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Assessment of Physico-Chemical Water Quality Standard of Bayero University

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Abstract: *Safe drinking water is essential for public health, yet water quality deterioration remains a concern in many developing regions. This study assessed the physico-chemical and selected heavy metal quality of drinking water within Bayero University Kano (BUK), Nigeria, and compared it with the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organisation (WHO) guidelines. Water samples were collected from boreholes, underground reservoirs, and overhead storage tanks across both the Old and New Campuses of the university. Standard analytical methods recommended by the American Public Health Association (APHA) were used to analyse the parameters. The results revealed variations in water quality along the distribution system. Most parameters, including turbidity, electrical conductivity, sulphate, chloride, calcium, magnesium, manganese, and dissolved oxygen, were within the permissible limits of WHO and NSDWQ. However, all samples showed acidic pH values ranging between 5.32 – 5.38 which is below the recommended range. The concentrations of nitrate (ranging from 56.04 to 434.31 mg/L) and ammonia (ranging from 1.40 to 2.94 mg/L) in all samples surpass the recommended guideline limits, indicating potential contamination from agricultural practices and other human-related sources. High nitrate content in drinking water can cause methemoglobinemia in infants. Additionally, isolated instances of elevated iron and potassium levels were detected. The study underscores the need for continuous monitoring, improved water treatment, and effective management strategies to ensure safe and sustainable drinking water supply within the BUK community.*

Key words: Water quality; Physico-chemical parameters; Groundwater; Nitrate contamination; Drinking water standards.

1 Introduction

All living organisms depend on water for survival, reproduction, and other essential life processes. Despite recent progress, access to safe and high-quality water remains a major concern (Levallois and Villanueva, 2019). About 1 billion people worldwide do not have access to safe water (Chidiac *et al*, 2023), and there are approximately 2.2 million deaths annually due to waterborne disease in developing countries (Ighalo and Adeniyi, 2020). In Nigeria, about 66.3 million of the populaces lack access to safe drinking water (Nwanisobi *et al*., 2025). The safety of drinking water is therefore very critical to public health. Having access to safe drinking water is a basic human right for all people, regardless of nationality, religion, colour, wealth, or creed. The sixth sustainable development goal emphasises the importance of the availability of clean water, improvement of water quality and addressing the issue of water scarcity (Ighalo and Adeniyi, 2020).

Contaminated drinking water and poor sanitation are linked to the transmission of diseases such as cholera, diarrhoea, dysentery, and polio (WHO, 2018). Poor drinking water quality is significantly affecting the health of consumers (Li and Wu, 2019). To reduce the morbidity and mortality from infectious diseases in developing countries, safe drinking water and sanitation need to be improved, including the quality and availability, proper excreta disposal, personal and environmental hygiene. It is also critical to have an effective quality control mechanism for water supplies to reduce the potential for explosive epidemic outbreaks (Alhassan and Ujoh, 2012).

Although drinking water quality is regulated and monitored in many countries, increasing knowledge leads to the need for reviewing standards and guidelines on a nearly permanent basis, both for regulated and newly identified contaminants.(Levallois and Villanueva, 2019).The primary aim of the water quality standards is for the protection of public health. Accordingly, there are various criteria for water quality standards, i.e. safety of drinking water, acceptable water quality for industrial use, water used for agriculture, and for sustaining natural aquatic ecosystems (Aizawa and Magara, 2015). The quality of water defined by potable drinking water standards is such that it is suitable for human consumption, free of health-related chemicals and microbiological constituents, aesthetic, suitable organoleptic characteristics, and usable for all normal domestic purposes, including personal hygiene (Aizawa and Magara, 2015). Water analysis alone is not sufficient to maintain quality but must be combined with the periodic review and acceptance of the facilities used.

This study is aimed to conduct a detailed investigation into the water quality of Bayero University Kano, in terms of the physico-chemical and some heavy metal parameters. The result of the analysis is compared with the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organisation (WHO) standards. This research could serve as a water quality database for BUK, and can be utilised for the development and improvement of sustainable water supply.

2. MATERIALS AND METHODS

2.1 Location of the study area

Bayero University Kano has two campuses: Bayero University Old Campus (BOC) and Bayero University New Campus (BNC). They are situated in the Gwale local government area of Kano state, Nigeria. It is in the southwestern part of the old Kano city. The BOC is located between latitude $11^0$59’00.7” N to $11^0$58’49.2” N and longitude 80^0 28’35.3” E to $8^0$29’00.8” E (Saleh *et al*., 2011), while the BNC is located at Latitude 11.9708° or 11° 58' 14.9" north and Longitude 8.4347° or 8° 26' 4.7" E (Saleh *et al*., 2011).

2.2 Description of the water supply system in BUK Old Campus

The main source of water supply to BOC is approximately seventy percent (70%) underground (borehole) water and thirty percent (30%) from Kano State Water Board. The boreholes are situated at three different locations within the campus, namely, the sports complex, PTF, and Yankosai. The sports complex area comprises seven (7) boreholes and contributes fifty percent of the total underground water supply. In this research, the sport complex borehole was considered since it supplies the major water supply to the campus. Kano, Nigeria).

2.3 Description of the water supply system in BUK New Campus

The BNC is completely dependent on underground (borehole) water for its activities. A combination of seven boreholes dug within the campus supplies water to the overhead tank situated at the main water pump station, which is located at the staff quarters area near Rimin-gata gate. To enable wide coverage of water distribution in the campus, water is pumped from the main water pump station to two underground reservoirs located near Ibrahim Gambabri Square before it is pumped to the overhead tank in the same area for onward distribution.

2.4 Water sample collection

Water samples were collected in clean 100 cL bottles thoroughly washed with detergent, rinsed with distilled water, and finally rinsed with the sample water. All samples were collected in June, 2021. The preservation and analysis of the samples were done within the recommended holding times in accordance with APHA Standard Methods.

Water samples were collected from different points in both BOC and BNC. A total of three water samples were collected from BOC. The first sample (BH1**)** was taken directly from the collection point of the seven combined boreholes, the second sample (R1**)** was taken from the underground reservoir and the third (OT1**)** sample was collected from the overhead tank. In BNC, samples were taken directly from the collection point of the boreholes, the two underground water reservoirs and the overhead tank located at the water station near Ibrahim Gambabri Square; the samples were labelled BH2, R1, R2, and OH2, respectively. The samples were then brought to the laboratory for analysis.

2.5 Methodology

Analysis of the collected groundwater samples was done in accordance with the American Public Health Association (APHA) standard methods for the examination of water and wastewater (APHA, 2017). All chemicals and reagents used in this research are of analytical grade unless stated otherwise.

2.5.1 pH measurement

The pH of the samples was determined using the electrometric method (4500-H^+ B). The pH meter (Jenway 3520) was calibrated using buffer solutions of pH 4 and pH 7 before actual reading of the samples were taken to ensure accurate reading.

2.5.2 Electrical Conductivity (EC)

Electrical conductivity was measured using a conductivity meter (Jenway 4520) in accordance with APHA 2510 B.

2.5.3 Turbidity

Turbidity was measured using a nephelometric turbidity meter (Hach Turbidimeter) in accordance with APHA 2130 B.

2.5.4 Nitrate (NO_3^-)

Nitrate concentration was determined using the UV spectrophotometric method (APHA 4500-NO_3^- B).

2.5.5 Chloride (Cl^-)

Chloride was analyzed by the argentometric titration method (APHA 4500-Cl^- B).

2.5.6 Ammonia (NH_3–N)

Ammonia was determined using the phenate method (APHA 4500-NH_3 G) with spectrophotometric measurement.

2.5.7 Alkalinity

Total alkalinity was determined by titration with standard acid using the titrimetric method (APHA 2320 B).

2.5.8 Calcium (Ca^{2+})

Calcium concentration was determined using the EDTA titrimetric method (APHA 3500-Ca B).

2.5.9 Magnesium (Mg^{2+})

Magnesium was calculated from total hardness after calcium determination, in accordance with APHA 3500-Mg B.

2.5.10 Sodium (Na^+) and Potassium (K^+)

Sodium and potassium were determined using a flame photometer following APHA 3500-Na B and 3500-K B, respectively.

2.5.11 Heavy Metals

Heavy metals were analysed using Atomic Absorption Spectrophotometry (AAS) following APHA 3111 B method. In brief, samples was aspirated into a flame for atomisation, and the element specific absorbance was measured after wavelenght selection by a monochromator.

2.5.12 Dissolved Oxygen (DO)

Dissolved oxygen was determined using the Winkler iodometric method (APHA 4500-O B).

3 RESULT AND DISCUSSION

3.1 Results

Table 1 shows the results for the water quality analysis of the samples collected from the study area. The result of the physicochemical analysis shows that there are changes in the water quality parameters as the water flows through the distribution system. The concentration levels of the various parameters analysed are compared with the NSDWQ and WHO standards.

3.2 Discussion of Results

3.3 pH

This study reveals that the pH value for all the samples is lower than the standard specified by WHO and NSDWQ (6.5-8.5). The pH decreases as the water flows from the collection point of the boreholes to the underground reservoir and to the overhead tank in BOC (Table 1). The variation of pH in the distribution system may be as a result of corrosion in distribution pipes and overhead tanks. Lower pH indicates a higher acidity level in all the samples, though the human body can maintain pH balance through the action of the kidneys and lungs. However, drinking acidic water can lead to low retention of calcium, causing rapid bone loss over an extended period of time (Arhin *et al.,* 2024). The pH of the stomach fluid is within the range of 1.0 to 3.5 (WHO, 2007), therefore, the level reported in this research is not harmful for consumption. Low pH value can cause corrosion and dissolve metals such as iron from metal pipes and tanks into the water, causing flavour, staining problems and higher levels of heavy metals in the bloodstream (Hunter *et al*., 2022).

Table 1: Results for the water quality analysis of samples collected from BUK

PARAMETER	UNIT	BH1	R1	OT1	BH2	R2	R3	OH2
pH	-	5.76	5.54	5.34	5.38	5.32	5.35	5.88
Turbidity	NTU	3.10	2.52	2.70	2.12	2.43	3.38	3.38
Electrical conductivity	(µS/cm)	171.8	135.5	122.9	120.1	152.7	163.9	169.9
Nitrate	mg/L	56.04	56.04	434.31	112.08	208.12	210.15	56.04
Ammonia	mg/L	1.681	1.68	1.40	1.96	2.87	2.94	1.96
Sulphate	mg/L	13.73	13.68	13.73	13.80	13.62	13.68	13.82
Chloride	mg/L	195.25	142.00	159.75	142.00	175.12	177.50	142.00
Calcium	mg/L	5.24	2.16	4.46	9.32	11.50	11.51	2.46
Magnesium	mg/L	5.26	4.31	3.68	11.44	12.20	12.21	4.36
Potassium	mg/L	2.05	10.59	6.15	1.69	3.66	3.67	15.03
Iron	mg/L	0.293	0.6013	0.1346	ND	0.2176	0.2188	0.0401
Manganese	mg/L	ND	ND	ND	0.0174	ND	ND	ND
Dissolved Oxygen	mg/L	5.09	4.23	4.98	4.93	5.04	5.11	4.67

KEY: ND (Not Detected)

2.5.13 Turbidity

The turbidity of all the samples falls within the permissible limit of 5 NTU for both WHO and NSDWQ, as shown in Figure 1. The test for turbidity is used to indicate the quality of water in relation to colloidal matter (Yirdaw and Bamlaku, 2016). Therefore, low turbidity in the samples is a good indication of no or less harmful pathogens in the water (WHO, 2018).

2.5.14 Electrical Conductivity

No major difference in the electrical conductivity of all the samples, the values vary between 120.1 µS/cm and 171.8 µS/cm, which falls within the permissible limit of 1000 µS/cm for WHO and NSDWQ standards (Figure 1). The presence of inorganic dissolved solids such as chloride, nitrate, sulphate, phosphate anions, sodium, magnesium, calcium, iron, and aluminium cations affect conductivity in water (APHA, 2017). Conductivity is also affected by temperature. Significant changes in conductivity could be an indicator that a discharge or some other source of pollution has entered the water (WHO, 1998).

2.5.15 Nitrate

The Nitrate level of the samples is very high when compared with the WHO and NSDWQS permissible limit of 50 mg/L, as shown in Figure 2. This substance is of major health concern in drinking water. High nitrate content in drinking water can cause methemoglobinemia in infants (Dinka, 2010). Nitrate can reach both surface water and underground water as a result of agricultural activity (including excess application of inorganic nitrogenous fertilisers and manures), from wastewater treatment and oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. Nitrate can also be formed chemically in distribution pipes by Nitrosomonas bacteria during stagnation of nitrate-containing oxygen and poor drinking water in galvanised steel pipes, or if chlorination is used to provide a residual disinfectant, and the process is not sufficiently well controlled (WHO, 2016). The maximum contaminant level (MCL) was established to prevent infant methemoglobinemia, but it did not account for other potential health risks, such as cancer or reproductive effects. Nitrate can undergo endogenous nitrosation to form N-nitroso compounds, many of which are carcinogenic and teratogenic. Consequently, nitrate intake from drinking water and food may increase the risk of cancer, birth defects, and other adverse health outcomes (Ward *et al.,* 2018). Several studies have correlated health problems such as ovarian and bladder cancer, stomach cancer, miscarriage, and adverse effects on the nervous system, with increased nitrate consumption (Vogiatzi *et al.,* 2024).

2.5.16 Ammonia

The values of the ammonia concentration in the samples are all above the WHO and NSDWQ standards as presented in Figure 3. The presence of ammonia at levels higher than the geogenic levels in groundwater is often associated with anthropogenic sources such as sewage effluent, leaking manure lagoons, and landfill leachate (WHO, 2008). Ammonia has a toxic effect on human health only if the intake becomes higher than the capacity to detoxify (WHO, 1996). The toxic effects of ammonia occur only at exposures above about 200 mg/kg body weight (WHO, 2022). Natural levels in groundwater and surface water are usually below 0.2 mg/l. The recent WHO guideline on ammonia has not been established because it occurs in drinking water at concentrations well below those of health concern.

2.5.17 Sulphate

Sulphate occurs naturally in many minerals, the dissolution of these minerals contributes to the mineral content of many drinking waters (Greenwood and Earnshaw, 1984). The sulphate level in all samples in this study is relatively the same and below the NSDWQ suggested level of 100 mg/L, as seen in Figure 3. The recent WHO guideline did not suggest any value, however, concentrations above 500 mg/L in drinking water might cause gastrointestinal effects and noticeable taste (WHO, 2022). It may also lead to corrosion of metallic pipes and tanks.

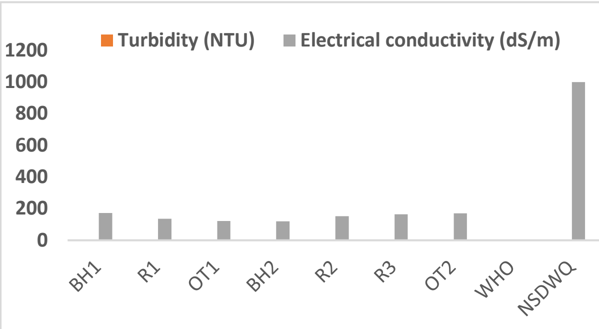

Figure 1: Comparison of turbidity and electrical conductivity levels of the samples with WHO and NSDWQ standards

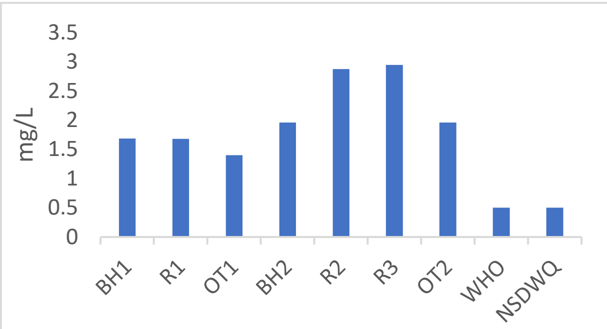

Figure 1: Comparison of nitrate level with the WHO and NSDWQ drinking water guideline

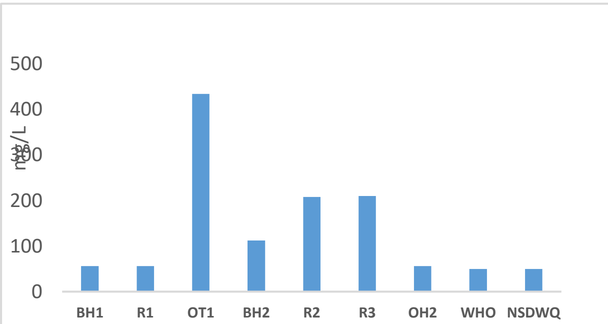

Figure 2: Comparison of ammonia level with the WHO and NSDWQ drinking water guideline

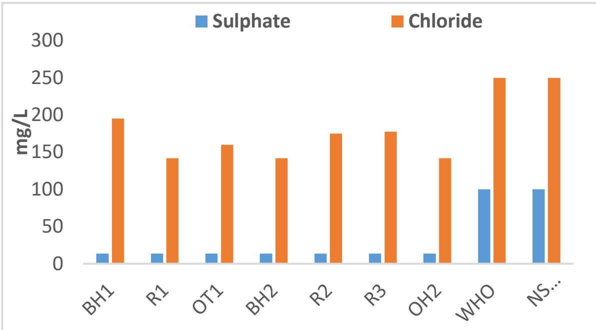

Figure 3: Comparison of chloride and sulphate levels with the WHO and NSDWQ drinking water guideline

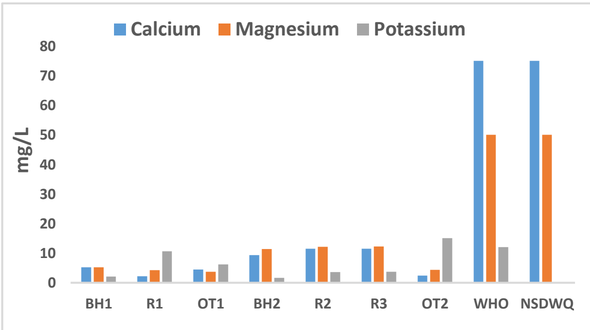

Figure 4: Comparison of calcium, magnesium and potassium level with WHO and NSDWQ drinking water guideline

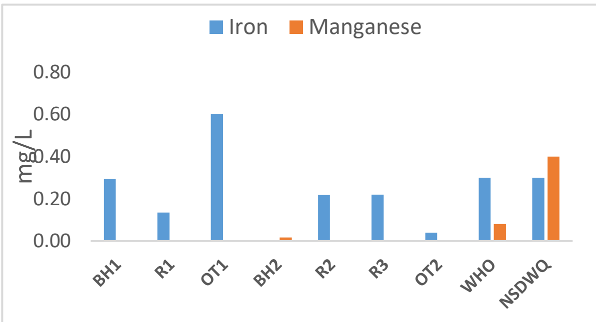

Figure 5: Comparison of iron and manganese level with WHO and NSDWQ drinking water guideline

3.3.1 Chloride

The chloride value varies across the samples and is within the WHO and NSDWQ permissible standard of 250 mg/L, as presented in Figure 4. Chloride in underground water may be associated with the presence of sodium in drinking water at high concentrations, often from saltwater intrusion, mineral dissolution, industrial and domestic waste (Roger, 1982). No health-based guideline value is proposed for chloride in drinking water. However, chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water.

3.3.2 Calcium

The calcium content for all samples falls within the WHO and NSDWQ standards (Figure 5). Excess ingestion of calcium by healthy individuals is not a major health concern as it is tightly regulated by the action of 1,2,5-dihydroxyvitamin D, but may likely affect people prone to milk alkali syndrome and hypercalcemia (Cotruvo and Bartram, 2009). High calcium content may lead to corrosion of piping materials and scaling effects in installations. Corrosion and scaling can be associated with adverse effects on health and reduce the lifespan of the distribution network and appliances using the water.

3.3.3 Magnesium

Magnesium concentration of all samples falls within the permissible limit of WHO (50mg/l) and NSDWQ (30 mg/l) as presented in Figure 5. Magnesium and other alkali metals are responsible for water hardness. Magnesium in water is beneficial to human health. Water containing moderately higher magnesium concentration can reduce cardiovascular mortality by 30-35 % (Rosanoff, 2013). It lowers intracellular calcium and sodium, which decreases blood pressure. At large doses, magnesium may cause vomiting and diarrhea (WHO, 2013).

3.3.4 Potassium

Potassium concentration of all samples is below the WHO recommended limit except for sample OT2 (Figure 5), while NSDWQ did not set any limit. Potassium occurs widely in the environment, including all natural waters and is an essential element in humans. Potassium is essential for the body as it helps regulate fluid balance, supports blood pressure control, and is crucial for nerve signalling and muscle contractions (Banerjee and Prasad, 2020). Potassium concentrations normally found in drinking water are generally low and do not pose health concerns. The recommended daily requirement is greater than 3000 mg; higher concentrations could lead to significant health effects, especially in people with kidney disease or other conditions, such as heart disease (WHO, 2009). Also, an increased level of potassium and other dissolved polyvalent metallic ions in water causes water hardness, which leads to considerably more soap or detergent usage to produce lather.

3.3.5 Iron

The concentration of Iron in all the samples is below the recommended WHO and NSDWQ, except for sample OT1 (Figure 6). Iron is found naturally in water and can be present in drinking water as a result of the use of iron coagulants or the corrosion of steel and cast-iron pipes during water distribution (WHO, 2008). Iron is a vital mineral nutrient which plays an important role in the maintenance of energy metabolism. Elevated iron levels in drinking water may not cause immediate harm, but long-term consumption can lead to iron overload. This condition disrupts blood cell formation by damaging progenitor cells and their environment. If untreated, it can progress to hemochromatosis, a disorder that harms various organs (Khatri *et al*., 2017). Although a low level of iron cannot harm your health, high iron content in water can cause diabetes, hemochromatosis, stomach problems, and nausea. It can also damage the liver, pancreas, and heart (WHO, 2003).

3.3.6 Manganese

Manganese was only present in sample BH2, and the concentration is below the recommended standards of WHO and NSDWQ standards (Figure 6). Manganese is naturally occurring in many surface and underground water sources, particularly in anaerobic or low oxidation conditions (WHO, 2008). The safe concentration of manganese (Mn) in drinking water, especially for sensitive groups such as children, is still uncertain. While Mn is an essential nutrient, it is also a recognised neurotoxicant, with both insufficient and excessive levels linked to harmful effects on the nervous system (Friedman *et al*., 2023). However, manganese levels can increase at the tap because of accumulation and periodic release in the distribution system (WHO, 2022). Manganese is known to cause adverse neurological effects following extended exposure to very high levels in drinking water (WHO, 2008).

3.3.7 Dissolved oxygen (DO)

The dissolved oxygen concentration in all samples analysed is below the NSDWQ of 7.5 mg/L. Currently, WHO has not recommended any health-based guideline value for dissolved oxygen (WHO, 2022), but have suggested DO concentration should not be below 3 mg/L for domestic and recreational water usage (Sila, 2019). A high dissolved oxygen level in water supply is good because it makes drinking water taste better (WHO, 2018). However, very high levels of dissolved oxygen may intensify corrosion of metal pipes and tanks (WHO, 2022).

4 CONCLUSION

The study of water samples from the BUK distribution system reveals that while most physicochemical parameters, such as turbidity, electrical conductivity, sulphate, chloride, calcium, magnesium, and manganese, are within WHO and NSDWQ standards, there are notable concerns. Low pH levels, though not immediately harmful, can lead to metal leaching and infrastructure damage. More critically, nitrate and ammonia concentrations exceed permissible limits, posing significant health risks and indicating contamination from human activities like agriculture and sewage. Additionally, isolated exceedances in potassium and iron levels suggest localised issues. These findings highlight the need for targeted interventions, ongoing monitoring, and improved water management to ensure long-term safety and infrastructure integrity.

5 RECOMMENDATION

In line with the findings, the study suggests the urgent need for

- Proper planning and management are required to mitigate the problem of drinking water contamination in the study area.
- To construct and develop good boreholes which penetrate the aquiferous zones and to monitor the sanitary conditions of the school community.
- Continual research on issues relating to potable water sources in the BUK community to identify and address grey areas in water quality delivery.
- Sanitation and waste management strategies to be put in place for effective disposal of waste to avoid the possibility of groundwater contamination.
- The reservoir tank should be properly washed and regularly monitored to improve its sanitation.
- The school management should consider replacing the ageing galvanised pipes with PVC to avoid pipe corrosion, especially at the source.

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