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Geo-Location Based Analysis on Impact of Transportation Material on Potable Water Using IoT

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Abstract*:* Managing the distribution of freshwater requires a complex network of transportation and storage systems that operate at various levels and locations. Throughout the entire process, water comes into contact with a wide range of natural and man-made materials, including soil, iron, cement, steel, cast iron, rocks, plastic, and more. This interaction can be either short-term or long-term, and depending on the nature of the materials involved, it may or may not influence water quality. The impact of material contact on water quality often varies based on the condition of the materials, and in some cases, the water itself can damage these materials. For example, the use of iron pipes for water transportation can lead to corrosion, which in turn contaminates the water. This issue is critical, highlighting the need for continuous water quality monitoring systems across multiple points in the supply chain. The aim of this study is to assess the impact of water's contact with different materials over time and to propose an IoT-based solution for a centralized water quality monitoring system.

Keywords: *heavy metals, environment, contamination, legal requirements, pollution.*

I. INTRODUCTION

Consumable water distribution is one of the most important work under municipal corporation responsibilities. Water sources for city consumable water is from natural water sources and authorities need to deploy the system to pull the water to consumers through different methods like pipelines or the water tanker. While water flowing between different sources through different materials including CPVC, concrete, iron pipes or the plastic pipes may affect the water quality. This problem needs real-time and regular water quality check. After start point of water supply, water is nearly flows from pipelines mainly and user will not find the way to detect the water quality in between. Proposed system is novel design and development of pipe fixable consumable water quality monitoring system. This device would be fix into existing pipeline with its sensor probes dipped in flowing water and its statistics will be monitored through central server using remote communication and software data analytics.

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1. Environmental contamination

The environment can be polluted or contaminants. Pollution is different than contamination; However, contaminants can be pollutants and have harmful effects on the environment. In the literature, pollution is defined as the identification by humans, environmental substances or energy, which has detrimental effects on life resources, endanger human health, impede environmental function and make it impossible to use quality. Lack of atmosphere and facilities. Contamination, on the other hand, is the presence of elevated concentrations of substances in the atmosphere above the level of the natural background for and around the environment. Unwanted and unwanted changes in the physical, chemical, and biological properties of the environment, pollution, air, water, and soil may be indicated that are detrimental to both the animal and the fauna. Pollution can take the form of chemical substances or energy such as sound, heat or light [2].

Pollutants, contaminants could be either foreign energy/ substances or naturally occurring contaminants.

a. Types of pollutants

Environmental pollutants have become a global concern and a major challenge facing the global community. Pollutants can be naturally compounds or foreign substances that cause adverse changes when in contact with the environment.

There are different types of pollutants like inorganic, organic and organic. Although pollutants come in a variety of forms, they attract a wide range of attention due to their impact on the environment. The relationship between environmental pollution and the world's population has become an inseparable direct standardized relationship as it appears that the amount of toxins released into the environment is increasing with the alarming growth of the global population. Pollution has become an environmental problem due to this problem.

b. Inorganic pollutants

Industrial, agricultural and household waste contribute to environmental pollution, causing adverse damage to human and animal health. From such sources, inorganic pollutants are released. Inorganic pollutants are usually substances of mineral origin, examples of metals, salts, and minerals [2]. Studies have shown that naturally occurring materials are inorganic pollutants but have been replaced by human products to increase their numbers in the atmosphere. Inorganic substances enter the atmosphere through various anthropogenic activities such as mine drainage, gluten, metallurgy, and chemical processes as well as natural processes. These pollutants are poisonous as they collect in the food chain. [3].

c. Organic pollutants

Organic pollution can be briefly defined as biodegradable contaminants in the atmosphere. These sources of pollution are naturally found and caused by the environment, but anthropogenic action to meet human-needs is also contributing to their intense production. Human waste, food waste, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDs), polycyclic aromatic hydrocarbons (PAHs), pesticides, petroleum and organochlorine pesticides (OCP) are some of the common ones. Environmental pollutants have caught their attention as it has become a major environmental problem. The properties of organic pollutants, among others, such as high lipid solubility, stability, lipophilicity and hydrophobicity, have recently been called organic pollutants persistently. These properties give organic pollutants the ability to easily bioaccumulate in various areas of the environment, which can lead to toxic effects. [5, 6].

d. Biological pollutants

Biological pollutants are described as pollutants which exist as a result of humanity's actions and impact on the quality of aquatic and terrestrial environment. This type of pollutants include bacteria, viruses, moulds, mildew, animal dander and cat saliva, house dust, mites, cockroaches and pollen. Studies have documented different sources of these pollutants, including pollens originating from plants; viruses transmitted by people and animals; bacteria carried by people, animals, and soil and plant debris [7].

There are many myths about the dangers of water pipe corrosion and leeching to tap water quality. Some of them are simply urban legends and others are spread by water filtration companies to support the sales of their products. But there are also real dangers such as lead pipes and unknown risks of leaching plastic pipes.

Impact of Transportation material

The materials used for water transportation and storage, such as pipes, tankers, and storage tanks, can significantly affect the quality of water over time. These materials may interact with water in ways that alter its chemical composition, introduce contaminants, or influence its physical properties. The degradation of water quality can occur as a result of chemical leaching, microbial growth, corrosion, sedimentation, and other factors. The impact of these materials on water quality varies depending on their composition, age, maintenance, and environmental conditions.

- **Plastic (PVC, CPVC)**: While cost-effective and easy to install, plastic pipes and storage tanks can leach harmful chemicals like BPA and plasticizers may promote microbial growth if not properly maintained.
- **Steel and Iron**: These materials are highly susceptible to corrosion, which can lead to the release of rust and other contaminants into the water. They also tend to promote microbial growth due to their rough surfaces.
- **Concrete**: Concrete materials tend to leach alkaline substances, raising the pH of the water. Concrete tanks and pipes are also susceptible to cracking and erosion, which can introduce particulate contaminants.
- **Metal (Aluminum)**: Metal tanks and pipes can corrode, releasing metal ions and affecting water aesthetics and safety. They are often prone to microbial growth in areas with poor maintenance.

The choice of material for water transportation and storage is crucial for maintaining water quality over time. Each material has specific advantages and disadvantages, and these should be considered based on the local environment, usage patterns, and maintenance capabilities. Proper cleaning, regular maintenance, and using suitable protective coatings can mitigate many of the negative impacts associated with each material.

Comparative Analysis of Material Impact on Water Quality

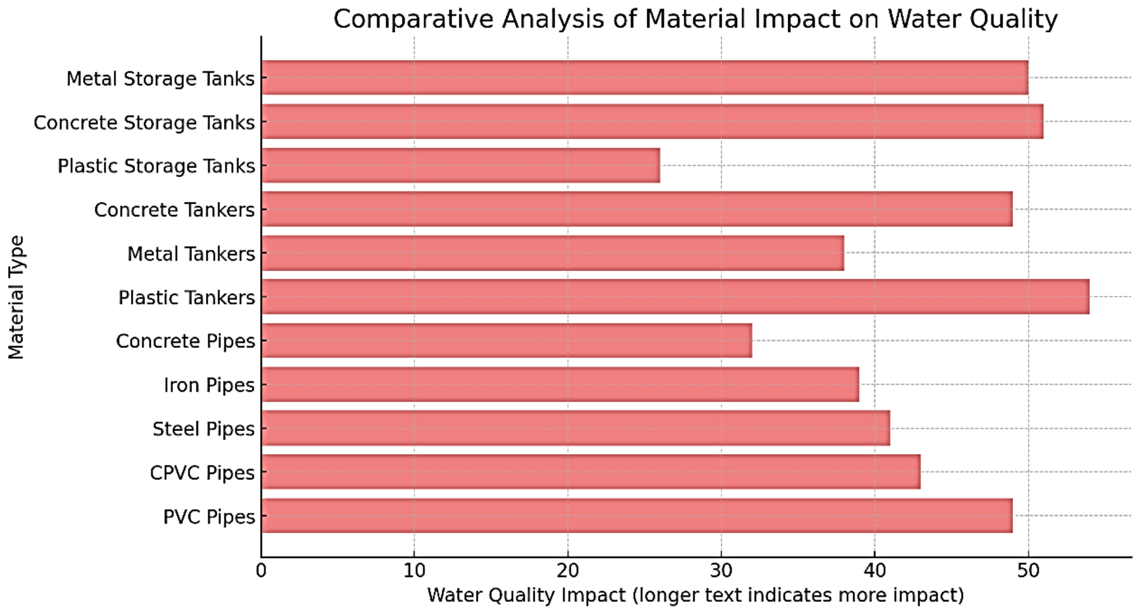


Figure 1.0: Comparative Analysis

comparative analysis of the different materials used for water transportation and storage in terms of their impact on water quality over time. The graph above visualizes how each material type affects water quality based on factors like chemical contamination, microbial growth, and corrosion.

Common water pipe contamination myths

Following are the most common myths about old pipes and water infrastructure.

- Old corroding pipes in the city water network are the cause of bad taste, odor and contaminated water.
- Old pipes are causing bacteria growth that can make me sick
- Contaminants from water leaks are polluting the tap water making it unhealthy.
- Plasticizers used in the manufacture of PVC pose a health issue

Tap water is never pure or perfectly clean. Normally it contains hundreds of substances in addition to H2O of which most are nothing to worry about. There are essentially 5 sources of tap water contaminants/substances:

1. The original source of the tap water which can be a river, lake, groundwater, aquifer or sea water (desalinated) – depending on the source my contain nitrates, bacteria, microplastics, pharmaceuticals and hundreds of other chemicals
2. The water treatment plant / provider that treats the water with chemicals such as chlorine or chloramine and sometimes changes the properties of the water (softening, pH, sulphates, etc) – generally all regulated substances have been reduced to "safe" levels
3. From the pipelines, pipes in homes, connections or faucet – e.g. lead, copper, zinc flakes)
4. From local water tanks or pipes where the water sits for a long period of time which may cause bacteria growth
5. From water filters that have not been changed on time (e.g. bacteria, contaminants that get released or filter elements that get released such as activated carbon)

Most pipes from the water source to your faucet are made of galvanised iron/steel, copper, PVC (UPVC, CPVC) or PEX. Some old pipes before it was banned are made of lead which is generally considered the worst problem. Your water supplier is obliged to inform you if the network contains lead pipes.
Nearly all metals will corrode to some degree. The rate and extent of corrosion depends on the degree of dissimilarity of the metals and the physical and chemical characteristics of the media, metal, and environment.

Iron cast pipes also known as galvanized steel pipes: Iron cast pipes will typically start rusting after a period of time and eventually the rust builds up and blocks the pipe. In the meantime, the rust may collect in aerators and contaminate your tap water. There is no scientific evidence that this should cause health concerns.

Copper pipes: Corrosion of copper pipe can lead to levels of copper in the drinking water that exceed health guidelines and cause bitter or metallic tasting water. Water experts generally claim that it will be visible in terms of color of the water before it causes a health risk.

PVC or PEX: After 30+ years use there is limited evidence of PVC corrosion or leaching posing a health risk. However, preliminary findings show different PEX brands affect water quality at different levels, and even pipes that pass safety tests may contain enough contaminants to affect water's taste and smell.

Lead pipes: The problem is that there is no safe level of lead for young children. In USA in the 90s exposure was associated with a 37 percent increase in fetal deaths and hundreds of cases of elevated blood lead levels in young children. It's also been found to cause an average 4-point decrease in IQ.

Bacteria growth in pipes

All types of pipes can experience bacteria growth although old dirty pipes are more at risk. Biofilm forms when biomass such as bacteria, fungi, algae and mold adhere to surfaces in wet environments. These may sometimes release into the tap water stream whereof most will be neutralized by the chlorine. Despite this, some bacteria will be found in all tap water even if it's chlorinated. Fortunately, this is very unlikely to pose any health risks based on 100 years of tap water research and studies. Water providers constantly monitor the risk of pathogens (bacteria and viruses) in the water network.

There are two ways, how can pipe corrosion could be detected or identified:

1. Visual, taste or odor
2. By testing the water quality

Identifying pipe corrosion and leaching through visual taste and odor: Water quality complaints that may be due to corrosion include

Customer complaint	**Possible cause**
Red water or reddish-brown staining of fixtures and laundry	Corrosion of iron pipes or presence of natural iron in raw water
Bluish stains on fixtures	Corrosion of copper lines
Black water	Sulfide corrosion of copper or iron lines or precipitations of natural manganese
Foul taste and/or odors	Byproducts from microbial activity
Loss of pressure	Excessive scaling, tubercle (buildup from pitting corrosion), leak in system from pitting or other type of corrosion

Identifying pipe corrosion and leaching by testing the water quality: These are a couple of the key indicators:

- pH: Water with a low pH (less than 6.0) tends to be more corrosive.
- Turbidity: Pipe corrosion for iron and copper pipes can usually be detected by measuring water turbidity.
- TDS: Higher Total Dissolved Solids and temperature than the source water also can indicate corrosivity.

The most used method is the Langelier Saturation Index is a means of evaluating water quality data to determine if the water has a tendency to form a chemical scale. In order to use this index, the following laboratory analysis is needed: pH, conductivity, total dissolved solids, alkalinity, and total hardness. By calculating LSI, it could be possible to predict and sense pipe corrosion before it becomes a serious issue. Lead contamination still needs to be tested for specifically though. The best way of testing for lead is contacting a professional lab and asking them for a test kit.

Impact of cement pipes on water:

Both cement mortar lined (CML) and asbestos-cement pipes (A-C) are widely used in many water systems. Cement linings are also commonly applied in-situ after pipe cleaning, usually to prevent the recurrence of red water or tuberculation problems. Unfortunately, little consideration is often given to the stability of these materials in different water quality, and unwanted side-effects are sometimes generated. Occasionally utilities notice considerable pH increases, turbid water, material accumulation in dead ends, ineffectgive lead or copper control with phosphate inhibitors, or decreased chlorine residual effectiveness. Sometimes the adverse effects are not picked up in normal regulatory monitoring programs, and utilities first find out by calls from irate consumers. Aside from water quality degradation, filling new CML pipes or freshly rehabilitated ones with aggressive water also can cause utilities to lose much of their monetary investment in cleaning, replacement ore relining of the pipes in a short period of time. An overview will be given of principles of cement corrosion and effects of water quality on leaching properties. Research from studies of asbestos-cement pipe corrosion and other corrosion control studies will be used to provide guidelines to the beneficial and detrimental combinations of Lead and Copper Rule and red water control strategies that could affect the stability and longevity of cement and cement-lined pipes. New regulations affecting organic or microbial removal may also provide a motivation for substantial treatment changes, including the use of membrane processes. One internationally reported case occurred where the combination of membrane treatment and sequestration caused deaths of kidney dialysis patients from elevated aluminum levels coming from the pipes. Critical considerations and decision points for post-treatment requirements for water stabilization will be described, and pros and cons of different corrosion control approaches will be covered for utilities of all sizes. Topics included will be: orthophosphate versus zinc orthophosphate; silicates versus caustic; lime versus caustic or inhibitors; balancing iron and manganese sequestration with corrosion control; silicates versus polyphosphates; aeration versus limestone contactors and chemical additions; integrating cement corrosion control with lead and copper control. Ways ot monitor for water stability and cement pipe deterioration will also be covered.

II. PROPOSED SYSTEM

Municipal water supply companies are responsible for the distribution of drinking and usable water across various regions, typically using traditional methods. Throughout this process, both laboratory and field tests often reveal challenges related to water quality and quantity management. Issues such as water leaks, inadequate distribution, and the terrain height can impact water delivery, but another crucial factor is the materials used in water transportation. The pipes and materials involved in the system may also have an effect on the water quality. Additionally, wells or open wells, which are often relied upon as a dependable water source after basic purification, also require careful management.

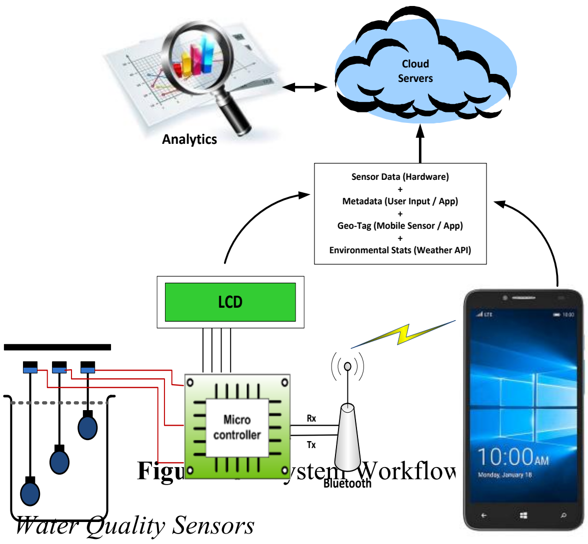
To optimize this process and leverage technology, IoT (Internet of Everything) can be employed to monitor the full scope of water distribution, including both quality and quantity. Achieving this requires extensive research, fieldwork, and data analysis. This study aims to integrate various water quality testing sensors, electronically controlled valves, and quantity measurement tools, all linked through IoE technology, to enhance the efficiency of the water distribution system. The research will contribute to the broader goals of smart city initiatives by analyzing the water distribution supply chain. The study will proceed through several key stages: the design and development of a remotely monitored quality sensor, the collection of water sample data from various locations, mapping and understanding different drinking water sources using GIS technology, and proposing improvements to the current water distribution process. Additionally, this work will include the development of a cloud-based system to monitor municipal pipeline statistics and assess the impact of different pipeline materials on the quality of the water being delivered.

The potable water supply chain involves the movement of water from multiple sources to its end destination, requiring various stages of processing, storage, and transportation through reservoirs, storage tanks, and transport tankers. Water quality must be checked at each stage, as the water changes contact points and locations along the way. Ensuring the quality of water cannot be a task left for periodic checks alone; it must be continuously monitored during the distribution process. While water quality testing can be done manually at multiple locations, this method can be challenging and prone to errors due to human intervention. Water quality cannot be compromised, making the security of the water supply chain a major concern for governments. One proposal is to implement in-pipe water quality testing systems in all water transport pipes, which would continuously monitor the quality of water in real-time. This system could issue alerts in case of significant anomalies, ensuring immediate action can be taken. Such systems would need to be implemented at various locations along the distribution network, including at each storage or release point.

Further, water quality testing should be carried out each time water is delivered to consumers, as they generally assume that the responsible authorities are ensuring the water's safety. It is not only the water quality that needs constant monitoring but also the sensors and electronic components involved in the testing process. Given that these devices can be affected by environmental factors, regular calibration and accuracy checks are essential to maintaining reliable readings.

Figure 1.0 presents the proposed system overview where complete process flow including data gathering notification analysis and further action plan can be seen.

The core of the proposed system is the integration of a microcontroller, water quality sensors, and a GPS module, which work together to monitor water quality in real time and provide geo-tagged data. The water quality sensors measure specific parameters that are indicative of water contamination or pollution, and these values are then processed by the microcontroller. The microcontroller sends the data to a cloud-based server for analysis, storage, and visualization, enabling remote monitoring of water sources.



Figu … ystem Workflow

Water Quality Sensors

Each water quality parameter (e.g., pH, turbidity, dissolved oxygen, etc.) requires a different type of sensor, each with its own working principle. The sensors selected for the system must be capable of operating in the field without frequent calibration or maintenance.

- **pH Sensor**: The pH of water is a measure of its acidity or alkalinity, and it significantly affects the solubility of nutrients and pollutants. A pH sensor typically uses a glass electrode or an ion-sensitive field-effect transistor (ISFET) to measure hydrogen ion concentration in water. The output is a voltage proportional to the pH value.
- **Turbidity Sensor**: Turbidity refers to the cloudiness of water caused by suspended solids such as dirt, silt, and microorganisms. Turbidity sensors work based on the scattering of light. A laser or LED light source is directed through the water sample, and a photodetector measures the amount of light scattered by the particles.
- **Dissolved Oxygen (DO) Sensor**: Dissolved oxygen is essential for aquatic life. A DO sensor works by detecting the partial pressure of oxygen in water. There are various types of DO sensors, but electrochemical sensors (such as Clark-type electrodes) are commonly used. These sensors measure the oxygen concentration through a redox reaction.
- **Temperature Sensor**: The temperature of water influences the solubility of gases and the rate of chemical reactions. Temperature sensors, often thermistors or thermocouples, measure the temperature by detecting changes in electrical resistance.
- **Conductivity Sensor**: Conductivity sensors measure the ability of water to conduct electricity, which is influenced by the concentration of dissolved ions, such as salts and metals. These sensors work by passing a small electrical current through the water and measuring the resulting voltage drop.

Microcontroller

The microcontroller serves as the brain of the system, interfacing with the sensors, processing the raw data, and sending it to the cloud. A low-cost microcontroller such as the Arduino or Raspberry Pi is ideal for this application due to its flexibility, ease of use, and extensive support from the maker community. The microcontroller reads the analog signals from the sensors, converts them into digital data, and processes this information to determine the water quality parameters.

GPS Module

A GPS module is used to collect geographic coordinates (latitude, longitude) where each water sample is taken. This ensures that each data point is geo-tagged, allowing for mapping of water quality across different locations. The GPS module communicates with the microcontroller to synchronize location data with sensor measurements.

Data Transmission to Cloud

Once the data is processed by the microcontroller, it is transmitted to a cloud-based server via a communication module (such as Wi-Fi or cellular network). This allows for real-time monitoring of water quality. The cloud platform stores the data and provides a dashboard for visualization, enabling stakeholders to view water quality trends over time and take action if necessary.

III. CONCLUSION

The purpose of this research work is to use various quality test sensors, electronically controlled valves and volume measurement devices with IOE technology to analyze the water distribution supply chain to improve the performance and efficiency of this entire process. Part of smart city initiatives. This entire investigation goes through different stages, which include the design and development of remotely monitored quality sensors, the collection of data from water samples at multiple locations, understanding of various consumable water sources and GIS-based mapping and in the end. Suggests a new improved version of the water distribution process. This investigation is also concerned with the development of a system for monitoring urban mapping and cloud-based GIS data, and the effect on the outgoing water of various types of pipes used for water supply. It is expected outcome from the system is to identify the gap between the actual water supply and the quality of water received by the consumer and finally prepare the report to understand where user need to improve the existing system or come up with new implementation in order to improve water quality

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