.

Parameter Standards and Guidelines

Assessing water and sediment quality begins with comparing observed levels to scientifically defined permissible limits. Regulatory authorities like the Central Pollution Control Board (CPCB) in India, the Environmental Protection Agency (EPA) in the USA, and the Canadian Council of Ministers of the Environment (CCME) in Canada set water quality criteria tailored to specific uses, recognizing that the needs for irrigation differ greatly from those required to protect aquatic life. These pollutant-specific thresholds help evaluate whether water is safe for human health, aquatic ecosystems, and wildlife.

Criteria may be shared in the form of standards or guidelines. Standards such as the European Union Environmental Quality Standards (EQS) have regulatory enforcement measures. Guidelines are advisory rather than regulatory. Water pollution standards and guidelines are based on our current understanding of pollutant toxicity. As science advances, permissible limits are regularly refined to incorporate new knowledge about the impacts of pollutants on both human and ecological health.

In India, the **Use-Based Classification of Surface Waters defined by CPCB uses just 8 parameters** to evaluate water quality - far fewer than the more rigorous frameworks set by international guidelines such as those of the US EPA, European Union (EU), and CCME. To ensure a more comprehensive understanding of pollution levels and their impacts, we have incorporated these international benchmarks into our assessment, bridging the gap and providing a clearer picture of environmental risks.

The earlier guidelines, IS 2296:1982, titled 'Tolerance Limits for Inland Surface Water Subject to Pollution[13], classified water into designated use classes (A to E) and included a comprehensive set of 43 parameters covering physical, chemical, and biological aspects. However, this standard has been withdrawn, leaving a critical gap in assessing and maintaining water quality for specific purposes
The national and international standards and guidelines shown in Table 5 are used to benchmark the parameter values to recommended levels.

Table 5: Parameter Guidelines

Guideline	Description
Designated-Best-Use Water Quality Criteria	Central Pollution Control Board (CPCB) criteria (guidelines) outlining five recommended groups for water use ranging from irrigation to drinking water
National Recommended Water Quality Criteria for Human Health (Consumption of Organism Only)	Recommended criteria (guidelines) to not have adverse effect to human health from consumption of organisms from a body of water
Environmental Quality Standards (EQS) for Priority Substances and Certain Other Pollutants	Standards to achieve good surface water chemical status considering harmful priority substances
Water Quality Guidelines for the Protection of Aquatic Life (Freshwater Long Term)	Water quality guidelines intended to protect all forms of aquatic life across life cycles
Sediment Quality Guidelines for the Protection of Aquatic Life (Freshwater Interim Sediment Quality Guideline)	Guidelines to protect aquatic life from exposure to substances associated with bed sediments
Water Quality Guidelines for the Protection of Agricultural Water Uses*	Guidelines to ensure water quality for irrigation and agriculture purposes defining safe limits of various pollutants

*This report contrasts India's Designated-Best-Use Water Quality Criteria to Canada's Water Quality Guidelines for the Protection of Agricultural Water Uses to illustrate discrepancies between the guidelines. A full analysis of Canada's Water Quality Guidelines for the Protection of Agricultural Water Uses is not performed in this study.

13 Surface Water Quality Standards (as per IS: 2296)

Test Results

This section presents site-specific test results and trends, and their correlations to the known pollution sources. Complete test results are included in Appendix B through F. These results are based on a grab sample analysis, providing a snapshot of their presence. While indicative of pollution, these levels may not fully represent the overall magnitude of the contamination and should be supplemented with additional studies.

💡 **How to interpret this data**
As a general rule, guidelines for water and sediment quality set upper limits for acceptable pollution levels. Higher parameter values indicate poorer water and sediment health at a given site. For certain illegal pollutants (e.g. DDT) the existence of even trace amounts is a cause for concern.

Two exceptions present in this study are pH and Dissolved Oxygen (DO). Healthy pH levels for a waterbody typically range between **6.5 and 8.5**. For DO, values below **4 mg/L** indicate an environment with insufficient oxygen to support aquatic life.

Overall, **all seven sites show elevated levels across the five test categories**: Physicochemical Parameters, Pesticides, and Industrial & Hazardous Organic Pollutants in water; and Heavy Metals and Physicochemical Parameters in sediments. This indicates that both visible and invisible pollutants from a variety of sources pose a threat to river health. By evaluating pollution levels in order of river flow we can observe trends across sites and potential point source causes of high pollution levels.

Figure 12: Water Sample Collection at Site G

Physicochemical Results in Water

Water samples were tested for a total of 27 Physicochemical parameters listed in Figure 13. This sample set extends beyond the 8 physicochemical criteria in the CPCB's Designated-Best-Use Guidelines to provide a more comprehensive assessment of Arkavathi water.

Figure 13: Physicochemical Parameters

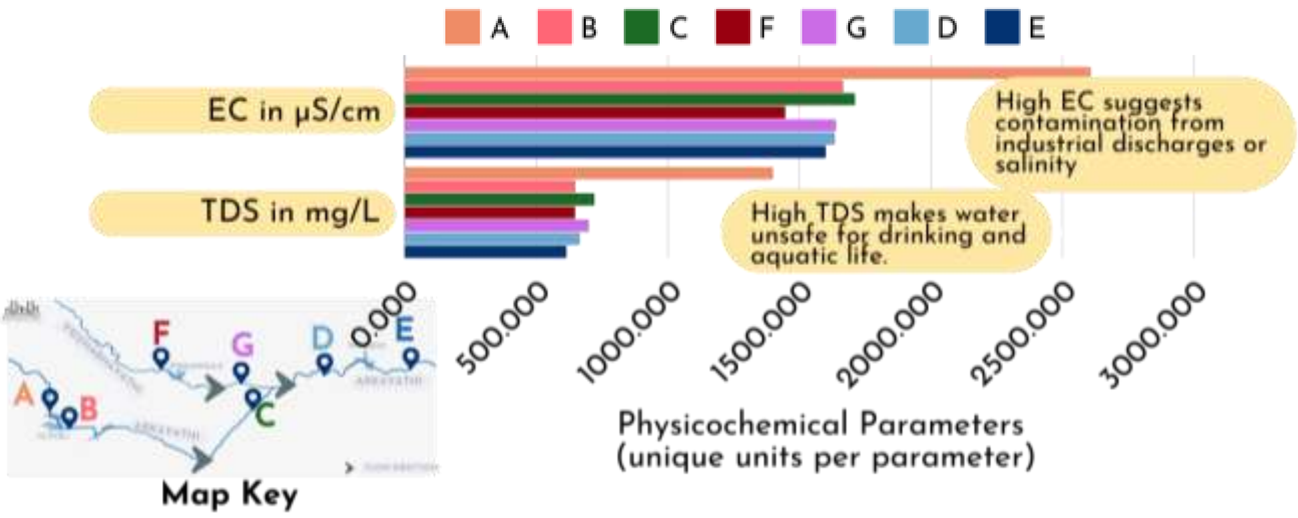
Biochemical Oxygen Demand (BOD), pH, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Temperature, Electrical Conductivity (EC), Turbidity, Ammonia as NH_3, Sulphide as S^{2-}, Chloride as Cl^-, Total Hardness as $CaCO_3$, Calcium as Ca, Magnesium as Mg, P-Alkalinity as $CaCO_3$, OH-Alkalinity, CO_3-Alkalinity, HCO_3-Alkalinity, Total Alkalinity as $CaCO_3$, Nitrate as NO_3, Nitrite as NO_2, Fluoride as F^-, Sulphate as SO_4, Total Phosphorus , Hexavalent Chromium (Chromium (VI)), Chemical Oxygen Demand (COD), Oil & Grease, and Total Suspended Solids (TSS)

Physico-chemical parameters are fundamental measurements that describe the physical and chemical properties of water. They often serve as indirect indicators of pollution sources and environmental conditions.

The figures below highlight trends in select physicochemical indicators across sites. For exact metrics for all physicochemical parameters see Appendix B.

Among these indicators, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) provide valuable insights into water quality. EC measures water's ability to conduct electricity, determined by dissolved salts. Low EC indicates freshwater, while high EC suggests salinity or pollution. While EC doesn't identify specific pollutants, it helps detect the presence of contamination. Total Dissolved Solids (TDS) indicate the presence of solids in water that can deteriorate water quality in high values. The high concentrations of EC and TDS, particularly at Site A, is shown in Figure 14.

Figure 14: Salinity and Solids Parameters Across Sites



Other useful physicochemical parameters to develop a basic understanding of water health include pH, Dissolved Oxygen (DO), and Turbidity. Extreme pH values can harm aquatic life. Similarly, if DO is too low, there is not enough oxygen to support aquatic life. Turbidity and DO have an inverse relationship and generally higher turbidity contributes to lower levels of DO by blocking sunlight. This is shown in Site F, which has extremely high turbidity and low DO. See Figure 15 for an overview of these parameters.

Figure 15: Basic Physicochemical Parameters Across Sites

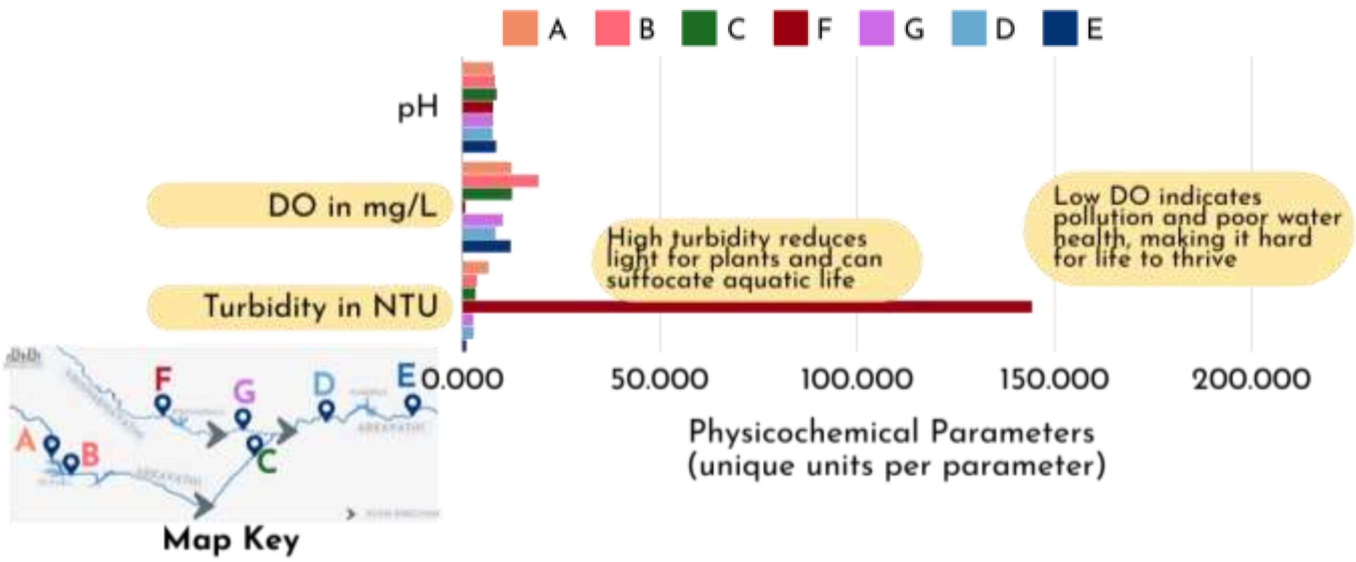
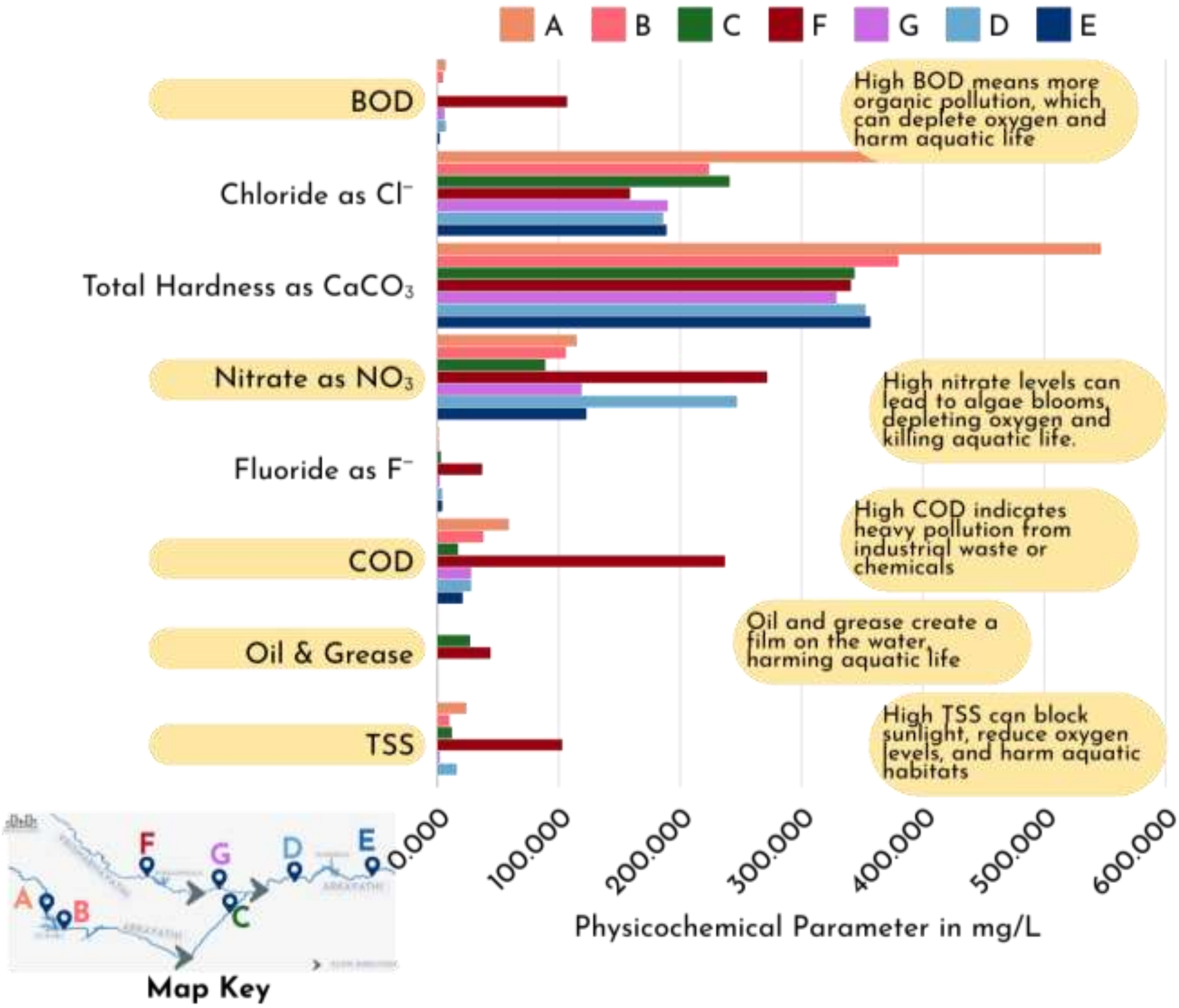


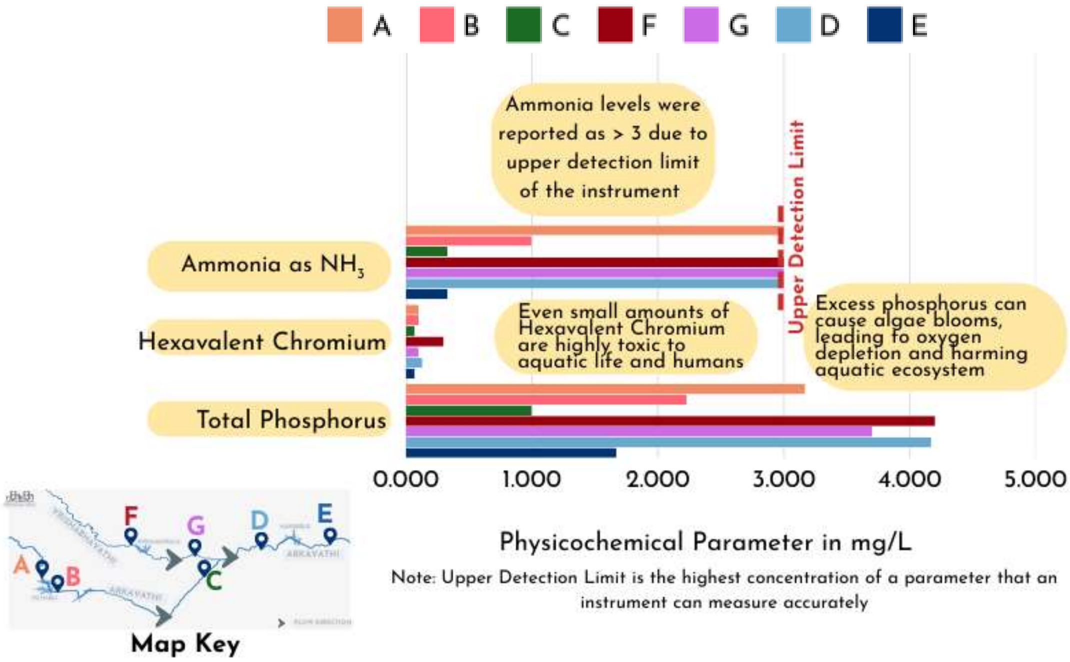
Figure 16 highlights other physicochemical parameters that, in high concentrations, can harm river health. Notably, these parameters are present across all sites, with significant spikes observed at Sites A and F.

Figure 16: Physicochemical Parameters Across Sites



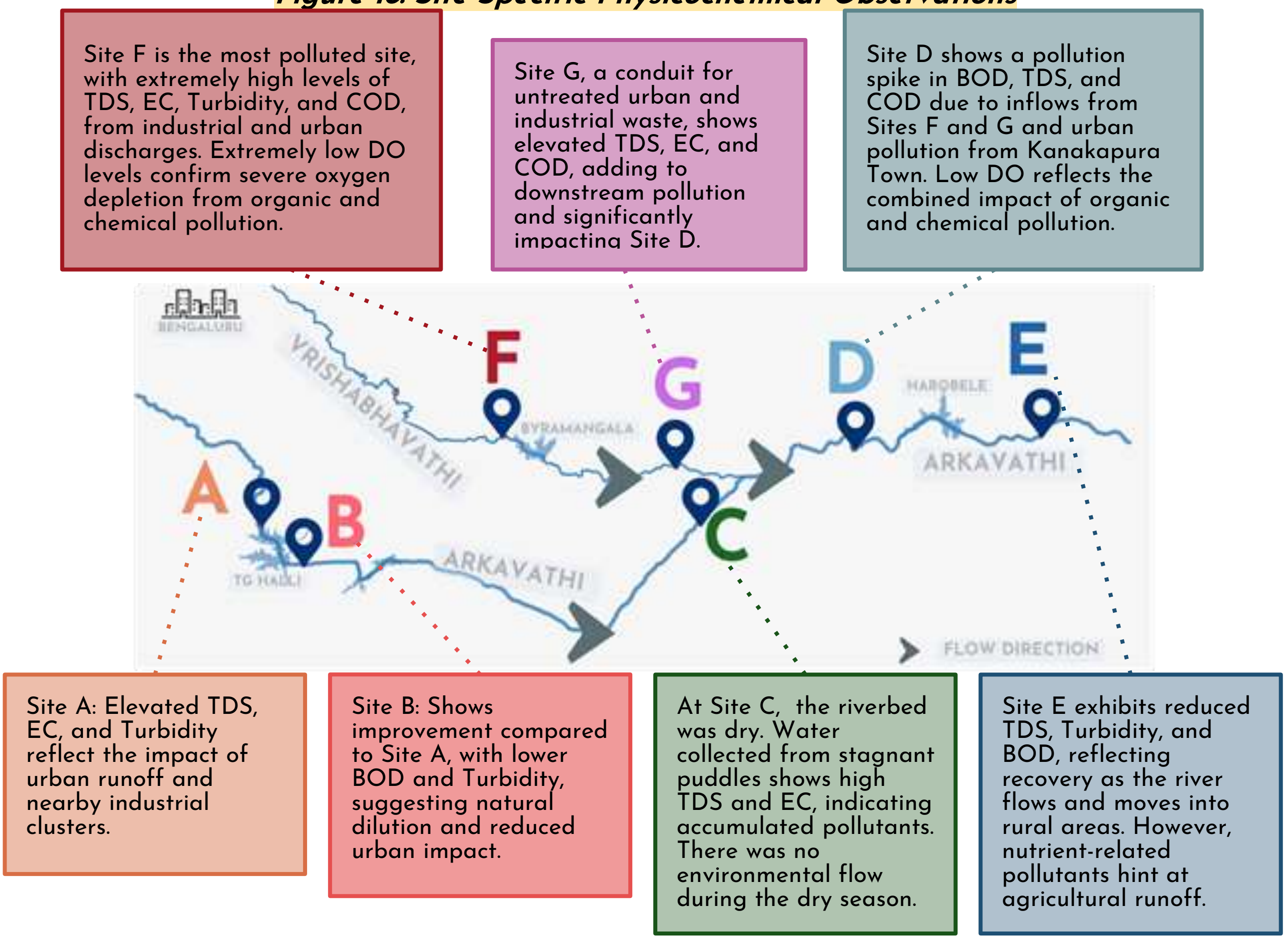
For certain physicochemical properties even relatively small concentrations can be toxic to aquatic and human life. Figure 17 demonstrates the presence of such pollutants in quantities that pose risk to river and human health.

Figure 17: Sensitive Physicochemical Parameters Across Sites



See Figure 18 for a synopsis of trends in physicochemical parameters across sites.

Figure 18: Site Specific Physicochemical Observations



Site F just upstream of Byramangala Reservoir emerges as an outlier with high levels of physicochemical pollution. These elevated levels highlight severe pollution from urban and industrial discharges. This polluted water is currently used to irrigate downstream fields, where crops like baby corn (see Figure 19) and cattle fodder are cultivated - allowing harmful pollutants to enter the food chain through produce and milk, ultimately impacting public health.

Figure 19: Baby Corn Grown in the Byramangala Reservoir Command Area

Despite the severity of the issue, efforts to address it remain misdirected. The ₹110+ crore Byramangala Lake "restoration" plan (Figure 20) opted to construct a concrete channel to divert these pollutants downstream, bypassing the root causes of contamination. This shortsighted solution not only perpetuates the pollution but also shifts its devastating impact onto already vulnerable downstream communities. The High Court stayed this project after the Bangalore Environment Trust, along with local farmers, [filed a PIL] highlighting the issues posed by this river-diversion project.

Figure 20: Concrete Channel Built for Byramangala Reservoir Restoration

Pesticides in Water

Paani conducted pesticide testing at Site A for 16 parameters shown in Figure 21. Paani selected Site A considering the substantial agricultural area and the presence of pesticide manufacturers[14] in the Peenya industrial area, to ensure that proposals to use TG Halli as a water source for Bengaluru adequately address pesticide treatment. The parameters tested include both pesticides that are illegal in India and under the international Stockholm Convention on Persistent Organic Pollutants (POPs)[15]. See Appendix C for full test results.

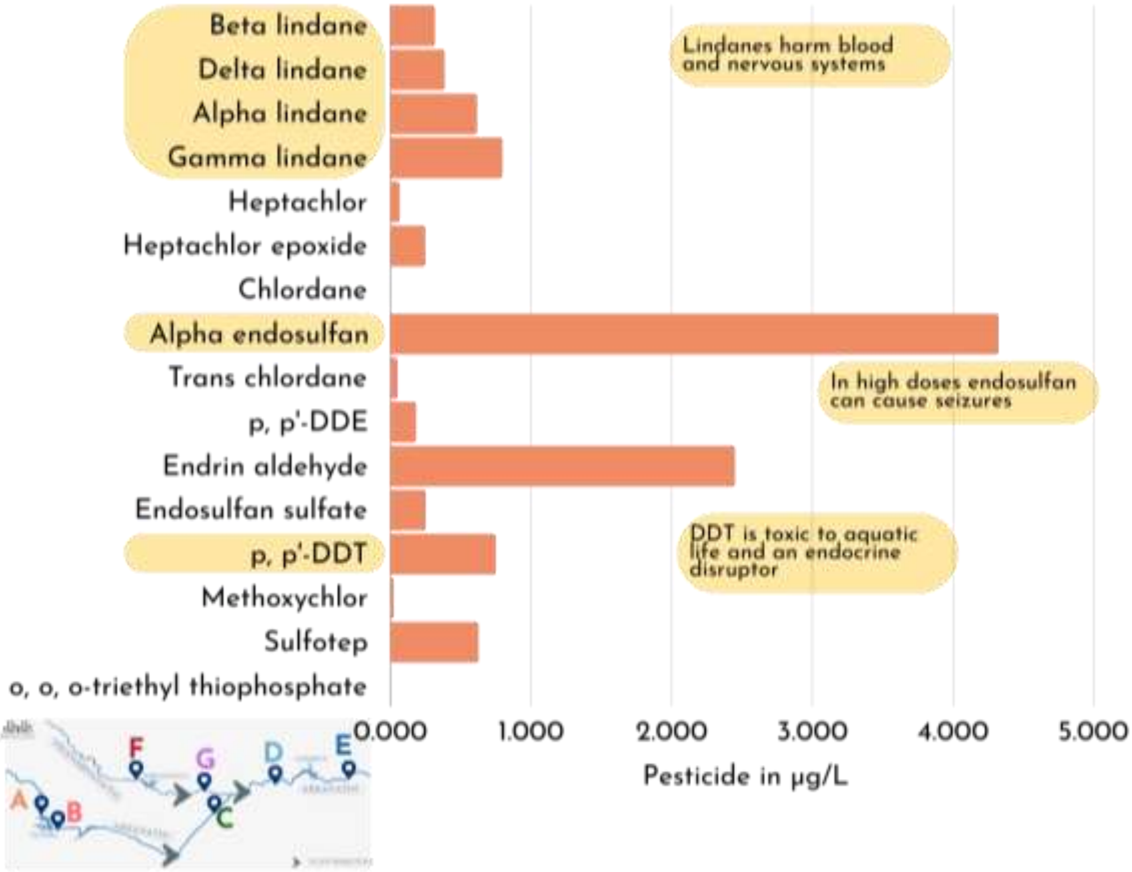
Figure 21: Pesticide Parameters

Beta lindane, Delta lindane, Alpha lindane, Gamma lindane, Heptachlor, Heptachlor epoxide, Chlordane, Alpha endosulfan, Trans chlordane, p, p'-DDE, Endrin aldehyde, Endosulfan sulfate, p, p'-DDT, Methoxychlor, Sulfotep, o, o, o-triethyl thiophosphate

Banned chemicals under the Stockholm Convention include Lindane, Heptachlor, and Methoxychlor. India ratified the Stockholm Convention in 2006. DDT is restricted under the Stockholm Convention and banned for agricultural use in India. **Known toxin Endosulfan sulfate has been banned in India for over a decade and was found at the site in high concentration**[16]. The presence of the pesticides in the water pose a risk to human and aquatic health.

See Figure 22 for an overview of the pesticide levels found at Site A.

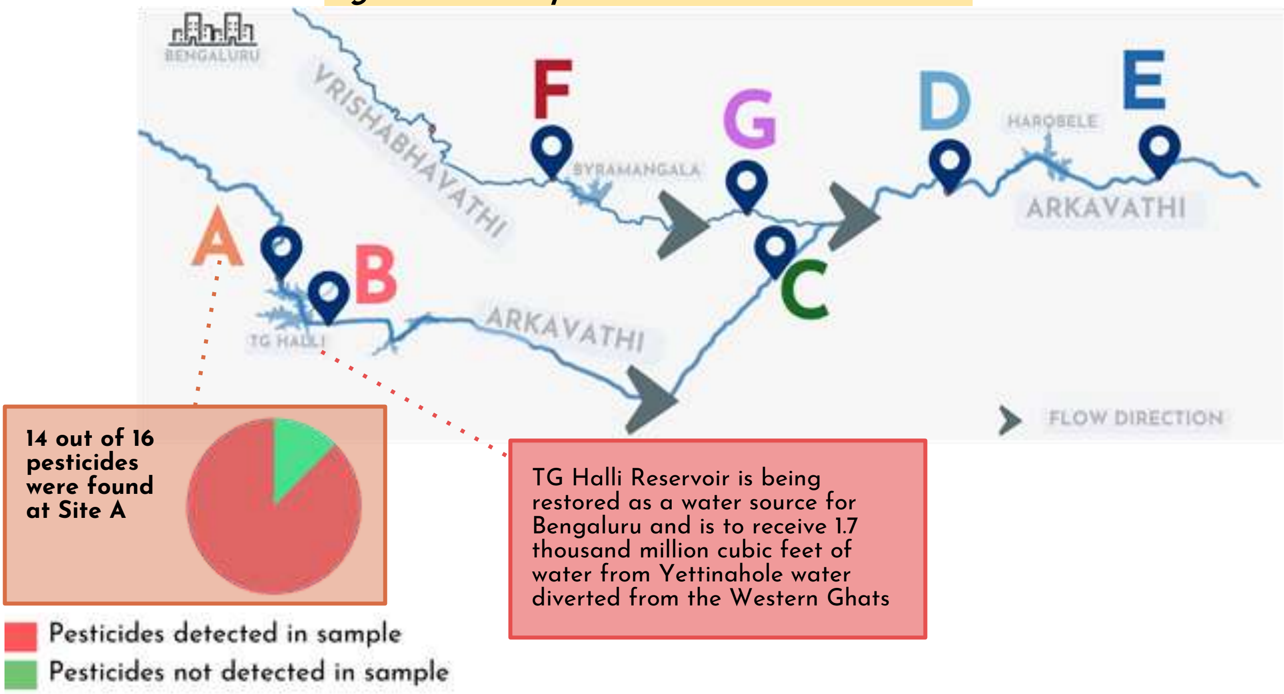
Figure 22: Pesticide Parameters at Site A



[14] Includes details of pesticide manufacturers in Karnataka
[15] Stockholm Convention on Persistent Organic Pollutants (POPs)
[16] Endosulfan: A year of the ban

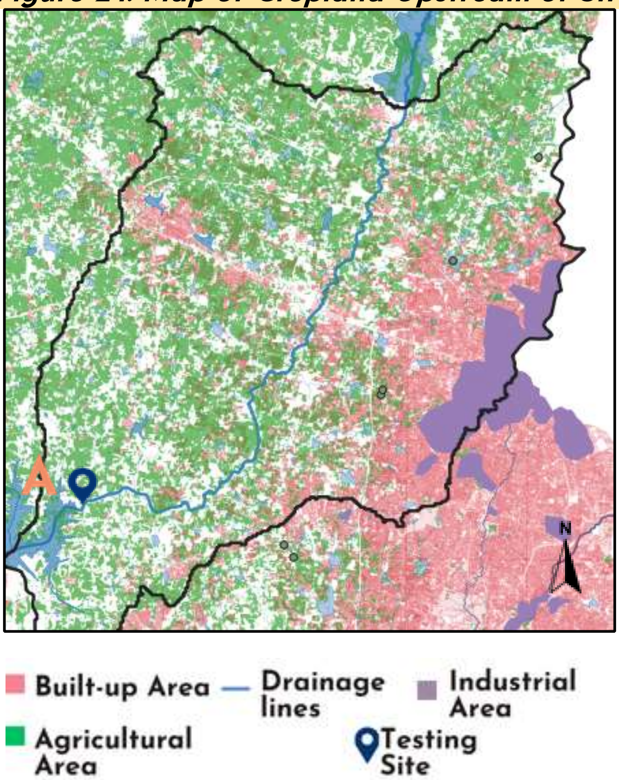
The high levels of pesticides present at Site A have immediate downstream repercussions for projects that use TG Halli water in Bengaluru as shown in Figure 23. Pesticide pollution must be treated and addressed at the source to avoid harm to human health when implementing the [project to supply water from TG Halli Reservoir].

Figure 23: Site Specific Pesticide Observations



As shown in Figure 24, there is significant cropland in the river catchment surrounding Site A which is a non-point source of pesticide pollution as well as point source pollution from pesticide manufacturers in Peenya Industrial Area.

Figure 24: Map of Cropland Upstream of Site A



Industrial and Hazardous Organic Pollutants in Water

Paani analyzed a total of 22 industrial and hazardous organic pollutants, which are not included in the CPCB's designated best use criteria, in the water samples as shown in Figure 25. Access Appendix D for full test results.

Figure 25: Industrial and Hazardous Organic Pollutant Parameters

Polycyclic Aromatic Hydrocarbons (PAHs): Naphthalene, 2-Chloronaphthalene, Acenaphthene, Fluorene, 9h-Fluorene-9-Methylene, Fluoranthene, Pyrene, Triphenylene, Benzo[j]Fluoranthene, Chrysene, Dibenz[a,h]Anthracene, Benzo[ghi]Perylene

Phenols: 2,4-Dimethylphenol, 2,4-Dichlorophenol, 4-Chloro-3-Methylphenol

Phthalates: Dibutylphthalate, Benzylbutylphthalate, Bis(2-Ethylhexyl)Phthalate

Other Compounds: Bis(2-Chloroethyl)Ether, Nitrobenzene, Isophorone, Bis(2-Chloroethoxy)Methane

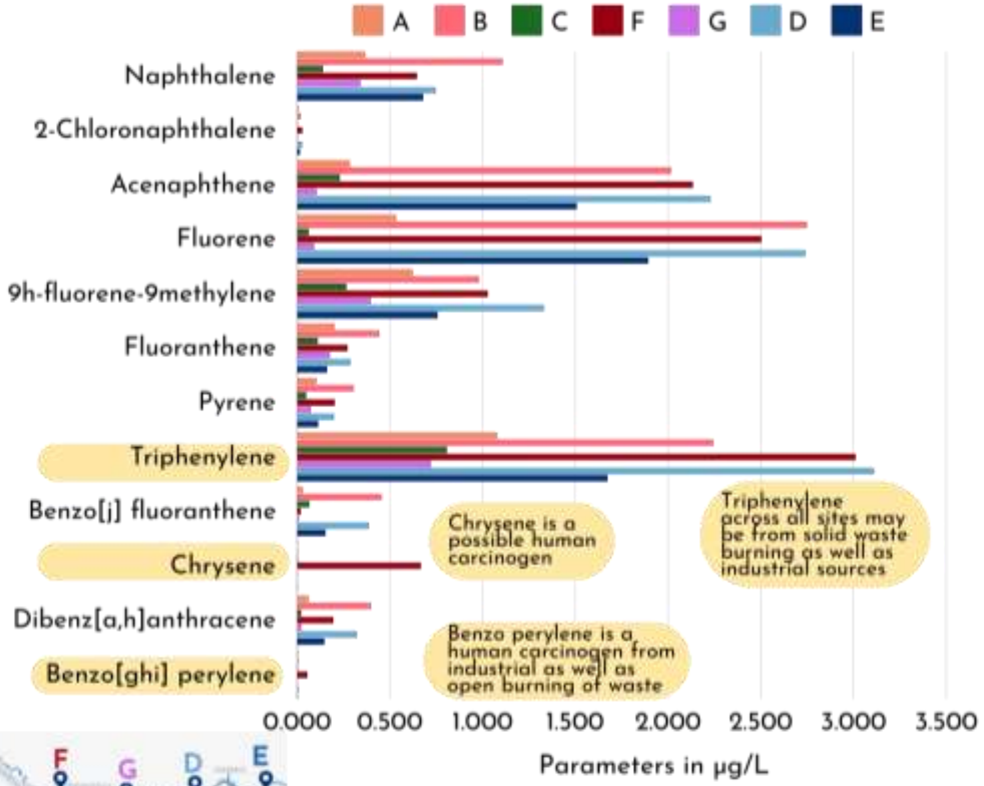
Industrial and hazardous organic pollutants may enter water from a variety of sources including open waste burning and industrial effluent discharges common in industrial parks. PAHs and phthalates are chemical additives added to many plastics[17]. The disposal of plastic waste through improper channels such as informal recyclers (shown in Figure 26) and open burning of solid waste may introduce PAHs and Phthalates to the river.

Figure 26: One of the many Informal Recyclers' Clusters Located next to the Vrishabhavathi River Upstream of Site F

Figure 27 demonstrates the presence of PAHs in Arkavathi water. Polycyclic aromatic hydrocarbons (PAHs) are chemicals formed during the incomplete burning of materials like coal, oil, gas, wood, or waste. Some PAHs can harm health and are linked to cancer[18]. All test sites demonstrated PAH pollution indicating the prevalence of industrial pollution in the Arkavathi Basin. In the Arkavathi, Sites B, D, and F exhibited major spikes in PAH levels compared to other test sites.

[17] Chemicals in Plastics
[18] Polycyclic Aromatic Hydrocarbons (PAHs) Fact Sheet

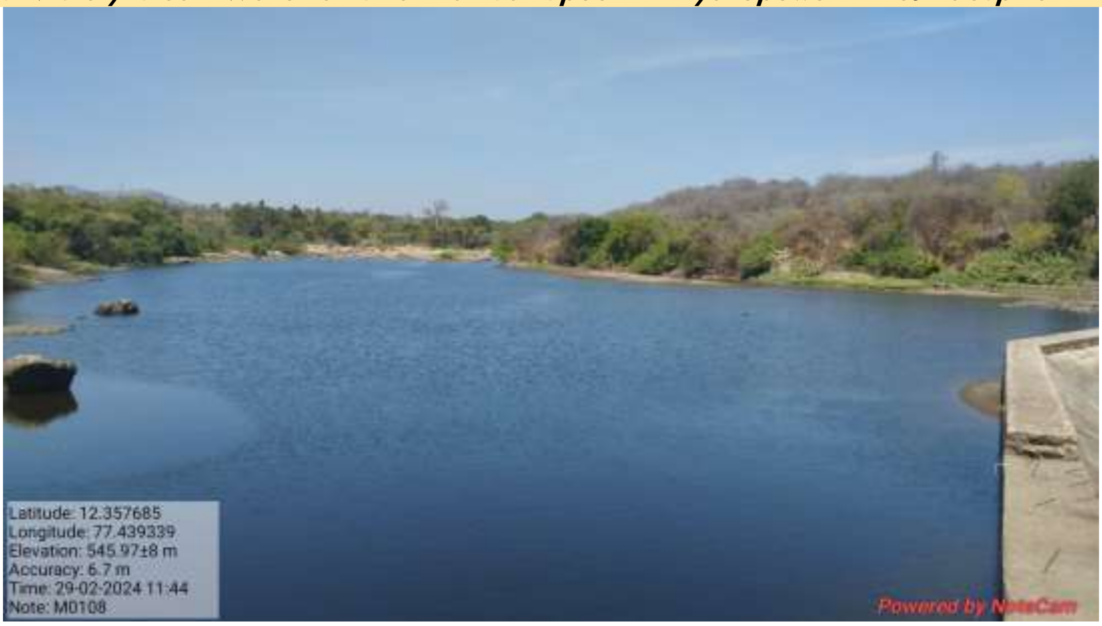
Figure 27: PAHs Across Sites



Map Key

Even at sites like E where the river water looked visibly cleaner, as shown in Figure 28, PAHs were still present in comparable concentrations to other sites. PAHs are an invisible pollutant that require focused study to identify and should be considered in future programs to clean the Arkavathi.

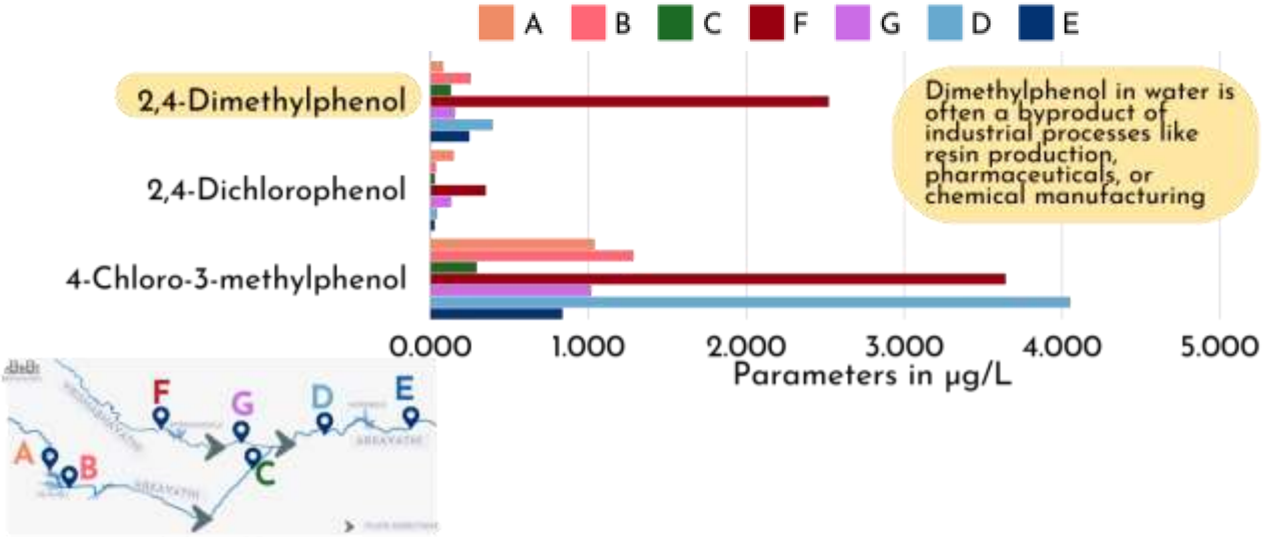
Figure 28: Visibly Clean Water at Site E at Sai Spoorthi Hydropower Anicut despite PAH Levels



Phenols, such as 2,4-Dichlorophenol, 2,4-Dimethylphenol, and 4-Chloro-3-Methylphenol, are widely used in industrial processes as preservatives, disinfectants, and in pesticide production. These compounds are now significant environmental pollutants, contaminating water, soil, and air. Many, especially chlorophenols, are toxic, carcinogenic, and persistent, posing serious risks to ecosystems and human health.[19]

Figure 29 demonstrates the presence of phenolic compounds in Arkavathi water. Noticeable spikes are observed in the levels of 2,4-Dimethylphenol, and 4-Chloro-3-Methylphenol at Sites F and D.

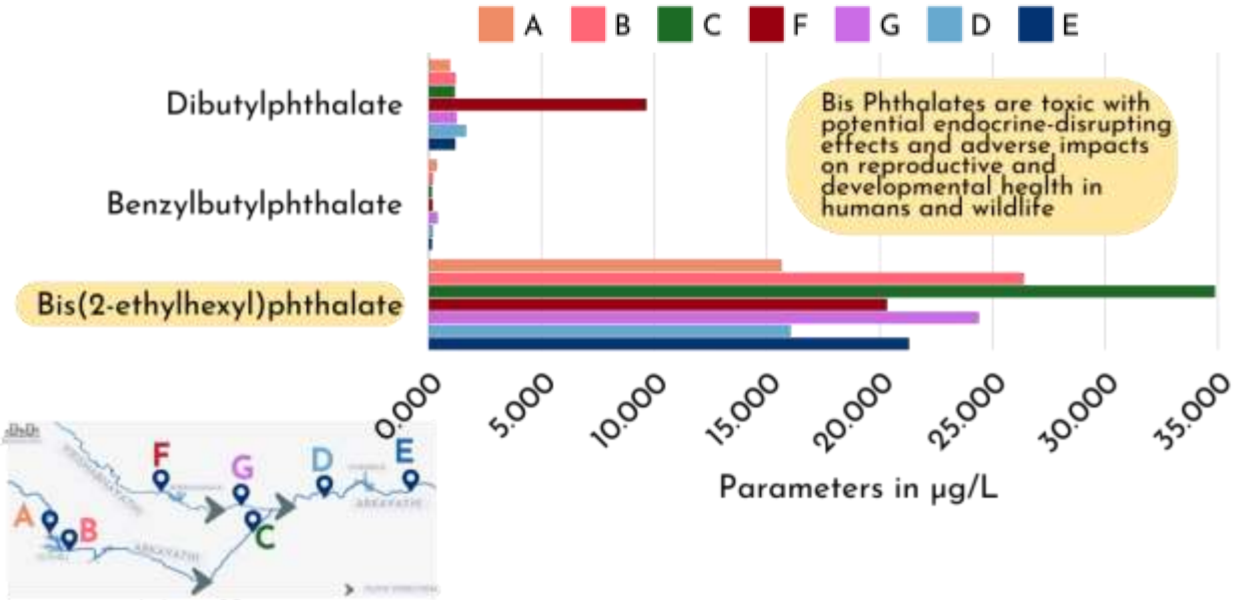
Figure 29: Phenols Across Sites



Map Key

The results also show that certain harmful pollutants may concentrate in a region. This is the case of Site C, which demonstrated relatively low levels of PAHs, but a spike in plasticizer Bis(2-ethylhexyl)phthalate compared to other sites. The presence of phthalates across sites is shown in Figure 30.

Figure 30: Phthalates Across Sites

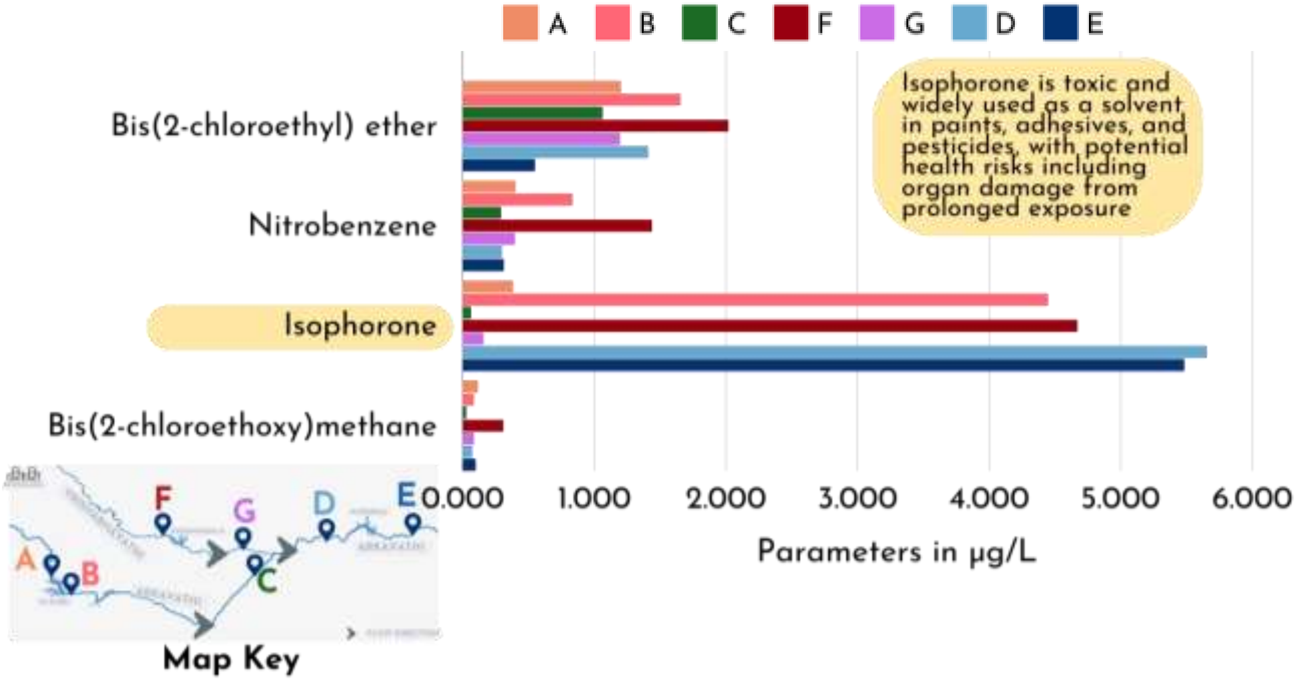


Map Key

[19] CPCB 2017 Newsletter about Phenolic Compounds

Finally, other toxic pollutants such as ethers, benzenes and Isophorone were identified during the study as shown in Figure 31.

Figure 31: Other Hazardous Pollutants Across Sites

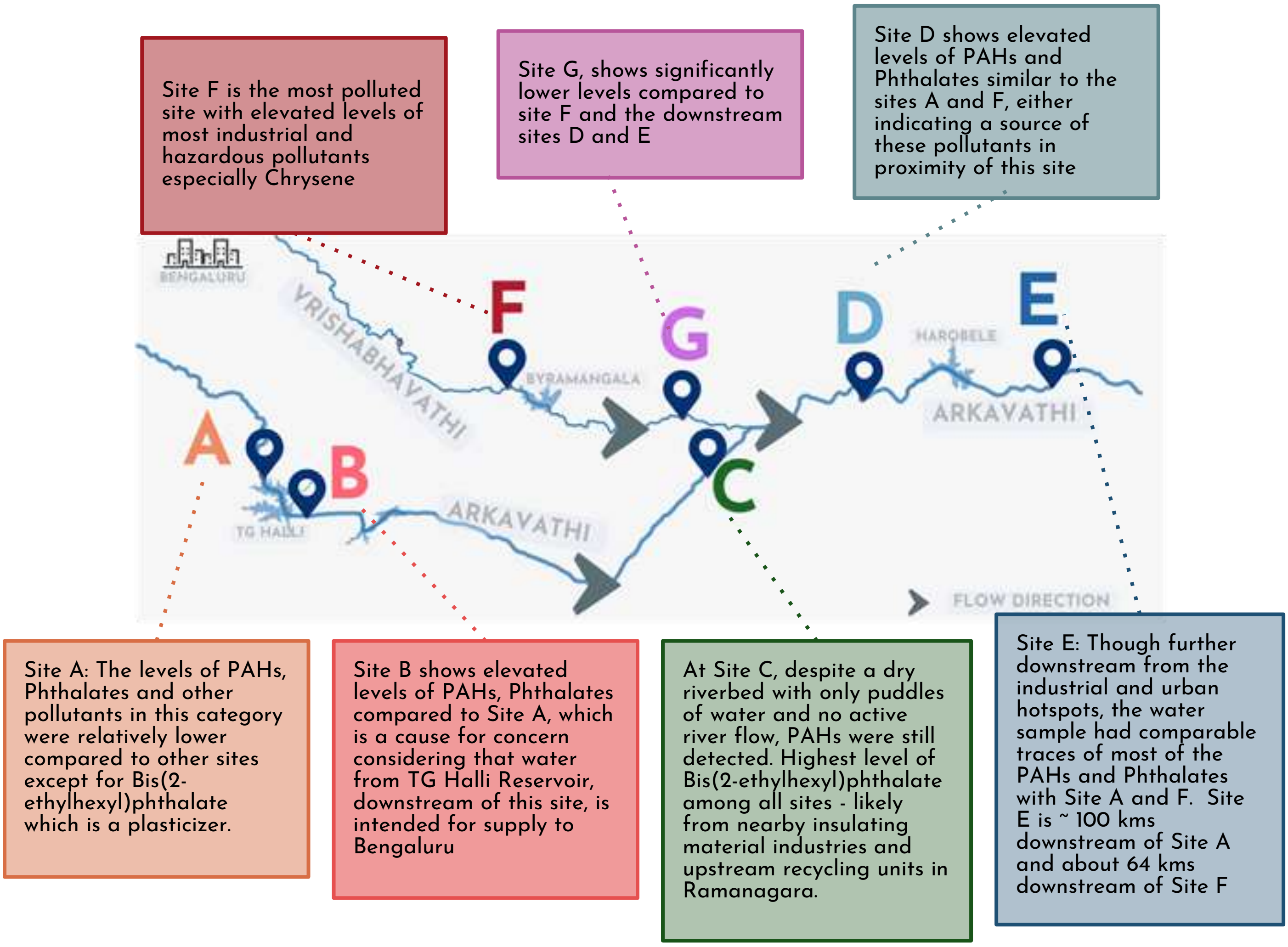


The smell of burning plastic in the air is a common occurrence in the [outer limits of Bengaluru](). Burning plastic waste and e-waste (visible in Figure 32) releases harmful pollutants like **PAHs and phthalates** into the air and water, posing serious risks to the environment and public health.

Figure 32: Pile of Mixed Waste Including E-waste in Kambipura, Upstream of Site F

The site-specific trends across all four types of industrial and hazardous organic pollutants are shown in Figure 33.

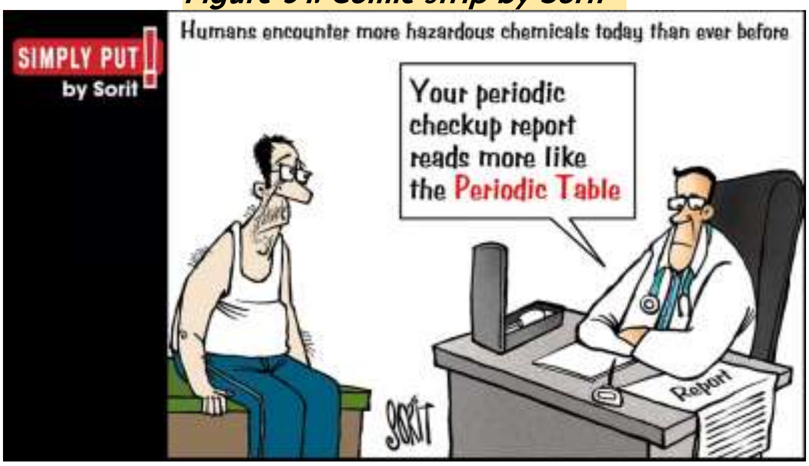
Figure 33: Site Specific Industrial and Hazardous Organic Pollutant Observations



The trend analysis across river sites reveals widespread concentrations of hazardous and organic pollutants, including PAHs, phthalates, and other chemicals in the Arkavathi River. Figure 34 features a comic strip by Sorit that humorously highlights the growing presence of hazardous chemicals in our lives.

It underscores the alarming extent of chemical exposure, as harmful substances from everyday products like cosmetics, food, water, and household items enter water bodies through industrial discharges or sewage from our homes, posing significant risks to human health and aquatic ecosystems.

Figure 34: Comic strip by Sorit[20]



[20] Simply Put: Periodic Table

Heavy Metals in Sediment

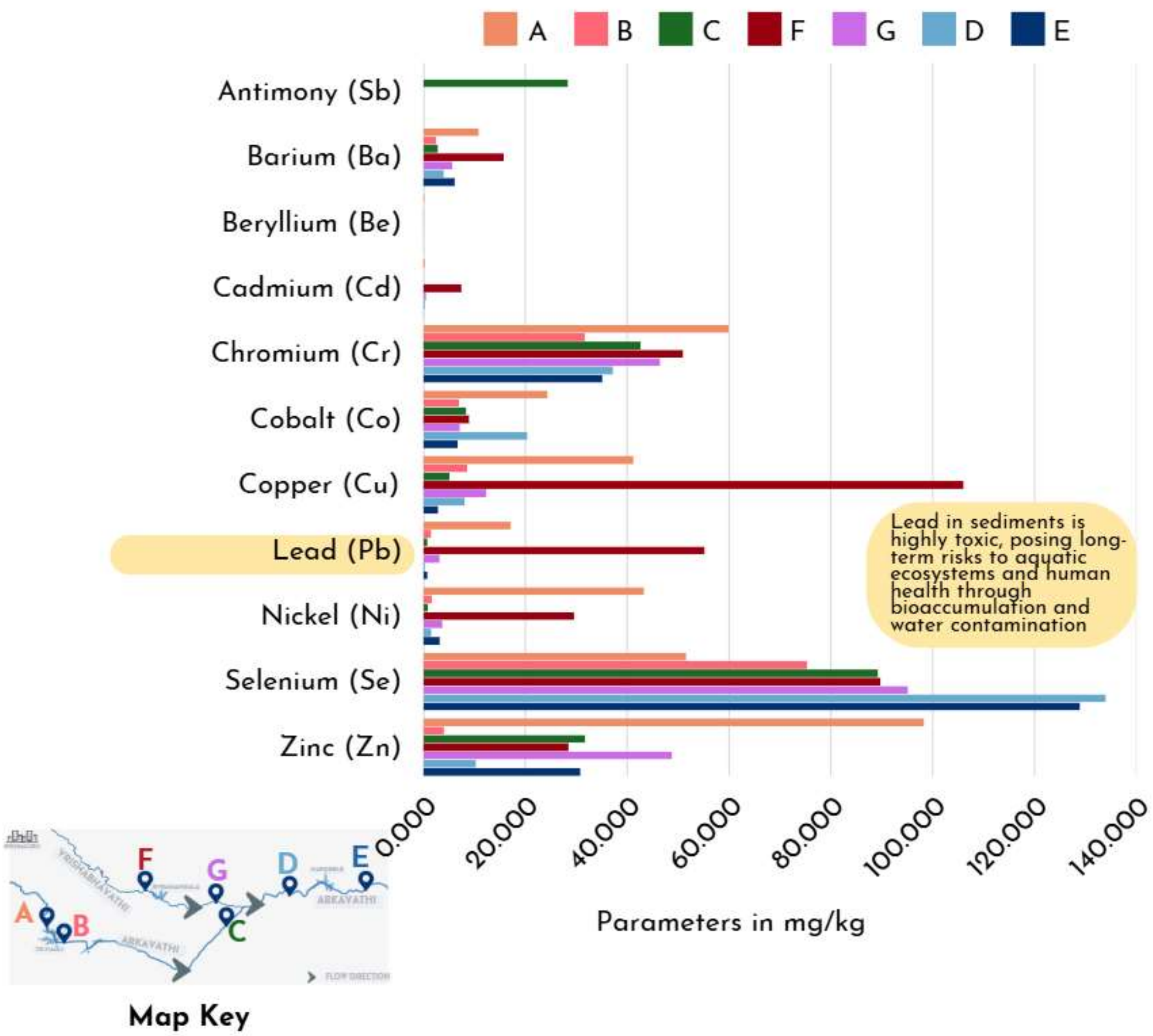
A total of **17 heavy metals** shown in Figure 35 were analyzed in the surface sediments. Elevated concentrations, particularly of **Chromium**, **Lead**, and **Hexavalent Chromium** were detected. These levels indicate pollution from mining, industry, and other sources. See parameter outcomes in the tables below and detailed results in Appendix E.

Figure 35: Heavy Metal Parameters

Antimony (Sb), Arsenic (As), Barium (Ba), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Lithium (Li), Mercury (Hg), Nickel (Ni), Selenium (Se), Sodium (Na), Zinc (Zn), and Hexavalent Chromium (Chromium (VI))

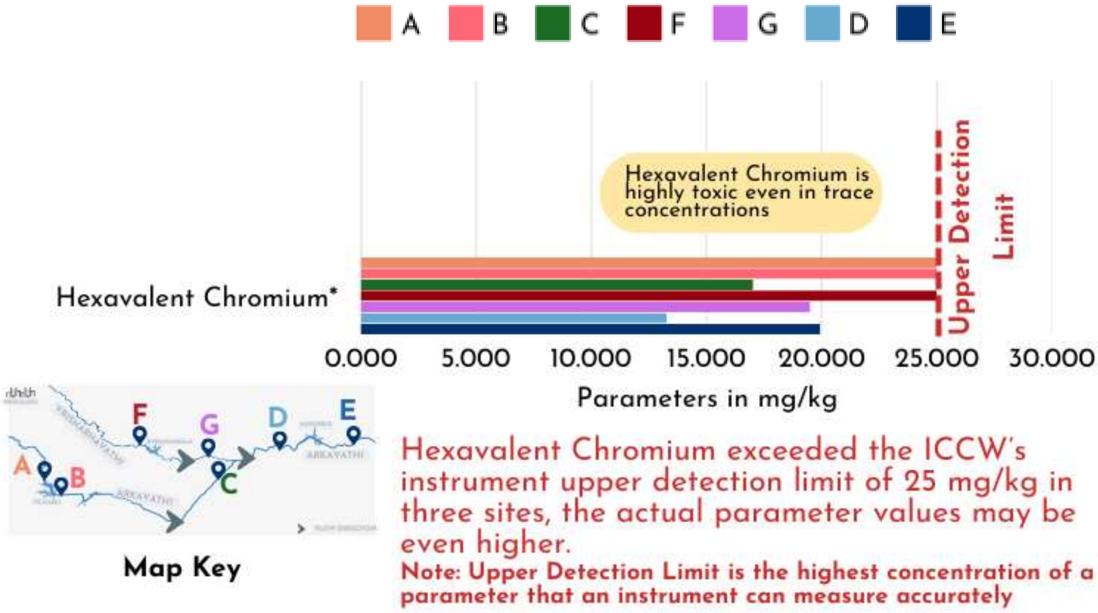
Compared to other testing categories, heavy metal pollution was distributed across sites. For example, Sites D and E demonstrated a spike in Selenium and Site C was the only site with detected levels of Antimony. The presence of heavy metals across sites is reflective of mining and industrial pollution in the area. See Figure 36 for an overview of heavy metals detected.

Figure 36: Heavy Metals Across Sites



As shown in Figure 37, extremely high levels of Hexavalent Chromium were detected, even exceeding the upper detection limits possible with ICCW instruments.

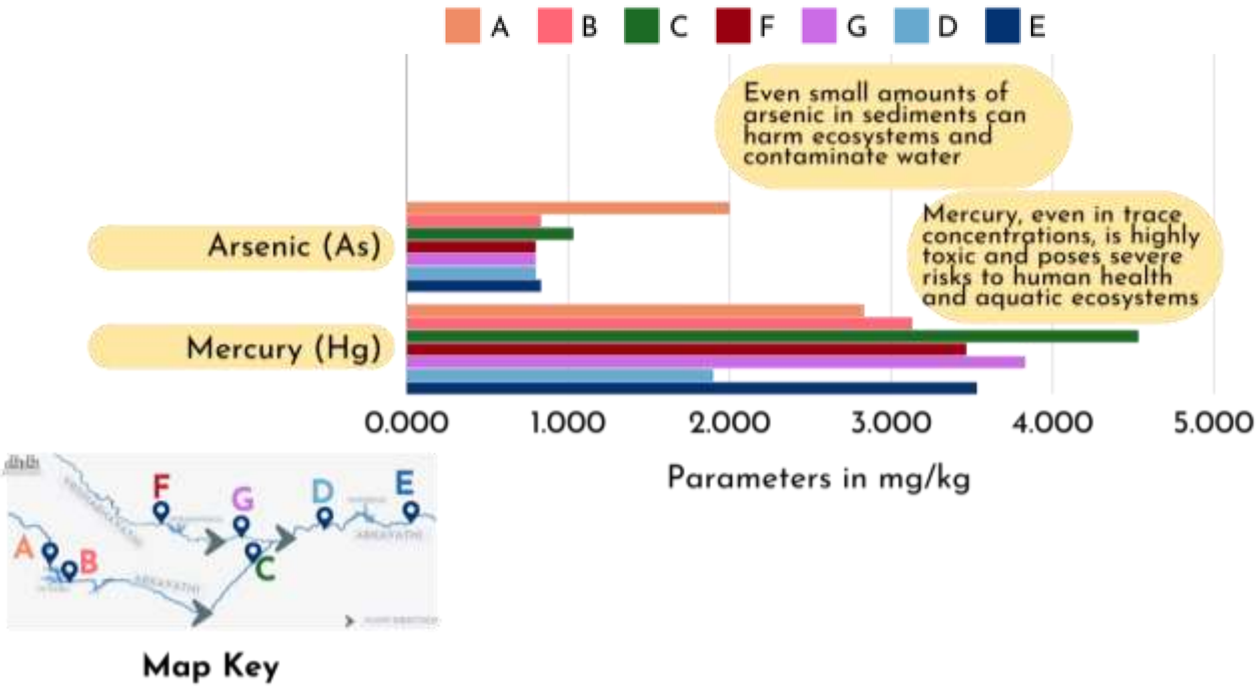
Figure 37: Hexavalent Chromium Across Sites



High levels of Chromium in surface sediments, along with elevated EC and TDS in water samples, indicate ongoing chromium pollution likely originating from electroplating industries. This aligns with chromium contamination in groundwater highlighted in the action plan for the Peenya Industrial Area. As per the Ministry of Environment, Forest & Climate Change (MoEFCC), Government of India, Office Memorandum No. J-11013/5/2010-1A.II(I) dated 13.01.2010, Peenya Industrial Area has been declared a severely polluted area with a CEPI score of 65.11, further reinforcing its status as a pollution hotspot.

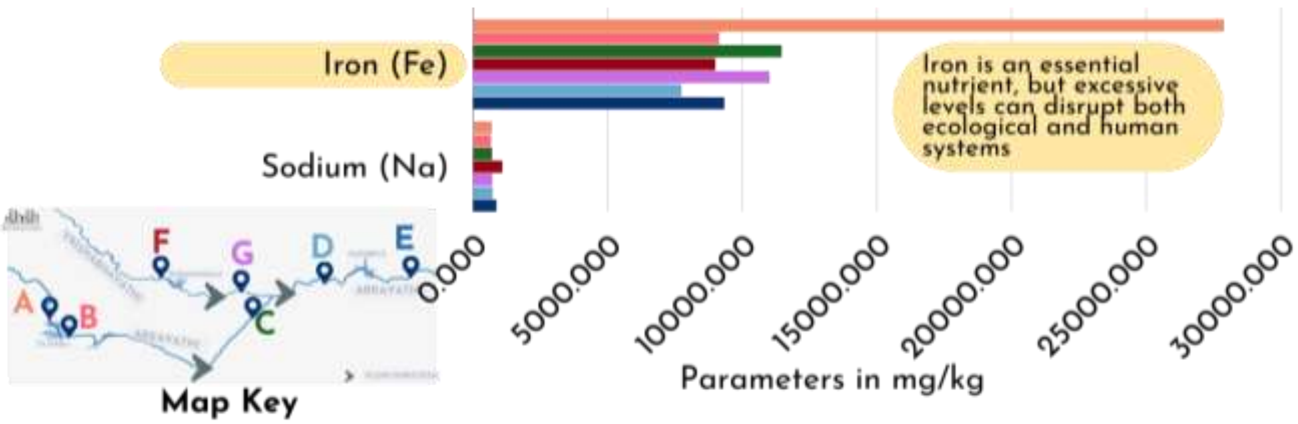
The presence of Arsenic and Mercury (Hg) across all sites is shown in Figure 38. These parameters indicate significant industrial pollution, likely from e-waste recycling, chrome plating, insulating materials manufacturing, and discharges from paint factories. Their widespread detection highlights the urgent need for stricter industrial regulations.

Figure 38: Sensitive Heavy Metals Across Sites



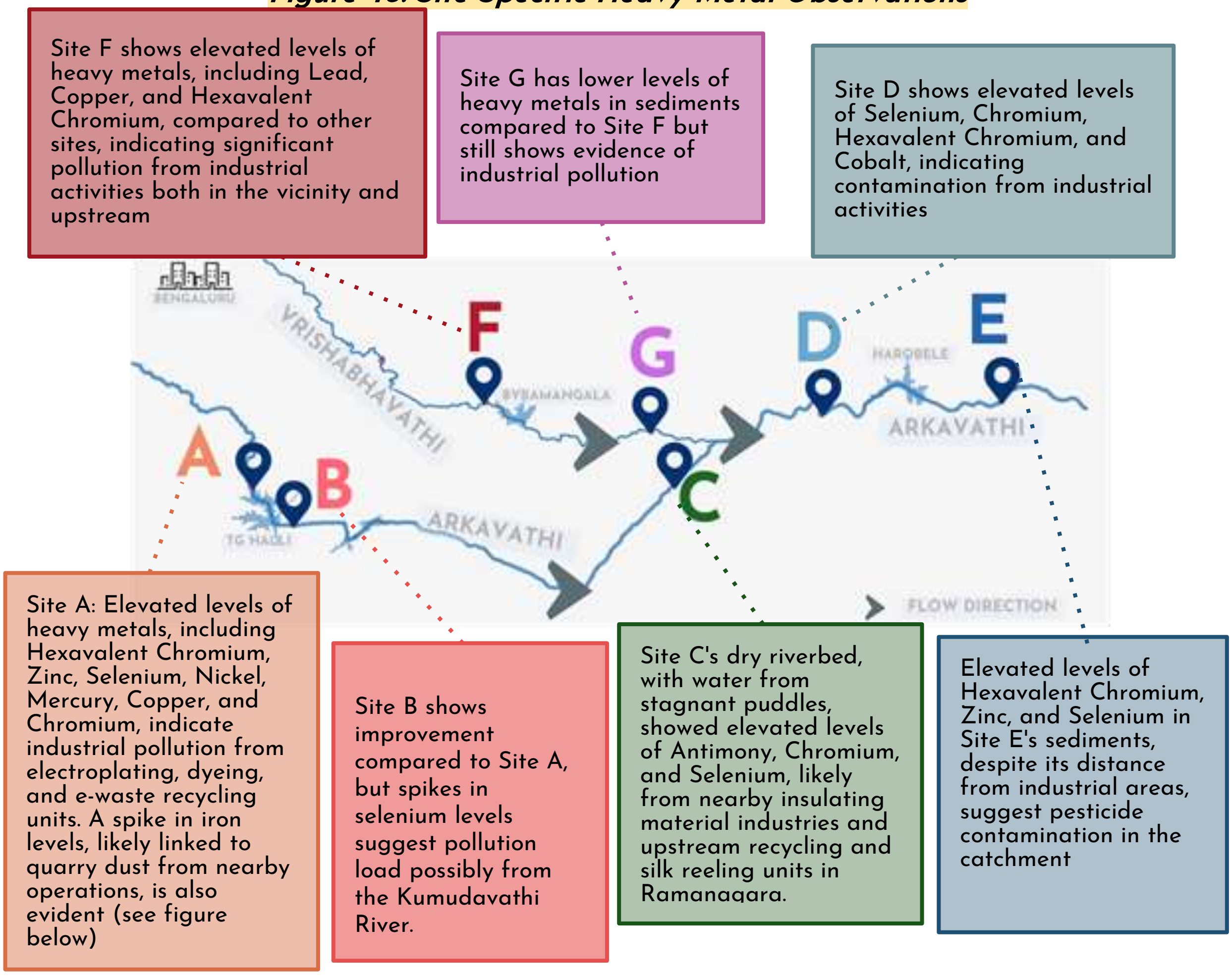
While Iron and Sodium occur naturally in soil in relatively high concentrations compared to other heavy metals, excess levels such as those exhibited at Site A can indicate pollution. See Figure 39 for an overview of these parameters.

Figure 39: Iron and Sodium Across Sites



The heavy metal concentrations stand as evidence of rampant industrial pollution—an open secret repeatedly highlighted over the years by news media and Citizen Matters. Despite this, the long-promised Common Effluent Treatment Plant at Peenya remains incomplete and unlikely to address the wide range of toxic effluents, including those from chrome plating, dyeing, and paint manufacturing industries. Trends across sites are shown in Figure 40.

Figure 40: Site Specific Heavy Metal Observations

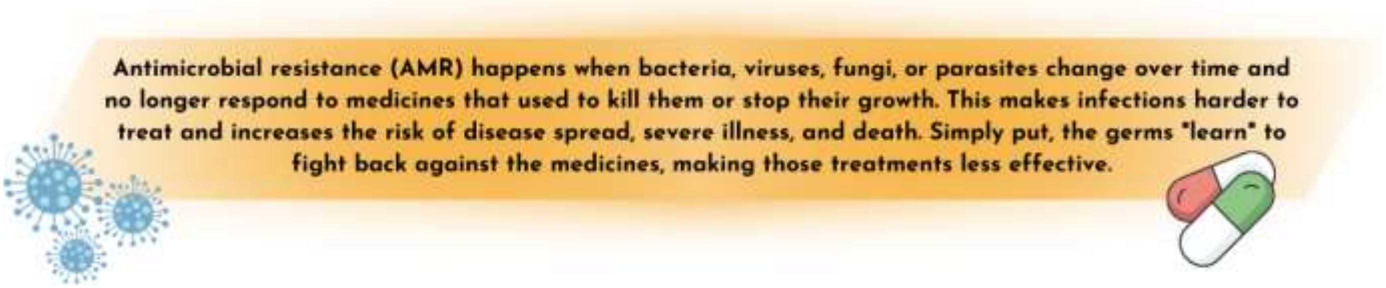


Aligned with the high levels of heavy metal pollution, Paani observed quarry dust adjacent to the river upstream of Site A possibly contributing to the iron concentration in the sediments. This dumping is shown in Figure 41.

Figure 41: Quarry Dust Dumped next to the Arkavathi River Bank, Upstream of Site A

Heavy metals in water contribute to the rise of antimicrobial resistance (AMR) described in Figure 42. They pressure bacteria to become resistant to both metals and antibiotics. This happens because the same genes often control resistance to both, and these genes can spread between bacteria. Heavy metals in rivers and sediments create conditions where resistant bacteria can grow, worsening the AMR problem[21]. Antibiotic resistance has caused over a million deaths annually since 1990 and could claim over 39 million lives by 2050 without urgent action, according to the Global Research on Antimicrobial Resistance (GRAM) Project. **South Asia, including India, Pakistan, and Bangladesh, is projected to bear the highest burden, with 11.8 million AMR-related deaths expected between 2025 and 2050**.

Figure 42: What is Antimicrobial Resistance?



The presence of heavy metals in river sediments indicates that effluents containing these pollutants are entering the river, likely from industrial discharges or other sources. These metals settle into the sediment but can leach into the water, contaminating it further. When this polluted water is used for irrigation, heavy metals are absorbed by crops and accumulate in their tissues - a process known as bioaccumulation. Metals like Mercury, Cadmium, Arsenic, and Lead concentrate in the edible parts of plants, posing significant health risks to consumers, including kidney damage, neurological disorders, and cancer. A study by researchers from the Environment Management and Policy Research Institute (EMPRI) highlights this issue, flagging heavy metal contamination in vegetables across Bengaluru. They collected 400 samples from 20 stores, including high-end supermarkets and local markets, and found alarming levels of contamination in commonly consumed vegetables.

[21] Heavy Metal Pollution Impacts Soil Bacterial Community Structure and Antimicrobial Resistance at the Birmingham 35th Avenue Superfund Site | Microbiology Spectrum

Physicochemical Results in Sediments

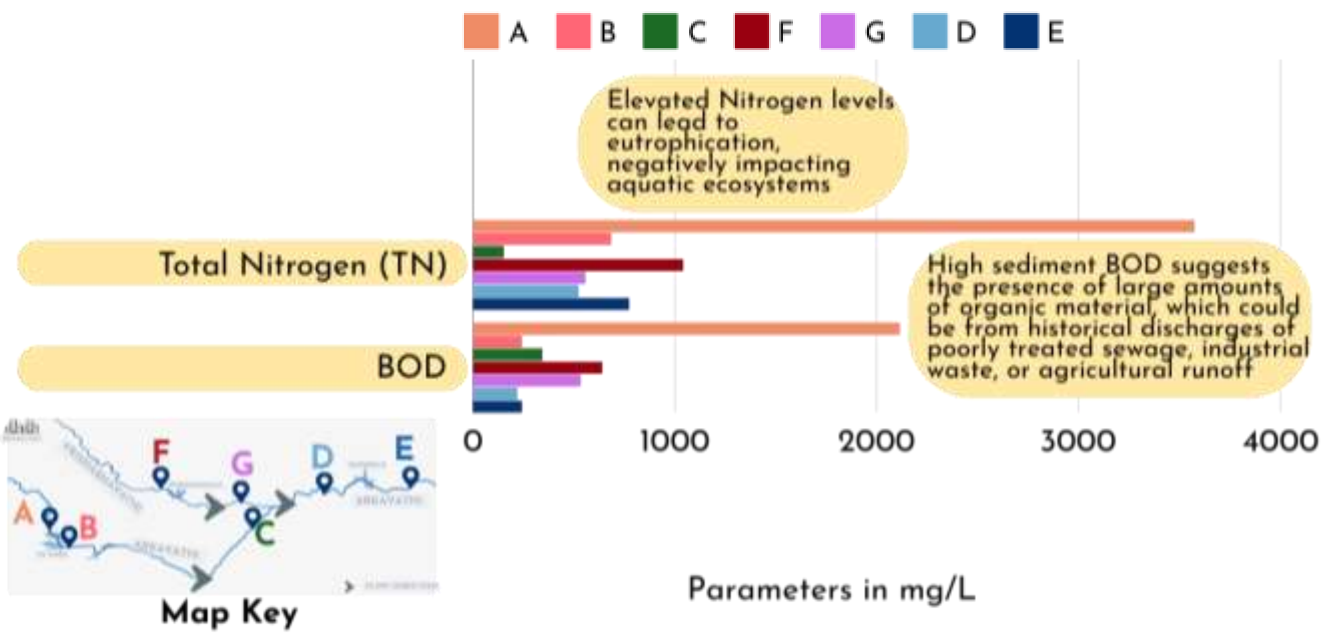
Figure 43 lists the three physicochemical parameters that Paani tested. Physicochemical parameters of sediments including Total Nitrogen and Available Phosphorus indicate the viability of the sediment to support aquatic life and potential agriculture in the region. Access Appendix F for detailed results.

Figure 43: Physicochemical Parameters in Sediments

Total Nitrogen (TN), BOD, Available Phosphorus

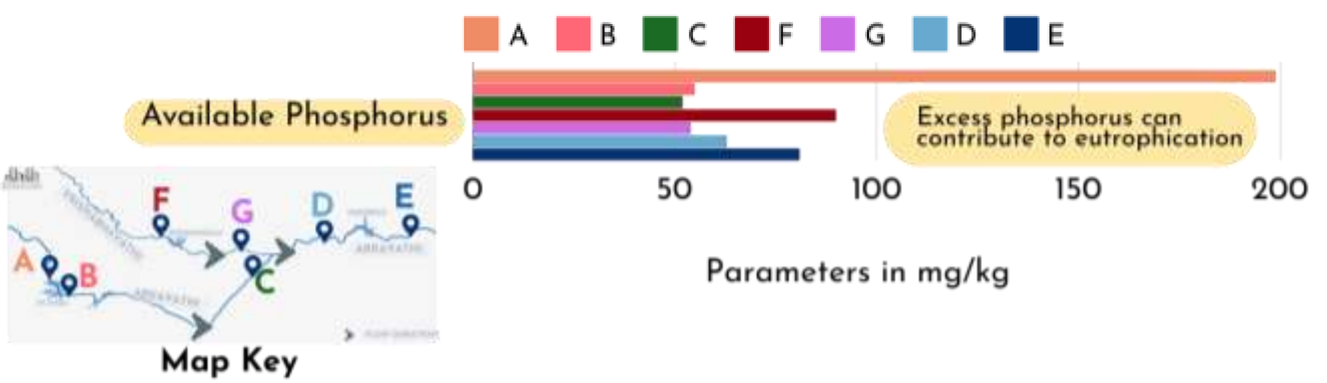
The Arkavathi River's deteriorating health is evident in the **physicochemical parameter levels** of its sediments, which reveal the extent of pollution it endures. Figure 44 tells a troubling story: elevated nitrogen levels threaten aquatic ecosystems through eutrophication, high BOD signals the presence of excessive organic waste, and phosphorus concentrations shown in Figure 45 point to nutrient overloading, often from detergents and other domestic discharges. These findings, linked to untreated sewage, industrial discharges, and agricultural runoff, highlight critical pollution hotspots.

Figure 44: Physicochemical Parameters in Sediments Across Sites



Phosphorus was identified in high concentrations across multiple sites as shown in Figure 45 further contributing to eutrophication in the Arkavathi.

Figure 45: Phosphorus in Sediments Across Sites

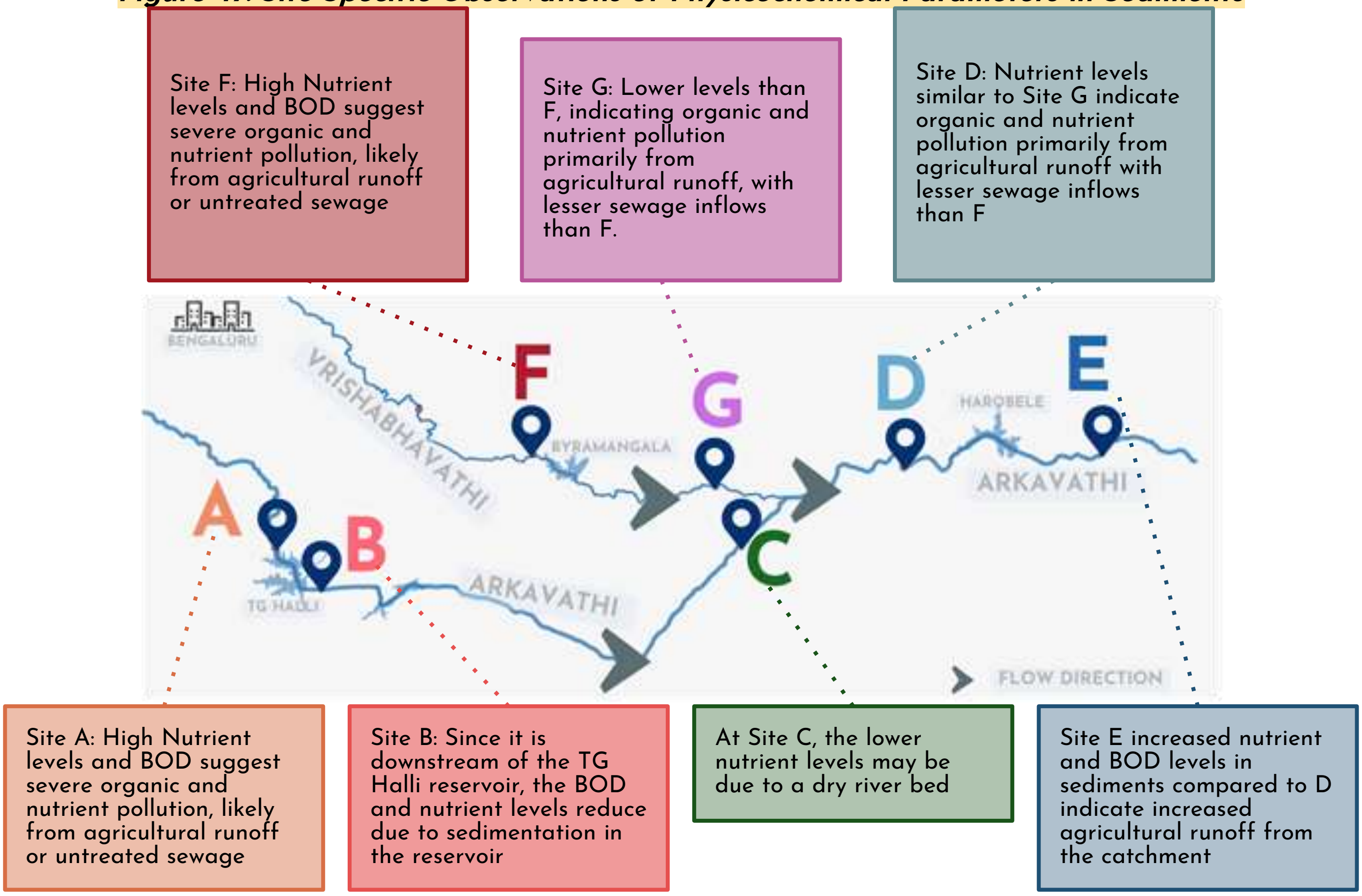


India has made limited progress in regulating phosphates in detergents, despite their role in water pollution and eutrophication. Unlike the USA and EU, where strict bans exist, India relies on voluntary standards set by the Bureau of Indian Standards (BIS). Phosphate-laden wastewater continues to degrade rivers and lakes, causing foaming and ecosystem collapse, as seen in Bengaluru's lakes. Experts emphasize the urgent need for a nationwide ban to protect aquatic ecosystems. Experts have also called for a ban on phosphates in detergents to protect Bengaluru's lakes. See Figure 46 where visible foaming is seen along the Vrishabhavathi.

Figure 46: Foaming Downstream of Byramangala

Figure 47 shows trends in physicochemical parameter trends in sediment across test sites.

Figure 47: Site Specific Observations of Physicochemical Parameters in Sediments



Analysis

The results of this study demonstrate that Arkavathi water and sediment fall short of the following five national and international recommended pollution standards and guidelines:

- India's Designated-Best-Use Water Quality Criteria
- United States' National Recommended Water Quality Criteria for Human Health
- European Union's Environmental Quality Standards (EQS) for Priority Substances and Certain Other Pollutants
- Canada's Water Quality Guidelines for the Protection of Aquatic Life
- Canada's Sediment Quality Guidelines for the Protection of Aquatic Life

*In addition to the above, we contrast India's Designated-Best-Use Water Quality Criteria to Canada's Water Quality Guidelines for the Protection of Agricultural Water Uses to illustrate the gap in the rigor of the guidelines.

In particular, PAH and pesticide levels were far above guidelines.

Paani selected this set of standards and guidelines to provide a greater level of rigor than national Designated-Best-Use criteria. These international standards and guidelines consider human health and aquatic health outcomes of water quality and sediment prior to treatment. They consider invisible pollutants like PAHs, phthalates and pesticides, and heavy metals not considered under Central Pollution Control Board guidelines.

Paani used the formula in Figure 48 to determine pollutants of concern per these international guidelines.

Figure 48: Methodology for Comparing Parameters to Guidelines

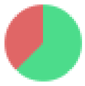
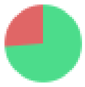
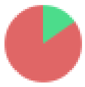
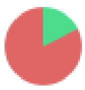
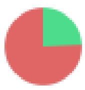
$$\frac{\text{Paani Parameter Measurement}}{\text{Regulatory Guideline}} \times 100$$

>= 75%	CONCERNING
< 75%	WITHIN LIMITS

Given that many pollutants in Indian waters lack specific regulatory thresholds, we have adopted a precautionary benchmark of 75%. This precautionary approach acknowledges that rivers subjected to continuous pollution rarely operate within ideal parameters and allows for early detection of concerning trends. The majority of parameters far exceeded international guidelines with some pollutants found at levels up to 2500000% (or 25,000 times above the guideline limits). While it is easy to focus on these large concentrations, any pollutant approaching a guideline limit poses a risk to the Arkavathi.

For each guideline, Paani testing covered a subset of all regulated pollutants. Pollutants were matched to guidelines using the CAS numbers shown in Appendix G. Table 06 provides a description of each standard/guideline and the scope and outcomes of Paani's testing as compared to each standard/guideline. Following this, we provide a detailed overview of testing outcomes per each guideline.

Table 06: Test Results Compared To International Guidelines

Guideline		Description	# Criteria Tested	Parameters in Guideline Tested Red indicates at least one site over 75% of limit
	Designated-Best-Use Water Quality Criteria	CPCB criteria outlining five recommended groups for water use ranging from irrigation to drinking water	5/8 	1 BOD 2 pH 4 DO 6 EC 8 Ammonia as NH_3
	National Recommended Water Quality Criteria for Human Health (Consumption of Organism Only)	Recommended criteria to not have adverse effect to human health from consumption of organisms from a body of water	28/38 	28 Beta lindane 30 Alpha lindane 31 Gamma lindane 32 Heptachlor 33 Heptachlor epoxide 34 Chlordane 35 Alpha endosulfan 37 p, p'-DDE 38 Endrin aldehyde 39 Endosulfan sulfate 40 p, p'-DDT 41 Methoxychlor 45 2-Chloronaphthalene 46 Acenaphthene 47 Fluorene 49 Fluoranthene 50 Pyrene 53 Chrysene 54 Dibenz[a,h]anthracene 56 Dibutylphthalate 57 Benzylbutylphthalate 58 Bis(2-ethylhexyl)phthalate 59 2,4-Dimethylphenol 60 2,4-Dichlorophenol 61 4-Chloro-3-methylphenol 62 Bis(2-chloroethyl) ether 63 Nitrobenzene 64 Isophorone
	Environmental Quality Standards (EQS) for Priority Substances and Certain Other Pollutants	Standards to achieve good surface water chemical status considering harmful priority substances	5/33 	40 p, p'-DDT 44 Naphthalene 49 Fluoranthene 55 Benzo[ghi] perylene 58 Bis(2-ethylhexyl)phthalate
	Water Quality Guidelines for the Protection of Aquatic Life (Freshwater Long Term)	Water quality intended to protect all forms of aquatic life across life cycles	21/119 	2 pH 4 DO 5 Temperature 7 Turbidity 8 Ammonia as NH_3 10 Chloride (Cl^-) 19 Nitrate (NO_3) 21 Fluoride (F^-) 23 Total Phosphorus 24 Hexavalent Chromium (Chromium (VI)) 31 Gamma lindane 32 Heptachlor 34 Chlordane 44 Naphthalene 46 Acenaphthene 47 Fluorene 49 Fluoranthene 50 Pyrene 56 Dibutylphthalate 58 Bis(2-ethylhexyl)phthalate 60 2,4-Dichlorophenol
	Sediment Quality Guidelines for the Protection of Aquatic Life (Freshwater Interim Sediment Quality Guideline)	Guidelines to protect aquatic life from exposure to substances associated with bed sediments	8/33 	67 Arsenic (As) 70 Cadmium (Cd) 71 Chromium (Cr) 73 Copper (Cu) 75 Lead (Pb) 77 Mercury (Hg) 81 Zinc (Zn)

Results: India Designated-Best-Use Water Quality Criteria

The CPCB's Designated-Best-Use Criteria outlines five recommended classes for water use based on eight physicochemical parameters (see Appendix H) ranging from stringent to less stringent criteria:

- Class A: Drinking Water Source without conventional treatment but after disinfection
- Class B: Outdoor bathing (Organised)
- Class C: Drinking water source after conventional treatment and disinfection
- Class D: Propagation of Wildlife and Fisheries
- Class E: Irrigation, Industrial Cooling, Controlled Waste disposal
- N/A: Fails to meet any class

When compared to other frameworks, such as those of the EU and United States, there are relatively few best-use criteria and limited means of enforcement in India. Nonetheless, Arkavathi water was not found suitable for the majority of uses. Testing results varied across test sites with the highest class of C and the lowest of N/A (fails to meet any class) at Site A as shown in Table 07 and visualized in Figure 49. Overall, Ammonia and BOD levels were the primary limiting factor for river water quality when compared to best-use criteria.

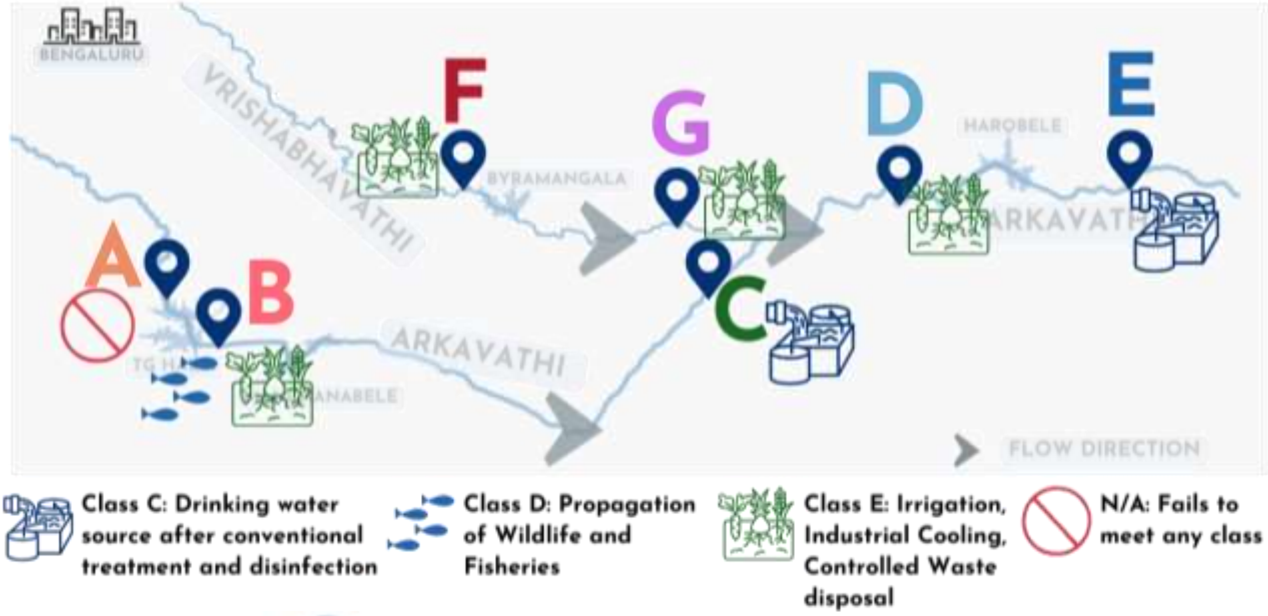
Table 07: Test Results Compared to India Designated-Best-Use Water Quality Criteria

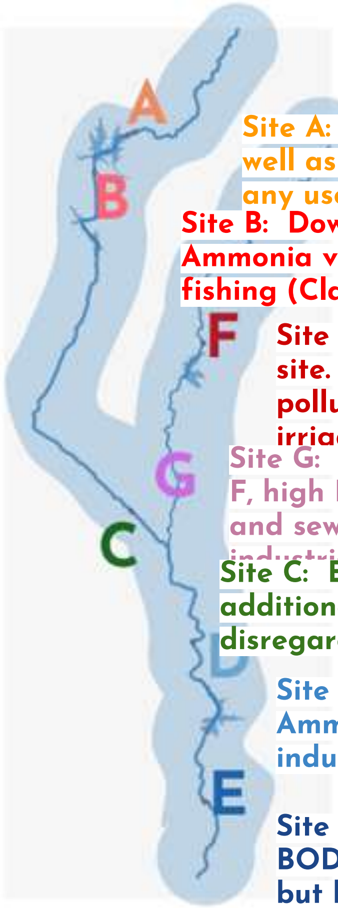
Alphabets in blue indicate the recommended use at test site based on each parameter in the CPCB criteria.
Cells highlighted in pink indicate that the parameter concentration is a concern at the specific site.
Alphabets in red in the last row indicate the recommended use based on all parameters in the CPCB criteria.

				RECOMMENDED USE AT TEST SITE BASED ON EACH PARAMETER IN THE CPCB CRITERIA						
				ARKAVATHI					VRISHABHAVATHI	
#	PARAMETER	LIMIT	UNIT	Site A	Site B	Site C	Site D	Site E	Site F	Site G
1	BOD*	Class A: <= 2 Class B: <= 3 Class C: <= 3 Class D: N/A Class E: N/A	mg/L	D, E	D,E	Not Tested	D,E	B,C,D,E	D,E	D,E
2	pH	Class A: 6.5 - 8.5 Class B: 6.5 - 8.5 Class C: 6.5 - 9.0 Class D: 6.5 - 8.5 Class E: 6.5 - 8.5	pH Scale	A,B,C,D,E	A,B,C,D,E	C	A,B,C,D,E	C	A,B,C,D,E	A,B,C,D,E
4	DO	Class A: >= 6 Class B: >= 5 Class C: >= 4 Class D: >= 4 Class E: N/A	mg/L	A,B,C,D,E	A,B,C,D,E	A,B,C,D,E	A,B,C,D,E	A,B,C,D,E	E	A,B,C,D,E
6	EC	ClassA: N/A ClassB: N/A ClassC: N/A ClassD: N/A ClassE: <= 2250	μS/cm	A,B,C,D	A,B,C,D,E	A,B,C,D,E	A,B,C,D,E	A,B,C,D,E	A,B,C,D,E	A,B,C,D,E
8	Ammonia as NH_3	Class A: N/A Class B: N/A Class C: N/A Class D: <= 1.2 Class E: N/A	mg/L	A,B,C,E	A,B,C,D,E	A,B,C,D,E	A,B,C,E	A,B,C,D,E	A,B,C,E	A,B,C,E
RECOMMENDED USES FOR EACH SITE BASED ON ALL PARAMETERS IN THE CPCB CRITERIA				**N/A**	**D,E**	**C**	**E**	**C**	**E**	**E**

* BOD testing measured 3 day BOD, while the CPCB criteria addresses 5-day BOD.

Figure 49: Recommended uses based CPCB Designated Best Use Along River





Site A: High BOD, Ammonia and EC indicating industrial as well as sewage pollution are making the water unsuitable for any use (Class N/A)..

Site B: Downstream of the TG Halli reservoir, the BOD, EC and Ammonia values improve to allow for more potential uses like fishing (Class D) and irrigation (Class E).

Site F: Exhibits the highest EC and Ammonia of any site. This pollution is likely caused by industrial pollution and sewage and it limits appropriate use to irrigation and industrial cooling (Class E).

Site G: Though the parameter values improved from Site F, high EC and Ammonia, likely from industrial pollution and sewage limit appropriate use to irrigation and industrial cooling (Class E).

Site C: EC and Ammonia levels improve but high pH limits additional uses (Class C). Notably, best use at Site C can be disregarded, as the river bed was dry at this location

Site D: Downstream of Kanakapura Town, high BOD and Ammonia limit the appropriate use to irrigation and industrial cooling (Class E)

Site E: The final site downstreams shows the lowest BOD and Ammonia levels compared to other sites but high pH limits additional best uses (Class C).

Are the polluted waters of Arkavathi truly suitable for Agriculture?

Indian criteria for agricultural use (Class E) are limited. In contrast, Canada's Water Quality Guidelines for the Protection of Agricultural Water Uses considers 41 unique pollutants for irrigation. Of the four pollutants with Canadian guidelines tested in our study, we found:

- Hexavalent Chromium ranging from **8 to 36x** permissible levels across sites
- Fluoride levels above limits at five out of seven sites
- Chloride levels **unsuitable for fruit production**
- TDS levels **unsuitable for fruit production**

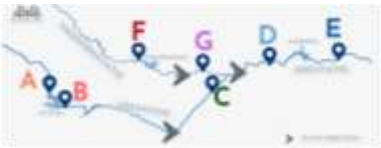
In short, Arkavathi water fails to meet stricter guidelines for irrigation and agriculture.

Results: United States National Recommended Water Quality Criteria for Human Health (Consumption of Organism Only)

The United States Environmental Protection Agency (US EPA) maintains 38 recommended criteria that U.S. states may use to facilitate the safe consumption of water and organisms that live in water bodies. Given that the Arkavathi River is home to fishing activity and is not used as a direct source of drinking water, only guidelines for consumption of organisms were considered in this analysis. The full guidelines are available in Appendix I.

The US EPA also maintains a list of "priority pollutants" to limit the discharge of highly toxic pollutants in waterways. Every single one of the 28 US EPA parameters tested by Paani, except for Methoxychlor, are regulated as priority pollutants.
Table 08 compiles all parameters where at least one Test Site exceeded 75% or more of the US EPA recommended values. All values over Paani's recommended limit of 75% are highlighted in red.

Table 08: Test Results Compared to US EPA Recommended Water Quality Criteria for Human Health (Consumption Of Organism Only)



				PERCENT OF GUIDELINE LIMIT FOUND AT EACH TEST SITE						
				ARKAVATHI					VRISHABHAVATHI	
#	**PARAMETER**	**LIMIT**	**UNIT**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
28	Beta lindane	0.014	µg/L	**2269%**	Not tested					
30	Alpha lindane	0.00039	µg/L	**158376%**						
32	Heptachlor	0.0000059	µg/L	**1135593%**						
33	Heptachlor epoxide	0.000032	µg/L	**780208%**						
37	p, p'-DDE	0.000018	µg/L	**1024074%**						
38	Endrin aldehyde	1.00	µg/L	**245%**						
40	p, p'-DDT	0.00003	µg/L	**2502222%**						
41	Methoxychlor	0.02	µg/L	**123%**						
53	Chrysene	0.13	µg/L	4%	4%	4%	1%	2%	**514%**	3%
54	Dibenz[a,h] anthracene	0.00013	µg/L	**49744%**	**307692%**	**17436%**	**249744%**	**113590%**	**151538%**	**18462%**
57	Benzylbutyl Phthalate	0.10	µg/L	**378%**	**201%**	**146%**	**203%**	**148%**	**181%**	**419%**
58	Bis(2-ethylhexyl) phthalate	0.37	µg/L	**4236%**	**7139%**	**9428%**	**4344%**	**5760%**	**5495%**	**6597%**
62	Bis(2-chloroethyl)	2.2	µg/L	55%	**75%**	48%	64%	25%	**92%**	54%

The high levels of pesticides and industrial and hazardous organic pollutants identified in the Arkavathi pose a major risk to human and ecosystem health alike. In many cases, the pollutant levels did not just exceed US EPA guidelines for organism consumption, but were more than 1000 times above limits. Per these outcomes, consumption of organisms from the Arkavathi is not recommended.

High pesticide levels such as those of DDT and Heptachlor may cause liver damage, accumulate in body tissues, and impact reproductive health[22]. In addition to health impacts, the excessive use of pesticides can create pesticide resistance which could impact productivity of agriculture around Site A.

[22] DDT - A Brief History and Status | US EPA

High PAH levels can cause cancer, reduce lung function, and may impair cognitive ability in children (WHO). Of the PAHs tested, Dibenz[a,h]anthracene most exceeded limits for safe consumption. This PAH is associated with neuroblastoma risk in children and stomach tumors (NIH).

Results: European Union Environmental Quality Standards (EQS) for Priority Substances and Certain Other Pollutants

The EU EQS were created in 2008 with the intention to protect aquatic organisms, biodiversity, and human health from 33 harmful pollutants listed in Appendix J. Of the EQS tested by Paani in this study, four out of five were above quality standards. Table 09 compiles all parameters where at least one Test Site exceeded 75% or more of the EU recommended values. All values over Paani's recommended limit of 75% are highlighted in red.

Table 09: Test Results Compared to European Union Environmental Quality Standards

				PERCENT OF STANDARD LIMIT FOUND AT EACH TEST SITE						
				ARKAVATHI					VRISHABHAVATHI	
#	**PARAMETER**	**LIMIT**	**UNIT**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
40	p, p'-DDT	0.01	µg/L	**7507%**	Not Tested					
49	Fluoranthene	0.1	µg/L	**204%**	**445%**	**113%**	**290%**	**163%**	**273%**	**178%**
55	Benzo[ghi] perylene	.002	µg/L	**283%**	**350%**	**250%**	**433%**	**217%**	**2867%**	**83%**
58	Bis(2-ethylhexyl) phthalate	1.3	µg/L	**1206%**	**2032%**	**2683%**	**1236%**	**1639%**	**1564%**	**1877%**

Of these parameters, levels of the pesticide DDT most greatly exceeded EU standards. DDT was found at site A at a concentration 75 times above standard levels. This high concentration not only poses risks to human health, but indicates prevalence in use of an illegal substance.

All test sites performed poorly in Industrial and Hazardous Organic Pollutant levels, with notably high exceedances for Bis(2-ethylhexyl) phthalate and a major spike in Benzo[ghi]perylene levels visible at Site F. Benzo[ghi]perylene is extremely toxic to aquatic life and can cause growth and increases in adrenal and nasal gland weight in birds[23]. Bis(2-ethylhexyl)phthalate, also known as DEHP, is a chemical substance used in industry to make plastic more flexible. At high concentrations it is a carcinogen associated with liver and reproductive health issues[24].

Results: Canada Water Quality Guidelines for the Protection of Aquatic Life (Freshwater Long Term)

The Canadian Water Quality Guidelines for the Protection of Aquatic Life emphasize the importance of pollution management to preserve aquatic ecosystems. The guidelines consider all aquatic life stages, from egg to adulthood to set limits for 119 physicochemical properties, pesticides, and industrial and hazardous organic pollutants included in Appendix K. The guidelines include recommended limits for both marine and freshwater ecosystems and long and short-term exposure. This study compares test site parameters to the long-term freshwater guidelines. Notably, at least two parameters from each category (physicochemical properties, pesticides, and industrial and hazardous organic pollutants) exceeded guideline limits, indicating the challenges facing aquatic life in the Arkavathi. The inclusion of

[23] BENZO(ghi)PERYLENE | C22H12 | CID 9117 - PubChem
[24] Di(2-Ethylhexyl)Phthalate (DEHP) | Toxic Substances

physicochemical elements in criteria shows that high levels of organic pollution also places a burden on ecosystem health.

14 out of 21 parameters tested exceeded guidelines values. Table 10 compiles all parameters where at least one Test Site exceeded 75% or more of Freshwater Longterm guideline values. All values over Paani's recommended limit of 75% are highlighted in red.

Table 10: Test Results Compared to Canada Water Quality Guidelines for the Protection of Aquatic Life (Freshwater Long Term)

#	PARAMETER	LIMIT	UNIT	A	B	C	D	E	F	G
				PERCENT OF GUIDELINE LIMIT FOUND AT EACH TEST SITE						
				ARKAVATHI					VRISHABHAVATHI	
4	DO	6000	µg/L	Within Range	Within Range	Within Range	Within Range	Within Range	**Below Range**	Within Range
8	Ammonia as NH_3	19	µg/L	**15789%**	**5263%**	**1754%**	**15789%**	**1754%**	**15789%**	**15789%**
10	Chloride (Cl^-)	120000	µg/L	**305%**	**186%**	**201%**	**155%**	**158%**	**132%**	**158%**
19	Nitrate (NO_3)	13000	µg/L	**882%**	**818%**	**685%**	**1900%**	**944%**	**2095%**	**918%**
21	Fluoride (F^-)	120	µg/L	**722%**	**667%**	**2611%**	**3444%**	**3417%**	**30722%**	**1472%**
23	Total Phosphorus	Mesotrophic: 10-20 Meso-eutrophic: 20-35 Eutrophic: 35-100 Hyper-eutrophic: >100	µg/L	**Hyper-Eutrophic**	**Hyper-Eutrophic**	**Hyper-Eutrophic**	**Hyper-Eutrophic**	**Hyper-Eutrophic**	**Hyper-Eutrophic**	**Hyper-Eutrophic**
24	Hexavalent Chromium (Chromium (VI))	1.0	µg/L	**10000%**	**10000%**	**6667%**	**13333%**	**6667%**	**30000%**	**10000%**
31	Gamma lindane	0.01	µg/L	**7980%**	Not Tested					
32	Heptachlor	0.01	µg/L	**670%**						
44	Naphthalene	1.1	µg/L	34%	**101%**	13%	68%	62%	59%	31%
47	Fluorene	3.0	µg/L	18%	**92%**	2%	**91%**	63%	**84%**	3%
49	Fluoranthene	0.04	µg/L	**510%**	**1113%**	**283%**	**725%**	**408%**	**683%**	**445%**
50	Pyrene	0.025	µg/L	**423%**	**1227%**	**199%**	**803%**	**460%**	**815%**	**305%**
58	Bis (2-ethylhexyl) phthalate	16	µg/L	**98%**	**165%**	**218%**	**100%**	**133%**	**127%**	**153%**
60	2,4-Dichloro phenol	0.2	µg/L	**75%**	18%	15%	22%	14%	**176%**	67%

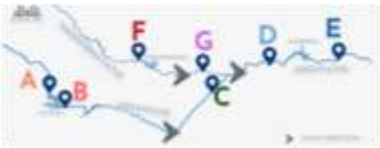
Canadian guidelines for physicochemical parameters are stricter than Indian guidelines. Compared to Designated-Best-Use, the allowable level of Ammonia for Class D is over 60x higher than Canadian guidelines. Additionally, ammonia levels are not regulated for other water use classes in India. Per the US EPA, Ammonia is toxic, known for causing fish kills and abnormal organ growth in fish. Assessment of phosphorus levels demonstrates that Arkavathi water is eutrophic and unsuitable for aquatic life. This was also affirmed by visual observations of water hyacinth and other plant growth.

Results: Canada Sediment Quality Guidelines for the Protection of Aquatic Life (Freshwater Interim Sediment Quality Guideline)

The [Canadian Sediment Quality Guidelines for the Protection of Aquatic Life](#) establish guidelines to protect all stages of aquatic life for an indefinite period of time from 33 substances associated with river bed sediments. The regulated substances are listed in Appendix L. This comparison is critical because it evaluates the longer term pollutants stored in river sediment. Similar to Canadian guidelines for water, the Sediment Quality Guidelines specify values for freshwater and marine environments. The guidelines also specify recommended values for longer term known as interim sediment quality guidelines (ISQG) and shorter term probable effects level (PEL). This study compares parameter measurements to the freshwater ISQG.

Five out of eight parameters tested under this guideline exceeded recommended values. Table 11 compiles all parameters where at least one Test Site exceeded Freshwater ISQC. All values over Paani's recommended limit of 75% are highlighted in red.

Table 11: Test Results Compared to Canada Sediment Quality Guidelines for the Protection of Aquatic Life (Freshwater Interim Sediment Quality Guideline)



				PERCENT OF GUIDELINE LIMIT FOUND AT EACH TEST SITE						
				ARKAVATHI					VRISHABHAVATHI	
#	PARAMETER	LIMIT	UNIT	A	B	C	D	E	F	G
70	Cadmium (Cd)	600	µg/kg	44%	5%	8%	44%	14%	**1239%**	89%
71	Chromium (Cr)	37,300	µg/kg	**161%**	**85%**	**114%**	**100%**	**94%**	**137%**	**125%**
73	Copper (Cu)	35,700	µg/kg	**115%**	24%	14%	23%	8%	**297%**	35%
75	Lead (Pb)	35,000	µg/kg	49%	4%	2%	1%	2%	**158%**	9%
77	Mercury (Hg)	170	µg/kg	**1667%**	**1843%**	**2667%**	**1118%**	**2078%**	**2039%**	**2255%**
81	Zinc (Zn)	123,000	µg/kg	**80%**	3%	26%	8%	25%	23%	40%

Of the heavy metals tested, mercury levels most exceeded guidelines, ranging from **11 to 20x** higher than ISQG at all test sites. Mercury is toxic and easily stored by fish and wildlife and passed to humans through consumption. Mercury consumption can harm fetal development, is associated with cancer, and accordingly is considered a top ten chemical of public health concern by the World Health Organisation[25]. Site F along the Vrishabhavathi had the worst performance compared to Canadian guidelines, and demonstrated a notable spike in Cadmium not present in other test sites. Cadmium is toxic to humans and affects kidneys and the skeletal system. It is produced through industry, sewage, and fertilizer use[26].

Finally, Chromium is a toxic chemical produced frequently as a byproduct of chrome plating that poses a great threat to human and ecosystem health. Chromium may cause skin irritation, harm plant growth, and accumulate in tissues over time[27]. Chromium and other heavy metals present a toxic environment for aquatic life in the Arkavathi.

[25] Mercury Factsheet
[26] Cadmium | UNEP - UN Environment Programme
[27] Chromium contamination and effect on environmental health and its remediation: A sustainable approaches - PubMed

Evidence Through the Years

Paani's testing results in 2024 build on research from the last two decades that has consistently highlighted the alarming extent of pollution in the Arkavathi River and its connected water bodies. The evidence has long been there - from heavy metal contamination to the evolution of multidrug-resistant bacteria - revealing the severe impact of industrial effluents, untreated sewage, and inadequate monitoring systems. Key findings from a few studies are listed below:

2021: Indian Institute of Technology Madras Researchers have found that the waters of River Cauvery are polluted by a range of emerging contaminants that include pharmaceutically-active compounds, personal care products, plastics, flame retardants, heavy metals, and pesticides, among many others. One of the sampling stations is along the river Arkavathi[28]

2020: NEERI study highlighted industrial pollution from the Peenya Industrial Area as a significant contributor to the degradation of the Vrishabhavathi River. The study noted that the V200 drain, which runs alongside the Peenya Industrial Area, displayed a clear demarcation between untreated industrial effluents and domestic sewage, indicating direct discharge from industries. This finding underscores the pressing need for stricter enforcement of effluent management in the area.

2018: An analysis of effluent samples collected from tankers illegally discharging into the river at RR Nagar in January 2018 revealed that the effluents contained high levels of pollutants, including heavy metals, Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD). These concentrations exceeded permissible limits, indicating that untreated or inadequately treated industrial waste was being dumped into the river. Such illegal discharges contribute significantly to the degradation of water quality, posing serious environmental and public health risks.

2018: Central Pollution Control Board (CPCB) study revealed severe pollution in the Vrishabhavathi Valley due to inadequate sewage treatment, illegal industrial discharges, and poor waste management. Key findings included elevated BOD, COD, NH_3-N, and zero DO, indicating critically low water quality and oxygen levels

2014-2019: Central Water Commission reported elevated presence of heavy metals in sediment and water samples at T.Bekuppe (Site D), Arkavathi River

2012: The Byramangala Reservoir study on the Vrishabhavathi River revealed that most isolated bacteria exhibited multidrug resistance, marking the evolution of "superbugs" in this water body. This is the first study in South India to report such resistance in pathogenic bacteria from the reservoir. The dual threat of multidrug resistance and toxin production by these bacteria poses a severe risk to public health, underscoring the urgency for intervention and further research.

2012: ATREE's findings reveal significant heavy metal pollution in the Peenya Industrial Area sub-catchment, with concentrations of Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni), and Manganese (Mn) peaking during the night and early morning hours. The intensive 24-hour sampling over a year demonstrated that these peak concentrations coincide with major industrial effluent discharges, which are missed by the Karnataka State Pollution Control Board's (KSPCB) one-time grab sampling approach. This underscores the inadequacy of the current monitoring system and the need for continuous, time-based sampling to accurately assess industrial pollution levels.

2009: Kuvempu University's research study highlighted the critical impact of industrial pollutants on heavy metal contamination in river water, with Lead (Pb), Chromium (Cr), Nickel (Ni), Manganese (Mn), and Iron (Fe) exceeding permissible limits, especially during summer when dilution is minimal. Industrial effluents were identified as a major source, with localized spikes in heavy metal concentrations near discharge points, despite a general downstream decrease. The study also found that these pollutants leach into the soil, contaminating groundwater, and exceeding hardness limits in some samples.

See Paani's Arkavathi Interactive Map for more details

[28] Distribution of PhACs along the River Cauvery

Key Takeaways

Alarming Pollutants: The Arkavathi River and its sediments are contaminated with harmful pollutants, including pesticides (Heptachlor, DDT), heavy metals (Mercury, Chromium), and industrial compounds (PAHs, phthalates). Many pollutants far exceed national and international standards, causing severe risks to human and aquatic health, including cancer and hormone disruption. Heavy metals also contribute to the development of antimicrobial resistance (AMR), posing an additional threat to public health and the environment

Widespread Pollution: Every single test site exhibited pollution values above national and international standards and guidelines. Even remote areas with no visible pollution had high levels of persistent pollutants, highlighting the river's vulnerability to long-range contamination. Across test sites, Paani observed notable spikes in pollution levels, frequently downstream of industrial areas or other zones with known pollution discharges. Additionally, the results demonstrated that high pollution levels from Urban Bengaluru enter the Arkavathi via the Vrishabhavathi and degrade water quality. Many of the river sites had high phosphorus levels causing eutrophication

Evidence over the years: Numerous studies, including those by ATREE, highlight unregulated industrial pollution as a major driver of the Arkavathi's pollution crisis.

Inadequate Monitoring Practices: Water quality monitoring guidelines of Central Pollution Control Board consider emerging contaminants like pesticides, PAHs, and phthalates, and emphasize the importance of classifying sampling sites to identify and address pollutant sources effectively. However, the Karnataka State Pollution Control Board's monitoring program under the National Water Quality Monitoring Program (NWMP) falls short. It simplifies the process by assigning sites basic rankings (A, B, C, D, or E) based on limited parameters, failing to account for critical emerging contaminants.

Need for Better Monitoring: ATREE highlights the need for continuous monitoring to replace the current one-time sampling, which misses changes in pollution throughout the day. Tools like Bhuvan's Water Bodies information System (WBIS) and remote sensing can help track water quality in real time. A 2012 ATREE study showed that toxic pollutants peak during the night and early morning, making round-the-clock monitoring essential.

Limited Restoration Plans: The Arkavathi restoration plan, developed under the National Green Tribunal's order to address 351 polluted river stretches, relies solely on BOD values derived from one-time sampling. This narrow focus overlooks the full extent of pollution, minimizing efforts to restore the river comprehensively. Such diluted measures perpetuate high pollution levels impacting aquatic life and public health.

Citizen Asks: Immediate Steps to Secure Our Water Future

Restoring and protecting the Arkavathi and its tributaries - once vital lifelines and now reduced to lifeless drains - requires many actions. As an urgent first step, we propose these measures to lay the foundation for long-term river health and water security

1. **Strengthen the implementation of the water quality monitoring program to monitor emerging contaminants**

   "What can't be measured can't be improved". There is clear evidence of industrial pollution and emerging contaminants threatening public health. The water quality monitoring program (NWMP) must be made robust to effectively measure emerging contaminants and other alarming pollutants and address the pollution sources. The water quality raw data and trend analysis should be accessible in the public domain.

2. **Mandatory Standards for Phosphates in Detergents:**

   High phosphorus levels are causing eutrophication in river sites, degrading water quality and aquatic ecosystems. Although BIS standard IS 8180 provides guidelines for phosphate levels in detergents, it is not legally binding. Mandating this standard and introducing economic incentives for manufacturers to comply will significantly reduce pollution. *(Source:* SANDRP Article Jan 1 2023*)*

Clean water is vital for life, jobs, and the economy. Without it, **industries struggle, jobs are lost, and lives are impacted**. Relying on distant water sources like the Cauvery, Netravathi, and Sharavathi raises costs for infrastructure, energy, and water, straining public funds and household budgets. **Restoring rivers** like the Arkavathi isn't just about protecting the environment - **it's crucial for a healthy economy too.**

The Arkavathi River and its tributaries are contaminated and the sources of pollution can be identified. **The time to act decisively and stop pollutants at their source is now - a critical step for both our environment and economy.**

Figure 50: Frothing Vrishabhavathi River few kms downstream of Byramangala Reservoir

Appendix Link

Due to the large file size, the appendix for this report is available as a separate document at the following link: Uncovering the Hidden Pollution in the Arkavathi: Emerging Contaminants Impacting Bengaluru & Beyond - Appendix