Smart Cities:
Water Quality Management

Presenters: Lucas Colias & Aaron Ramirez

Why is water quality management important?

It provides us with the clean crystal fluid we need to survive!

Our motivations

- Initially inspired by the netflix docuseries, “Down to Earth with Zac Efron”
  - Second episode covered the tap water infrastructure of France.
  - More robust than other first world countries.
- This lead us to research the infrastructure and methods used to monitor the local water supply in Long Beach.
  - Much of the data and information is acquired through manual procedures.
  - Information isn’t necessarily the easiest to understand.

Our problem

We wanted to view information about the water supply quality in long beach in real time, but there is no real time monitoring being done. This provided us with out problem, “How could a system like this be created and how could it be implemented?” Our research goals were broken up into two main categories:

- How to build the system
- How to interpret data from the system

The research

1. Water Flow Driven Sensor Network
2. Water Quality Modeling in Morocco
3. An IoT Based System
4. Web Tools for calculating and Visualizing Water Quality

Water Flow Driven Sensor Networks for Leakage and Contamination Monitoring in Distribution Pipelines

Authors: Amitangshu Pal and Krishna Kant

Motivations: Freshwater supplies are dwindling so it is important for Water Distribution Systems to be maintained as well as possible.

- Stress on urban water systems continues to increase as population increases
- Most of these systems are in poor condition
- Traditional monitoring techniques are largely manual.
- These techniques are inadequate for increasingly stressed systems.
- There is a growing need for the development of monitoring systems that detect leaks and contamination.
- Quicker detection increases the working lifetime of these water systems.

The main objective

- The main objective of this article is to develop a sensor network that continuously monitors water leaks and contamination in water pipes and reports relevant data to a control station that can do the necessary analytics for detection and localization.

Obstacles to overcome:

- Pipes are underground which means
  - Access to pipes is limited
  - No simple solution for power
  - Radio Frequency Communication requires high power(especially underground)

Solutions to these problem:

- Powered by water flow via a small hydro fan unit.
- A super capacitor stores harvested energy.
- Installed only at pipe connections through manholes.
- In practice only certain connection points need to be monitored.
- Lower part consists of the fan and sensors for detecting contaminants and leaks.
- Upper part consists of power storage, voltage boosters and regulators, and a computing/communication unit.
- Upper part must also have the means to connect to the network via a radio frequency(e.g. WiFi)

Powering Solution

- Since the flow rate in the pipes may at times be inadequate to harvest adequate energy to keep the sensor network alive, we propose an optimal sampling and transmission rate adaptation scheme based on the nodes energy budget.

- In systems where an automated artificial water circulation is feasible, we examine the problem of minimal circulation to keep the sensor network alive.

Powering Solution

- Find the maximum amount of power required to run the system.
- This power can be converted into the required velocity of the water needed to run the system
- This velocity is passed onto a pumping station that artificially pumps water if the system is low use

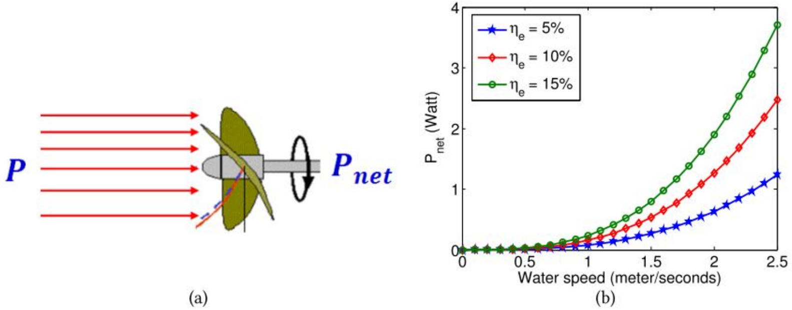

Fig. 3. (a) A fan-based energy harvester. (b) P_{net} with different water velocities.

Future works

- Predicting Energy Harvesting
- Computing Optimal Sampling Rate
- Various Water Quality Indicators
- Simulations

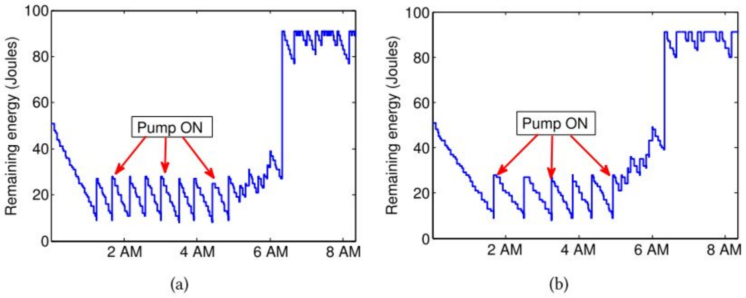

Fig. 16. Remaining energy over time for (a) ERA scheme, (b) CARA scheme.

Hydraulic and Water Quality Modeling of the Drinking Water Supply Network: Fnideq City (Morocco) as a Case

Author:Mohamed BEN-DAOUD, Abderrahmane BEN-DAOUD, Ahmed SAYAD, Bouabid ELMANSOURI, Malika KILI, Radouane ELAOUFIR, Houssine ELGASMI

Motivations: Modeling of water networks is an essential step to understand the behavior of different parameters, such as flow, pressure, velocity, head loss, chlorine, and others.

- Calculation of flow velocity
- Pressure calculations
- Contamination Identification
- Field Measuring for comparison
- Model a Simulation
- Calibrate the Model

Model results(Contaminants)

The Chlorine calibration model was based on eight measurement points. These locations were chosen to determine the water quality at the center and thus calibrating the model to ensure the presence or absence of chlorine at the extremities of the system where chlorine residual does not meet standards.

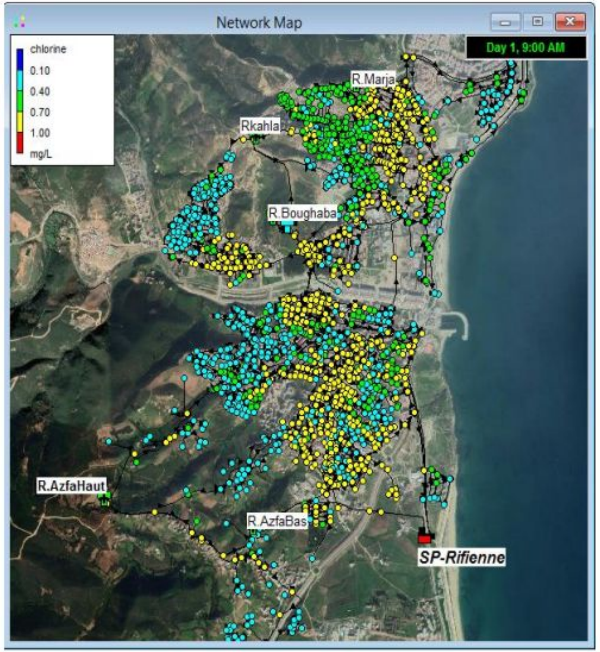

Figure-2-Chlorine model results

Model results(Pressure)

It is important to maintain pressure balance inside piping infrastructure. Generally, the minimum operating pressures are above 25 m.w.c (2.5 bar), which guarantees the correct service for users. At the consumption nodes, the maximum pressures are less than 80 m.w.c (8 bars), except in specific over-pressed sectors .

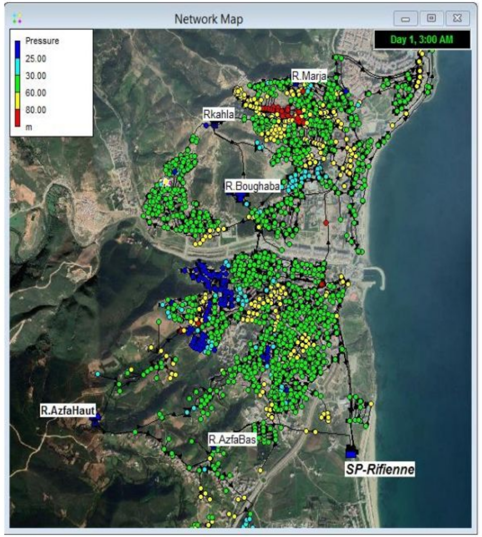

Figure-5- Maximum pressures map on 24 hours of simulation with the daily peak hydraulic model.

Model results(Flow Velocity)

Speed mon

1. Low-speed zone: speeds are generally low (<0.1 m/s) observed throughout the extremities of the network.
2. Medium speed zone: speeds between 0.1 and 2 m/s are observed in the main lines of the network.
3. High-speed zone: speeds over 2 m/s are observed on a few mains in the network at peak day times.

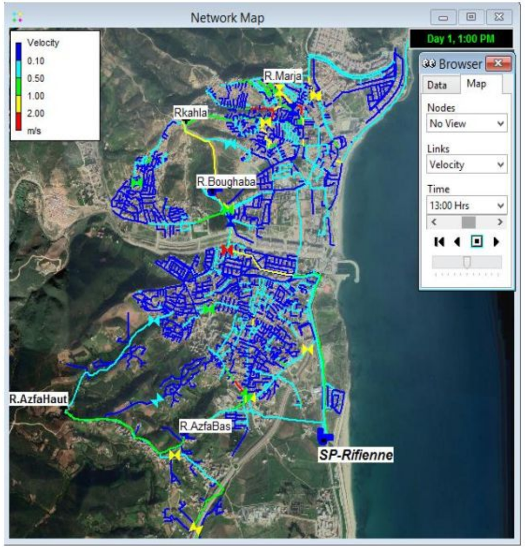

Figure -6-Speed maps

An IoT Based Monitoring and Controlling System for Water Chlorination Treatment

Authors: Nael Zidan, Mohammed Maree, Subhi Samhan

Background

- The authors want to develop an internet of things based system that will monitor the concentration of chlorine and control the dosing pump to keep chlorine concentration as desired with as little as possible human interaction

- IoT based System
    - low cost sensors and the evolution of the Internet of Things (IoT), lead to the development of remote real-time monitoring and controlling systems. Without the need of direct human intervention - has expanded significantly in various applications domains.

Problem: Water Contamination throughout MENA

Throughout the MENA (Middle East and North Africa) region an ongoing problem that occurs is that they suffer from water problems of various forms and at different levels.

Problems:

- Scarcity of water resources
- Weak water infrastructure,
- Untraceable non-revenue water,
- **Lack of fully automated water treatment systems.**

Water Pump Station (WPS)

Water Pump station are buildings that contains all mechanical machines needed for water pumping from wells.

- Chlorine Sensors
  - Pump takes liquid chlorine material from ground tank with direct connection to a pipe
  - Manually configured on same pipe after each dosing pump
  - Connected to analog analyzer which reads chlorine concentration

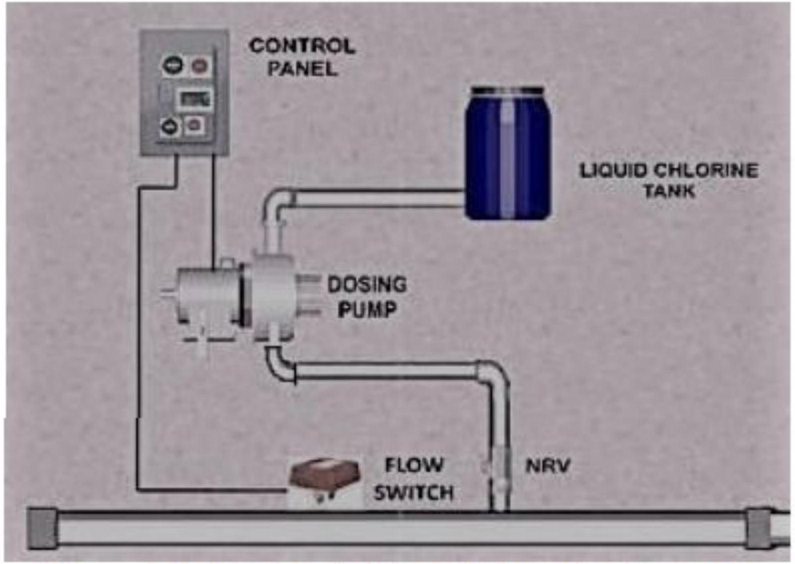

Figure 1: Architecture for Water Chlorination Treatment

Water Chlorination Process

- Process of water chlorination begins with:
    - Manual configuration (controlling)
        - Chlorine concentration for each one liter of water
            - 0.5 mg/L
        - Chlorine Concentration should be between a range of a minimum concentration
            - 0.2 mg/L

- Concentration becomes
    - **Under 0.2 mg/L**
        - the water will be risky for people to be able to drink
    - **Over 0.8 mg/L**
        - It will cause severe danger on human lives.
- Case: Chlorine liquid material tank is empty
    - Dosing pump will continue working without dosing the needed chlorine leading to a concentration less than 0.2 mg/L

Overview proposed a solution(s).

Develop an internet of things based system that will monitor the concentration of chlorine and control the dosing pump to keep chlorine concentration as desired with as little as possible human interaction

The authors propose two solutions in their studies

- Water Pumping Station Component
- Smart Water Management System (SWMS)

Water Pumping Station Component

The application itself is constructed of two sub-application, the first one is the application program that uploads to Arduino controller

- Reader Chlorine Tank Level
- Reads Chlorine Concentration from Analyzer
- Upon Chlorine Concentration readings, it will control dosing pumps
- Send all the above reading to Web Restful API, the API responsible to sending data to cloud

The second application is a web API that receives information from Arduino through Wi-Fi

- NoSQL database “MongoDB”
- The API will be responsible for saving the received information from Arduino and for saving it to the internal MongoDB.

Components

- Ultrasonic Sensor (HC-SR04)
  - Provides 2cm to 400cm of non-contact measurement functionality, the ranging accuracy can reach up to 3mm.
- Arduino Uno 3
  - Microcontroller board

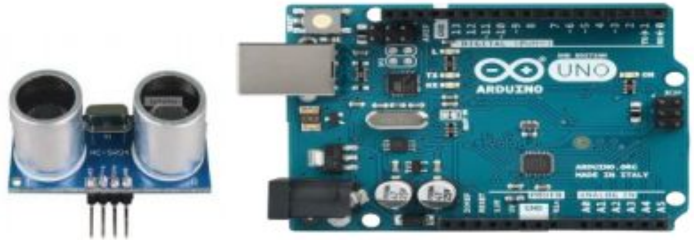

Figure 3: Ultrasonic Sensor (HC-SR04) and Arduino Uno 3

The produced output form the ultrasound reflects the distance of how far away the liquid is from the ultrasound sensor

- Determine the level of chlorine in tank

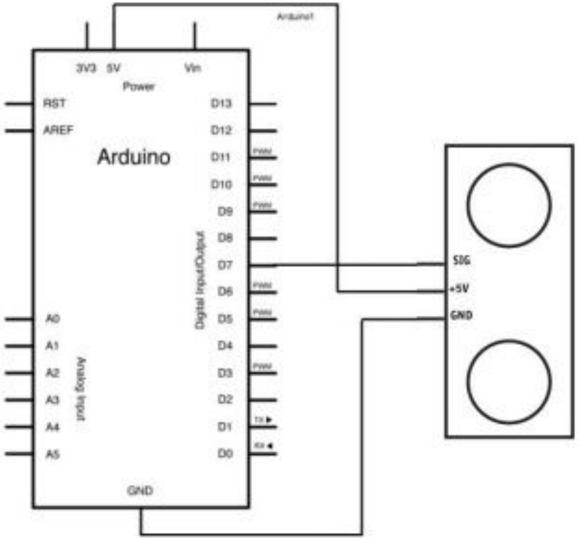

Figure 4: Arduino and Ultrasonic Circuit

Components pt. II

WPS are connected to an Analyzer that reads chlorine concentration in milligram for each liter of water mg\L

- "Liquisys M CCM223/253"
  - A transmitter for determining the amount of free chlorine, chlorine dioxide or total chlorine dissolved in water

The data that is produced by the equipment are mapping values for current, Arduino Analog value, and chlorine concentration

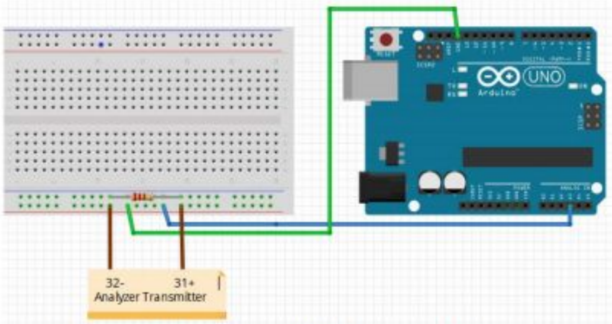

Figure 5: Arduino Controller Connected to Analyzer Transmitter

- Current (mA)
- Arduino Analog Value (0-1023)
- Chlorine Concentration (mg\L)

Table 1: Mapping Values for Current, Arduino Analog Value, and Chlorine concentration

Current (mA)	Arduino Analog Value (0-1023)	Chlorine Concentration (mg\L)
0	0	0
4	80	0.2
8	160	0.4
16	320	0.8
20	400	1

Smart Water Management System (SWMS)

The data that is collected from the controllers:

- Temperature
- Conductivity
- Chlorine concentration

Aim to analyze and study the effectiveness of:

- Controlling decisions
- Proposing recommendation for better control
- Minimizing chemical usage
- Problem prediction

The monitoring parameters are:

- Conductivity
- turbidity
- Level of water
- pH

Wireless Sensor Network (WSN) to automate the monitoring of water quality

- Solution of three main blocks
  - WSN sensor nodes
  - WSN gateway nodes
  - Application software

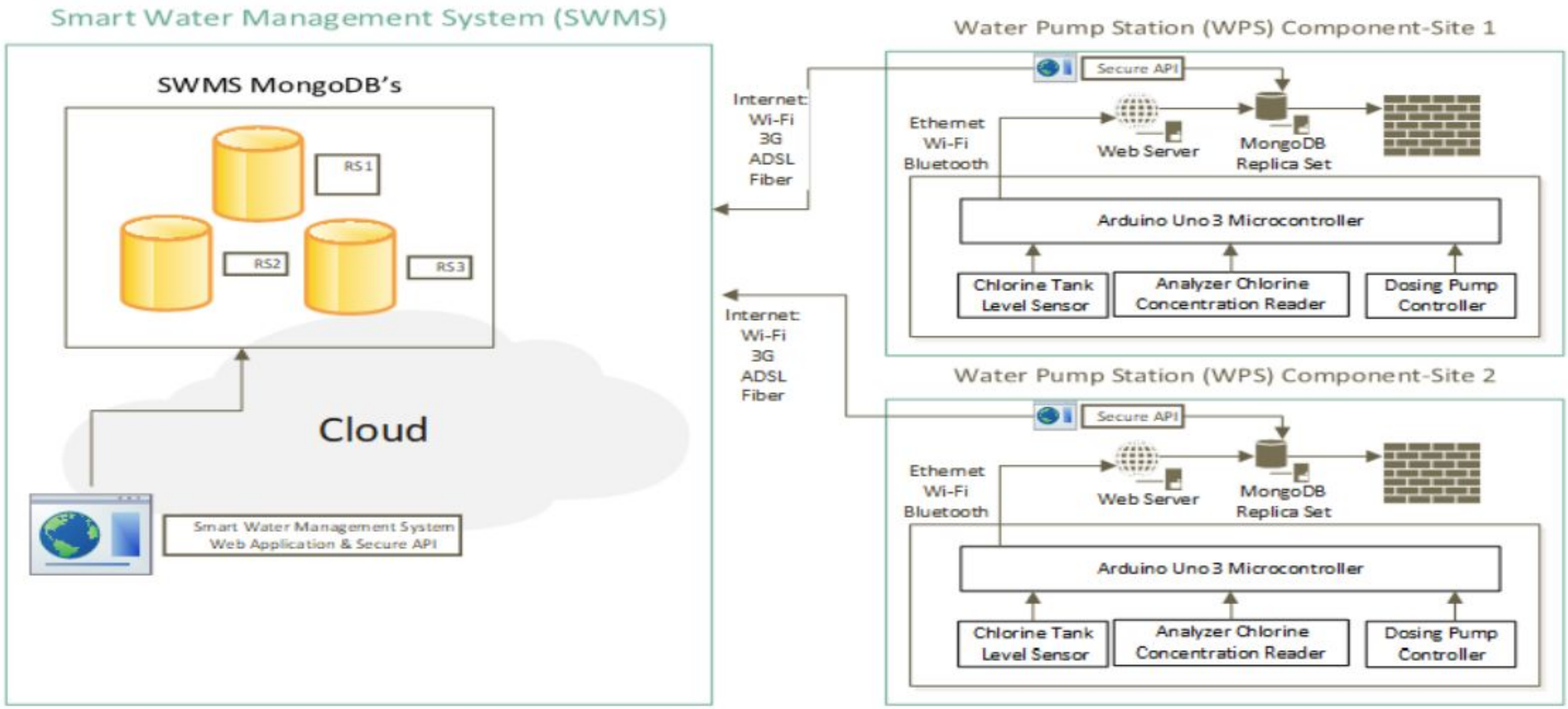

Figure 2: Proposed System Architecture with Various Components

SWMS Alert Module

A module that was build into the Smart Water Management System is the SWMS Alert Module

- The module is a system that directly alerts the user on abnormal cases
  - a chlorine concentration is higher than 0.8 mg/L or less than 0.2 mg/L, or a dosing pump stops working
- The module is developed based on the monitoring dashboard,
- This module is important because it alerts for abnormal cases.

Results

Water Pumping Station

- Prototype is able to read chlorine concentration from analyzer
- Upon reading they automated the control of dosing pump to preserve the chlorine concentration in a normal concentration

Smart Water Management System (SWMS)

- Prototype, we aim to eliminate the repeated manual configuration of dosing pumps
- They aimed to enable humans to monitor Water Pump Stations remotely

Conclusion

- The authors have performed an experimental and theoretical study of monitoring and controlling water chlorination treatment by employing Internet of Things devices
- Proposed two systems:
  - Water pumping station
  - Smart Water Management System (SWMS)
- The reason that they proposed the two system is build a safer water quality management

Analytic web tool for calculating and Geovisualization water quality based on different indices

Authors: Dániel Balla, Marianna Zichar, Emőke Kiss, Gergő Karancsi and Tamás Mester

Background

A breakdown of the paper is that the authors have developed an application accessible for all users which they will have the ability of monitoring contamination levels and capable of comparing the different indices

- Effects of sewage network construction on groundwater quality are evaluated using Backman’s contamination index (Cd) and the Water Quality Index (WQI)
    - contamination index is an effective tool for evaluating and mapping the degree of groundwater contamination
    - Water Quality Index provides a single number (like a grade) that expresses overall water quality at a certain location and time based on several water quality parameters.

Problem: Current setup for the purpose of describing water quality

The current setup consist of only be expressed by using numerous physical, chemical and biological parameters, and so the evaluation and compassion of certain indexes has proved to be challenging for previous developers.

Proposed Solution:

For their solution they developed an interactive web tool which was quantify the groundwater quality status of the investigated wells. It can also be used to publish the uploaded spatial data to a web map

- The web application site was created using five different technologies
    - Google Maps API V3 and KML tools
    - JavaScript
    - Calculations and geovisualization onto an excel sheet
    - Bootstrap for the front-end framework
    - jQuery framework to connect between the HTML code and client-side JavaScript

Workflow Model

Their motivation to conducting their research is to have a better understanding of the contamination on groundwater and surface water:

- They investigated 40 groundwater wells in the
- Tested contamination indexes
  - pH and EC
  - pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water
  - Measures ability to conduct an electrical current. Presence of ions in a solution that allows the solution to be conductivity. The greater the concentration of ions, the greater the conductivity.

Investigate Parameters

Search conducted for parameters resulted in finding that significant amount of organic material has accumulated in the soil and in the groundwater

Contained 5 out of the 8

- EC
- Ammonium (NH4 +)
- Nitrate (NO3 -)
- Chemical Oxygen Demand (COD)
- Sodium (Na+)

Table 2. Descriptive statistics of the parameters.

Parameter	*Standard*	*Mean*	*Min*	*Max*	*Upper Q.*	*Lower Q.*
pH	6.5-8.5	7.2	6.81	7.90	7.42	6.97
EC (µS/cm)	300	2773.4	695	8910	3792	1511
NH_4^+ (mg L^{-1})	0.5	0.5	0.12	3.37	0.618	0.289
NO_2^- (mg L^{-1})	0.5	0.3	0.001	1.94	0.308	0.2375
NO_3^- (mg L^{-1})	50	170.7	7.61	645.5	244.85	43.09
PO_4^{3-} (mg L^{-1})	0.5	0.5	0.04	2.14	0.604	0.137
COD (mg L^{-1})	4.5	7.7	1.66	16.65	10.12	4.57
Na^+ (mg L^{-1})	200	383.7	52.14	2019.77	477.9	301.4

Evaluation of Water Quality

Based on the index values, we determined the water quality state of the water (WQS). 47.5% of the samples were classified among the worst “very poor” and “unsuitable for any usage” categories

Five categories:

- Unsuitable
- Very Poor
- Poor
- Good
- Excellent

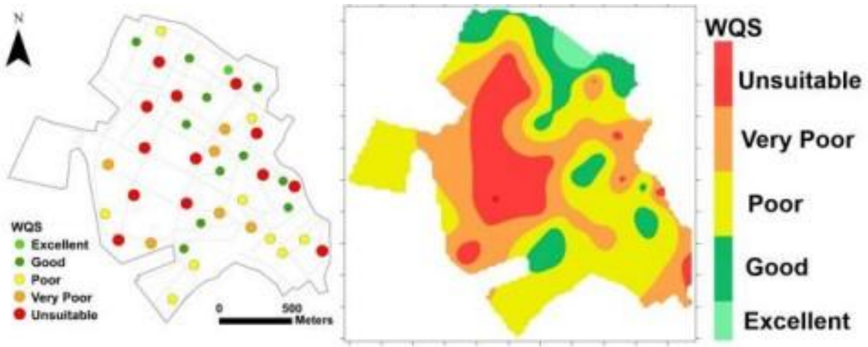

Figure 5: Spatial distribution of Water Quality Status (WQS) in 2019

Conclusion future work.

Focused on groundwater and surface water quality which they determined the contamination status of waters by calculating two water quality indexes,

- 8 important water chemistry parameters
- 2 water quality indexes

Water quality indices status and its location became easier after the geovisualization.

Geovisualization facilitates capturing the spatial pattern of water quality status and degree of contamination distribution

Correlation test shows a strong significant relationship, based on which we can conclude that both indexes are appropriate for describing water quality.

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