

# Intelligent Hard Water Management System

## Team Members

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## Brief Abstract

Hard water is a significant concern in urban areas like Vellore, impacting health, daily life, and appliance longevity. This project introduces an AI-driven platform for proactive hard water management, designed to function without physical sensors. It leverages a unique approach of utilizing open-access, synthetically generated, and simulated user behavior datasets to provide personalized, actionable recommendations. The core system integrates an advanced data pipeline for robust feature engineering, a hybrid prediction engine combining statistical and machine learning models for forecasting water hardness spikes, and a user behavior-aware planning module to suggest optimal times for maintenance.

A key innovation is the adaptive alert system which delivers explainable, timely advice. By demonstrating sophisticated AI functionalities through simulated environments, this project offers a cost-effective, scalable, and future-ready solution that can be integrated with live sensor data in the future, providing a vital tool for community well-being.

## 3 Major Functionalities

- **Hybrid Predictive Modeling & Data Fusion Engine (Extension/Upgrade):** This functionality focuses on enhancing water hardness forecasting by integrating diverse data sources - open datasets, advanced synthetic data, and simulated environmental factors (e.g., mock supply shifts). It employs sophisticated feature engineering and fuses outputs from statistical models (ARIMA) and machine learning algorithms (Random Forest, LSTM) to improve prediction accuracy and robustness for future hardness spikes.
- **Advanced Synthetic Data Generation & User Behavior Simulation Module (New):** This completely new module addresses the sensor-less constraint by generating realistic, time-series water hardness data with configurable seasonality, trends, and anomalies. Crucially, it also simulates diverse user routines (e.g., laundry schedules, peak water usage), providing essential input for the personalized planning engine, making the system self-sufficient for demonstration and testing.
- **Explainable & Context-Aware Recommendation System (New):** A novel functionality that generates highly personalized and actionable advice (e.g., "Pre-soften water tonight") based on predicted water hardness and simulated user routines. This system not only provides recommendations but also offers clear, simple explanations for *why* a particular action is advised (e.g., "due to forecasted high hardness and your usual laundry schedule tomorrow"), fostering user trust and understanding.

## Project Outcome

A **web application** visualizing water hardness data, forecasting trends, and delivering personalized, explainable hard water management recommendations.