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Critical Review on Water Quality due to Pipe Leakage in Water Distribution System

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Abstract: This paper reviews on the sources of pipe leakage in water distribution system from previous study and understand and analyze the data gathered from previous study on the characteristic of water quality affected by leaking pipe. Previous study on pipe leakage in water distribution has been gathered and analyze to identify the characteristic of water from leaking pipe and solve the problem of pipe leakage that will disturb the quality of water. Critical review was carried out by searching for journals on trusted sources such as Scopus and Science Direct to discuss the research findings, including describing the basic features of the component that are related to drinking water quality due to pipe leakage, and VOS viewer software has been used to generate a map based on the relationship between pipe leakage and water quality. Important parameters have been reviewed from previous paper such as BOD level, dissolve oxygen, chlorine and others related to the drinking water quality. Suggestions and recommendations such as sophisticated leak detection techniques and rehabilitation or replacement are proposed in order to improve the quality if water if there is pipe leakage in water distribution systems

Keywords: Pipe Leakage, Water Quality, Contamination

1. Introduction

Pipe is a frequently utilized material in the water supply system. Pipes assist in transporting purified water to consumers for use in their daily activities. There are numerous types of pipes used in water delivery, and each form of pipe serves a unique role in terms of facilitating the flow of water for distribution purposes. External pollutant entrance into drinking water distribution systems is possible if there is a physical breakdown, such as a pipe crack. Contamination events may have an impact on the drinking water treatment plan and waste disposal facilities [1]. The characteristic of water quality is vital in determining the condition of the water to be consumed. Water quality characteristics such as pH, temperature, dissolve oxygen, BOD value, and chlorine residue are all used to determine the water's quality [2]. Adequate pressure in the distribution system can result in pollutant incursion. Pipe suction and pollutant incursion occur as a result of pipe leakage during negative pressure in pipes. Microbial

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development can then degrade the water's quality during this stagnation time. The microbial makeup of any pipe segment is highly varied. Microorganisms' composition and activity can also be altered by the pipe surface. It is difficult to determine if the presence of microorganisms in drinking water poses an unacceptable risk [3]. As a result, even when pathogens are monitored using non-invasive approaches, the results frequently cast doubt on their public health significance. During water distribution, contaminants travel through the system to the point of consumption. Typically, chlorination is essential to ensure that the water is contaminant-free [3].

2. Review Methodology

Previous research has shown that a combination of leakage and low pressure is a source of pipe water contamination. Pollutants from the surrounding environment can infiltrate the pipe system when it is leaking. Pollutants can have physical, chemical, or biological features. Aside from that, the content of chlorine at the leaking pipe should be checked. During the leaking process, the remaining chlorine will be used to react with microorganisms in the piping system as well as those in the environment that will enter the pipe [4]. This critical evaluation examines the relationship between pipe leakage from the water distribution system and drinking water quality as a result of pipe leakage. Figure 1 shows the flow of the topic review or research framework. Previous research has been evaluated in order to identify aspects of drinking water quality caused by pipe leaking. The actual data collecting, and data analysis method was used to evaluate pipe leaks in the drinking water distribution system without sacrificing the quality of drinking water due to pipe leaking.

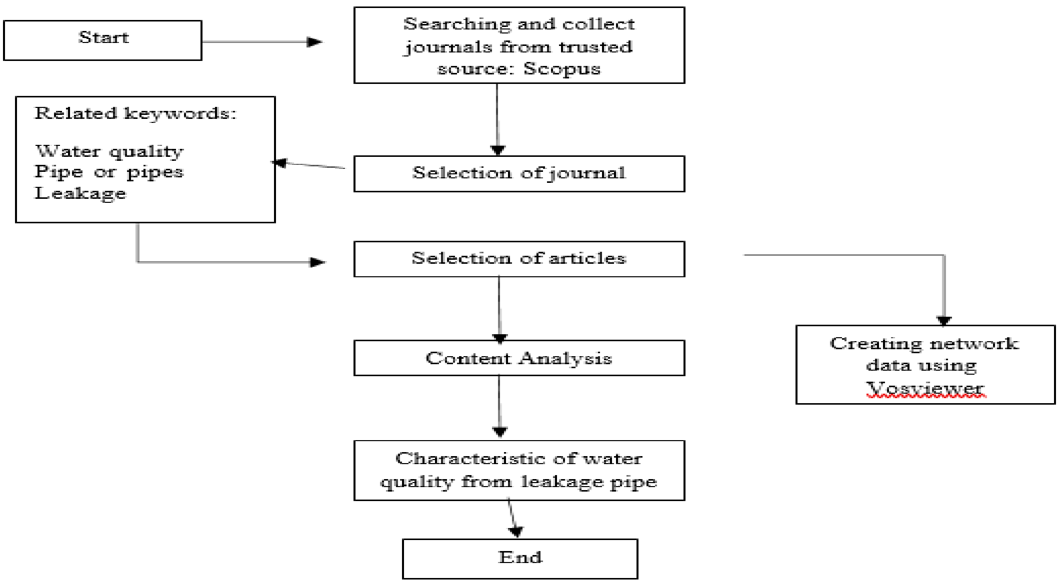

Figure 1: Research Framework

A critical review was carried out by looking for journals on a reliable source. The journals were chosen based on keywords relevant to the study's topic which are about water quality in pipe leakage. Certain parameters were chosen from earlier paper reviews because they are indicator which could effect on the quality of drinking water if a pipe leak occurs in the water distribution system [4]. The pH value, biological oxygen demand (BOD), dissolve oxygen (DO), total chlorine, total and suspended solid are the parameters. Temperature, colour, and odour are also included as aesthetic parameters. Contamination events may have an impact on the drinking water treatment plan and waste disposal facilities. The quantity of microorganisms associated with the iron release from pipe has a significant impact on the quality of water resulting from pipe leakage. The creation of network data by using VOS viewer software was purposed to visualize data based on the relationship between pipe leakage and water quality.

2.1 Collection of paper and journal

Leakage is vital in engineering research, as it is not only for assisting in the efficient management of water loss, but also for assuring consistent drinking water quality and preventing microorganism's incursion into distribution systems. Scopus was used as the journal and article source for this review study since it has a better and wider range of themes. The following question has been posed: TITLE-ABS-KEY TITLE-ABS-KEY TITLE-ABS- ("water quality" AND "pipe" OR "pipes" AND "leak" OR "leakage"). Other sources, such as Google Scholar and Science Direct, were employed to support the overall structure of this review study. In Figure 2, a total of 198 documents from 2000 to 2022 are relevant to the selected keywords which is from Scopus.

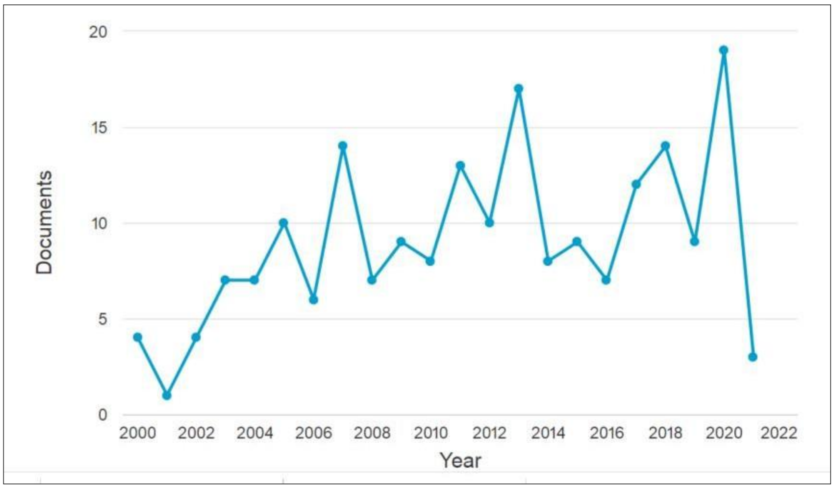

Figure 2: Related document from Scopus based on ("water quality" AND "pipe"OR "pipes" AND "leak" OR "leakage") keywords

2.2 Development of network data

After extracting data from Scopus, the VOSviewer software was used to visualise it. VOSviewer is a software application that enables the creation of maps based on network data, as well as the visualisation and exploration of these maps. VOSviewer visualizes a map in three ways which are network visualization, overlay visualization, and density visualization. The map is created based on the correlation between pipe leakage and water quality.

Figure 3 illustrates the result of the software's data network. Whereas the thickness of the lines denotes the degree of association between the terms (thicker means higher correlation). The colour of the keywords determines the colour of the lines. The similarity in colour between the keywords indicates correlation. A high degree of similarity implies a strong association. For example, goods coloured blue, such as portable water, water pipelines, and corrosion, all imply a strong link.

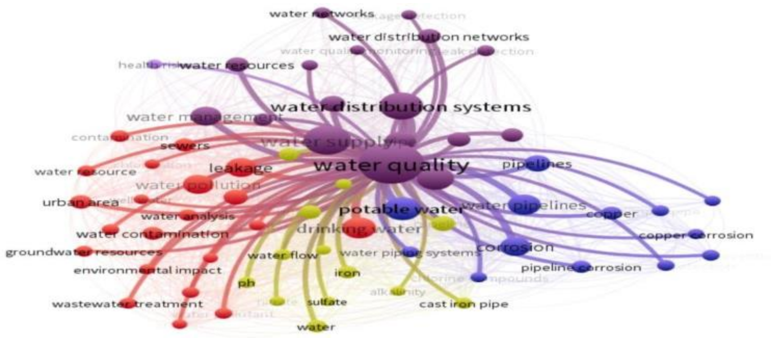

Figure 3: Network visualization using selected keywords by VosViewer software

3. Results and Discussion

The result of the data network generated by the VOSviewer programme was recorded as in Figure 2 in order to collect information regarding the relationship between water quality and leaking pipes. As can be observed, research on water quality and pipe leakage is concentrated on portable water, leakage, the water distribution system, and corrosion. It was noticed that water quality was mostly discussed as a result of observing since people consume drinking water for daily activities. If a leak happens, drinking water will become contaminated. Additionally, by summarizing the shape of water quality, it is clear that water quality caused by pipe leakage has a plethora of associated terms that are extremely useful in this critical review. Globally, around 32 billion cubic metres of treated water are lost each year as a result of physical cracks and leaks in water pipes, according to the study examined [5]. Typically, more than half of these losses occur in developing countries, escalating pre-existing problems caused by supply disruptions and low drinking water quality.

Besides that, water quality variables such as BOD, DO, free chlorine, and turbidity have been discussed. Aesthetic characteristics of water quality from a leaky pipe, such as pH, temperature, odour, and colour, are also covered in this discussion and must be considered. These parameters will be an indicator to determine the condition of water quality whether it can be consumed or not.

3.1 The colour and odour of water

The colour of the water sample was determined without the use of filters or centrifuges, based on a review study by Han et al [6]. The presence of coloured organic matter causes the colour of drinking water. Organic colour matter can be found in humic substances, industrial waste, and metal. Colorless water is the only colour that should be consumed. Color changes can simply be an indicator of a change in water quality, and further investigation is required to determine the water quality. The presence of organic substances caused a change in odour and taste. Odors can indicate the presence of biological activity in water. For odour measurements, just a simple visual comparison approach was used. Furthermore, they generally known as the vast majority of organic and inorganic compounds have a characteristic odour [6]. All water samples collected from the leaky pipe were found to be between 25 and 30°C.

3.2 The pH value

The value located in a specified range, comparable to temperature, is referred to as pH. The pH value is also a measurement of how acidic or basic water is. Water's pH cannot be used as a physical parameter because it cannot be quantified in quantity or concentration. It is preferable to use a rate between 0 and 14, which is a measurement scale that indicates how acidic or basic a water is. When the water measured is less than 7, it indicates that the water is more acidic, and when the water measured is greater than 7, it indicates that the water is more basic. If the pH value is 7, it is considered neutral. The pH scale denotes the "power of hydrogen." The molar concentration of hydrogen ions $(H+)^3$ used to calculate [7]. This can be completed by incorporating the negative logarithm of the H+ concentration, or (-log (H+)). The combined effects of hydrogen ions (H+) and hydroxylions (OH-) complete and decide the pH value [7]. Many factors can change the pH value of water, whether natural or synthetic. The water sample for examination must be chlorine-free, have a pH of between 6.5 and 7.5, and have a suitable quantity of microorganisms [7].

3.3 BOD level

BOD is a synthetic procedure used to measure the amount of dissolved oxygen necessary for aerobic of biological creatures in water. Water samples at a certain temperature and time require oxygen to break down organic substances. As an indicator of water quality, this approach is not a meaningful test. BOD_5, incubated at 20°C for 5 days, is a study proxy of the degree of organic contamination of water. BOD can alter dissolved oxygen levels in rivers and streams. pH, temperature, microorganisms, organic and inorganic elements in water can all alter oxygen consumption rates. High BOD levels decrease oxygen in rivers [8].

It signifies that there is not enough oxygen to sustain aquatic life. If the water has a high BOD level, aquatic organisms may suffer and die. In addition to leaves, topsoil, woody debris and feedlots, BOD is also found in urban storm water and wastewater treatment plants [8]. BOD concentration from water sample requires two measurements. The first is the initial dissolved oxygen, and the second is a water sample cultured for 5 days and then analyzed for the remaining dissolved oxygen. The amount of oxygen consumed by bacteria throughout the incubation time is shown in the final result [8].

The low BOD levels suggest the water is in good health. The samples have a BOD of 6.5 to 7.7. As the BOD concentration increases, oxygen becomes reduced, causing aquatic life die [8].

3.4 Dissolve oxygen

The amount of pure, uncombined oxygen in water or other liquids is called "dissolved oxygen." Dissolved oxygen (DO) is the concentration of free and non-compound oxygen in water or other liquids. This metric is vital in determining water quality since it affects aquatic life. In lakes, DO is only water. Low or excessive levels of dissolved oxygen can harm aquatic life and degrade water quality. Free oxygen (O_2) is also known as non-compound oxygen. Dissolved oxygen (DO) is free O2 molecules in water. Because H_2O is a compound, it does not count as dissolved oxygen. We can envisage free oxygen molecules dissolving in water in the same way salt or sugar dissolves [7].

A high DO content in the corrosive scale layer will avoid iron from being released [7]. After 18 hours of stagnation, the DO concentration rapidly falls from 7.68-7.82 mg/L to 0.11-0.97 mg/L in Figure 4. The consumption gradient of DO reduce as the leakage flow rate increase [7].

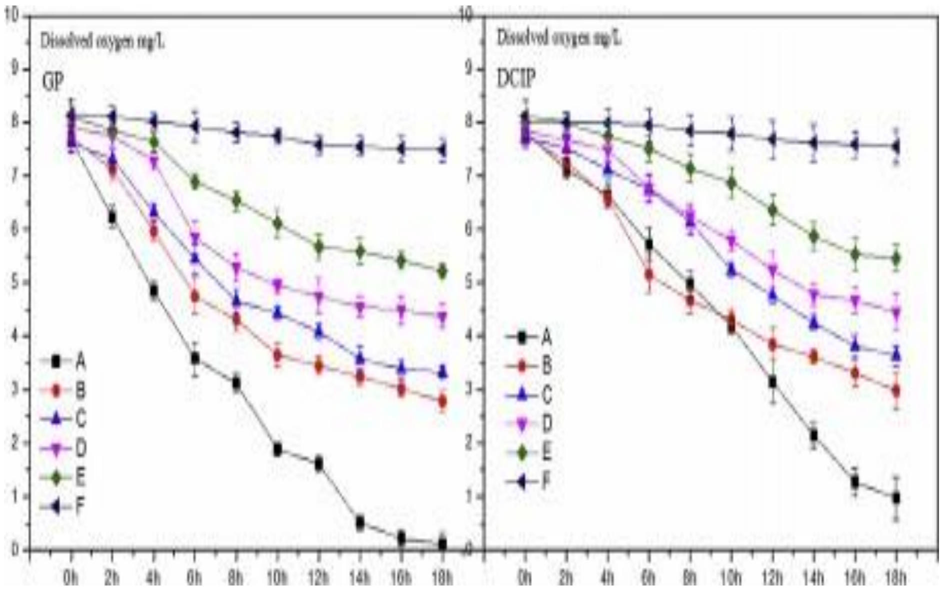

Figure 4: Changes in DO under different leakage flow rates

3.5 The Residual Chlorine

In water, chlorine is found as hypochlorous acid (HOCl) and hypochlorite ion (OCl -). These are called “free available” chlorine. Both species react poorly in pH 6.5-8.5 waters. As a potent oxidizer, chlorine reacts with many compounds. Chlorine disinfects water by reacting with nitrates, amino acids, and ammonia. Ammonia in water reacts with hypochlorite ion to form monochloramine, dichloramine, and trichloramine depending on pH and temperature. Break-point reactions are critical in water disinfection.

Break-point chlorination is the reaction of water with ammonia to generate trichloramine, oxidise to nitrogen, or other gases [9].. Prior to chloramination, water disinfection was at the crest of the curve. This adds a break point. Normally, free chlorine residual is kept at 0.2 mg/L Cl2 in water distribution [9].. The break-point reaction in chlorination controls the flavour and odour. It also improves hygiene. Residual free chlorine indicates water disinfection. Contact time, water temperature, ammonia and chlorine concentrations, and pH affect the break-point curve.

Level of the residual chlorine in the water has gradually decreased over time. Based on Figure 5, despite initial residual chlorine concentrations in the range of from 0.35 to 0.52 mg/L in pipe water, residual chlorine concentrations were consistently less than 0.05 mg/L after 5 hours at all flow rates, which was the lower limit for permissible residual chlorine in national standard drinking water quality requirements [9].

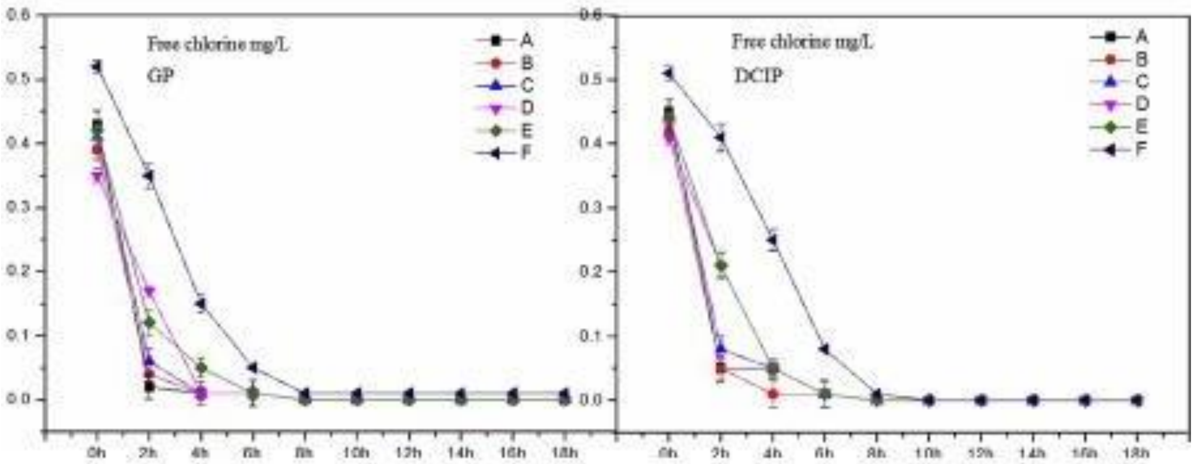

Figure 5: Residual chlorine decay curve at various leakage flow rates

3.6 Turbidity

Total suspended solid (TSS) is one of the parameters used to determine water quality. It denotes the amount of solid or particle suspended in water that has been caught by a filter. It is also the sum of total dissolved solids and total solids in a water sample. TSS is measured by filtering a water sample through a certain type of filter and comparing the weight of the filter before and after filtering.

Turbidity reduced in general as the rate of leakage became high, yet it shows a long-term trend toward increasing turbidity [10]. Based on Figure 6, although the turbidity was initially rather low, ranging between 0.13 and 0.31 NTU, it exceeded 1.0 NTU after six hours where it is the highest limit of the national standard in all conditions [10]. The turbidity index did not meet the threshold even after an hour of stagnation.

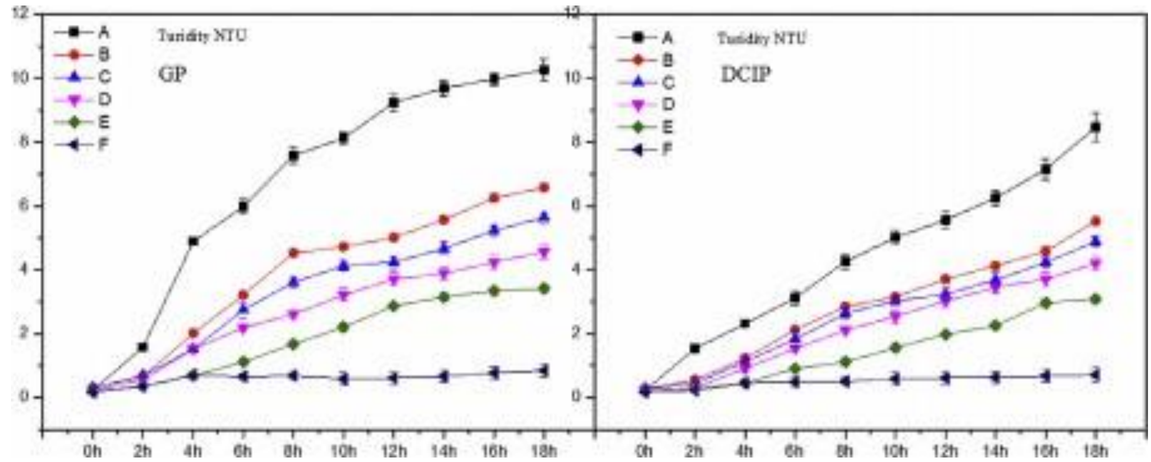

Figure 6: Changes in turbidity under different leakage flow rates

3.7 Changes in the quantities of microorganisms related to iron release

Figure 7 show the variation in the abundance of iron-oxidizing bacteria study [11]. The quantities of microorganisms change by time when pipe leakage occur due to iron release. After 18 hours of stagnation, iron oxidize bacteria (IOB) concentrations, the CFU/mL values for ductile cast iron and galvanized pipes were 1150 and 1520, respectively, roughly six and seven times their initial levels. Concentrations of sulphate reducing bacteria (SRB) were 362 and 512.31 CFU/mL, respectively, about fourfold that at the start. In general, IOB grew more than SRB, showing that bacterial growth can occur rapidly under standstill conditions [11].

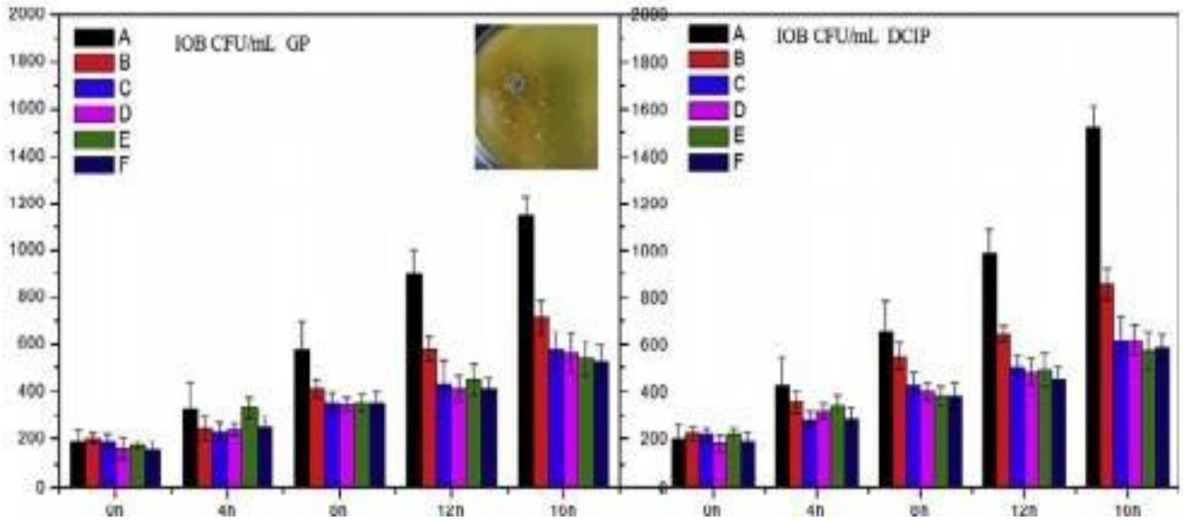

Figure 7: Variations in the abundance of iron-oxidizing bacteria

4. Conclusion

In summary, leaking pipes affect the quality of drinking water. A leaking pipe might cause non-revenue water. Contaminants have a longer time to enter the pipes and mix with potable water, resulting in larger peak pollutant concentrations and masses. Therefore, distribution network pollution comes from sporadic supplies. Positive pressure oscillation, on the other hand, aids in the prevention of temporary contamination by ejecting particles through pipe fractures. Iron release was found to be substantially associated with a variety of other essential characteristics such as redox potential, dissolved oxygen, pH, iron-oxidized bacteria, and sulphate reducing bacteria. While at relatively low leakage rates of 40% of the critical laminar flow velocity, they mitigated the impact. While the bulk water was flowing at the essential laminar flow velocity, the total iron content, as well as the quantity and rate of total iron release, were all within an acceptable range, which may help to ensure better water quality. High-tech leak detection techniques are needed to track both water and sewer breaches. Leak detection and control mainly depends on the utility's system and customer base. While new systems may form, older systems are most likely to be combined. Using several powerful instruments would be great, such as CCTV, current sensor, microwave sensor, neutron and gamma ray probe, and hydro chemical sensors. A key consideration for water agencies will be the public perception of sewer leaks. Sewers will be the priority when the media focuses on water pipe breaks in the future. Appropriate steps can be taken to decrease sewer and water system leaks. A sewer's only technical options are rehabilitation or replacement. One option for water reticulation pipes is pressure control or rehabilitation. For many utilities, pressure management can be a very cost-effective technique of reducing losses or moderating demand. Loss control, just like any other investment, must be modelled or calculated before implementation to satisfy system requirements while avoiding losses and inefficiencies. Despite the present knowledge gap, the choice of which rehabilitation strategy to utilize, or whether rehabilitation is even necessary, is a challenge. Casing decisions, lifetime costs, and customer disruption need to be taken into consideration while developing asset management systems.

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