Preventing Water Waste: Analysis of Leak Detection Systems for Underground Sanitation Networks

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***Abstract*— With time and population growth, the problem of water waste has increased. Despite increasing awareness about this issue, a lot of water is wasted due to leaks caused by the breaking of underground pipes. In order to prevent water waste in this context, it is essential to discuss the implementation of leak detection systems for underground sanitation networks. The purpose of this paper is to discuss leak detection systems for underground sanitation networks. To achieve the objective stated before, this work is organized into two parts. In the first part, a description is made of what the waste of water due to broken pipes is and all the problems that this entails. In the following three sections, possible solutions to properly address this problem are presented. Finally, the most efficient system will be chosen based on aspects related to cost, availability, and practicality of the systems. This paper is expected to contribute to the analysis of solutions to leaks in underground sanitation pipes in the civil engineering field.**

***Keywords:* water leaks, underground sanitation networks, underground pipes, drinking water waste, water leak detection.**

Resumen— **Con el tiempo y el crecimiento demográfico, el problema del desperdicio de agua ha aumentado. A pesar del creciente conocimiento sobre este problema, se desperdicia mucha agua debido a las fugas causadas por la rotura de tuberías subterráneas. Para prevenir el desperdicio de agua en este contexto, es esencial discutir la implementación de sistemas de detección de fugas para redes de saneamiento subterráneas. El propósito de este trabajo es discutir los sistemas de detección de fugas para redes de saneamiento subterráneas. Para lograr el objetivo mencionado anteriormente, este trabajo está organizado en dos partes. En la primera parte, se describe el desperdicio de agua debido a las tuberías rotas y todos los problemas que esto conlleva. En las siguientes tres secciones, se presentan posibles soluciones para abordar adecuadamente este problema. Finalmente, se elegirá el sistema más eficiente en función de aspectos relacionados con el costo, la disponibilidad y la practicidad de los sistemas. Se espera que este documento contribuya al análisis de soluciones para las fugas en tuberías de saneamiento subterráneas en el campo de la ingeniería civil.**

***Palabras clave*: Fugas de agua, redes subterráneas de saneamiento, tuberías subterráneas, residuos de agua potable, detección de fugas de agua.**

I. Introduction

With time and population growth, the problem of increased waste of water has increased. Today a great deal of awareness must be made about the waste of water since it is a non-renewable resource, which means that one day the global population will run out of it. However, even if people take care of the water, a lot of water is wasted due to leaks caused by the breaking of underground pipes.

The problem raised should be globally addressed following the United Nations Sustainable Development Goals (SDG) report. In particular, SDG No. 6 aims to "Ensure availability and sustainable management of water and sanitation for all" by 2030 [1]. Some of the targets proposed by goal 6 for 2030 are: achieve universal and equitable access to safe and affordable drinking water for all; substantially increase water use efficiency across all sectors and ensure sustainable freshwater withdrawals and supplies to address water scarcity and substantially reduce the number of people experiencing water scarcity [2]. By improving the sanitation system, water scarcity can be controlled more effectively.

Leaks in the underground network cause water to be wasted and large amounts of money are spent changing pipes and fixing pavements and streets. When a fault in the pipes is seen on the surface, the problem is serious since the leaks have already damaged the pavement. Therefore, any damage to a pipe network must be detected and remedied as quickly as possible [3]. In order to prevent water waste, it is then essential to discuss the implementation of leak detection systems for underground sanitation networks. The purpose of this paper is to discuss leak detection systems for underground sanitation networks.

To achieve the objective stated above, this work is organized in two parts. In the first part, a description is made of what the waste of water due to broken pipes is and all the problems that this entails. In the following three sections, possible solutions to properly address this problem are presented. Finally, the most efficient system will be chosen based on aspects related to cost, availability, and practicality of the systems. This paper is expected to contribute to the analysis of solutions to leaks in underground sanitation pipes in the civil engineering field.

II. Analysis of Leaks in the Sanitation Pipes

This paper is about the loss of water due to broken pipes, which is a problem that has a great impact in society. Loss of water “is often referred to as non-revenue water (NRW), which is water that is produced in a network but never reaches the consumer" [4, para. 2]. This is commonly due to breakings in storm drains.

There is a wide variety of factors that increases the probability of pipeline failure, as Fig. 1 shows. Pipeline failures are more likely in older and weaker pipelines and further failures occur if these pipelines are in aggressive soils where weather and operating conditions are extreme and unstable. Failures increase when the pipe is in an environment with sudden changes in temperature, pressure, or soil moisture levels, which causes an increase in internal and external stresses in the pipes, causing cracks [5].

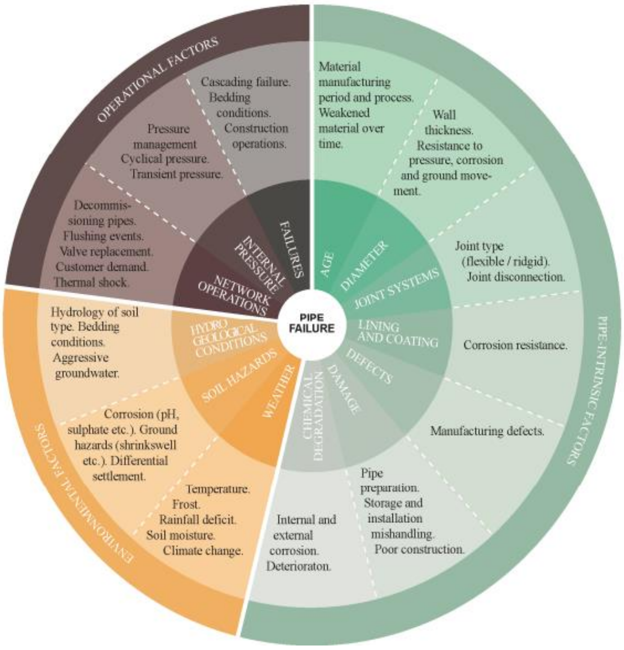

Fig. 1. Factors influencing the failure of drinking water pipes [5]

As for the pipeline failure problems, three main groups of factors can be considered. They are 1) intrinsic to the pipeline, 2) operational, and 3) environmental. When it comes to problems intrinsic to the pipe, they may be related to the pipe age, diameter, joining systems, coating and lining, defect damage, and chemical degradation of the pipe. Operational problems are pump failure, internal pressure, and network operation. Environmental problems also affect pipes causing them to fail [5].

Typical failure modes for main water mains are the causes for the pipe to crack. These are circumferential rupture, longitudinal splitting, joint failure, and pinholes (both burst and pinhole leakage). Failure modes are associated with different forces acting on the pipeline [5].

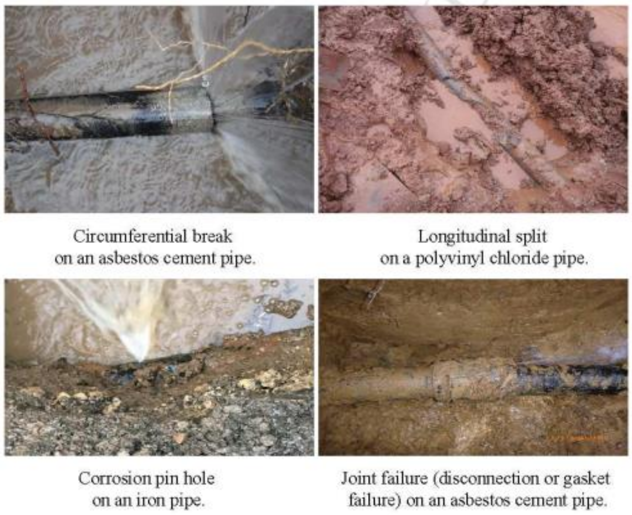

Fig. 2. Failure modes [5]

This paper seeks to analyse methods to quickly detect leaks in pipes. These methods have the advantage of avoiding wide street breaks, impairing traffic, and raising costs. The cracks are detected promptly to later access from the surface and fix or change the damaged pipe section.

III. Approaches to Leak Detection in Underground Sanitation Networks

To avoid wasting water, it is essential to discuss the implementation of leak detection systems for underground sanitation networks. With this aim, three approaches are presented, namely, a robot that detects small leaks, a system for satellite-based leak detection and analysis, and a sonar technology tool.

A. Robot that Detects Small Leaks

One of the solutions to leaking pipe detection is a robot that is a novel autonomous system that works inside the pipe. This robot controls the movement inside the pipeline and can operate in real pipeline conditions. It is made up of a series of modules whose functions are sensing, communications, data processing and mobility [6].

The modules are the small parts that add to the effectiveness of this robot in leak detection, as stated in [6]. Describing the function of the modules, the sensing module is the one that supervises the leak detection through a hydrophone. The communications module is responsible for communication between the floating pipeline and a land-based receiver. As well as this, the data processing module supervises the subsequent processing of the data coming from the detection module and the communications module.

One of the main modules of the robot is the mobility module, since it is the one that allows driving through a complete network of pipes, as Fig. 3 illustrates. According to [6], this module can circulate through straight pipes and curved sections, float with the same or different speed, and stabilize within the pipe to avoid disturbing noise and turbulence. This module is designed with an external hull with six stabilizing legs and a tip where the hydrophone is located.

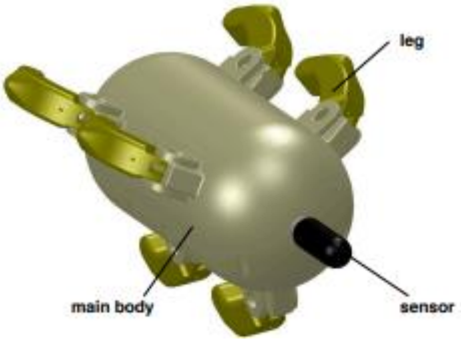

Fig. 3. 3d model of the mobility module. [6]

This robot is a free-floating, untethered, autonomous leak detection system. Above all, it is efficient since it can be used with the sanitation network in operation without the need to cut off the water supply.

B. Satellite-Based Leak Detection and Analysis System

Apart from an in-pipe robot to detect leaks, another approach is the use of an out-pipe satellite system. Asterra Recover is a satellite solution to locate leaks without the need to block traffic or break the pavement. As [7] describes, Asterra Recover locates leaks in underground pipes for a quick repair.

The satellite works effectively under different circumstances. It can find leaks not only in drinking water networks but also in wastewater networks. It can locate leaks even when they are not visible on the surface. Once the leak is located with Asterra Recover, the teams that will fix the leak can be more exact and dig and break only where necessary.

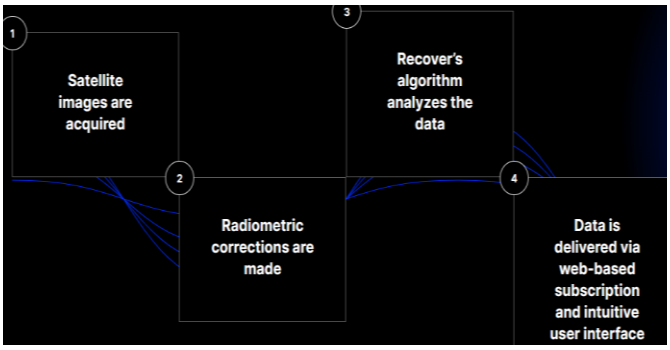

Fig. 4. Operation of a satellite-based leak detection system [7]

Asterra Recover has many advantages when used as a leak detector, as mentioned in [7]. With this system, the pipeline can be monitored throughout the year. Crews working on the ground can be assigned directly to fix leaks and not to locate them. The satellite receives data at high altitudes, which makes it possible to cover large areas of pipelines.

The function of this technology, based on Recover's satellites, is to identify leaks and increase the efficiency of field personnel. It allows monitoring the pipes throughout the year, without damaging the pavement, traffic and locating the leak in the exact place.

C. Sonar Technology Tool

Continuing with the leak detection technologies, it is necessary to analyze a land-based one called Sonar Technology Tool. This tool uses sound waves to locate broken or leaking pipes. Since it provides a very precise location of the problem, it can be fixed without digging up a large area.

As presented in [8], the operation of the device is a sonar system, like the one used by bats and dolphins to communicate. This acoustic system fulfils the function of identifying and indicating the location of an obstruction or leak.

In most countries, to assess the quality of sewage pipes, the water supply must be cut off and the pavement must be drilled, which affects people, traffic and requires a lot of time and money. Therefore, this solution described in [8] addresses this problem, since it is a non-invasive approach. It is accessed through the fire hydrant, and a sensor listening device is placed. Then, the sound waves are heard and faults in the pipes are detected; leaks, signs of corrosion or obstructions in the pipes, by means of a hissing sound from the device.

Fig. 4. The sonar technology for detecting blocked and damaged underground water pipes [8]

This system is complete since, in addition to locating leaks, other pathologies that pipes may have, such as corrosion, are identified. This allows the pipe to be fixed, preventing a leak from occurring.

IV. Final Choice of the System

In this section, the system that is considered most suitable for leak detection is chosen. With this aim, the main characteristics of the three approaches are highlighted.

On the one hand, the Asterra Recover robot is an autonomous, floating and moored leak detection system. It has the benefit of being easily implemented from a fire hydrant. As a drawback, the device can be damaged while working inside the pipe. In addition, it is a system that is beginning to be used, so it can be difficult for some regions to access, leaving cost aside.

On the other hand, the satellite leak detection and analysis system has the characteristic of being very complete and having many benefits. However, as a disadvantage, this system may not be available in some countries, mainly due to the cost of implementing it and the satellite signal itself, since there may not be coverage in all areas.

Finally, the leak detection system that is considered most appropriate is Sonar tech tool. This system is the most complete and it does not only detect leaks but also corrosion and obstructions in the pipes, which is why it is considered the most appropriate.

Sonar tech tool is suitable for all parts of the world, since only a fire hydrant and the device are needed. This is suitable for use in all pipes, regardless of diameter or material. The chosen system seems the most effective one of those mentioned along this paper since it is available in all countries, it is easily accessible, and it does not contaminate or damage sanitation while it works. This technology can be easily used by anyone without the need for them to be a specialist in the field.

V. Conclusion

As it is of global interest, water is a natural resource that should not be wasted by using it in abundance or wasting it. However, even though people are aware of the need to take care of water, drinking water is also wasted due to pipe leaks. This treated fluid, made drinkable, is already lost in the sewers, preventing it from reaching homes, schools, and businesses.

In this paper, the problem has been approached following the recommendations in the United Nations' Sustainable Development Goals (SDG) report. In particular, SDG No. 6 aims to water management sustainability. In line with this aim, three solutions have been discussed, with the aim of locating leaks in underground pipes to fix them and avoid wasting water.

Three approaches to leak detection in underground sanitation networks have been introduced. A robot that detects small leaks is an effective autonomous in-pipe detection system which can be, however, damaged inside the pipe. The satellite-based leak detection system is an out-pipe satellite system which has recently been implemented and may be restricted by cost and coverage limitations. The Sonar technology tool appears to be the most effective solution of the three since it uses sound waves to identify not only leaks but also corrosion in the pipes.

In conclusion, it can be said that, despite the abundant loss of drinking water caused by leaks in the pipes, these leaks can be found and repaired. By improving the detection of leaks in the sanitation system, water scarcity can be controlled more effectively.

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