PLASMA LAB



Prof. Lakshminarayana Rao

Associate Professor, Centre for Sustainable Technologies, Associate Faculty, Interdisciplinary Centre for Water Research; Associate Faculty, Department of Materials Engineering, Indian Institute of Science, Bengaluru

narayana@iisc.ac.in; https://www.plasmalabiisc.com/

Areas of Expertise & Technologies Developed

Water Technologies

Decentralized treatment & reuse — rural & urban lake systems

Plasma-Activated Water

Medical antimicrobial applications & sustainable fertilizers

AI & Data for Water / Air

Forecasting, quality monitoring, microplastics & foam detection

Waste-to-Energy

Low-carbon steelmaking, RDF conversion & lifecycle assessment

12 technologies · From lab-scale proof-of-concept to commercial deployment

Technologies & Tools — Portfolio Overview

TECHNOLOGIES DEVELOPED – 6 #'s	TRL
Biomass Co-Gasification for Green Steel	8
Rural Water & Wastewater Reuse	6
Inline Wastewater Treatment (Lakes)	6
PAW — Medical Applications	4
PAW — Agricultural Application	3
RDF Thermo-Chemical Conversion	3

TOOLS DEVELOPED – 6 #'s	TRL
Groundwater Outlook (Bengaluru)	4
Cross-City Air Quality Forecasting	4
Foam Detection & Monitoring	4
Freshwater Quality AI/ML	3
Microplastics Quantification	3
Solid Waste LCA Tool	3

● TRL 1–3 · Lab-scale ● TRL 4–6 · Pilot / Prototype ● TRL 7–9 · Commercial-ready

Commercial-Scale Biomass Co-Gasification for Low-Carbon DRI

World-first commercial-scale trial at JSPL Pvt. Ltd., Orissa

WASTE TO ENERGY

THE PROBLEM

- Steel sector emits ~7–8% of global CO_2 (39 $GtCO_2$ total)
- Need a low-carbon route to direct-reduced iron (DRI)

OUR SOLUTION

- Integrated biomass-coal co-gasification, 5–10% coal substitution
- Stable long-term operation (~8 hrs) with existing infrastructure

WHAT'S NOVEL

First commercial-scale demonstration of biomass co-gasification for DRI production.



On-site at the world-first commercial biomass co-gasification trial, JSPL

Media Highlights

- ANI
- Deccan Herald
- The Hindu
- The Times of India



Lurgi gasifier at JSPL

Commercial-Scale Biomass Co-Gasification for Low-Carbon DRI

WASTE TO ENERGY

TRL=8 **Coal replaced with biomass**	**10%** **Biomass substitution**
4.3 t/h **Coal replaced with biomass**	**1.47 vs 2.34** **tCO_2e/t: DRI-EAF vs BF-BOF**





Raw biomass pellet fed to the gasifier with coal

POTENTIAL IMPACT

- Reduced CO_2 & coal usage; works with existing plant infrastructure
- Agri-waste valorization; pathway to net-zero steel

Turn agricultural waste into cleaner steel—replacing 4.3 tonnes of coal per hour in a commercial-scale demonstration.

NEXT STEP

- Scale-up beyond pilot trial
- Existing system integration

PUBLICATIONS

→ Waste & Biomass Valorization

→ Env. Sci. & Pollution Res., 2024

COLLABORATORS

Prof. Govind S Gupta

Department of Materials Engineering



Decentralized Water & Wastewater Reuse (Rural)

Implemented at a government school (206 students), Berambadi village, Chamarajanagar district, Karnataka

WATER TECH

THE PROBLEM

- Limited access to safe water & sanitation in rural areas
- Greywater from sinks, baths & laundry is discharged untreated

OUR SOLUTION

- Modular, solar-powered decentralised treatment system (DWWTS)
- Greywater treatment & reuse + rainwater harvesting

WHAT'S NOVEL

Fully solar-powered, scalable modular unit designed for local O&M in low-resource rural settings.



The deployed treatment technology at the school site

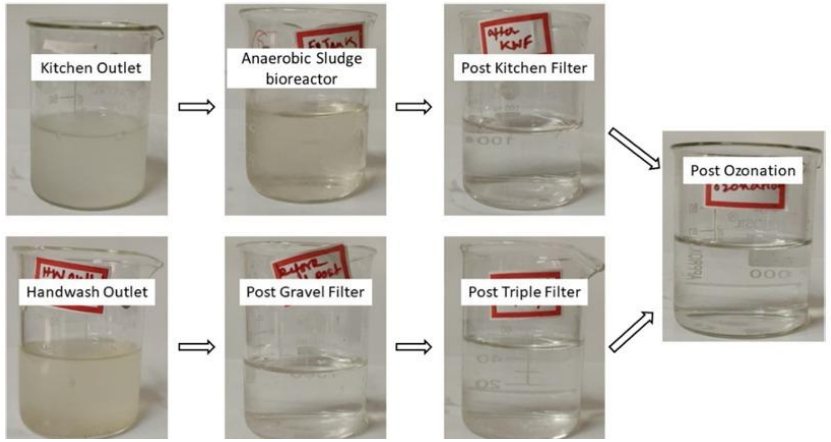
Decentralized Water & Wastewater Reuse (Rural)

TRL=6
Technology Readiness Level

50%
Less freshwater used (520,000 L/yr)

52%
Less grid electricity (solar)

Approved
For non-potable reuse



Visual appearance of water at different treatment stages

POTENTIAL IMPACT

- Scalable model for rural India — supports SDGs 3, 6, 11, 12 & 13

Save ~0.5 million litres of freshwater every year at a single school—with a model that can be taken to thousands of rural communities.

NEXT STEP

Institutional & community-scale rollout across water-stressed rural areas

PUBLICATIONS

→ Sust. Water Resources Mgmt, 2025

→ J. Water Process Engineering, 2020

Decentralized Inline Wastewater Treatment

Deployed & operating at Jakkur Lake, Bengaluru — a real-world urban water pilot

WATER TECH

THE PROBLEM

- ₹70–75 cr/month spent on STPs, yet ~50% of Bengaluru's sewage stays untreated
- 179 of 184 lakes of Bengaluru received untreated sewage

OUR SOLUTION

- Nature-based inline cascade: Anaerobic → Euglena → Algal stages
- Gravity-driven — zero energy, installed at the lake inlet



Jakkur Lake, Bengaluru — pilot deployment site

WHAT'S NOVEL

Zero-energy, nature-based treatment cascade requiring no external power at the point of inflow.

Decentralized Inline Wastewater Treatment

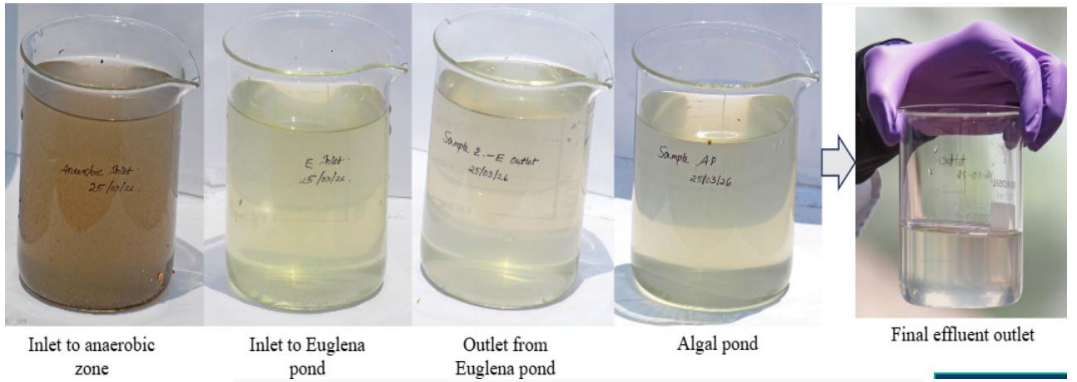
WATER TECH

TRL=6
Technology Readiness Level

85–90%
COD removal

70–80%
Nutrient removal

Real-site
Performance validated



Improvement in water quality

POTENTIAL IMPACT

Remove 85–90% of organic pollution before it reaches the lake—with a model that could be replicated across Bengaluru's 136 developed lakes.

COLLABORATOR

Dr. Chanakya HN



NEXT STEP

Extend to more lakes and drains across Bengaluru

PUBLICATIONS

→ Environmental Pollution, 2024

→ Chemical Engineering J., 2024

Plasma-Activated Water (PAW) for Medical Applications

PLASMA WATER

Antimicrobial resistance (AMR) is a growing global health threat

THE PROBLEM

- Rising antimicrobial resistance limits treatment options
- Need for non-antibiotic, sustainable antimicrobial solutions

OUR SOLUTION

- Plasma-activated water platform validated against MDR pathogens
- Wound-infection proof-of-concept demonstrated

WHAT'S NOVEL

A green, chemical-free antimicrobial water platform as an alternative to conventional antibiotics.



PAW generation reactor (5 L)

Plasma-Activated Water (PAW) for Medical Applications

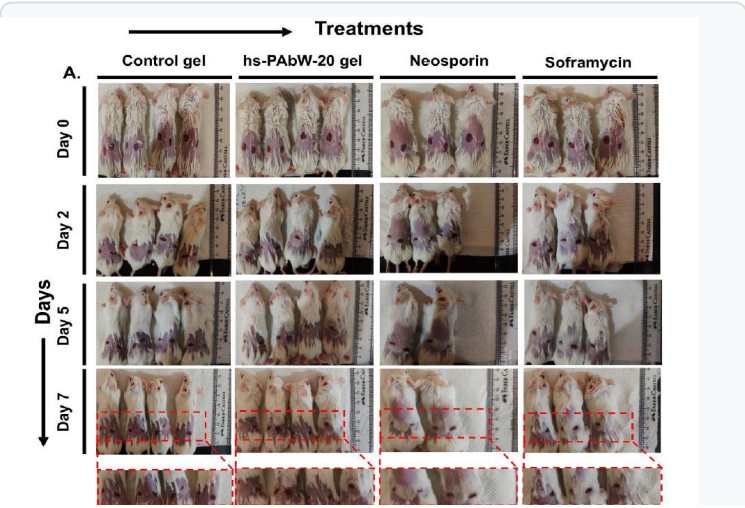
PLASMA WATER

TRL=4
Technology Readiness Level

7
Publications

2
Granted patents

₹2.0 Cr
Funding secured to date



Wound Closure Studies

POTENTIAL IMPACT

A new way to fight difficult infections without relying solely on antibiotics—opening a potential pathway against antimicrobial resistance.

COLLABORATOR

Prof. Dipshikha Chakravortty



NEXT STEP

Extended pathogen validation and pre-clinical studies

PUBLICATIONS

→ ACS Pharmacology & Transl. Sci.

→ Plasma Process. & Polym., 2022

→ Characterization of PAW for Medical Applications

→Generation of neutral pH

PAW as a Sustainable Nitrogen Source for Agriculture

Renewable electricity + water → on-demand nitrogen fertilizer

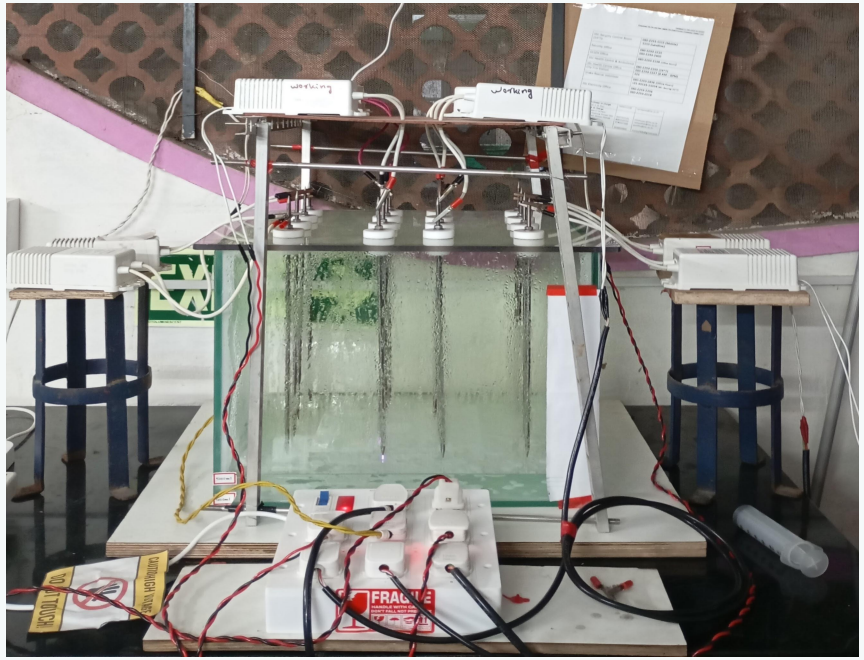
PLASMA WATER

THE PROBLEM

- Urea production is fossil-fuel dependent
- Much applied nitrogen is lost — driving pollution & GHG emissions

OUR SOLUTION

- Decentralized fertilizer production from renewable electricity + water
- Replaces fossil-based urea with PAW



PAW reactor schematic

WHAT'S NOVEL

On-demand, decentralized fertilizer synthesis integrated directly with renewable power.

PAW as a Sustainable Nitrogen Source for Agriculture

PLASMA WATER

TRL=3
Technology Readiness Level

7 MJ/kg N
Theoretical specific energy

~50 g/L
Nitrogen concentration

>30 days
Storage stability



Effect of PAW water on plant growth

POTENTIAL IMPACT

- Decentralized, on-demand, low-GHG fertilizer
- Lower pollution than conventional urea supply chains

Produce nitrogen fertilizer from air, water and renewable electricity—opening a path to replace part of India's ~40 Mt/year urea supply.

NEXT STEP

Field-test on crops

PUBLICATIONS

→ J. Applied Physics, 2021

→ IEEE Trans. Plasma Sci., 2021

Thermo-Chemical Conversion of Refuse-Derived Fuel (RDF)

Tested at CST, IISc Bengaluru — 2 kg/h downdraft gasifier

WASTE TO ENERGY

THE PROBLEM

- ~160,000 TPD MSW generated; ~50,700 TPD unaccounted for
- RDF-as-is causes unstable gasifier operation

OUR SOLUTION

- Optimize plastic content in RDF before gasification
- Defined a stable operating window for downdraft gasification

WHAT'S NOVEL

Identified the plastic-content threshold (15%) that keeps gasification stable.



2 kg/h downdraft gasifier test rig, CST, IISc

Thermo-Chemical Conversion of Refuse-Derived Fuel (RDF)

WASTE TO ENERGY

TRL=3
Technology Readiness Level

15%
Stable plastic content

~3 MJ/kg
Gas calorific value

1.4 g/Nm³
Tar content



RDF Pellets



Flaring of produced syngas

POTENTIAL IMPACT

- A practical MSW-to-energy route for small towns
- Energy recovery plus useful by-products

Develop a pathway to convert 20–40 tonnes/day of municipal waste into useful energy for small towns.

NEXT STEP
Move to 20–40 TPD municipal-scale demonstration

PUBLICATIONS
→ Waste & Biomass Valorization
→ Env. Sci. & Pollution Res., 2024
→ Bioresource Technology Reports 23. 2023
→ Fuel 308. 2022
→ Thesis: 2023

Groundwater Outlook for Bengaluru

Study funded by BWSSB, in partnership with IISc Bengaluru

AI & DATA

THE PROBLEM

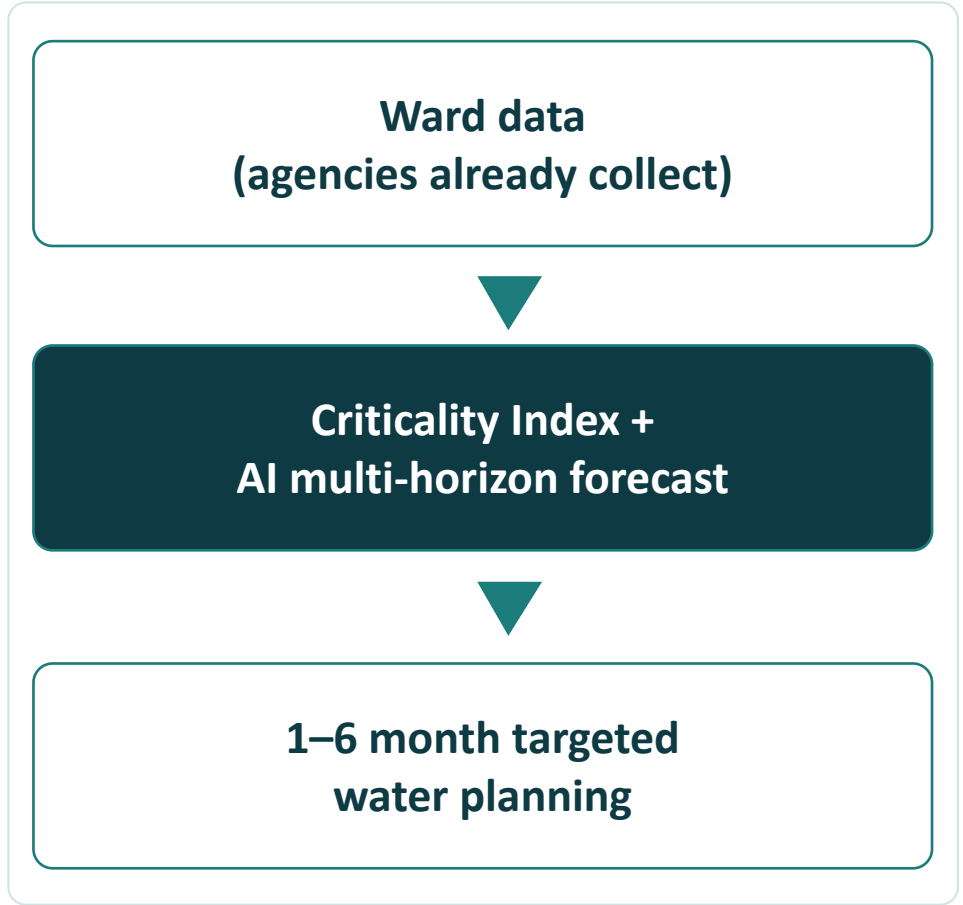
- Groundwater levels behave very differently ward to ward
- Planners see only past readings, not where stress is heading

OUR SOLUTION

- Ward Criticality Index + recursive AI forecast (1–6 months)
- Built entirely from data agencies already collect

WHAT'S NOVEL

Single pipeline links a ward-level criticality ranking to a multi-horizon forecasting model.



Groundwater Outlook for Bengaluru

TRL=4
Technology Readiness Level

0.90
Cross-validated R^2

±1.96 m
Mean absolute error

0.82
R^2 at 6-month horizon

POTENTIAL IMPACT

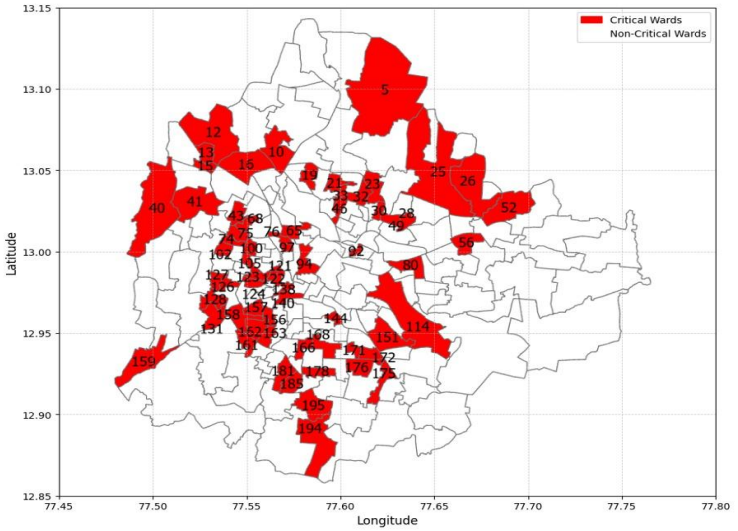
- Targeted recharge siting & borewell decisions
- Early warning ahead of summer shortages

Predict groundwater stress 1–6 months ahead across 198 Bengaluru wards—before summer shortages become a crisis.

COLLABORATOR

Prof. Sekhar M





Critical Wards of Bengaluru

NEXT STEP

Extend to all 198 BBMP wards; live monthly-refresh dashboard

PUBLICATIONS

→ Ecological Informatics, 2025

Transferable AI/ML Models for Freshwater Quality Monitoring

Applied across 30 urban lakes in Bengaluru

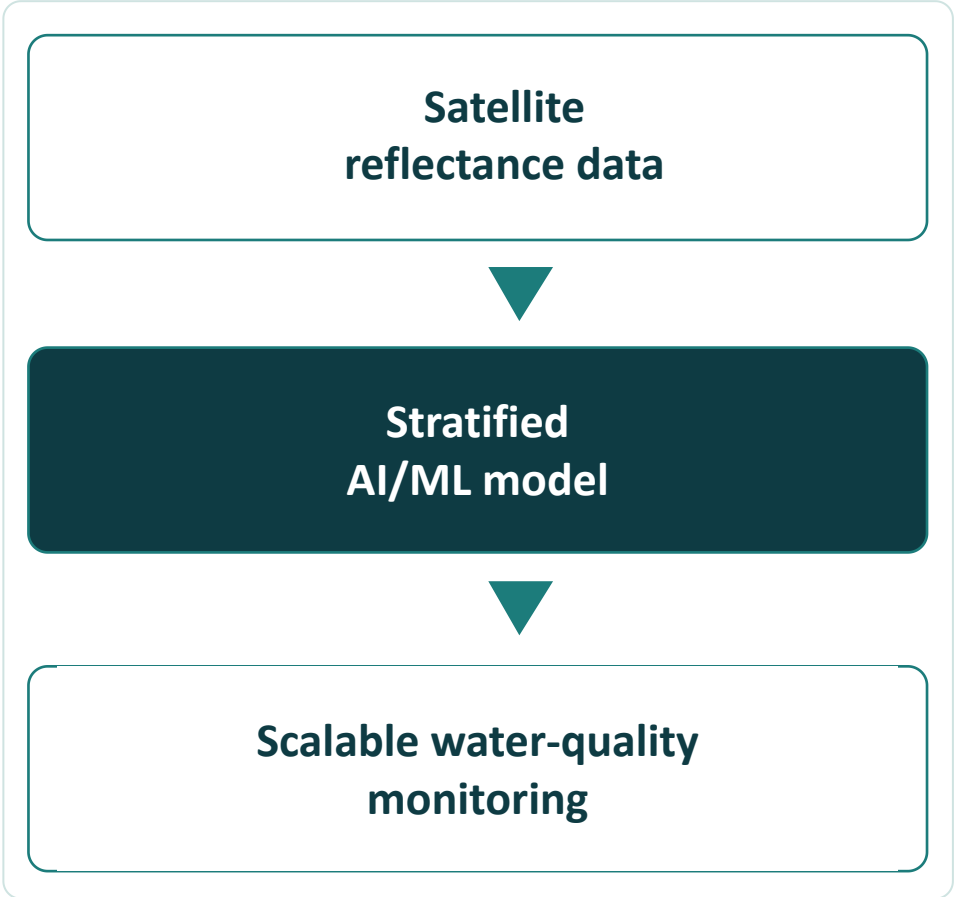
AI & DATA

THE PROBLEM

- Field sampling for water quality is costly, sparse & slow
- Can't scale across many highly variable urban lakes

OUR SOLUTION

- Satellite reflectance → stratified AI/ML modelling
- Class-specific models resolve spectral ambiguity across lakes



WHAT'S NOVEL

Links pollution clustering with class-specific ML models trained per lake type.

Transferable AI/ML Models for Freshwater Quality Monitoring

TRL=3
Technology Readiness Level

86%
Classification accuracy

0.79
Test R^2 for COD

109
Satellite scenes used

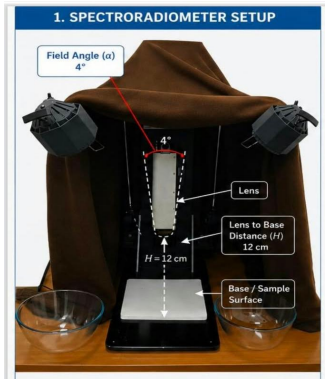
POTENTIAL IMPACT

- Scalable, near-real-time lake monitoring
- Earlier pollution detection, stronger water management

Watch 30 Bengaluru lakes from space—and detect pollution earlier without waiting for laboratory sampling.

COLLABORATOR

ISRO Bengaluru



Spectrophotometer



Hyperspectral camera

NEXT STEP

Pilot-scale hyperspectral tests; field validation across diverse lakes

PUBLICATIONS

Developing a Universally Transferable Model for Freshwater Monitoring via Multispectral Imaging and AI-ML (Under submission)

Microplastics Image Quantification

Custom annotation & detection pipeline built on a 10,000-image dataset

AI & DATA

THE PROBLEM

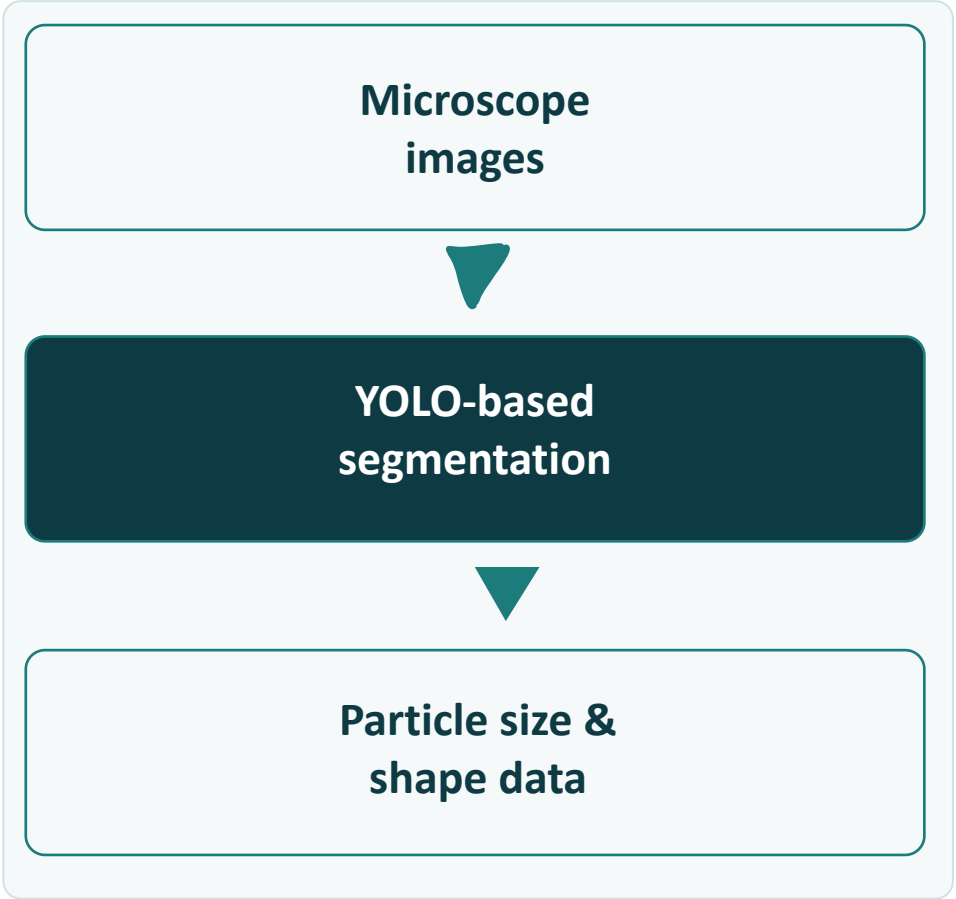
- Manual microplastic annotation is slow & subjective
- Doesn't scale to thousands of particles per image

OUR SOLUTION

- Custom annotation GUI + automated YOLO-based classification
- Best of 4 models tested, selected on accuracy

WHAT'S NOVEL

Combines a purpose-built annotation tool with automated shape/size analysis in one pipeline.



Microplastics Image Quantification

TRL=3
Technology Readiness Level

68.2%
Precision

0.465
F1 score

43.3%
mAP50 (box)



Identified microplastic particles

POTENTIAL IMPACT

- Faster, reproducible microplastic counting
- Standardized, scalable environmental monitoring

Make invisible plastic pollution measurable—automating analysis across a 10,000-image training dataset.

COLLABORATOR

Prof. Christina Bogner



NEXT STEP

Validate on unseen samples; package as a standalone tool

PUBLICATIONS

Assessing microplastics in India's first Large-Scale Recycling Study in Karnataka (Under preparation)

Foam Detection and Monitoring

Prototype running on live CCTV feed at a wastewater/effluent site

AI & DATA

THE PROBLEM

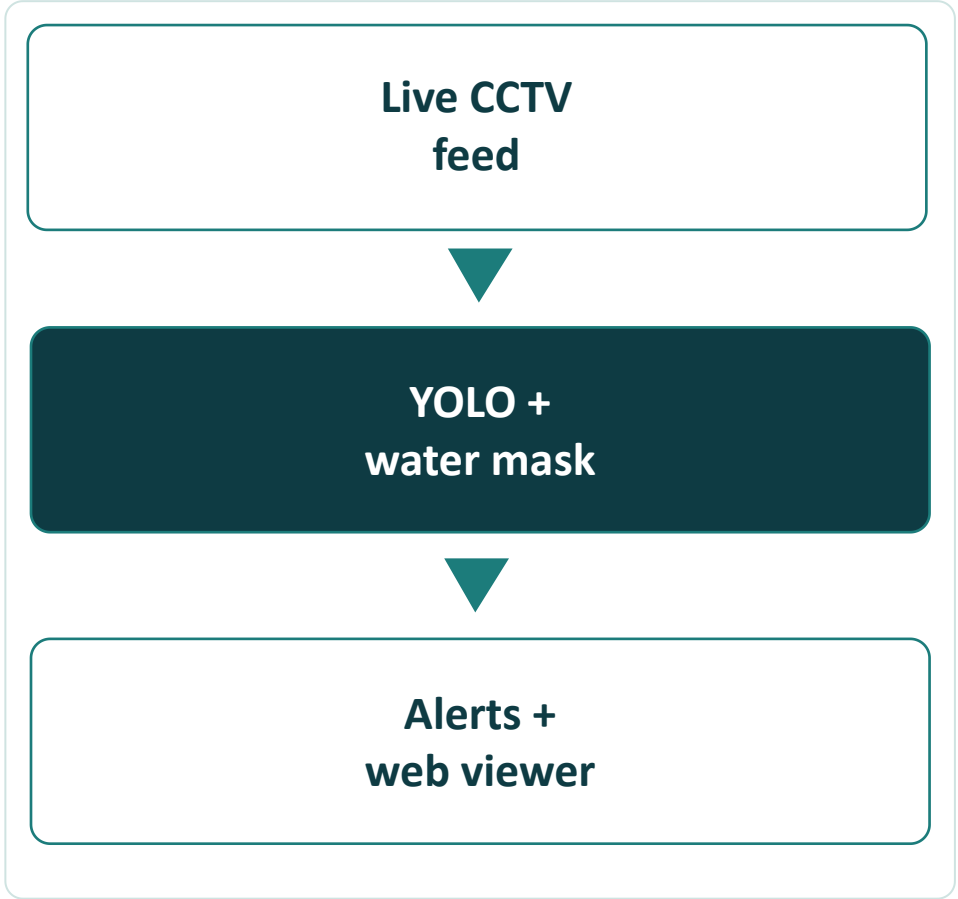
- Intermittent foam events are hard to track manually
- 24×7 CCTV watching isn't scalable across sites

OUR SOLUTION

- Automated foam detection on existing CCTV (YOLO + water mask)
- Alerts + web viewer with live / archive views

WHAT'S NOVEL

Combines YOLO with a spatial water mask and a 3-sector coverage rule for reliable detection.



Foam Detection and Monitoring

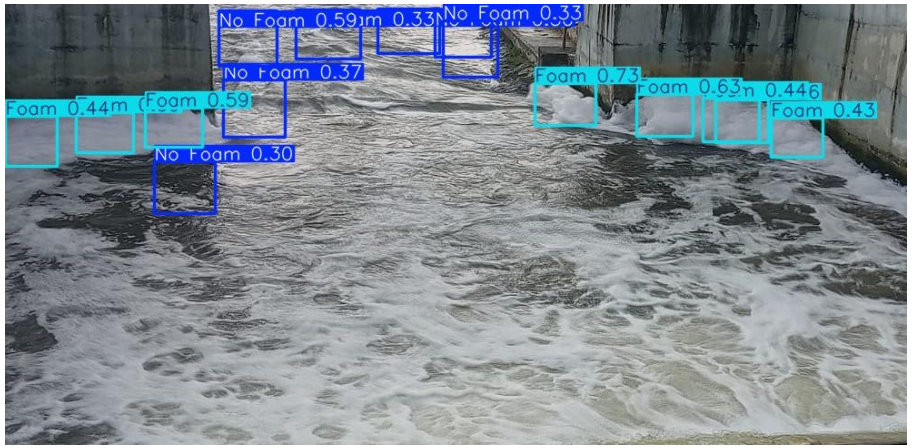
AI & DATA

TRL=4
Technology Readiness Level

6 month
Continuous field testing

3
Water sectors monitored

1-min
Clip classification



Foam detection

POTENTIAL IMPACT

- Faster response, cleaner receiving waters
- Reduces manual monitoring; scales on existing CCTV + PC

Turn existing CCTV into a 24×7 pollution watchdog—field-tested continuously for 6 months across 3 water sectors.

NEXT STEP

Long-term field trial to quantify reliability & false alarms

PUBLICATIONS

→ Chemical Engineering J., 2024

→ J. Environmental Mgmt, 2022

COLLABORATOR *Dr. Prasad Sudhakar*



Multi-Pollutant Air Quality Forecasting, Cross-City

Pune → Bangalore transfer study, using real CPCB air-quality & weather data

AI & DATA

THE PROBLEM

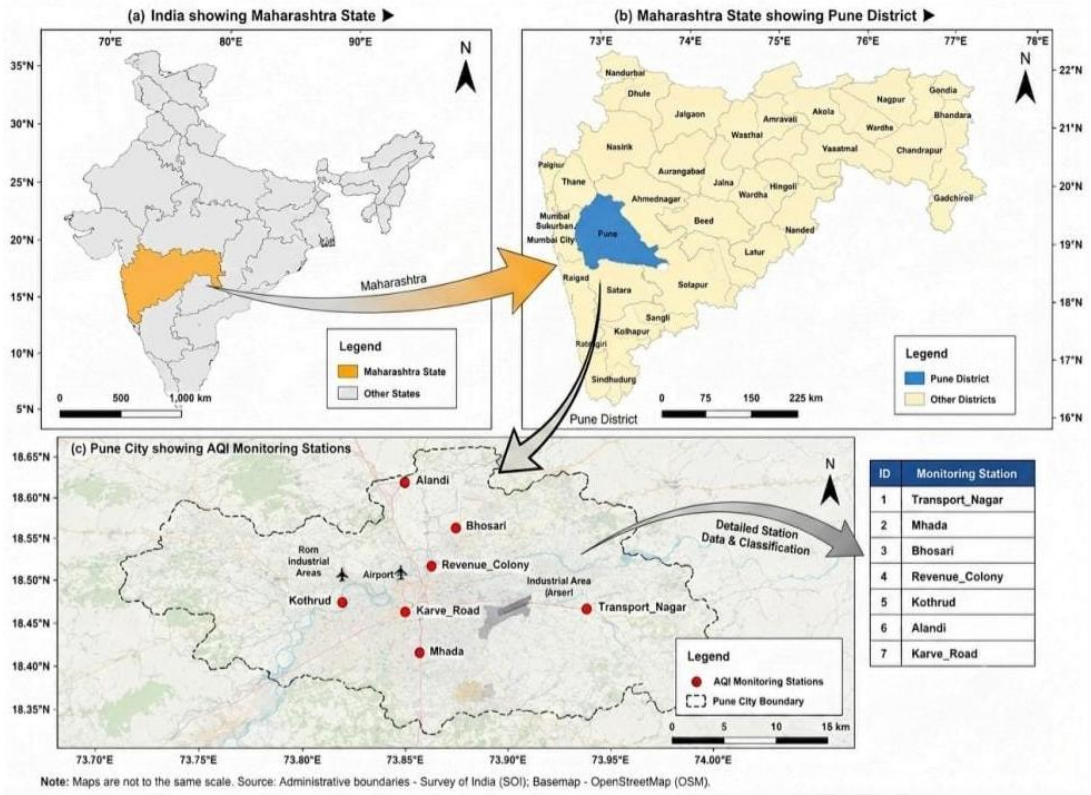
- Air-quality models trained in one city often fail elsewhere
- Retraining for every new city is costly & data-hungry

OUR SOLUTION

- ANN model trained on Pune, transferred to Bangalore — zero retraining
- Climate similarity checked before transfer

WHAT'S NOVEL

Validated cross-city transfer learning using only real CPCB monitoring data.



Area considered for study

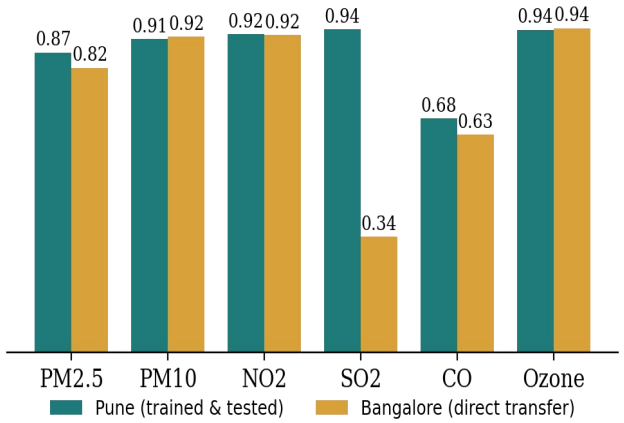
Multi-Pollutant Air Quality Forecasting, Cross-City

AI & DATA

TRL=4
Technology Readiness Level

0.83–0.94
R^2, most pollutants

7
CPCB stations, 2019–24



R^2 by pollutant — Pune (trained) vs Bangalore (transferred)

POTENTIAL IMPACT

- Predicts air quality in new cities without retraining
- Scalable early-warning framework

Let one city's air-quality learning help another city forecast pollution—demonstrated from Pune to Bengaluru without retraining.

NEXT STEP

Real-time streams; validate across more diverse climates

PUBLICATIONS

Transferable Multi-Pollutant Air Quality Forecasting Across Indian Cities Using Meteorological and Environmental Monitoring Data (Under preparation)

Life-Cycle Assessment of Solid Waste Treatment Technologies

Applied across Bengaluru, Mysore & Tumkur scenarios

WASTE TO ENERGY

THE PROBLEM

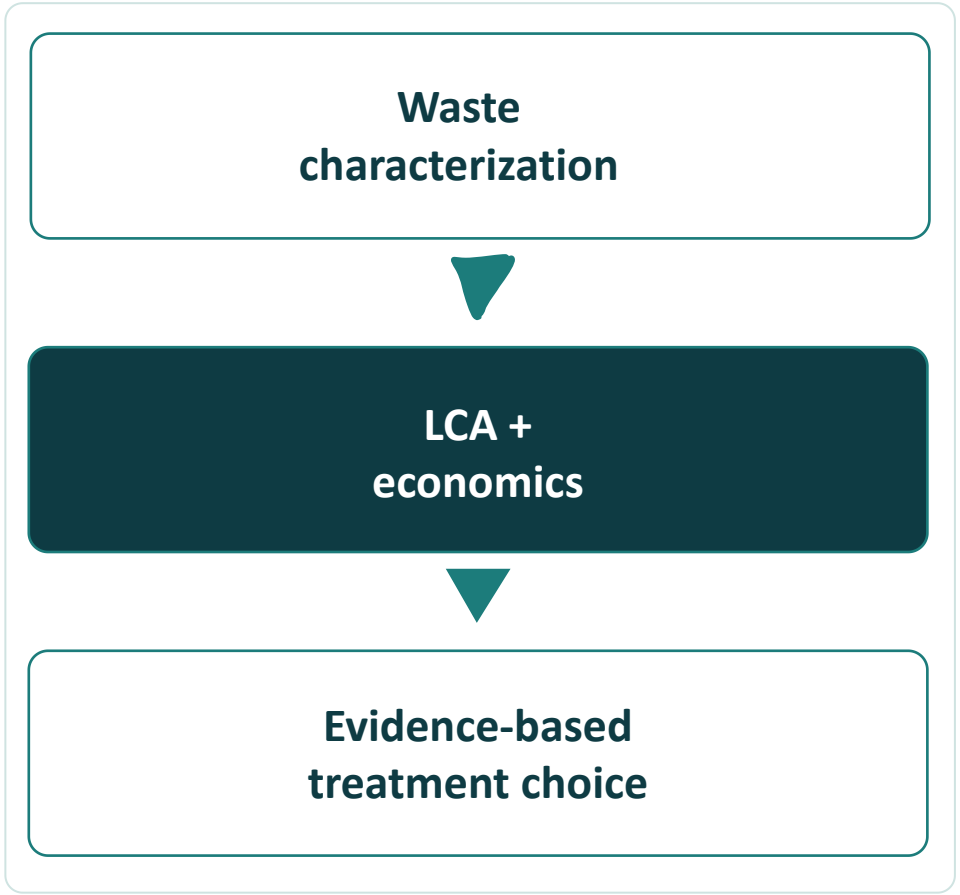
- MSW generation: 62 million tonnes/year in India
- Treatment choice must also account for waste quality & end-use

OUR SOLUTION

- Unified decision framework: waste → LCA → economics → choice
- Covers biogas, composting, WtE, landfill, leachate & biomining

WHAT'S NOVEL

Links waste characteristics, treatment route, GWP and economics in one decision tool.



Life-Cycle Assessment of Solid Waste Treatment Technologies

TRL=3
Technology Readiness Level

-714 to -1001
kg CO_2e/t-MSW (WtE+CC)

5–6 yrs
Payback for ~15% return

≥120 TPD
Min. bio-CNG scale



Waste to energy plant



Meeting with PSA

POTENTIAL IMPACT

- Better-fit treatment choices
- Lower GHG emissions & stronger project economics

Help cities choose waste solutions that can pay back in 5–6 years—before millions are committed to the wrong technology.

NEXT STEP

Pilot validation; develop as a policy/investment decision tool

PUBLICATIONS

→ Bioresource Technology, 2025

→ Fuel, 2026

COLLABORATORS

Prof. G L Sivakumar Babu



Dr. Chanakya HN



Let's Build Together

From lab-validated science to field-deployed, commercial-scale technology — we partner with companies and agencies to take these platforms further.

Prof. Lakshminarayana Rao

narayana@iisc.ac.in

Centre for Sustainable Technologies · Indian Institute of Science, Bengaluru

Team

