Monitoring and sensor performance assessment database

Deliverable D4.3

Final version (confidential)

WP4 Water monitoring, modelling and control
Task 4.2 Design, commissioning, quality control and operation of one stationary sensor monitoring network for one area
Lead beneficiary: VITO

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Approved by WP Manager	Sofie Van Ermen and Shaikh Ziauddin Ahammad
Date of approval	30/01/2024
Approved by Project Coordinator	Paul Campling
Date of approval	30/01/2024
Due date of deliverable	31/01/2024
Actual submission date	31/01/2024

Project number (EU)	821051 (H2020-SC5-2018)
Project number (India)	BT/IN/EU-WR/39/AJ/2018
Project coordinator	Paul Campling, VITO
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Project website	https://www.pavitra-ganga.eu/en

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821051.
This project has been co-funded by Department of Biotechnology (DBT), Government of India.

Dissemination level		
PU	Public	
CO	Confidential, restricted under conditions set out in Model Grant Agreement	X
CI	Classified information as referred to in Commission Decision 2001/844/EC)	
Deliverable type		
R	Document, report	
Other	Database	X
DEM	Demonstrator, pilot, prototype	
DEC	Websites, patent fillings, videos, etc.	
ORDP	Open Research Data Pilot	
ETHICS	Ethics	

History			
Version	Date	Reason	Revised by
0.1	06/03/2022	First draft	Paul Campling (VITO)
0.2	30/01/2024	Final	Paul Campling (VITO)

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SUMMARY

The objective of Work Package 4 "Water monitoring, modelling and control" is to deliver robust, smart, and comprehensive solutions for quality and quantity monitoring, control and management of water resources in the two case areas. In Task 4.2 "Design, commissioning, quality control and operation of stationary sensor monitoring networks for one case area" the project aims to establish a stationary sensor monitoring network. The purpose of the monitoring network is to evaluate the performance of technological solutions for improving water quality to receiving surface water bodies and improve operation and maintenance of facilities. This will be established for the Barapullah Drain catchment area in New Delhi. Deliverable 4.3 is therefore expected to provide the database of timeseries information collected at New Delhi.

In the last two years of the project Pavitra Ganga managed to establish a sensor-based monitoring network – a stationary sensor monitoring pH, Electrical Conductivity, water temperature and dissolved oxygen was established by VITO at the Barapullah Site in July 2022. In addition, two automatic grab samplers were procured and installed by IIT Kanpur in August 2023 at the Barapullah Drain site and the IIT Delhi site. The accompanying stationary sensors are still being procured by IIT Kanpur – these are expected to be installed by March 2024, so that the sensors and the automatic grab samplers can be integrated. Although the Aquatrack monitoring technology has been built – it was not possible to confirm a location for testing in India, therefore information on the monitoring which took place at Arboga STP, Sweden is included. Finally, a citizen-based water quality monitoring survey was carried out in the two case areas during 2023. The objectives were to: demonstrate the efficacy of using mobile water quality tools (Akvo Caddisfly) to explore existing water quality issues at these sites; generate data using mobile water quality monitoring tools to assess ambient water quality along with contextual information on water resource use and flag up potential water quality issues; monitor the potential impact of wastewater on groundwater in project locations especially in Kanpur. The parameters ph, EC and Nitrates were measured in line with the GEMS/UNEP approach to monitor ambient water quality (UNEP, 2018) and assess the "Proportion of bodies of water with good ambient water quality" (SDG 6.3.2).

The approach adopted for the sensor network water quality monitoring is to combine "robust" sensor monitoring that triggers "smart" automated surface water sampling of the drain water for further assessment in the laboratory. "Robust" sensors mean relatively cheap and reliable continuous monitoring of basic water quality parameters (Electrical Conductivity, pH and T°, with optionally turbidity and dissolved oxygen as well). These can work in tandem with automated refrigerated grab samplers to improve the representativeness of the sampling, backed up by laboratory analysis. One of the most critical issues for installing a sensoring network is security – any equipment that is not guarded 24 / 7 will not be secure – this means that there are basically only two options for an upstream and downstream positioning of the water quality monitoring stations – at the guarded IIT Delhi Campus and at the guarded Barapullah Drain treatment site.

The sensor water quality measurements confirm very low dissolved oxygen in Barapullah drain and the electric conductivity parameter can serve as indicator parameter as EC drops often indicate rainfall events and increased (especially during monsoon). Dissolved oxygen spikes after rain events. Recording a logbook as recommended, logbook data and rainfall data are welcomed for interpretation. A maintenance contract is advised as it supports data quality but does not replace maintenance and calibration by IIT Delhi.

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The monitoring data collected through the citizen-based water quality survey campaigns in 2023 provide insights into the water quality and management challenges in the selected villages. The use of Akvo Caddisfly, with its simplified design and user support, facilitated the participation of individuals from Solidaridad in water quality testing. Individuals from Solidaridad had a strong background in community facilitation and outreach but limited expertise in monitoring and assessing local water resources effectively. The collaborative approach, engaging the community in selecting sampling points and sharing observations, enhanced the overall data gathering process.

In both Delhi and Kanpur, the pH concentrations of the sampled water sources generally remained within the permissible limits for drinking. However, occasional deviations, particularly towards acidity, emphasize the need for continued monitoring and potential remediation measures. Electrical Conductivity (EC) readings across the monitored sources were consistently within acceptable limits, indicating overall compliance with acceptable standards.

Notably, instances of elevated nitrate concentrations in specific water sources were observed during the initial monitoring round in May 2023, particularly in Delhi. However, subsequent rounds showed a reduction in nitrate levels. Understanding the varied usage of water sources, such as for bathing and cleaning purposes rather than drinking, is crucial for appropriate interpretation and future deliberation.

The variation in nitrate levels between monitoring rounds highlights the dynamic nature of water quality and underscores the importance of continuous monitoring to capture temporal fluctuations. The results also point out the significance of considering the specific functions of water sources, as certain locations may be more prone to contamination due to their usage patterns or other reasons that could not be captured in detail during the baseline data collection.

In Kanpur, the differentiation between villages with concrete and earthen irrigation channels was observed. The collaboration with Solidaridad demonstrates the success of capacity-building efforts in enabling NGOs to contribute meaningfully to water quality assessments.

In conclusion, the monitoring results emphasize the need for sustained efforts in water quality management, community engagement, and continuous capacity building. It demonstrates a promising model for empowering non-experts to contribute to water management initiatives and understand water challenges in diverse communities, laying the foundation for informed decision-making and targeted interventions.

Finally all water quality monitoring (and modelling) information is accessible via the Pavitra Ganga water quality monitoring dashboard, which is embedded in the Pavitra Ganga website using the following URLs:

- https://pavitra-ganga.eu/en
- https://pavitra-ganga.eu/en/pavitra-ganga-dashboard
- https://pavitraganga.marvin.vito.be/region

The web-based dashboard tool visualizes data from available data sources: mobile monitoring (Task 4.1), stationary sensors (Task 4.2) and regional modelled data (Task 4.3). The dashboard was developed based on a user requirements analysis to define the functionalities of the tool. The starting point has been VITO's Sensorview but was quickly adapted to be of relevance to the Pavitra Ganga Project. The user of the dashboard can easily navigate between the two case areas and

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consult the data related to both water quality monitoring and modelling. This helps to integrate all monitoring information on one platform, enhancing transparency, engagement and trust with stakeholders.

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TABLE OF CONTENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821051.
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LIST OF FIGURES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821051.
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LIST OF TABLES

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CHAPTER 1 INTRODUCTION

The objective of Work Package 4 "Water monitoring, modelling and control" is to deliver robust, smart, and comprehensive solutions for quality and quantity monitoring, control and management of water resources in the two case areas. The specific objectives are to:

- Establish a benchmark assessment of local water quality and quantity and existing infrastructures (Task 4.1);
- Establish citizen involvement and interest in wastewater issues by engaging stakeholders to use low-cost mobile monitoring tools (Task 4.1);
- Establish a stationary sensor monitoring network to evaluate the performance of technological solutions for improving water quality to receiving surface water bodies and improve operation and maintenance of facilities (Task 4.2);
- Develop regional water quantity and water quality modelling scenarios for impact assessments and planning (Task 4.3); and,
- Develop an easy-to-use web based regional water management dashboard that incorporates water quantity and quality, and operational control (Task 4.4).

The third objective of WP4 defines Task 4.2 "Design, commissioning, quality control and operation of stationary sensor monitoring networks for one case area". In this task, we use the first results of Task 4.1 and Task 4.3, knowledge of the Barapullah Drain catchment area and the consortium's past experiences with water quality sensors to develop the sensor network design for the project. The sensoring approach allows us to gather high resolution information on basic Water Quality parameters (pH, Electrical Conductivity and temperature), with options to include Dissolved Oxygen and Turbidity parameters as well, to make timely water grab samples for further laboratory analysis. This allows us to gather more data to characterize the variations in the water quality of the Barapullah Drain at different locations (Task 4.1), as input for evaluating the performance of the technological solutions for improving water quality (WP3 and WP5) and developing models and scenarios to assess the impact of technologies and mitigation strategies on the water quality of the Barapullah Drain (Task 4.3). The outcome of the monitoring work is the delivery of a database that provides timeseries data of water quality measured.

Chapter Two provides an overview of the monitoring approaches at Barapullah Drain:

- Design location and time resolution of sensors to monitor the water quality of the Barapullah Drain (based on Task 4.1 and requirements for Task 4.3);
- Analysis of data collected at the Barapullah Drain;
- an overview of AquaTrack monitoring in Sweden.

Chapter Three provides an overview of the citizen based monitoring approaches at Kanpur and New Delhi:

- Village level monitoring of water resources in areas downstream of the STP/CETP Jajmau, that delivers partially treated wastewater for irrigation.
- Institutional monitoring of water resources across the Barapullah Drain.

Chapter Four provides an overview of the dashboard developed by Pavitra Ganga to showcase monitoring and modelling data

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CHAPTER 2 SUMMARY OUTLINE OF THE SENSOR NETWORK DESIGN AND SENSOR SPECIFICATIONS AT BARAPULLAH DRAIN, NEW DELHI

SENSOR NETWORK AREA – THE BARAPULLAH DRAIN

The Barapullah basin is situated on the western bank of the river Yamuna, spread over 5 sub-districts of Delhi and inhabited by approximately 3.4 million people. The areas in this basin are completely urbanized. The Barapullah drain (also referred to as Nizammuddin darya) was once a major storm drain. Due to limitations in urban water sewage treatment, the Barapullah currently discharges approximately 125,000 kiloliters of wastewater per day into the Yamuna river, accounting for 80% of the stormwater which is transported to the Yamuna from the region (Bhaduri, 2017). The drain is approximately 100m wide and 16km long (Trikannad, 2018). The Barapullah basin itself is 376 km2 with a population of approximately 3.5 million as of the 2011 Census. Domestic sources account for approximately 85% of pollution to the Yamuna river and include debris, untreated sewage and industrial effluents (Malik et al., 2014). Consequently, outflows contain concentrations of heavy metals (including lead (Pb), zinc (Zn), and copper (Cu)), biochemical oxygen demand (BOD) and dissolved oxygen (DO) which have historically exceeded recommended levels (Sehgal et al., 2012). More recent studies have highlighted the emergence of antibiotic resistant bacteria (ARB) originating from untreated sewage on the Yamuna river (Lamba et al., 2017).

The contaminant concentrations at the Barapullah Drain, are low compared to typical domestic wastewater due to dilution and anaerobic biodegradation within the drain. The main challenges for the Barapullah Drain site (as well as for similar sites with open drains) are health related issues such as microbiological contamination due to domestic use of contaminated water, pollution of surrounding water bodies (such as rivers) due to discharge of organics, nutrients and micropollutants (such as pharmaceuticals), clogging of open-drains due to lack of organized garbage and waste removal services, high flow and load variations in the drains due to lack of flood control (e.g. during monsoon) and the water drainage system.

SENSOR NETWORK APPROACH AND LOCATIONS – THE BARAPULLAH DRAIN

The approach adopted for the sensor network water quality monitoring is to combine "robust" sensor monitoring that triggers "smart" automated surface water sampling of the drain water for further assessment in the laboratory. "Robust" sensors mean relatively cheap and reliable continuous monitoring of basic water quality parameters (Electrical Conductivity, pH and T°, with optionally turbidity and dissolved oxygen as well). These will work in tandem with automated refrigerated grab samplers to improve the representativeness of the sampling, backed up by laboratory analysis. One of the most critical issues for installing a sensoring network is security – any equipment that is not guarded 24 / 7 will not be secure – this means that there are basically only two options for an upstream and downstream positioning of the water quality monitoring stations – at the guarded IIT Delhi Campus and at the guarded Barapullah Drain treatment site (Figure 1). The as built setup is shown in Figure 2.

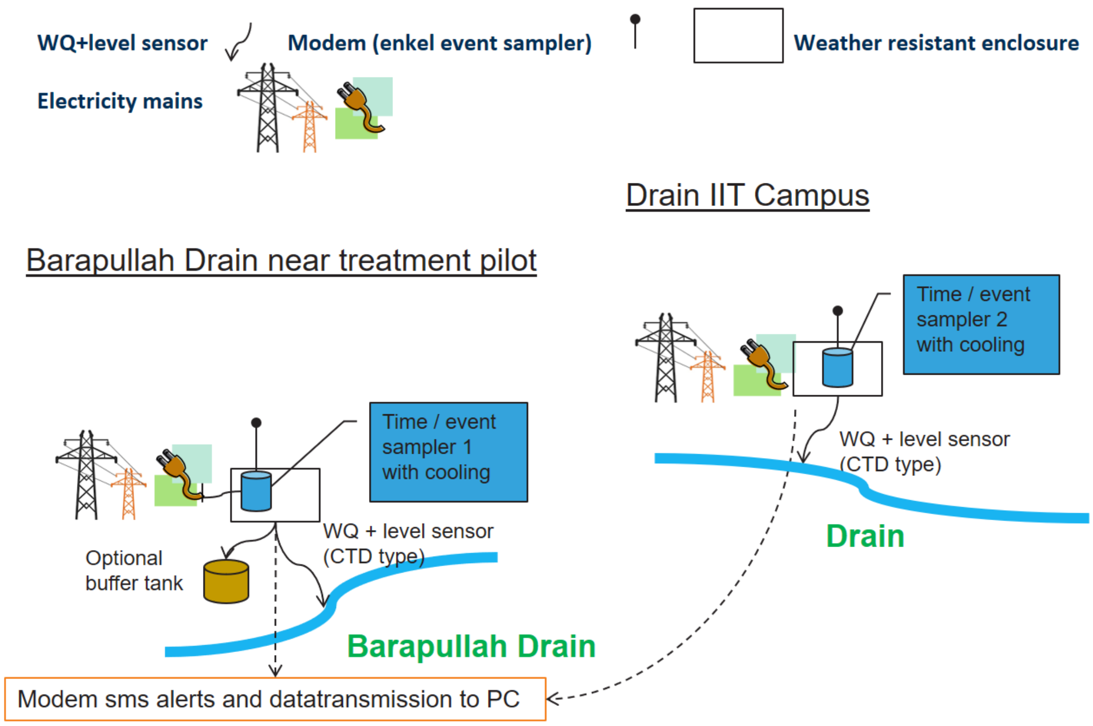

Figure 1: Schematic approach of up- and downstream monitoring by time and event paced sampling.

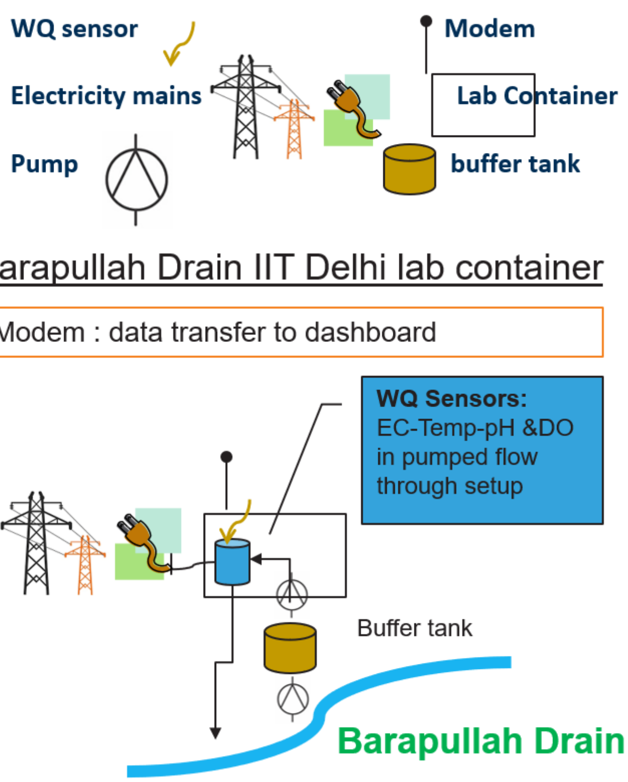

Figure 2: Schematic approach of as-built multi parameter monitoring setup and near real time data transfer.

The first water quality monitoring station at the IIT Delhi Campus is a canalized storm water drain that collects excess rainfall runoff but also receives wastewater from households, offices and small scale industry from outside the IIT Delhi Campus (Figure 1, Figure 3, Figure 4 and Figure 5). The second water quality monitoring station is next to the Barapullah Drain treatment site (Figure 6 and Figure 7), near the drain mouth to the Yamuna river. At both locations, a multi-parameter sensor and an automated sampling setup will be programmed to monitor continuously the water quality and take samples for refrigeration that will be later assessed in the laboratory.

The project monitoring program has 2 types of sampling options for the Barapullah Drain: (1) automated sampling at two hourly intervals merged into time-integrated sample(s) over a 24 hours interval, and (2) automated sampling due to a rainfall, open drain rise (level), water quality change event at 15 minutes intervals merged in to time-integrated samples over a 90 minutes interval.

In the project, we will focus on time-based sampling to take time integrated samples over a period which can be used for lab validation of the *in-situ* parameters from the multiparameter sensor.

This design brings the monitoring of the open drain water in the study area by grab sampling in the catchment to a higher level as the higher temporal resolution gains additional insight during events. The sensors enable measurements at short time interval (e.g. every minute). The dynamic character of the surface water quality parameter of interest and the intended use of the data will determine the measurement interval. We also designed to acquire continuous monitoring from robust and relatively inexpensive sensors **electrical conductivity, temperature pH parameters with the option to include turbidity and dissolved oxygen.** Sample collections from the automated event sampler could be organized less frequently when refrigerated samplers are deployed or collection occurs shortly after an **event notification** (e.g. by e-mail and/or text message) when no cooling is used. The **event trigger** could be set on a **water quality parameter** such as **electrical conductivity, dissolved oxygen, pH or water level** or even **a combination of parameter thresholds.**

The multiparameter sensors will be deployed in a bypass flow through setup that is guarded and or fenced to ensure security against equipment theft or vandalism.

PHOTOGRAPHIC OVERVIEW OF THE WATER QUALITY MONITORING STATIONS

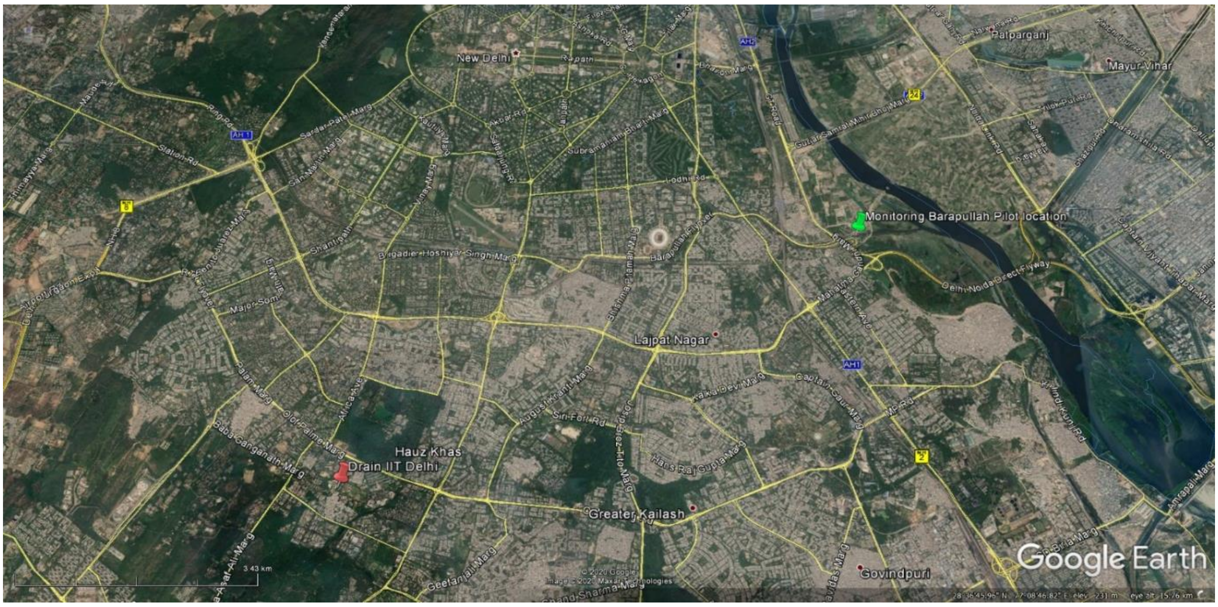

Figure 3: Aerial view of the locations of the proposed water quality stations (the red pinpoint inside the IIT Delhi Campus and the green pinpoint at the Barapullah Drain treatment site)

Figure 4: Aerial view of the location of the proposed monitoring station inside the IIT Delhi Campus (the red pinpoint)

Figure 5: Photo of the canalized IIT Delhi storm water drain where the proposed water quality monitoring station will be located

Figure 6: Photo of the location of the proposed water quality monitoring station near the Barapullah Drain treatment site

Figure 7: Aerial view of the proposed water quality monitoring station near the Barapullah Drain treatment site (the red pinpoint)

Sensor specifications

A survey was carried out of the commercial sensors, automated water samplers and the necessary ICT accessories for real time monitoring:

- water quality sensors (Table 1),
- desired water quality sensor specifications (Table 2),
- automated water samplers (Table 3),
- data communication for remote data collection and alerting and software (Table 4) to enable remote follow up of the water quality data and water sampling events in near real time, both by IIT Delhi and VITO.

Table 1: List of water quality sondes (probes)

Device	Type *	Parameters (bold = relevant for pavrita ganga)	Accuracy Conductivity	Memory**	Sensor ports	Supplier	Specs	Manuals	Distributor India	Price range EURO	Accesoires needed	Price EUR Accesoires needed
Aqua Troll 600	MPS	**Cond Temp Pressure** Barometric Pressure **pH ORP DO Turb** Ammonium Chloride Nitrate Chlorophylla BGA PC BGA PE Rhodamine	0,5% of reading	16 MB + 8GB SDcard	-	In Situ	Link	manual AQTROLL600	Distributor AT600	+- 5500	Power & SDI-12 field cable 10 meter?	approx 1000
EXO1	MPS	**Cond Temp Pressure** Barometric Pressure **pH ORP DO Turb** Ammonium Chloride Nitrate Chlorophylla BGA PC BGA PE Rhodamine	0,5% of reading or 1 µS/cm w.i.g	512 MB	4	Xylem, YSI	Link	Manual EXO	Distributor EXO1	+- 6000	Power & SDI-12 cable 10 meter Exo DCP 2,0 signal output adapter	approx 1000
EXO2	MPS	**Cond Temp Pressure** Barometric Pressure **pH ORP DO Turb** Ammonium Chloride Nitrate Chlorophylla BGA PC BGA PE Rhodamine	0,5% of reading or 1 µS/cm w.i.g	512 MB	6 + wiper or 7	Xylem, YSI	Link	Manual EXO	Distributor EXO2	+- 9000	Power & SDI-12 cable 10 meter Exo DCP 2,0 signal output adapter	approx 1000
EXO3	MPS	**Cond Temp Pressure** Barometric Pressure **pH ORP DO Turb** Ammonium Chloride Nitrate Chlorophylla BGA PC BGA PE Rhodamine	0,5% of reading or 1 µS/cm w.i.g	512 MB	4 + wiper or 5	Xylem, YSI	Link	Manual EXO	Distributor EXO3	+- 8500	Power & SDI-12 cable 10 meter Exo DCP 2,0 signal output adapter	approx 1000
Aqua Troll 200	CTD	**Cond Temperature** Depth (level)	0,5% of reading	4 MB		In Situ	Link		Distributor AT200			CTD
CTD10 Hydros21	CTD	**Cond Temperature** Depth (level)	10%	needs datalogger (sampler)**		The Meter Group	Link	Manual CTD10 Hydros21	Distributor CTD10	+-450		

*MPS: Multi parameter sonde; CTD: Conductivity, Temperature, Depth
** Sensor needs to be connected to datalogger with telemetry in this project

The Aqua Troll data can output to the VU situ Mobile App but need wireless comm via Bluetooth (625 Euro), Winsitu software (free) for PC, SDI-12 communication to sampler memory is possible for data storage and sensor triggering of the sampler.

Software In Situ: VU situ app and https://in-situ.com/vulink/ and Win Situ

The EXO needs PC connection via USB exo output adapter or Bluetooth to the free KOR software, SDI-12 communication to sampler memory is possible for data storage and sensor triggering of sampler.
Software KorEXO software

The CTD10 Hydros 21 is to be connected to sampler with SDI12 to store data in the Sampler memory.

The Meter group Integrator Guide CTD10

Table 2: Water quality sensor specifications

Sensor (minimum requirements)
<u>Conductivity</u> Range: 0 - 200 ms/cm Accuracy: 0-100 ms/cm: 0,001ms/cm or 0,5% of value 100-200 ms/cm: 1% of value (+temperature) Range: -5 to 50°c Accuracy: -5 to 35°c: 0.01°c 35 to 50°c: 0.05°c
<u>Dissolved oxygen</u> Range: 0 – 500% sat. 0-50 mg/l Accuracy: 0-200%: 1% or 1% of value 200-500%: 5% of value 0-20 mg/l: 0.1 mg/l or 1% of value 20-50 mg/l: 5% of value
<u>Turbidity</u> Range: 0-4000 fnu Accuracy: 0-900 fnu: 0,3 fnu or 2% of value 1000-4000 fnu: 5% of value
<u>Depth</u> Range: 0-250 meter Accuracy: 0-10 m.: 0.004 m. 10-100 m.: 0.04 m. 100-250 m.: 0.10 m.
<u>pH</u> Range: 0-14 units Accuracy: IF >+-10°C off calibration temp: 0,1 Other: 0.2 (+orp) Range: -999 to 999 mv Accuracy: 20 mv

Table 3: Automated samplers

Device	Supplier	Specs	Manuals	Distributor India	Price range EURO
Avalanche Transportable Refrigerated Sampler	Teledyne isco	https://www.teledyneisco.com/en-us/waterandwastewater/Pages/Avalanche.aspx	Manual Avalanche	http://aaxisnano.com/teledyne-isco/	+- 5500

Samplers to be ordered for AC power supply and including spare suction line and strainer, so 4 in total for the 2 samplers.
Avalanche refrigerated sampler: 5 gallon and 2.5-gallon composite or 4 x 1 gallon and 14 x 950 ml sequential.

Avalanche and 6712 are compatible with rain gauge and SDI12 environmental sensors. The data storage for SDI-12 CTD or MPS sensors and modem telemetry must be provided. The following design requirements have been defined for procurement.

The refrigerated automated sampler provides control, data logging and communication features.

- The controller enables sample pacing by time, non-uniform time, flow or external event sample collection.
- NEMA 4x, 6 (IP67) is minimum, so enclosure needs to be water tight and dust proof.
- Bottle configurations include 4 x 1 gallon and 14 x 950 ml sequential poly bottles.
- CFC-free refrigeration system maintains sample temperature at 3° C ± 1°C at ambient temperatures of 0°C to 40°C.
- Operation between 0 and 50°C.
- Volume repeatability ±5 ml or ±5% of the average volume in a set.
- Maximum water lift 28 ft (8.5m).
- Intake air purge before and after sampling.
- The device will be AC powered.
- Sample presence detector enables compensation in head height detecting liquid reaching the pump.
- The device is easily transportable by one person (cart preferred) and dry weight is less than 36 kgs.
- Sample delivery at the EPA-recommended velocity of 2 ft/sec., even at head heights of 26 feet.
- Patented pump revolution counter ensures accurate sample volumes and alerts user when tubing should be replaced.
- If no sample is detected, up to 3 retries are user selectable.
- 4 suction lines (minimum 30 feet) and 4 strainers.
- External triggers can initiate sample collection and cooling from contact closure signal.
- Sample volumes 10 to 9,990 ml in 1 ml increment.
- An SDI-12 sensor (water level, water velocity, water quality, rain, …) can trigger the sample collection.
- The data of an SDI12 sensor can be logged on the sampler memory and can be consulted and downloaded remotely via appropriate communication and software.
- The sampler can trigger text message or mail alarms when specific conditions are met:
    - the sampler is full

- event sampling is triggered/started
- defined parameter value was passed

The idea is to integrate the MPS sensor on a sampler via SDI12 so all data come together on the sampler and can be consulted in real time and also event alerts can be sent from the sampler.

Table 4: Remote data access, storage and visualisation software

Telemetry	Specs	Estimated cost
Teledyne modem or other ask local dealer	http://aaxisnano.com/teledyne-isco/	1000 €
Software for samplers and telemetry		
Teledyne isco (Flowlink)	https://www.teledyneisco.com/en-us/water-and-wastewater/flowlink-5-1	600€

Flowlink® 5.1 Software System Requirements	
Computer:	Windows based PC or compatible
Operating System:	Microsoft Windows 7, 8, and Windows 10
Microprocessor:	Client: 1GHz;
	Flowlink Pro Server: Consult the factory
RAM:	2 Gigabytes
Hard Drive:	2 Gigabytes
Disk Drive:	CD ROM
Monitor:	SVGA, 1024 X 768 resolution
Communication:	Serial or USB port with appropriate Teledyne Isco Interrogator Cable and/or Hayes™ compatible telephone modem
Printer:	Colour recommended

SENSOR MONITORING RESULTS BARAPULLAH DRAIN

In the IIT Delhi laboratory container near the Barapullah drain, a multi parameter setup (Aquatroll 500, In Situ Inc.) was installed measuring Electric Conductivity (EC) , water temperature,pH and dissolved oxygen (DO). The measurement data can be consulted on a dashboard https://pavitraganga.marvin.vito.be/region in near real time. A graph of the data download until April 2023 is shown in the Figure 8 below.

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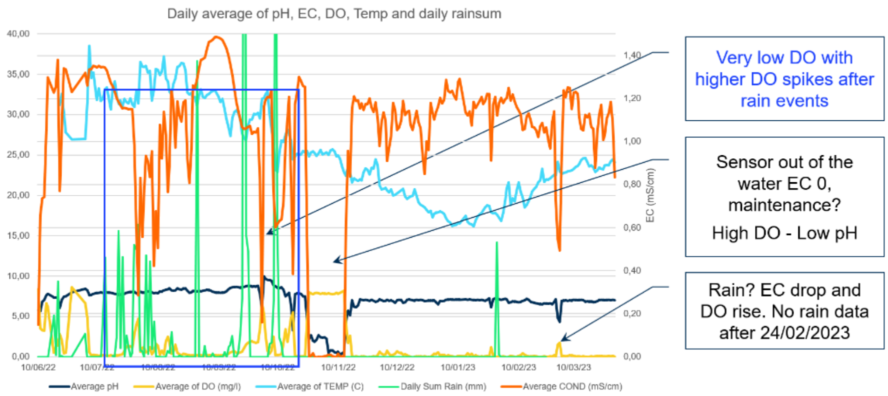
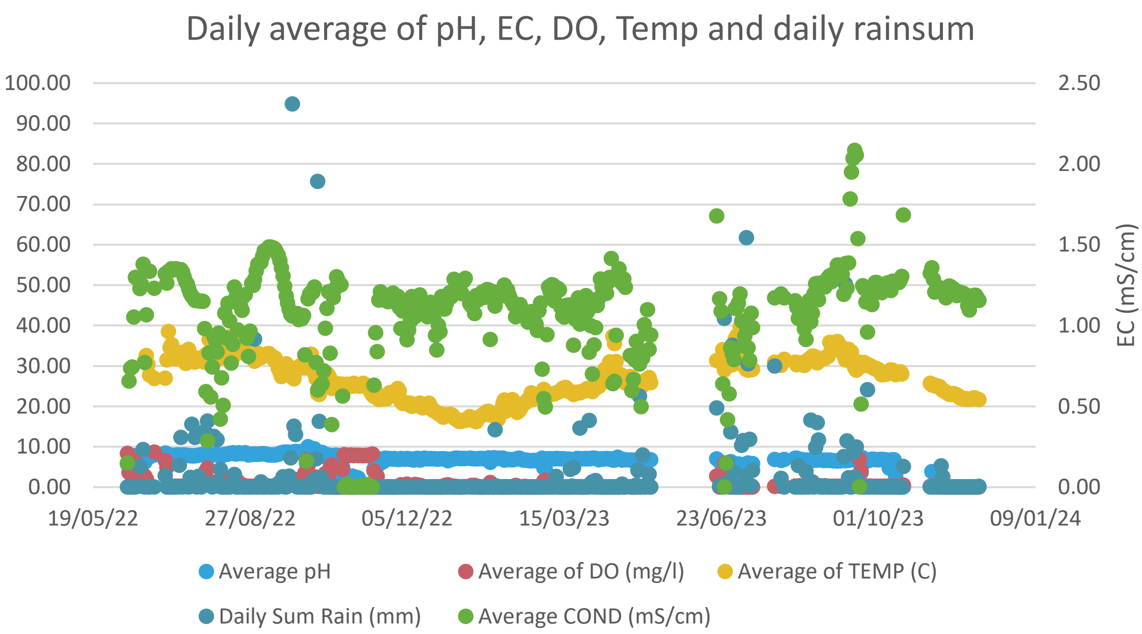
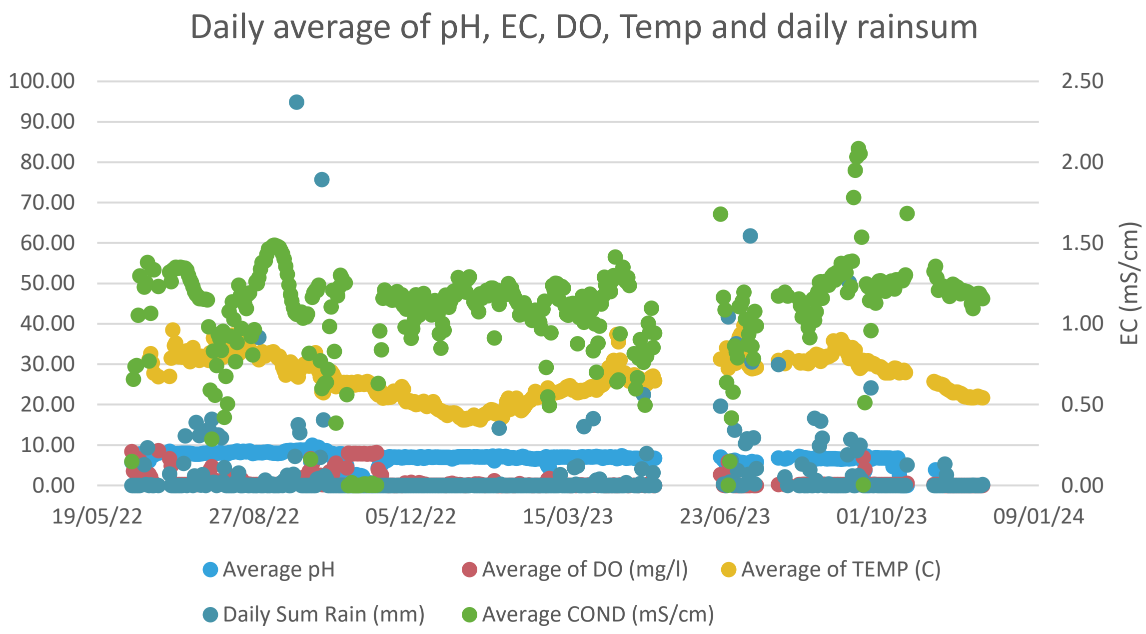


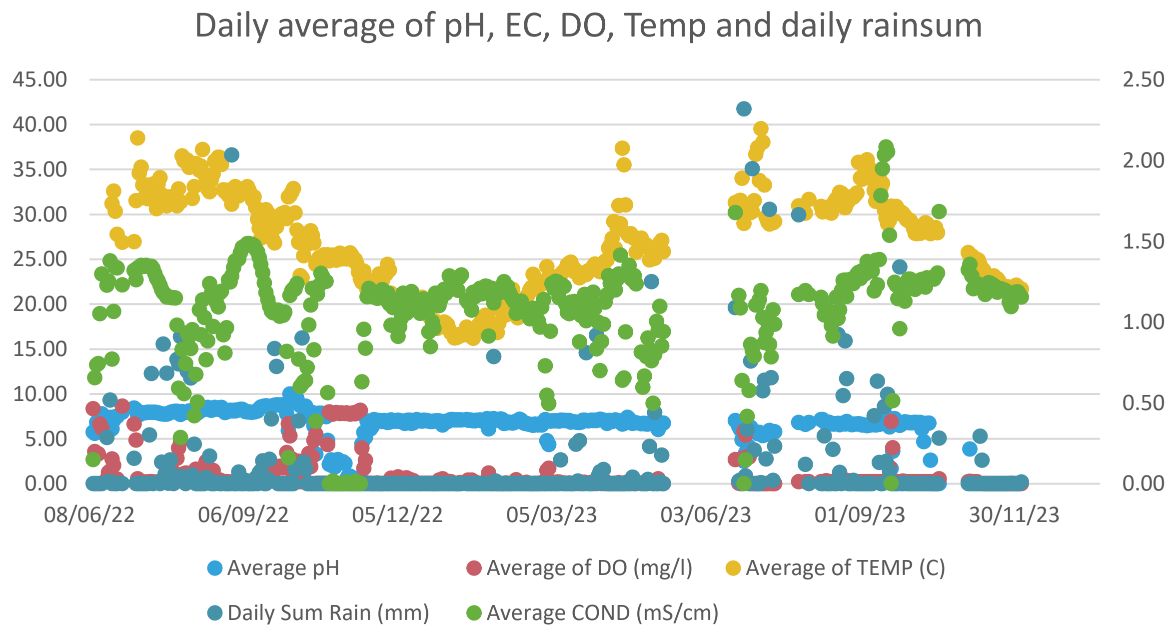
Figure 8: Graph of the water quality (EC, temperature, pH and dissolved Oxygen) and daily sum rainfall of the Barapullah drain with major comments allocated on the graph.



(a.)



(b.)



(c.)

Figure 9: A. Graph of the water quality (EC, temperature, pH and dissolved Oxygen) combined with daily sum rainfall (B. unrestricted Y axis; C. restricted to 45 mm on Y-axis) of the Barapullah drain until December 2023

Figure 10 represents outcomes and recommendations based on the experiments. Sensor measurements confirm very low dissolved oxygen in Barapullah drain and the electric conductivity parameter can serve as indicator parameter as EC drops often indicate rainfall events and increased

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runoff (especially during the monsoon). On the other hand, dissolved oxygen will spike after rain events. Recording a log book is recommended. Log book data and rainfall data are essential for establishing interpretation. A maintenance contract is advised as it supports data quality but does not replace maintenance and calibration by IIT Delhi research staff.

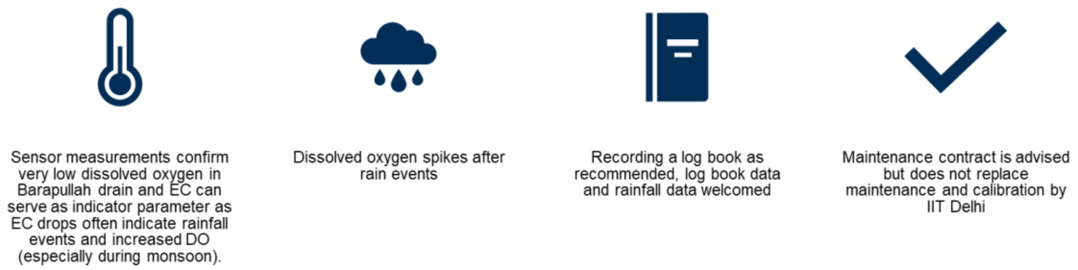

Figure 10: Outcomes and recommendations

OVERVIEW OF THE AQUATRACK® TECHNOLOGY TO MONITOR CONTAMINANTS OF EMERGING CONCERN

AQUATRACK® Early Warning System is an EU ETV verified technology. It is designed to online monitor and give early warning to the management of a treatment plant for increased biological and chemical load from the MBR, MBBR, SBR and STP wastewater process effluent.

During the project it has not been possible to establish the demonstration of the AQUATRACK ® technology in India as envisaged. In this report we include the real-time monitoring of micropollutants which took place at Arboga STP, Sweden in connection to the ozonation tests (**Error! Reference source not found.**). The CH1 data series represents micropollutants up to 1µm in size and CH2 data series represents micropollutants up to 5µm in size. The Y axis represents the number of micropollutants per mL. The information in the graphs shows that is a great deal of variation over a few hours, indicating that grab sampling and ozonation treatment is best served by having continuous monitoring (24/7) to ensure peak events are detected and dealt with by treatment.

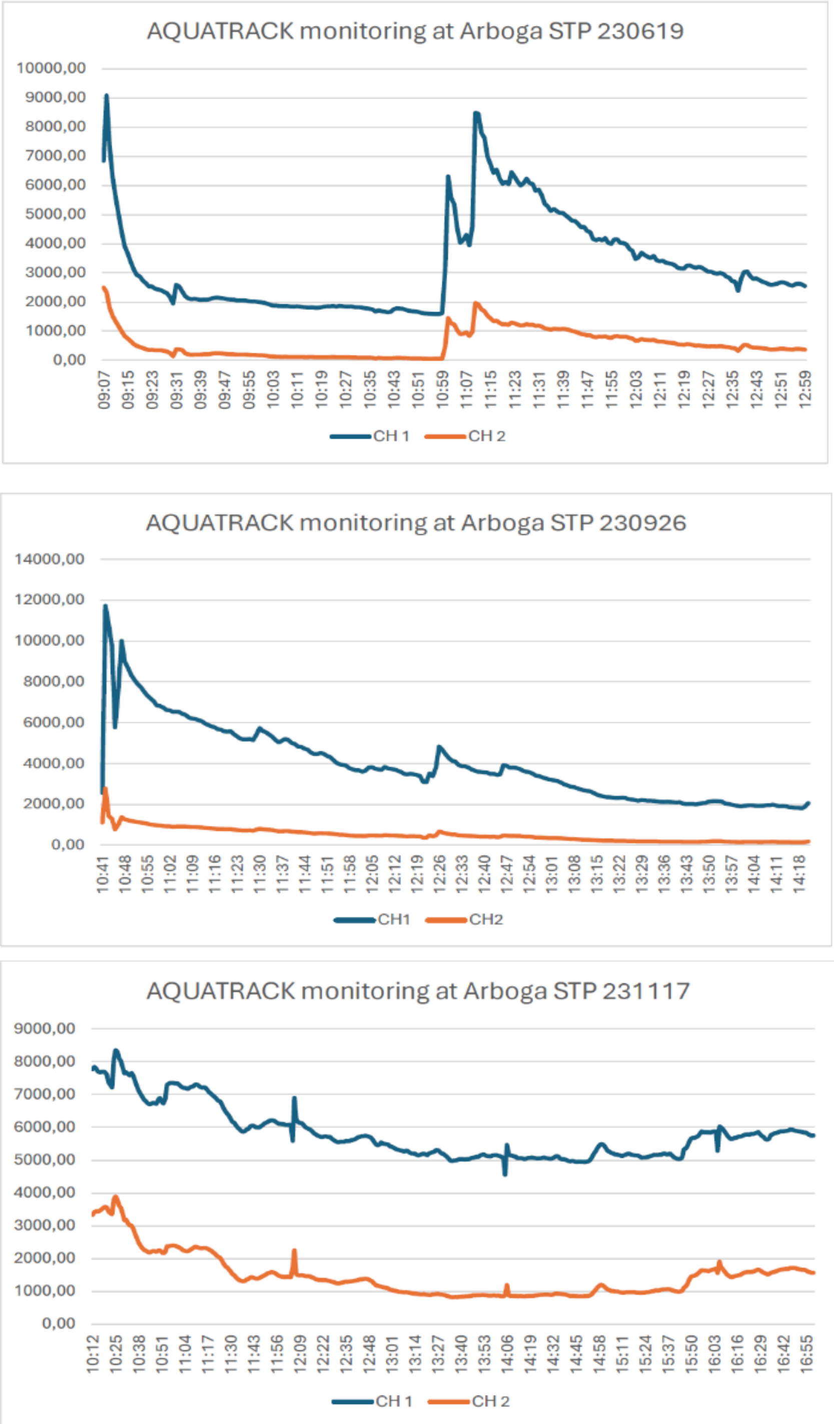

Figure 11 Monitoring of micropollutants on three sampling and ozonation actions at Arboga STP, Sweden

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CHAPTER 3 CITIZEN BASED MONITORING APPROACHES AT KANPUR AND NEW DELHI

ORIGINAL WATER QUALITY MONITORING PLAN

The plan during the first 12 months of the Pavitra Ganga project was to conduct water quality using hand held mobile devices. Due to COVID 19 restrictions this was unable to take place. In Kanpur the water quality monitoring plans have been established to take measurements at nine sites (Figure 12) using the Lovibond Photometer and the EC / pH hand held meter. The following parameters were to be monitored by IIT Kanpur staff on a monthly basis (Table 5).

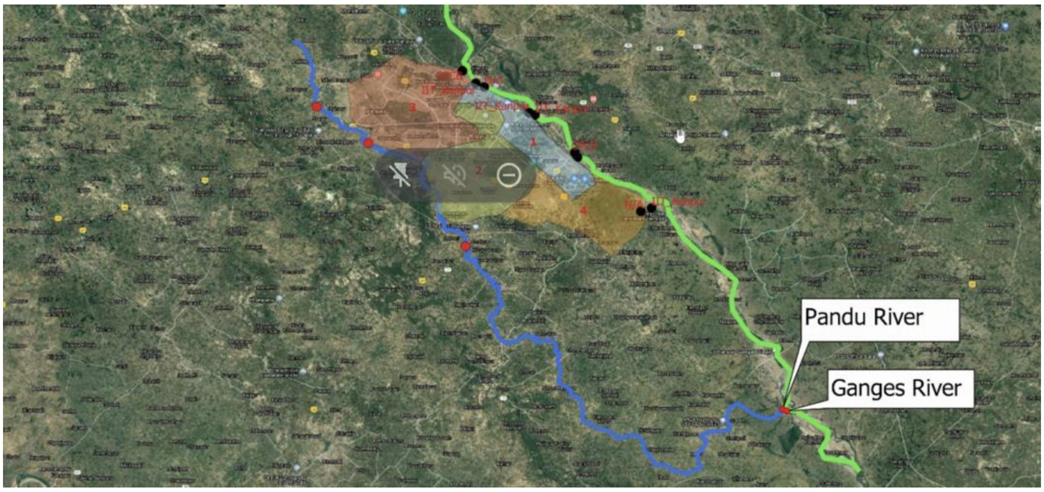

Figure 12: Location of the water quality monitoring sites in the Kanpur Metropolitan Area

Table 5: Water quality parameters to be monitored on a monthly basis

Parameter	Range	Testing method
Ammonia	0.02 - 2.5 mg/l N	Photometer
Phosphate	0 - 4 mg/l PO4	Photometer
Nitrate	1 - 30 mg/l NO3	Photometer
Nitrite	0.01 - 0.5 mg/l N	Photometer
Chromium-6	0.02 - 2 mg/l Cr	Photometer
Turbidity	10 - 1000 FAU	Photometer
Electrical Conductivity	0 - 20000 us/cm	Sensor

Temperature	0 - 60 °C	Sensor
pH	0 – 14	Sensor
DO	0 - 20 mg/l O2	Sensor
COD	-	Lab

IIT Kanpur carried out an assessment of the handheld photometer provided by AKVO for the project – comparing measurements taken by the hand held devices and measurements in the laboratory. pH, EC and DO measurements performed well, phosphates and ammonia measurement gave indications but were not accurate, and CrVI measurements showed a very large difference between the in-situ measurements and the lab protocols. On the basis of the assessment a campaign of monthly measurements at 9 sites for 12 months was dropped. It was proposed therefore that the handheld photometer is only used for restricted number of parameters and monitoring drinking water from handpumps.

Revised Water Quality Monitoring plan

A citizen based water quality monitoring plan (Figure 13) was devised for the two project case areas with the following broad objectives:

- Demonstrate the efficacy of using mobile water quality tools (Akvo Caddisfly) to explore existing water quality issues at these sites
- Generate data using mobile water quality monitoring tools to assess ambient water quality along with contextual information on water resource use and flag up potential water quality issues
- Monitor the potential impact of wastewater on groundwater in project locations especially in Kanpur.

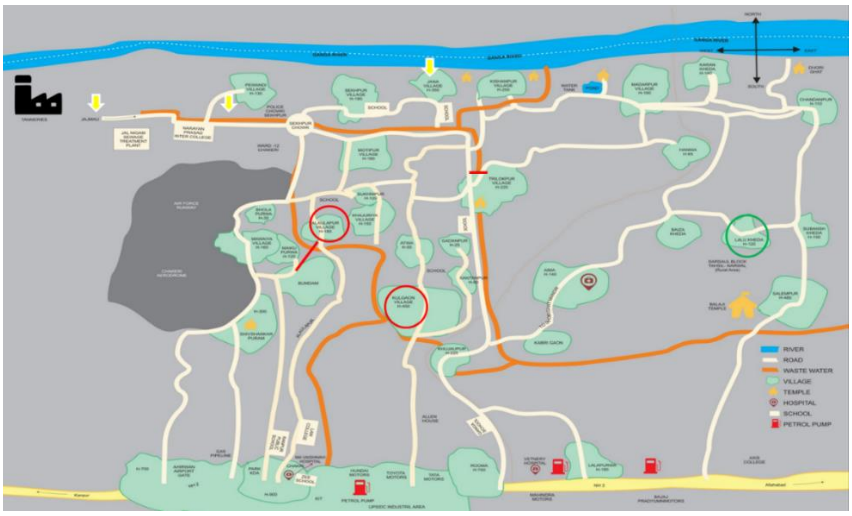

Figure 13: Map of the villages in the Jajmau Wastewater Re-use Irrigation Scheme

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The information from the monitoring and the village surveys would be integrated into the overall assessment of the water management challenges in the two case areas.

Approach

Akvo implemented the baseline survey employing the following approach:

- Defined the scope of monitoring campaign to focus on screening water quality for groundwater sources such as handpumps, submersible pumps, wells as found in the project sites;
- Focus on facilitating capacity building of regional organisation (Solidaridad) on testing and understanding local water quality challenges;
- Introduce easy to use, portable Akvo Caddisfly (Figure 14) with simplified design, and user support to enable individuals (from Solidaridad) without extensive scientific backgrounds and technical knowledge to monitor and assess the quality of their local water resources effectively; and,
- Data collection offered an opportunity to engage with community to contribute of selection of sampling points, and share observations about quality, quantity and usage of their water sources.

SCOPE AND METHODOLOGY

- Monitoring in both locations was conducted in two periods: February/March and June/July, 2023. Selected groundwater sources in each village / unauthorised colonies were mapped
- Samples were tested for Electrical Conductivity, pH and Nitrate. The parameters are proposed by GEMS/UNEP to monitor ambient water quality (UNEP, 2018) to assess the "Proportion of bodies of water with good ambient water quality" (SDG 6.3.2). Within this approach, it is recommended to engage with citizens in their water quality monitoring using handheld devices to complement laboratory methods.
- Along with water quality tests, data was collected on general Information about the village, usage and functionality of the sampled sources and perception and exposure of health risks

Figure 14: Mobile Water quality monitoring tool, Akvo Caddisfly

a. Data Collection: Delhi

- 13 water samples (2 HP and 11 Borewell) were tested during the first round of monitoring. These samples were taken around the Barapullah drain catchment area ("upstream" / "mid-stream" / "downstream" areas) with support of TERI. Data collection was conducted by Solidaridad.

- In the second round of monitoring, we could only sample 9 sources due to unavailability of persons from whose houses the data was collected earlier.

b. Data Collection: Kanpur

- Monitoring was conducted in six villages in Kanpur; Motipur, Trilokpur, Pewandi, Alalualpur, Kulgaon and Kishanpur. The criteria for selecting these villages is their location along the irrigation channel (connected to the Jajmau STP) and a combination of concrete lined irrigation and earthen irrigation canal. In total 30 samples were collected from the six villages.
- In each village, five groundwater sources are monitored (total 30 water sources) mainly included submersible pumps and handpumps
- Along with water quality tests, data was collected on general Information about the village, usage and functionality of the sampled sources and perception and exposure of health risks

Figure 15: Water quality monitoring in Kanpur and Delhi

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KEY SUMMARY OF MONITORING RESULTS

RESULTS: DELHI

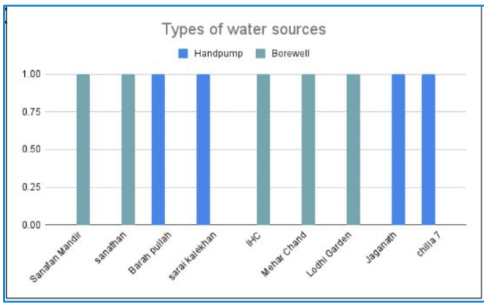
	pH May	pH October
Barah pullah surya ghadi 6 - Handpump	7.46	7.98
Chilla 7 - Handpump	7.28	7.44
IHC - Borewell	7.51	6.93
Jaganath Mandir - Borewell	7.51	5.29
Lodhi Garden Glasshouse - Borewell	7.31	7.93
Mehar Chand Harijan Camp - Borewell	7.41	7.04
Sanatan Mandir Jangpura - Borewell	7.32	7.79
Sanathan mandir panthnagar - Borewell	7.34	7.93
Sarai kalekhan, ganga vihar - Handpump	7.81	7.22

	EC (May)	EC(October)
Barah pullah surya ghadi 6 - Handpump	1013	563
Chilla 7 - Handpump	1626	2220
IHC - Borewell	2080	2500
Jaganath Mandir - Borewell	1603	1466
Lodhi Garden Glasshouse - Borewell	1427	2250
Mehar Chand Harijan Camp - Borewell	1359	1360
Sanatan Mandir Jangpura - Borewell	1223	1161
Sanathan mandir panthnagar - Borewell	1917	1400
Sarai kalekhan, ganga vihar - Handpump	591	562

	Nitrate (May)	Nitrate (October)
Barah pullah surya ghadi 6 - Handpump	7.8	16.5
Chilla 7 - Handpump	8	8.8
IHC - Borewell	12	14.3
Jaganath Mandir - Borewell	>30	25.9
Lodhi Garden Glasshouse - Borewell	17.8	1.4
Mehar Chand Harijan Camp - Borewell	17.5	14.3
Sanatan Mandir Jangpura - Borewell	23	11.4
Sanathan mandir panthnagar - Borewell	>30	14.7
Sarai kalekhan, ganga vihar - Handpump	18.2	8.3

Figure 16: Comparison of water quality parameters (pH, EC and Nitrate) in Delhi

- pH concentrations measured in the sampled sources remained consistently within the permissible limits for drinking (6.5-8.5) throughout the two monitoring cycles. However, at one of the sampling locations, a recorded pH concentration below 6.5 indicated an acidic condition.
- Electrical Conductivity in both monitoring rounds was recorded within the acceptable limit (> 2500 µS/cm)
- During the initial monitoring round in May 2023, two water sources, Jaganath Mandir and Sanathan Dharam Mandir, recorded nitrate concentrations exceeding 30 mg/l. However, these concentrations were reduced in the subsequent monitoring in October 2023. These sources are primarily utilized for bathing and cleaning purposes rather than drinking and cooking. It's also important to mention that the permissible limit of nitrate in drinking water in the Indian context is 40 mg/l.
- Additionally, the Nitrate results varied in a few sampling points between the two monitoring rounds.



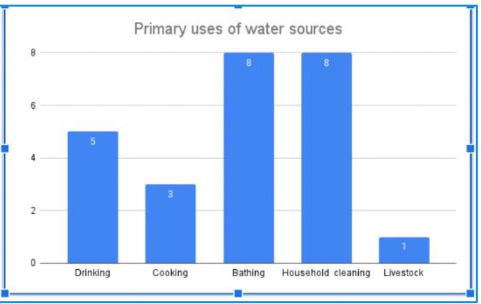


Figure 17: Type and primary usage of selected sampling points

- All sampling points monitored are mainly used by institutions such as temples, office complex or are public than private. The largest number of users are observed for two sampling points (7000-8000 users).

RESULTS: KANPUR

- In Alaulapur, pH concentration observed in sampled sources remained constant and within the permissible limits for drinking (6.5 -8.5) through the two monitoring cycles. However, one of the sampling locations recorded a concentration lower than 6.5 on the pH scale indicating its acidic.
- EC readings were within acceptable limits in the October esp. one of the sampling point which recorded 4940 µS/cm in May and significantly reduced during October
- Type of water sources selected in this village are Handpump and the type of irrigation channel is concrete lined

Alaulapur					
pH (May)	pH (October)	EC (May)	EC (October)	Nitrate (May)	Nitrate (October)
7.51	7.28	4940	1930	12.2	10.9
7.63	6.44	1910	1817	12.1	24.0
7.66	5.81	2250	1167	14.1	13.6
7.73	7.18	828	1249	14.5	14.7
7.86	6.53	1050	1254	18.5	14.3

Figure 18: Comparison of water quality results from Alaulapur

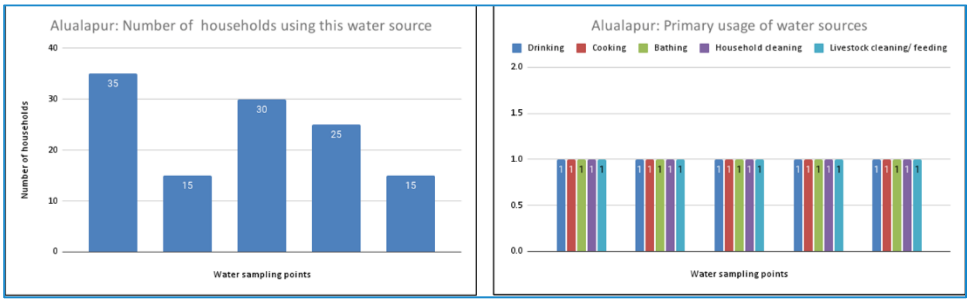


Figure 19: Number of households using the selected water sources and its primary usage (Alaulapur)

- In Kishanpur, EC readings of the two sampling points normalized during the second monitoring round as compared to reading above 2500µS/cm in May
- Nitrate concentration in three water sources reduced significantly during the second monitoring round except for one sampling point that was still observed >30 mg/l
- Kishanpur has earthen lining to the irrigation channel, possibly pervades into groundwater

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Kishanpur					
pH (May)	pH (October)	EC (May)	EC (October)	Nitrate (May)	Nitrate (October)
6.89	7.86	1388	1435	>30	18.3
7.04	6.78	1301	1131	>30	15.2
7.45	5.34	4230	1394	>30	11.6
7.5	5.65	4710	1150	>30	>30
8.11	7.48	1397	1510	12.7	11.1

Figure 20: Comparison of water quality results from Kishanpur

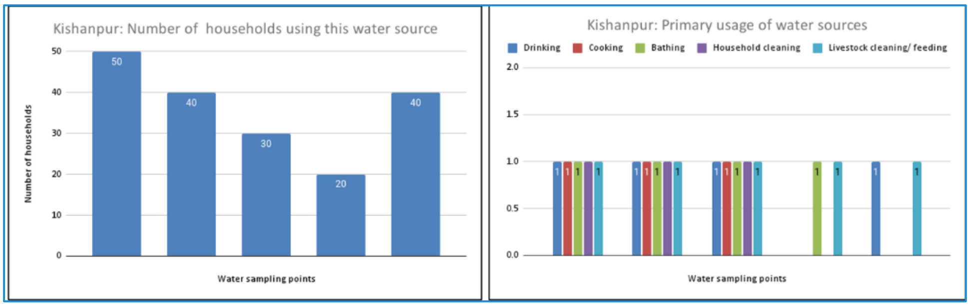

Figure 21: Number of households using the selected water sources and its primary usage (Kishanpur)

- In Kishanpur, 4 handpumps and 1 well was selected as sampling points
- Type of irrigation channel in this village: Earthen

Shiekpur					
pH (May)	pH (October)	EC (May)	EC (October)	Nitrate (May)	Nitrate (October)
7.11	7.76	3140	1978	25.5	11.9
7.33	8.39	3550	1976	17.5	19.5
7.4	6.14	4400	1497	23.5	20.1
7.44	7.91	4910	1422	22.8	15.9
7.66	7.85	5690	1426	12.8	12.6

Figure 22: Comparison of water quality results from Shiekhpur

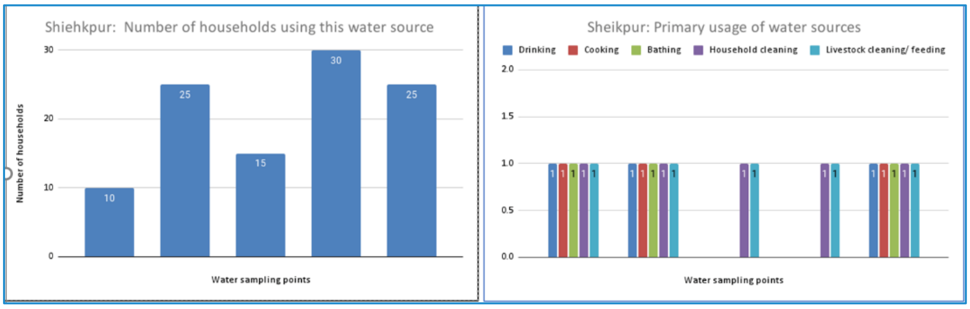

Figure 23: Number of households using the selected water sources and its primary usage (Shiekhpur)

- pH concentrations at sampling points in Shiekpur remained within permissible limits (6.5 -8.5) during both monitoring cycles

- In contrast to the elevated EC reading (>2500µS/cm) observed in the initial monitoring round, the values were observed within the acceptable limits during the October monitoring round.
- As observed in the first monitoring round, two of the selected water sources not used for drinking or cooking by households
- Type of water sources selected in this village are mostly handpumps
- Type of irrigation channel in this village is earthen
- Two water sources that were sampled were neither used for drinking or cooking. One of these water sources happens to be used by maximum number of households in the village but mostly for household cleaning or livestock cleaning

Trilokpur					
pH (May)	pH (October)	EC (May)	EC (October)	Nitrate (May)	Nitrate (October)
7.68	6.95	1611	5090	17	>30
7.81	5.9	1297	1482	27.8	17.3
7.83	7.59	1628	2220	19.5	20.6
7.93	7.69	1400	1302	29	<1
8.34	7.25	624	5430	20.1	26.4

Figure 24: Comparison of water quality results from Trilokhpur

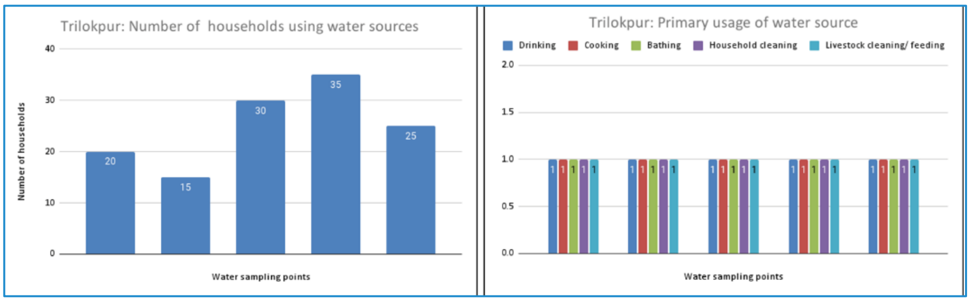

Figure 25: Number of households using the selected water sources and its primary usage (Trilokpur)

- In Trilokpur, the pH concentration at one of the sampling points fell below the permissible limit, suggesting an acidic condition.
- During the October monitoring, elevated EC readings were noted at two sampling points, in contrast to the previous monitoring round.
- Furthermore, at one of the sampling points where elevated EC readings were recorded in October, there was also an observation of nitrate levels exceeding >30 mg/l
- Handpump was selected as main source of sampling points
- Type of irrigation channel in this village is Concrete

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Kulgoan					
pH (May)	pH (October)	EC (May)	EC (October)	Nitrate (May)	Nitrate (October)
7.44	7.28	2950	2090	11.7	15.8
7.5	7.03	2100	2930	18.8	13.8
7.54	7.13	2160	3400	23.1	21.5
7.55	7.52	1492	2950	10	19.5
7.59	7.42	118	1681	15	16.2

Figure 26: Comparison of water quality results from Kulgaon

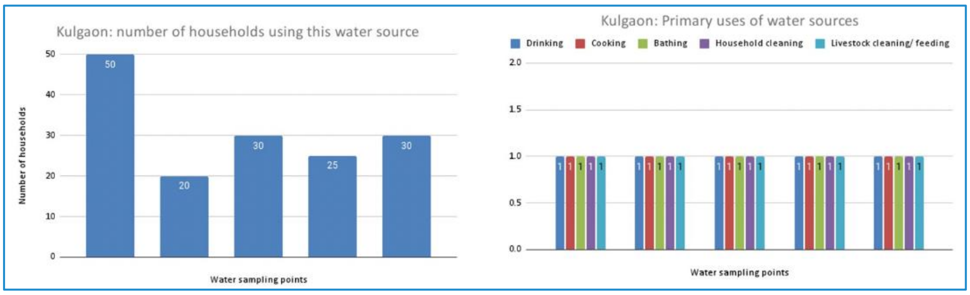

Figure 27: Number of households using the selected water sources and its primary usage (Kulgoan)

- In Kulgoan, EC was observed higher than the acceptable limit in three sampling points
- pH concentration was recorded lower than the permissible limit (6.5 - 8.5) in two sampling points in the second monitoring cycle in Motipur

Motipur					
pH (May)	pH (October)	EC (May)	EC (October)	Nitrate (May)	Nitrate (October)
7.61	7.37	1870	2290	12.1	9.6
7.69	5.59	1797	2330	12.5	16.0
7.72	5.81	1327	2230	11.2	18.1
7.83	6.0	925	2290	17.6	20.9
8.3	7.43	2610	1880	13.7	12.2

Figure 28: Comparison of water quality results from Motipur

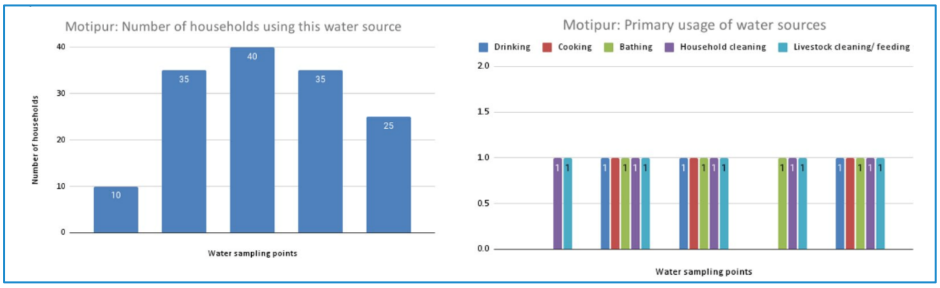

Figure 29: Number of households using the selected water sources and its primary usage (Motipur)

- In Motipur, pH concentration was recorded lower than the permissible limit (6.5 - 8.5) in two sampling points in the second monitoring cycle

- Two water sources are not used for drinking or cooking by the households. Out of which, one is used by minimum number of households that were sampled in Motipur
- Type of water sources selected in this village are handpumps
- Type of irrigation channel in this village is Concrete
- Only 3 out of 5 water sources were used for cooking / drinking

Conclusions

The monitoring data collected through Akvo's baseline survey in Delhi and Kanpur provides insights into the water quality and management challenges in the selected villages and case areas. The parameters ph, EC and Nitrates are proposed by GEMS/UNEP to monitor ambient water quality (UNEP, 2018) to assess the "Proportion of bodies of water with good ambient water quality" (SDG 6.3.2). The use of Akvo Caddisfly, with its simplified design and user support, facilitated the participation of individuals from Solidaridad in water quality testing. Individuals from Solidaridad had a strong background in community facilitation and outreach but limited expertise in monitoring and assessing local water resources effectively. The collaborative approach, engaging the community in selecting sampling points and sharing observations, enhanced the overall data gathering process.

In both Delhi and Kanpur, the pH concentrations of the sampled water sources generally remained within the permissible limits for drinking. However, occasional deviations, particularly towards acidity, emphasize the need for continued monitoring and potential remediation measures. Electrical Conductivity (EC) readings across the monitored sources were consistently within acceptable limits, indicating overall compliance with acceptable standards.

Notably, instances of elevated nitrate concentrations in specific water sources were observed during the initial monitoring round in May 2023, particularly in Delhi. However, subsequent rounds showed a reduction in nitrate levels. Understanding the varied usage of water sources, such as for bathing and cleaning purposes rather than drinking, is crucial for appropriate interpretation and future deliberation.

The variation in nitrate levels between monitoring rounds highlights the dynamic nature of water quality and underscores the importance of continuous monitoring to capture temporal fluctuations. The results also point out the significance of considering the specific functions of water sources, as certain locations may be more prone to contamination due to their usage patterns or other reasons that could not be captured in detail during the baseline data collection.

In Kanpur, the differentiation between villages with concrete and earthen irrigation channels was observed. The collaboration with Solidaridad demonstrates the success of capacity-building efforts in enabling NGOs to contribute meaningfully to water quality assessments.

In conclusion, the monitoring results emphasize the need for sustained efforts in water quality management, community engagement, and continuous capacity building. It demonstrates a promising model for empowering non-experts to contribute to water management initiatives and understand water challenges in diverse communities, laying the foundation for informed decision-making and targeted interventions.

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CHAPTER 4 PAVITRA GANGA WATER QUALITY MONITORING DASHBOARD

The water quality monitoring (and modelling) information is accessible via the Pavitra Ganga water quality monitoring dashboard (Task 4.4, Deliverable 4.5), which is embedded in the Pavitra Ganga website using the following URLs:
https://pavitra-ganga.eu/en
https://pavitra-ganga.eu/en/pavitra-ganga-dashboard
https://pavitraganga.marvin.vito.be/region

The web-based dashboard tool visualizes data (Figure 30) from available data sources: mobile monitoring (Task 4.1), stationary sensors (Task 4.2) and regional modelled data (Task 4.3). The dashboard was developed based on a user requirements analysis to define the functionalities of the tool. The starting point has been VITO's Sensorview but was quickly adapted to be of relevance to the Pavitra Ganga Project. The user of the dashboard can navigate between the two case areas and consult the data related to both water quality monitoring and modelling.

Figure 30: Pavitra Ganga Water Quality Monitoring Dashboard – the starting webpage