MALAYSIAN JOURNAL OF SCIENCE
MJS
ISSN 1394-3065

Regular Issue

Malaysian Journal of Science 43 (3): 98-108 (September 2024)
https://mjs.um.edu.my

AUTOMATED LEAK AND WATER QUALITY DETECTION SYSTEM FOR PIPED WATER SUPPLY

Eganoosi Esme Atojunere[1a]*, Godspower Elvis Amiegbe[2b]

Abstract: The volume of water loss because of leakage in the conveyance pipe has been alarming. Old and poorly constructed pipelines, inadequate corrosion protection, poorly maintained valves, and mechanical damage contribute to leakage. Water-carrying pipes were buried underground, so tracing leak points manually could be tasking, if not impossible. This work was to report on the effectiveness of a developed Automated Leak and Water Quality Detection (ALWQD) system. This device can detect leaks in the piped water system automatically and can also report any deterioration in the quality of water that flows through affected pipes. The ALWQD consisted of several drainpipe connections, pipe accessories, electronic components, and sensors to monitor water quality impairment. The control signal was the solenoid valves that interfaced with the ESP-32 microcontroller boards placed on the pipe manifold at intervals, along with water quality monitoring sensors of turbidity, Total Dissolved Solids (TDS), and pH. The fabrication and testing of the device followed standard procedures. Testing of ALWQD was done at 0, 5, and 10 minutes under load and no-load conditions, with average variation in reading recorded after three trials. The findings indicated that the efficiency of ALWQD was between 70% and 80%, which could be improved upon. The trend in the results of the monitored parameters was not different from that of similar previous work. Leaks caused pressure drops and disallowed the full flow of water found at pipe joints, which could be a pathway for the intrusion of contaminants into the water conveyance system.

Keywords: *Automation, leakage detection, deterioration, water quality, impairment.*

1. Introduction

Old and poorly constructed pipelines, inadequate corrosion protection, poorly maintained valves, and mechanical damage contribute to leakage (May, 2000). However, water leakage caused reduced pressure in conveyance systems and the loss of water resources in the supply system. The rise in such decline pressures by the water industry increases energy consumption. This rise in pressure could also make leaking worse and have adverse negative environmental impacts. Water supply through pipes gets contaminated when there is an opening along the pipe because of faulty pipe networks. This contamination renders water unfit for its intended purposes, especially for drinking. At loose joints in pipes, contaminants can intrude and cause dilution with flow water, deteriorating water quality. Leaks contribute to an economic loss to the water industry, thereby causing scarcity of water and raising the price of water per liter for water consumers. The challenges faced by the water industries in detecting water leakages are vast, as water pipes were laid underground with plastic PVC pipes that got broken when leak points were traced during excavation. Digging is done by hand without technology; it is costlier to dig a foot in dry soils than wet areas. Leak detection through analog pressure meter gauges has been used with inconsistent results based on the pressure that is readable on the gauge indicator because of the pressure drop in flow in conduit pipes. Intrusion in water pipes from surrounding agricultural soil occurred at the point of leakage and joint with a loose connection. The runoff water enabled emerging pollutants like over-agricultural chemicals, fertilizers, and pesticides to be dissolved and intruded into underground pipes at the leak point. Other leak-detecting methods, including pressure, acoustic, vibration, and sensors, have been deployed to detect water leakage (Al Qahtani et al., 2020). An effective way is a hybrid of processes that can autonomously detect leak points, measure deterioration in water pipes, and transfer information to a central processing unit for action. The two-way mechanism feeds the water supplier and the consumer with leak reports along with deterioration when the permissible level of set water quality parameter is exceeded. Water industries lack data on pipe leakages, and the quality of the distributed water is based on water quality data from the water at the waterworks because there has been no testing for deterioration along pipes to detect pollution. A hybrid leak detector provides data and monitors variations in water quality along the pipe in real-time with sensors and analog pressure combined to detect and record leaks and changes in water quality of water to detect intrusion from the surrounding soil (Fondriest, 2021). The built-in alarm system in the detector notifies both the water supplier and consumers of leak problems and deterioration in water quality for corrective actions.

Authors information:
[a]Department of Soil Science & Biosystems Engineering, College of Agriculture, Fisheries and Forestry, Fiji National University, Nasinu, FIJI ISLANDS. E-mail: atojunereeganoosi@yahoo.com[1]
[b]Department of Systems Engineering, University of Lagos, Lagos, NIGERIA. E-mail: elvydynasty1752@gmail.com[2]
*Corresponding Author: eganoosi.atojunere@fnu.ac.fj

Received: July 21, 2023
Accepted: November 25, 2023
Published: September 30, 2024

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

Pollutant Intrusion in Water Distribution Pipes at Leak Points

Leaks happen at faulty or broken points in water distribution network pipes connecting water suppliers and consumers (Beat and Dorothee, 2020). Furthermore, Beat and Dorothee (2020) reported that leakage assessment indicated that millions of cubic water get lost annually. Leakage detection in water supply pipes is imperative to minimize loss by facilitating faulty pipe repairs and preventing water quality deterioration because of exposure to the surrounding soil (Eytan and Spuhler, 2021). There is a possibility of pollutant intrusion into water conveying pipes through leak points when in contact with soil surroundings (Oyedele, 2021). This finding is important because loose joints and openings at broken pipes not only leak water but also enter harmful pollutants that are residual from the use of fertilizers, pesticides, and herbicides that are non-biodegradable by farmers with farmland surrounding water pipe layout. The residual pollutant takes a longer time to denature and could cause damage to human and livestock animals that consume the contaminated water. When such pipes are broken or open, the water distribution becomes a receptacle for the migrating pollutants, thereby causing water quality impairment in the public water supply. These pollutants have no biological benefits. Intrusion of pollutants may occur because of the opening created at loose pipe connections, broken pipe points, damaged rubber seals at joints, and lost and faulty control valves. There is a need for regular monitoring of the quality of water in distribution systems to protect public health. Available technologies are expensive and unaffordable to some water industries. Water leakage detection methods such as hydrostatic testing and infrared and laser technology have been tested with advantages and disadvantages. One of the most used methods is the pressure/flow measurement method, which operates on the basis that a drop in flow pressure when open is detected, affecting the continuity of water flow in pipes as in Equation 1. Reduction in pipe pressure is readable through a pressure gauge placed at the interval to detect the drop in pressure or flow rate. Leak detection through pressure drops in fluid-flowing pipes has been used by the oil industry to detect leaks in hydrocarbon-conveying pipes such as petrol, kerosene, and diesel. Leak detection through infrared and laser technology works by scanning the entire length of the fluid-carrying pipes to detect irregularities or damages in the structure and recording weak spots in the pipe system as potential leak points.

$$P_1 v_1 = P_2 v_2 \quad (1)$$

$P_{1,} P_{2,} v_{1,} v_2$ are initial pressure, final pressure, initial velocity, and final velocity, respectively.

Review of Some Technologies for Leak Detection in Water Pipes

The Infrared Thermography

Thermography technology involves the use of a device that can determine a leak in a water distribution network in wet conditions. A leak is detected when there is a noticeable change in the thermal properties of the surrounding soil, leading to a change in temperature around the pipe (Mashhadani and Thompson, 2011). This section pinpoints leak points along the water distribution systems. However, thermography is not widely used in most countries because it is dependent on climate exchange. Leak develops in a buried piping system when fluid is lost to the surrounding earth, and the leak from a heated or cooled piping system is sufficiently large. A temperature change will occur at the surface of the ground in the vicinity of the pipe leak. Leaks from buried piping are generally characterized by amorphously shaped thermal anomalies that appear along the pathway of the subject piping system.

Leak Detection through the Excavation of Buried Water Pipes

Excavation is an old technology to find leaks in fluid-conveying pipes. It involves creating an opening through the earth with either hand or power tools. Excavation involves digging out soil particles to trace existing underground water pipes. This method, though considered effective, is tasking, time and labor-consuming, and a destructive testing method. Water Pipes often get damaged during excavation. Some public water suppliers still use excavation to trace leaks. It is challenging when physical structures are built on laid pipe networks (McEvoy and Wyatt, 2012). This method is a destructive leak detection method that could be replaced by a hybrid of a fast, real-time-based sensor and analog systems based on low pressure.

Leak Detection through the Wireless Method

The wireless method involved the use of wireless sensor networks to replace the analog leak detection method, which is often cumbersome. Wireless sensors are emerging technologies used to detect leaks, and they are portable, user-friendly, and reliable compared with other leak-detecting methods. The sensors were equipped with electrical and mechanical components that communicate using Bluetooth. Some of the sensors are equipped with their algorithm software for leak detection and the capacity to record deterioration of the inflow water quality. The sensors are placed at intervals on the water main pipe, transfer the pollution status of the flow of water and leakages in the pipe to the central system through Bluetooth technology (Sinha et al., 2007). These sensors are effective because of the automation, unlike thermography, which is based on the change in thermal properties of the surrounding soil because of leakage. Optimal detection of leak points is achievable with minimum noise interference, as noise from hooting from traffic vehicles affects the reliability of the result. This problem could be resolved by taking leak measurements at night when interference from noise is minimal. The detected leak points are exchanged among sensors through the Wireless/Bluetooth Technology to central control systems operated by the water industry.

Combined Leak Detection using Wireless and Analogue System.

A hybrid leak detector that detects leaks and reports deterioration in the quality of water in a pipe distribution network

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

because of pollutant intrusion. Data of the detected leak points were transferred through wireless technology to a central processing unit that coordinates networks of pipes for prompt action. Hybrid leak detectors are in sharp contrast to manual and excavation methods of detecting leaks in pipe water systems. It is fast and automated and allows flexibility in checking water quality at different points in the system and reporting water quality deterioration (Smith and Naud, 2013). The number of sensors is a function of the size of the pipe network, the length of the main pipes, and the bandwidth of the Wi-Fi of the microcontroller. This leak and deterioration technique can be modeled and incorporated into Progressive Web App(PWA). This modified technique will allow the water industry and the consumer to monitor the quality of water that leaves the waterworks and deliver it into household piping systems. This work adopted the hybrid approach for developing leak-detecting and deterioration systems for water pipes. Some previous works and their viewpoints adopted in this work are presented in Table 1.

Table 1: Leak detection technologies in literature.

S/N Title	Year	Reference
Review and analysis of pipeline leak detection methods	2022	Naga Venkata Saidileep Korlapati et al. (2022)
Leak detection in water distribution Networks	2019	El-Zahab and Zayed (2019)
A review of different pipeline fault detection methods.	2016	Datta and Sarkar (2016)
Statistical process control-based system for approximate location pipe bursts and leaks in water distribution systems	2017	Romano et al. (2017)
Leak Detection, Size Estimation, and Localization in Pipe Flows	2016	Aamo (2016)
Wireless Gas Leak Detection and Localization	2016	Chraim et al. (2016)
An accelerometer-based real-time monitoring and leak detection system for pressurized water pipelines	2016	El-Zahab et al. (2016)
Mobile sensor networks for optimal leak and backflow detection and localization in municipal water networks	2016	Gong et al. (2016)
Non-destructive visual-statistical approach to detect leaks in water mains.	2015	Al Hawari et al. (2015)
Locating leaks in water mains using noise loggers	2016	El-Abbasy et al. (2016)
Acoustic Detection of Leaks in Water Pipelines Using Measurements Inside Pipe	2011	Khulief et al. (2011)
Adaptive extended Kalman filter-based geolocation using TDOA/FDOA.	2011	Kim et al. (2011)

Sealant and adhesive substances pervade our environment and are used in almost every company and sector, as a result, significant efforts have been made to develop these compounds (Sunday, 2015; Ali *et al.*, 2021; Almashhadani, 2021; Kun & Pukánszky, 2017). Polar compounds with ionic groups, *i.e.,* hydrophilic molecules, readily absorb and dissolve in polar solvents such as water, where they generate hydrogen bonds. Thus, hydrophilic substances are polar (molecules) that easily establish hydrogen bonds and dissolve in water (Al-Lhaibi & Al-Shabander, 2022).

Natural polymers such as polyvinyl alcohol (PVA), corn starch(CS), and arabic gum (AG), have unique qualities that include non-toxicity, water solubility, and biodegradability, as well as physical traits such as high optical clarity (Hussein *et al.*, 2020; Abd-Elnaiem *et al.*, 2022). Surface coating and engineering boost polymer performance by applying synthesized film coatings, rendering itsuitable for use in energy harvesting, water treatment, and insulating barriers. The relevance of thin layers of polymeric substances on metal production is influenced by various factors such as lightweight and shock-resistant (Ali *et al.*, 2023). Homogeneous or heterogeneous blends of at least two polymers or co-polymers are known as polymer blends or as polymer mixtures. The polymers can interact chemically or physically, and their physical characteristics diverge from those of their parent components (Ali *et al.*, 2021). Polymer blends can be classified into five broad categories, each of which has received extensive research: Thermoplastic-thermoplastic, thermoplastic-rubber, thermoplastic-thermosetting, rubber-thermosetting, and polymer-filler blends (Parameswaranpillai *et al.*, 2014). Elastomers (EL) are polymers that, at typical ambient temperatures, are above their glass transition temperatures and are amorphous in their unstretched condition (Christenson *et al.*, 2005). The EL polymer was utilized in this investigation and had the following characteristics: strong, waterproof, flexible, chemically resistant, and temperature resistant up to 120 °C. They often have low glass transition temperatures, which fall between −50 and −70 °C. A network of cross-links holds the irregularly shaped chain molecules that make up EL together, preventing the chains as a whole from moving around but allowing individual chain segments to move locally. The network of cross-links may

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

result from physical connections between chain molecules or covalent bonding (Ebewele, 2000). The method used to synthesize polymer blends affected the structural and mechanical properties of polymer blends especially the adhesion strength (Awaja *et al.*, 2009).

Wood and Al have been used as natural building materials, furniture, tools, vehicles, and ornamental items since the dawn of time due to their distinctive properties and relative availability. Engineers, architects, and carpenters should have more accurate knowledge of wood variation to use it more effectively (Mohammed *et al.*, 2022). High-density fiberboard (HDF) wood is prepared when natural wood has a high density and a low amount of chemical additives. HDF wood is a scientific word that informally means the wood is of high quality and hence expensive (Henke *et al.*, 2022).

Certain polymers are more susceptible to bacterial attack due to the physical qualities of their surfaces or the chemical makeup of the polymer. The microbial population increases in polymers as it is usually used in humid conditions with large levels of organic materials (Hussein *et al.*, 2019). The use of hydrogen peroxide (H_2O_2), a silane coupling agent, and an olefin monomer as an oxidant, a cross-linking agent, and a comonomer, respectively, allowed for the creation of high-performance starch-based wood adhesives (Zhang *et al.*, 2015). It was demonstrated that starch-based wood adhesives' bonding strengths equal 7.88 MPa and 4.09 MPa in dry and wet conditions, respectively. The addition of silicon dioxide (SiO_2) as a filler affected the adhesive qualities of PVA (Hameed, 2016). Their findings revealed that the increases in SiO_2 content, increase the tensile strength and enable it to be used as an adhesive. High-performance, environmentally friendly starch-based glue was synthesized using cassava starch as the primary raw ingredient (Chen *et al.*, 2022). The plywood with modified starch adhesive demonstrated the maximum wet shear strength, 1 MPa, at a pH of 4.5 to 5.5, which was 163% greater than the nontreated starch adhesive.

The need for sustainable and alternative raw materials has increased as a result of the world's energy problems and reliance on petroleum resources. Unfortunately, the limitations include workability at low temperatures, poor water resistance, and limited heat resistance. It is generally known that D, AG, and CS are not moisture-resistant polymers, therefore can be used in damp settings significantly reducing their strength. Adhesive connections that withstand moisture may be created by blending EL and AG, D, PVA, or CS. Therefore, this study aims to improve the shear strength, pull-off adhesions, color intensity, thermal insulation, wearability, and antibacterial activity of EL mixed with naturally mentioned polymers so it may be used for HDF wood and Al coatings and adhesives. In addition, the effect of surface treatment by plasma jet on the wettability and roughness was investigated and compared.

2. Materials and Methods

The items used for developing the Automated Leak and Water Quality Detection (ALWQD) system and their functions are presented in Table 2. The development of ALWQD followed standard procedures.

Table 2: List of items used for developing the ALWQD and their purposes.

S/N Items	Quantity	Purpose
½ inch Polyvinylchloride (PVC) pipes	5 m long	Drainpipe/water flow
Set of control valves	10	To close and open taps
Samples of tap and polluted water	10 litres	For set up during loading condition
Total Dissolved Solid module (Portable E-1 TDS)	2	To determine TDS in the setup
pH meter (pH Tester PH-107)	2	To determine the pH value in the setup
Turbidity meters module	2	To determine turbidity in the setup
Flow meter	2	To determine the flow rate
A laptop computer system	1	Control the setup
Electrical power source	1	To power the electric components
Solenoid valves	3	To shut off, release, dose, distribute, or mix fluids.
ESP32 CH340 NodeMCU Wi-Fi Module	3	Interface with other systems; To provide Wireless Fidelity Wi-Fi and Bluetooth functions
Relay Module with Optocoupler Relay Output	3	Input interface

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

Liquid pH 0-14	2	To determine the pH value in the setup
Male Thread Solenoid Valve 220V	2	To control the flow of water
Pipe Connectors	5	To Join pipes together
Electrical Casings	3	To house electrical components
Length of Wires and Jumper Cables	10 yards	To connect electrical components
Light Emitting Diodes (LEDs) and Light Dependent Resistors (LDRs)	2	To detect the light level
Liquid Crystal Display (LCD) display	2	Display parameter readings
Candle Gum	2	Joining items together as adhesive
Buck Converter and 12V Adapter	1	To step down voltage needed by Universal Serial Bus (USB)

The present study reviewed similar works by Atojunere and Ogundipe (2022), Daugirdas (2013), Nriagu et al. (1996), Atojunere et al. (2018), Howard et al. (1985), APHA (2022), and those in Table 1. The ALWQD setup involved two reservoirs: one holding 10 liters of water of known quality while the other was 10 liters of polluted water with known water quality parameters. Figure 1 shows the schematic diagram of the ALWQD system. Under loading and no loading conditions, the ALWQD system comprised sets of ½ inches of PVC pipes (2 meters long), the reservoirs, and the electrical components. The two reservoirs had on/off control and were also made to meet at a T-shaped junction before supply flow through a single 2-meter pipe where all sensors were located at different intervals. The ALWQD system included two identical systems, acting as senders/initiators, connected to an ESP32 NodeMCU microcontroller, a TDS meter turbidity meter, a pH level sensor with a water flow sensor to measure the pH values, turbidity, total dissolved solids, and flow rate along the pipe. System 3 acted as a responder that gathered measurements from sensors on the pipe and transferred them to the master unit, which controlled all other sensors. Systems 1 and 2 were not connected; they only sent measured readings to the master device connected to a computer. Arduino Integrated Development Environment (IDE)/Arduino Software was used to write the code to connect the ALWQD hardware's sensors: pH, turbidity, total dissolved solids, and the flow rates of the devices (systems 1 and 2) to interface with all the ALWQD components to the computer, to upload programs, and to allow interaction and communication. The master system/responder displayed Water Quality Indicator (WQI) readings received from devices 1 and 2 compared with the permissible level library data provided by WHO installed on the computer to call for action. This comparison prompted action by switching off the unpolluted water tap if pollution was recorded in the water pipes. The master system/responder turned off the tap control of the pipe that took supply from reservoir 2 through solenoid valve 2 and opened solenoid valve 1 once systems 1 and 2 deteriorated in water quality in the adjacent pipe. The ALWQD systems under loading and no loading conditions are shown in Figure**s** 2 and 3. The ALWQD systems were run on three trials, and average results of WQI of pH, TDS, Turbidity, and flow rates on distilled, tap, and polluted water and points of leaks on the pipes were recorded at 0, 5, and 10 minutes. The efficiency of ALWQD was calculated, and data results were statistically analyzed. Visualization of ALWQD data (producing bar charts) was carried out using *Jupyter Notebooks (JN)* and Microsoft Excel 2016 software for comparison.

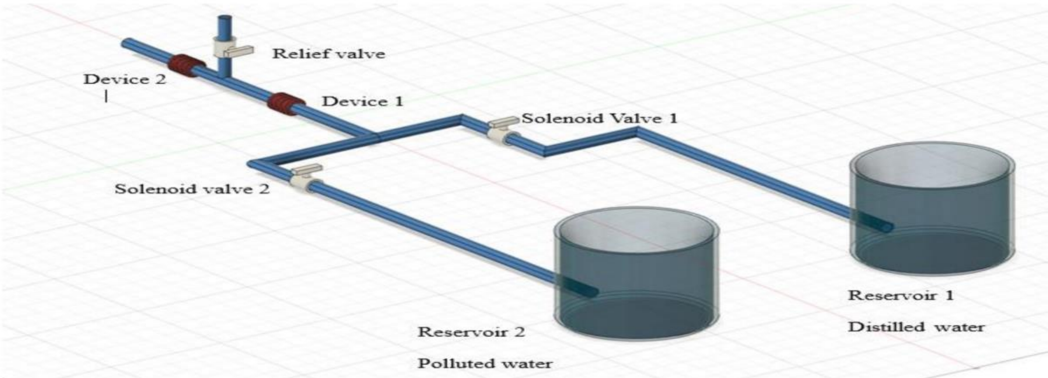

Figure 1. Schematic diagram of the ALWQD system

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

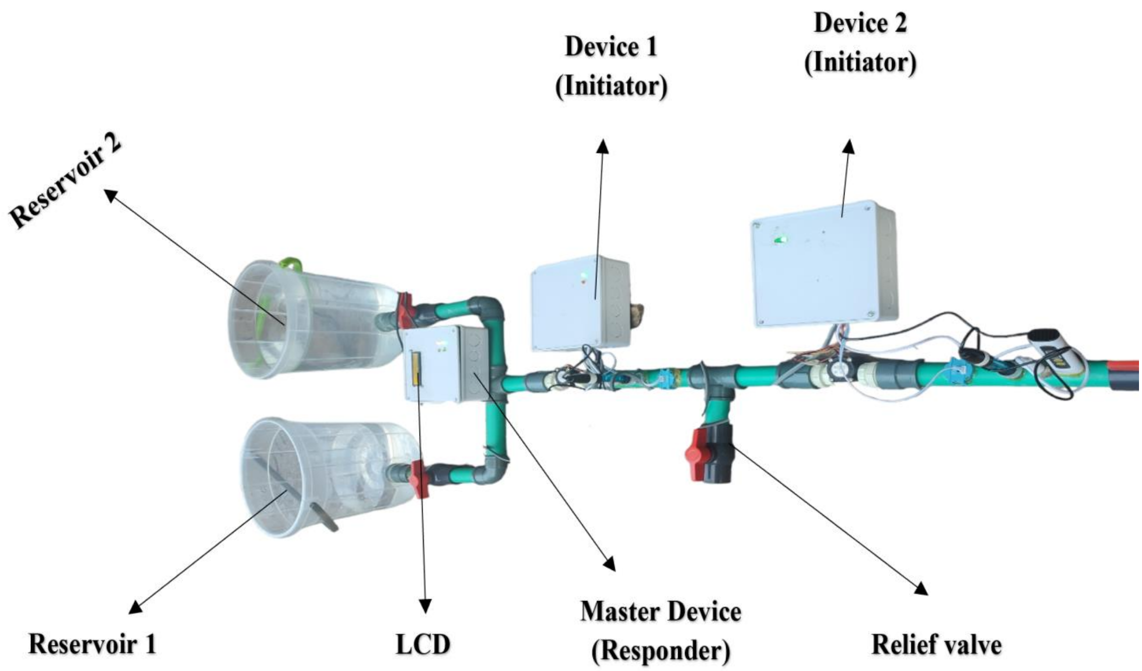

Figure 2: Setup of the ALWQD systems under no load conditions.

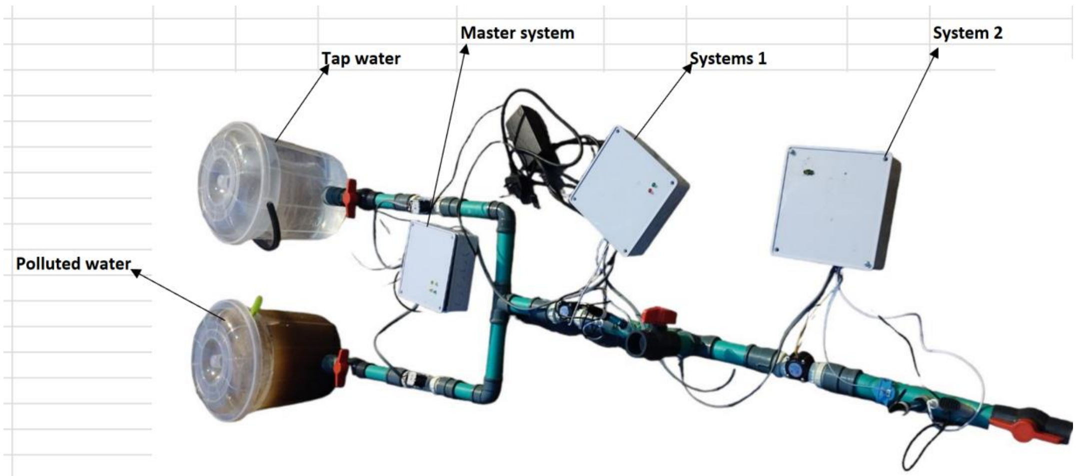

Figure 3: Setup of the ALWQD systems during testing under load condition

3. Results and Discussion

The results of the water quality test for pH value, turbidity, and total dissolved solid test through the ALQWD for different samples are presented in Tables 3–6 for load and no-load conditions.

Table 3: Testing results of ALWQD under no load condition on distilled water.

Water Quality Indicator (WQI)	No load	
	System 1	System 2
Turbidity NTU*	0.00	0.00
pH value	6.99	6.98
Total dissolved solids (TDS) mg/L	0.00	0.00
Water Flow rates m^3/s	1.04	1.07

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

Table 4: Testing results on the ALWQD system under load conditions.

Water Quality Indicator (WQI)	Tap water sample		Polluted water sample	
	System 1	System 2	System 1	System 2
Turbidity NTU	4.94	5.3	4.92	5.20
pH value	6.94	7.20	9.37	10.60
Total dissolved solids (TDS) mg/L	57.43	98.06	1088.21	1208.47
Water Flow rates m^3/s	1.36	1.30	1.42	1.35

Table 5: Testing results of ALWQD under load conditions after 5 minutes

Water Quality Indicator (WQI)	Tap water sample		Polluted water sample	
	System 1	System 2	System 1	System 2
Turbidity NTU	4.90	5.2	4.95	5.30
pH value	6.52	6.92	8.65	8.82
Total dissolved solids (TDS) mg/L	59.10	101.86	1092.32	1143.05
Water Flow rates m^3/s	1.52	1.36	1.42	1.33

NTU* Nephelometric Turbidity Unit

Table 6: Testing results of ALWQD under load conditions after 10 minutes.

Water Quality Indicator (WQI)	Tap water sample		Polluted water sample	
	System 1	System 2	System 1	System 2
Turbidity NTU	4.90	5.2	4.95	5.30
pH value	8.11	7.98	9.05	9.12
Total dissolved solids (TDS) mg/L	100.28	99.6	1219.83	1206.86
Water Flow rates m^3/s	0.35	0.36	0.46	0.49

The determined water quality parameters align with those of previous works by Fashanu et al. (2019), Mala-Jetmarova (2015), Atojunere and Ogedengbe (2019), and water quality standards by Bartram and Balance (1996), WHO (2016), and WHO (2017). The ALQWD results demonstrated variations in the water quality indicators taken by systems 1 and 2 for distilled, tap, and polluted water, as shown in the graphs of Figures 5-11. The relative height differences recorded during testing were small and might be due to either instrument/component or human error. This finding indicates that ALQWD detected impairment in water quality along the water flow pipe and reported its leakages at loose joints. Leaks were detected by pressure drop and reduced flow rates in the pipes. The efficiency of ALQWD was from 70% to 80%. The TDS values in System 1 were greater than those of System 2, 59.10 mg/L > 101.86 mg/L; for tap water, System 2 > System 1: 1092.32 mg/L > 1143.05 mg/L for polluted water. A similar trend was recorded for pH and flow rates, except for turbidity values with a reverse trend. There was a significant difference among measured parameters in all the water tested. The turbidity values were above the 5 NTU recommended by WHO, suggesting that there could be other contaminants responsible for the higher turbid level. This result might not be unconnected to the possible intrusion of pollutants from surrounding soils or runoff from agricultural activities that migrated into the pipe through leak pipe and loose pipe joints.

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

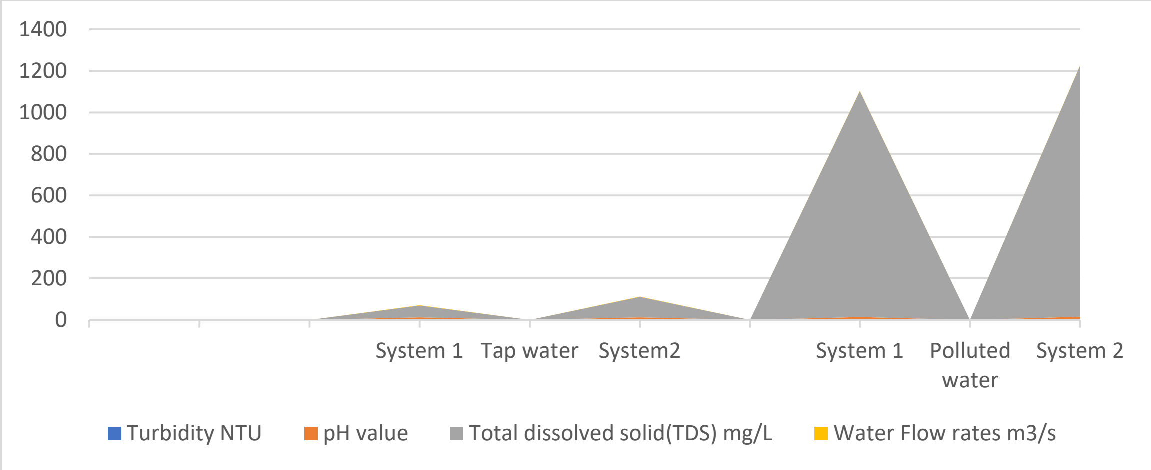

Figure 4: Plot of Turbidity value, TDS, and flow rates for tap and polluted water for 5 minutes.

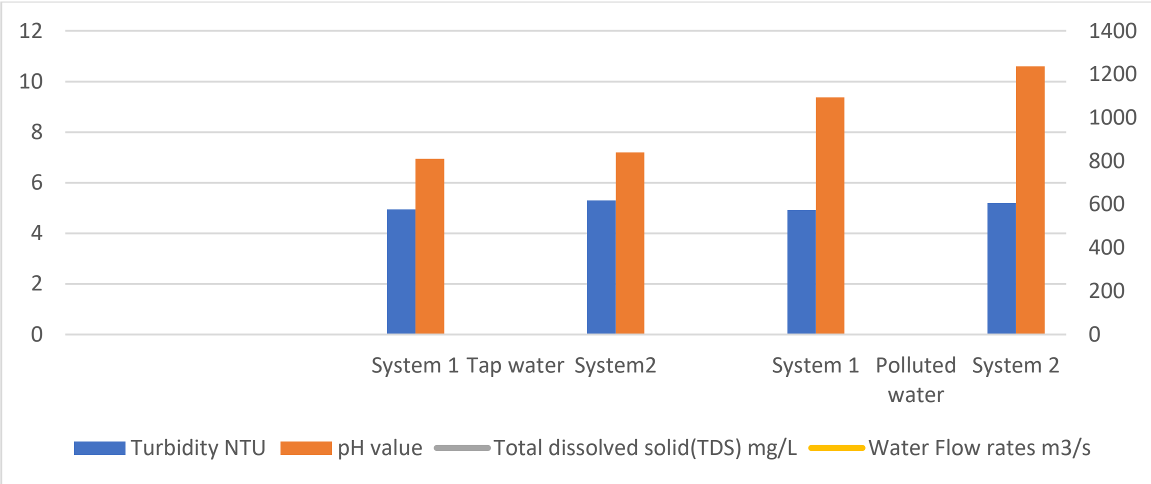

Figure 5: Turbidity value, TDS, and flow rates for distilled, tap, and polluted water for 5 minutes.

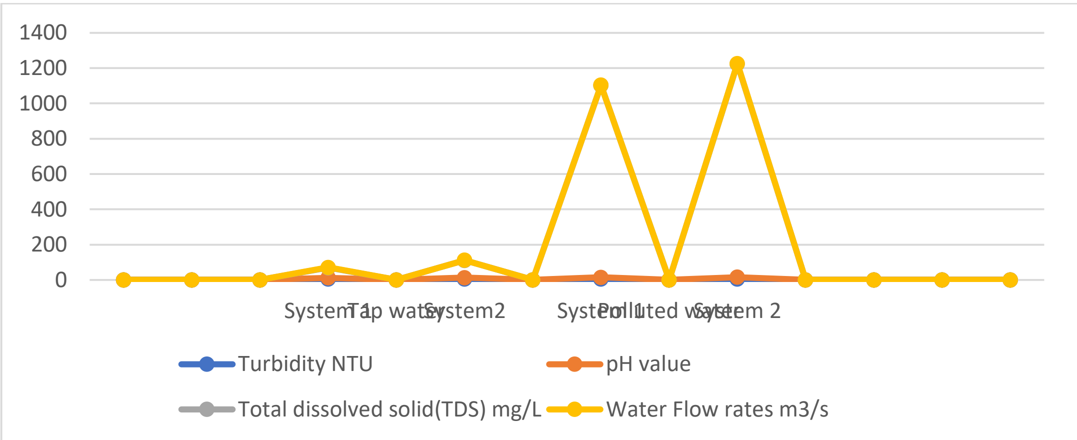

Figure 6: Turbidity value, TDS, and flow rates for tap and polluted water for 10 minutes.

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

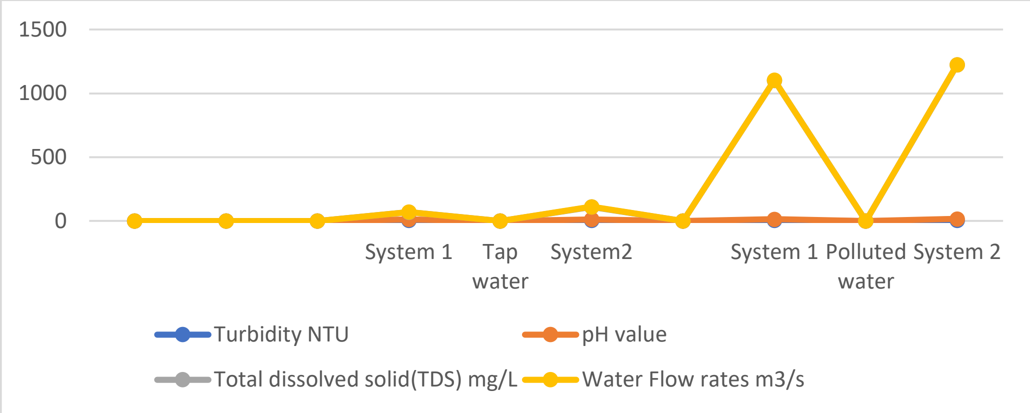

Figure 7: Turbidity value, TDS, and flow rates for tap and polluted water at 10 minutes

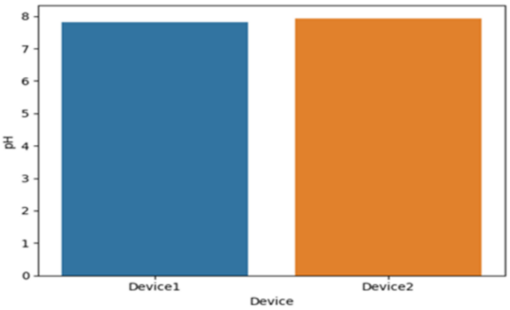

Figure 8 : Visual of turbidity of device 1 against 2 for tap water

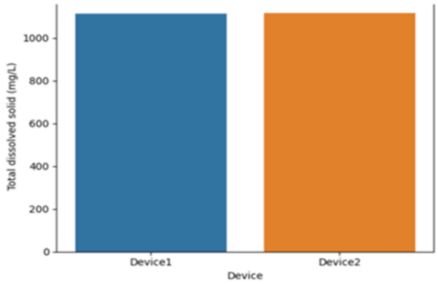

Figure 9 Visual of TDS of device 1 against 2 for polluted water

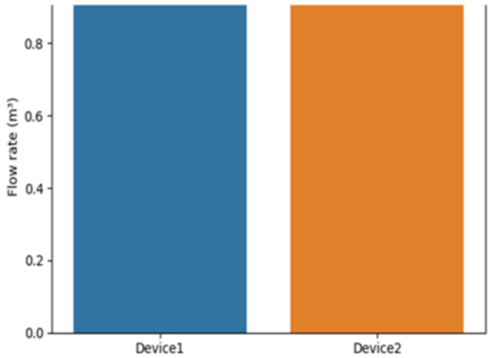

Figure 10 Visual of flow rate of device 1 against 2 for polluted water

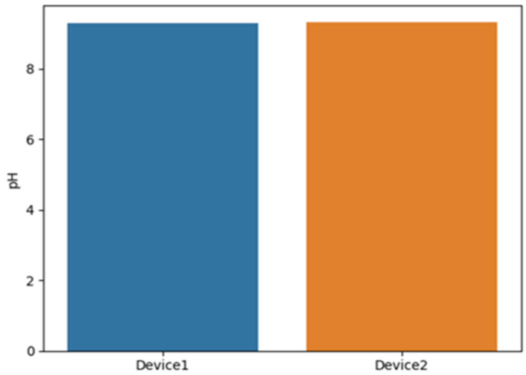

Figure 11 Visual of pH of device 1 against 2 for polluted water

4. Conclusion

The developed ALWQD system resolved the leakage problems associated with the water conveyance system. The development and testing of the ALWQD system followed standard procedures. The ALWQD system detected leaks in the simulated water pipes used for testing by indicating pressure drops at several points of leakage. The efficiency of ALWQD was 70%–80%. There were variations in some of the readings; however, they were considered insignificant. With modification, ALWOD will be a reliable water detection technology in the future as manual detection of leaks is becoming impracticable.

5. References

Aamo O.M (2016) Leak detection, size estimation and localization in pipe flows. IEEE Trans Autom Control 61(1):246–251 IEEE

Al Hawari A, Khader M, Zayed T, Moselhi O (2015) Non-destructive visual-statistical approach to detect leaks in water mains. World Acad Sci, Eng Technol, Int J Environ, Chem, Ecol, Geol Geophys Eng 9(3):230–234

Al Qahtani, T., Yaakob M. S, Yidris N., Sulaiman S., and Ahmad, K. A, (2020) "A Review on Water Leakage Detection Method in the Water Distribution Network". *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *68*(2), 152–163.

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

Al-Mashhadani, K.A, and D.J. Thompson (2011) "Leak Detection in Water Distribution Systems: A Review accessed date March 2023

APHA Public Health Association APHA(2022).Standard Methods for the Examination of Water and Wastewater (21st edition), American Public Health, Association, Washington DC.

Atef A, Zayed T, Hawari A, Khader M, Moselhi O (2016) Multi-tier method using infrared photography and GPR to detect and locate water leaks. Autom Constr 61:162–170 Elsevier

Atojunere,E.E, and O, Ogundipe(2022). Artificial Intelligence into Drip Irrigation of Roselle's *(Hibiscus Sabdariffa Linn*) Cultivation, *Agricultural Mechanization in Asia, Africa, and Latin, America*) *AMA* (ISSN: 00845841) 53(01) 6883-6895

Atojunere, E.E, and K.Ogedengbe (2019) Evaluating Water Quality Indicators of Some Water Sources in the Bitumen-Rich Areas of Ondo State, Nigeria, *International Journal of Environmental Pollution and Remediation*(IJPER) Avestia Publishing, Ontario, Canada,7(1) 9-22 https://ijepr.avestia.com/2019/002.html

Atojunere, E.E., K.Ogedengbe and E.B.Lucas (2018)The Development of Filtration and Bioremediation Technique for Decontaminating Bitumen-Polluted Water. *Proceedings of the 2nd International Conference of Recent Trends in Environmental Science and Engineering (RTESE'18),* Academy of Science, Engineering and Technology, (ASET),NiagaraFall, Canada DOI:10.11159/rtese18.111

Bartram, J., and R. Balance(1996). Water quality monitoring–a practical guide to the designand implementation of freshwater quality and monitoring study UNEP/WHO, Chapman andHall. London. UNEP/WHO(1996)

Beat, S and S. Dorothee(2020) Water Distribution Pipes [Blog post]. Sustainable Sanitation and Water Management Toolbox https://sswm.info/sswm-university-course/module-centralised-and-decentralised-systems-water-and-sanitation-1/network-design- and- dimensioning accessed date May 2023

Chraim F, Erol YB, Pister K (2016) Wireless gas leak detection and localization. IEEE Trans Ind Inf 12(2):768–779 IEEE

Datta S, Sarkar S (2016) A review on different pipeline fault detection methods. J Loss Prev Process Ind 41:97–106 Elsevier

Daugirdas, J. T., (2013) "Handbook of water and wastewater treatment plant operations (3rd ed.)". BocaRaton, FL: CRC Press.

El-Zahab S, Mosleh F, Zayed T, El Zahab S, Mosleh F, Zayed T (2016) An accelerometer-based real-time monitoring and leak detection system for pressurized water pipelines. Pipelines:257–268

El-Zahab and Zayed (2019) Leak detection in water distribution networks: an introductory overview, https://doi.org/10.1186/s40713-019-0017-x

El-Abbasy MS, Mosleh F, Senouci A, Zayed T, Al-Derham H (2016) Locating leaks in water mainsusing noise loggers. Journal of Infrastructure Systems. 22(3):04016012

Eytan, G.and D, Spuhler(2021) Water Distribution Pipes accessed on https://sswm.info/sswm-University- course/module-2-centralized-and-decentralised systems-water- and-sanitation-1/water- distribution- pipes Accessed on February 2023

Fashanu, T.A. J.P.Eche, J.A Akanmu, O.J.Adeyeye and E.E. Atojunere(2019) . A Virtual Auto-desk-Simulink Reference Plant for Wastewater Treatment, Nigerian Journal of Technology (NIJOTECH), Faculty of Engineering, University of Nigeria, 38(1):267-267

Fondriest,F.J.(2021) .Conductivity, Salinity, and Total Dissolved Solids accessed on https://www.fondriest.com/Environmental-measurements/parameters/waterquality/conductivity salinity-TDS/ Accessed on December 2022.

Gong W, Suresh MA, Smith L, Ostfeld A, Stoleru R, Rasekh A, Banks MK (2016) Mobile sensor networks for optimal leak and backflow detection and localization in municipal water networks Environ Model Softw 80:306–321 Elsevier

Howard, S.P, D. R. Rowe and G.Tchobanoglous(1985). Environmental Engineering. McGraw-Hill, New York.

Khulief YA, Khalifa A, Mansour RB, Habib MA (2011) Acoustic detection of leaks in water pipelines using measurements inside the pipe. J Pipeline Syst Eng Pract 3(2):47–54 American Society of Civil Engineers

Kim D, Ha J, You K (2011) Adaptive extended Kalman filter based geolocation using TDOA/FDOA. Int J Control Autom 4(2):49–58

Nriagu, J.O, M.I. Blackson and K. Ocram(1996). Childhood Lead Poisoning in Africa, a GrowingPublic Health Problem. *Journal of Science Total Environment*. 181(2):93-101

Mala-Jetmarova, H .A.Barton A. A. Bagirov(2015) History of Water Distribution Systems andtheir Optimization. Water Science & Technology Water Supply https://www.researchgate.net/publication /274699540_accessed date June,2023

Mays, W. L(2000) Water Distribution Systems Handbook. American Water Works Association. New York: McGraw-Hill.

McEvoy, M.J. and S.J. Wyatt (2012) "Water Quality Monitoring: A Review" Accessed date January,2023

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)

Naga Venkata Saidileep Korlapati, Faisal Khana, Quddus Noor, Saadat Mirzac,Sreeram Vaddirajua(2022) Review and analysis of pipeline leak detection methods, *Journal of Pipeline and Engineering, https://doi.org/10.1016/j.jpse.2022.100074.*

Oyedele, A.(2021) Water Distribution System Challenges and Solutionswww.wateronline.com/doc/water- distribution-system-challenges-and-solutions-0001 Accessed March,2023

Romano M, Woodward K, Kapelan Z (2017) Statistical process control-based system forapproximate location of pipe bursts and leaks in water distribution systems. Procedia Eng186:236–243 Elsevier.

Smith, T.F. and D.R. Naud (2013) “A Review of Water Quality Monitoring and Management inWater Supply Systems” Accessed date January 2023

Sinha, P.K. C.V. Madhava, and S.M. Shaikh (2007) “Leak Detection in Water Distribution Systems: A Review” Accessed date May 2023World Health Organization. Health Aspects of Plumbing (2016) Accessed date April,2023 https://www.who.int/water_sanitation_health/publications/plumbinghealthasp.pdf World Health Organization. (2017) Guidelines on drinking water quality 4th Edition Geneva, Switzerland, Accessed date January 2023

DOI:https//doi.org/10.22452/mjs.vol43no3.10
Malaysian Journal of Science 43(3): 98-108 (September 2024)