

Study of the Ways and Methods of Searching Water Leaks in Water Supply Networks of the Settlements of Ukraine

Iryna Remeshevska¹, Ganna Trokhymenko², Nataliya Gurets²,
Olena Stepova^{3*}, Inna Trus⁴, Veronika Akhmedova²

¹ Department of Environmental Chemistry, Admiral Makarov National University of Shipbuilding, Heroiv Ukrainy ave., 9, 54025, Mykolaiv, Ukraine

² Department of Ecology and Environmental Technologies, Admiral Makarov National University of Shipbuilding, 54025, Heroiv Ukrainy ave., 9, Mykolaiv, Ukraine

³ Department of Applied Ecology and Environmental Sciences, Poltava National Technical University named after Yuri Kondratyuk, Pershotravnevyi 24, 36011, Poltava, Ukraine

⁴ Department of Ecology and Technology of Plant Polymers, Faculty of Chemical Engineering, Igor Sikorsky Kyiv Polytechnic Institute, Peremogy Avenu 37/4, 03056 Kyiv, Ukraine

* Corresponding author's e-mail: alenastepovaja@gmail.com

ABSTRACT

The problem of search of accidental and unauthorized water leaks in water supply networks is considered. The analysis of the current state of water supply sector in Ukraine based on information data of the Ministry of Regional Development, Construction and Housing Communal Services of Ukraine and data of the State Statistics Service of Ukraine is conducted. Existing methods of finding and determining places of water leakage in water supply networks are considered. The findings of the comparative analysis of the practical capabilities of search devices are reported. The primary causes and rates of water losses of the settlements of Ukraine have been determined. The results of the leakage search using device APGK-015/2, the calculations of the volume of water losses and the total cost of the water saved during the study are represented.

Keywords: water losses, water leaks, water supply, leak detector, pipelines.

INTRODUCTION

Water supply sector is one of the main sectors of the national economy, it has a significant impact on other sectors of the national economy of Ukraine, development of the regional economy and the well-being of the population. Health of water supply sector of Ukraine, from year to year, is characterized by the following criteria: shortage of the financial resources necessary for the proper operation and maintenance of the water supply systems, unsatisfactory technical condition of the structures and equipment, imperfection of the sector management structure and of the sector legal framework to ensure its reliable and effective functioning. The water supply sphere

is divided into the main components: centralized water supply and wastewater sector and non-centralized water supply sector. The centralized water supply sector is served by 2716 of the water supply companies of communal property mainly, the non-centralized sector is served by companies of various forms of ownership [Krylova, 2018; National report on drinking water quality and drinking water supply in Ukraine in 2018].

Water leaks in external water supply pipelines are quite common. Many main and distribution pipelines in Ukraine have been laid relatively long ago and have a high percentage of wear. The production facilities of the water supply companies are most in need of restoration of the water supply and wastewater network, whereon

the quality of service and the environment situation significantly depends. As a rule, water pipeline accidents are caused by corrosion of a pipe section, but they can also be caused by mechanical damage to the pipeline during construction work or by other factors. Nevertheless the cost of the network recovery is very high. For example, the total length of the water supply networks of licensees of the National Energy and Utilities Regulatory Commission is 54.4 thousand km, 46% whereof are timeworn and unsafe. The assets of the companies that can be used for recovery purposes (annual depreciation) are about UAH 393 million, and the cost of the recovery is higher by 573 times. In addition to the financial losses, water leakage that is not detected in a prompt manner entails risks to life and health as it may cause ingress of harmful substances and microorganisms into the pipeline. At the same time, the quality of water also decreases, as a result of which it ceases to meet the requirements of sanitary rules and standards [Findings of the National Energy and Utilities Regulatory Commission in 2018; Halysh et al., 2020].

Water losses in water supply systems can be classified into two main groups as follows: consumer (loss of the marketed products) and technological (loss of drinking water in the process of its extraction, production and transportation to consumers). Water losses in different countries vary considerably. Thus, in Germany, water losses are 8%, in Spain – 11%, in Japan – 11, 2%, in Italy – 18%, in Sweden and Brazil – 20%, in Ukraine – 38%. In 2018, the highest volumes of water wastage and losses, which exceeded 50% of the volume of raised water, were in Chernivtsi region – 56.7% and Zhytomyr region – 50.1%. The water wastage and losses are higher than 40% in Zakarpatskyi region – 48.4%, Kharkiv region – 48.3%, Ivano-Frankivsk region – 46.2%, Lviv region – 43.3%, Donetsk region – 41.2% and Mykolaiv region – 40.7%; the lowest water losses were in Chernihiv region – 19,1% [Findings of the National Energy and Utilities Regulatory Commission in 2018; National report on drinking water quality and drinking water supply in Ukraine in 2018].

By the end of the standard service life, hidden water losses increase more than 6 times compared to the permitted level and can reach 30 thousand m³ per year per kilometer of pipeline. Considering that the main and distribution systems of municipal water supply in the settlements of

Ukraine provide with an average of 17 million m³ of water per day, it can be noted that the amount of the material damage nears to catastrophic values [Nasonkina et al., 2007]. The volume of water losses depends mainly on the age of the network, the pipe material, specifics of the company's operation, number of the leakages, unauthorized connections, undercount of water consumption, etc. In recent years, emergency leaks and unaccounted water flow rates amount to nearly 34% of the water released to all consumers in the settlement [Methodology for calculating water losses by companies providing centralized water supply services, 2014].

In Ukraine, the most pipes are cast-iron (48.8%) and steel (44.8%). The least in number are asbestos cement pipes (1.9%). New plastic pipes are 3.4% only. Exactly the plastic pipes have the greatest advantages and no disadvantages. They are cheaper than metal pipes. It is easier to install and operate plastic. And, most importantly, plastic pipes are more resistant to external conditions and impact thereof – corrosion and fragility. More than 35% (20.4 thousand km) of water supply networks are timeworn, i.e. the deterioration rate is more than 90%. 19.5% (11.3 thousand km) – the deterioration rate is 76–90% and 22.1% (12.8 thousand km) – the deterioration rate is 50-75% (Fig. 1) [Water supply networks of Ukraine: deterioration, service life, unsafe condition].

The object of the article is to study the ways and methods of the prompt detection of the points of water leakage in water supply networks of all Ukrainian settlements.

MATERIALS AND METHODS

Detection of the points of damages in pipelines is one of the most important tasks for the operation of water supply systems. Given that most of such communications are underground and consist of pipelines of different composition, diameter, condition, the use of special technical means is required for this purpose. Devices designed to find hidden cracks, holes in the walls of pipelines, tanks and to detect leaks are called leak detectors. They allow you to determine the leakage location with high accuracy regardless of the type of soil, depth of the pipeline, fluid temperature, pressure and other operating conditions. Operating principle of leak detectors is based on the detection of the release of fluid through the damaged area

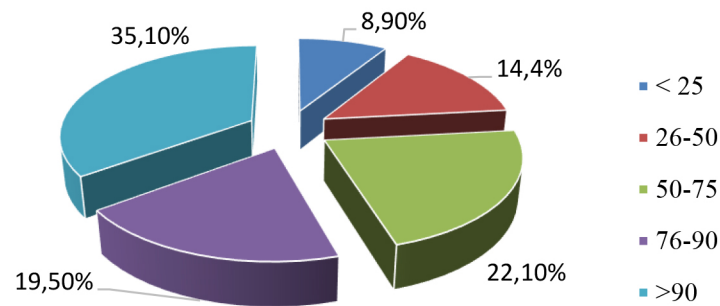


Figure 1. Water supply network length on the deterioration rate, %

into the environment under the influence of high pressure. Currently, there are a number of methods for finding water leaks from pipelines, but there is no unified and effective one that works in all conditions. The acoustic method became the most widespread. Devices that use this method are divided into three categories [Shtaiar, 2010; Popovych, Karpash, 2014].

The first category includes devices that use control without filtration. The spectrum of the acoustic signal of the water flowing from the damaged pipe depends on the pressure in the pipeline, as well as on the size of the damage and is in the range from 100 Hz to 3 kHz. Devices of this type are good in practice in rural areas far away from roads. The operation of the devices of this class is based only on the sensor sensitivity, which varies from 80 mV/g to 500 mV/g.

The second category includes devices with electronic filtering of the input signal. The main task of the filter is to extract the useful signal from loud noise when used in urban conditions. The main characteristic is the filtration degree: the higher it is, the higher effective the obstacle clearing is. Devices of this category are also characterized by the presence of sensors for different surfaces: grass, ground, snow, asphalt, soil.

The third category includes leak detectors with a pseudo-correlator function. These are devices that allow you to estimate the distances to the damage by the difference between the noise values depending on the distance to the place of damage. This method uses mainly leak detectors with indication that visually display the noise level by a sensor of specialized type.

One of the well-known ways to detect leaks from pipelines is the correlation method. This method is used for difficult noisy areas. The main advantage over acoustic devices is that the sensors are connected to the pipeline only at two points.

As a result of signal processing, the distance to the leak from one of the sensors is determined. This method is more effective for finding leaks in the pipes laying in ducts. The probability of leaks detection is from 50% to 90%. The disadvantage of the correlation method is the acoustic sensitivity to internal inhomogeneities in the pipes – to restrictions, bends, branches, deformations, changes in diameter [Vashchyshak et al., 2013; Kolesnytskyi et al., 2014].

Another method of finding leaks in the pipeline is to determine the temperature distribution on the surface above the route of the pipes, the so-called thermal method. Contact thermometers with dip probes, pyrometers and thermal imagers of various modifications are used to determine the temperature. The method is based on tracking the change in surface temperature above the heating main. The temperature differences range from fractions of a degree to tens of degrees. When choosing contact thermometers, it is necessary to pay attention not to the accuracy of measurement, but to the sensitivity. Similarly, when working with thermometers by this method, an important characteristic is the speed of the probe.

Temperature monitoring devices are pyrometers that have a high degree of speed and are much easier to operate. Thus, the range of speed is from fractions of a second to 1–2 seconds. The pyrometer allows to carry out continuous measurements of temperature that increases efficiency and accuracy of control. Due to the ease of use and high probability, this method is the best among thermal control methods. The thermal imaging method, given the high cost of the equipment and requirement for a skilled group of specialists, is used mainly for periodic inspection of the condition of heating mains during preventive inspection [Zamikhovskiy, Shtaiar, 2007; Latyshev, Nasyrova, 2006].

Less common control methods include gas analysis method. The essence of the method is as follows: the pipeline is filled with a special gas. The place of the damage is detected by gas analyzers [Zapukhliak et al., 2012]. The manometric method is used to control the tightness of pipelines and valves. The water pressure is created in the pipeline, and on reducing the pressure we can make an inference on the serviceability of the valves or on the damage [Khymko et al., 2015]. There are methods of controlling the electromagnetic field over the surface of pipelines. These methods allow to detect overwatering of the soil under ground, but they are quite expensive and still imperfect [Vashchysyak et al., 2013].

Each of the methods is effective in some conditions and less effective in others. So, at ductless laying of pipelines, it is most effective to use an acoustic method of control. Correlation and thermal methods work well. The latter can be used only in case of heat-transfer liquid leakage, i.e. in the control of heating networks and hot water supply pipelines. It is much more difficult to control leakage in duct pipelines. In this case, the effectiveness of acoustic and correlation methods is saved, and the thermal method is less acceptable, because the spreading of hot water in the duct ‘blurs’ the thermal picture on the surface. Therefore, the most effective is use of combined control methods. This greatly rises the chances of detecting a leak. Acoustic and thermal control methods are often used along.

RESULTS AND DISCUSSION

In order to determine ways to reduce unaccounted water flow rates and prompt elimination of emergencies in water supply networks of the settlements of Ukraine, on the networks of ‘Mykolaivvodokanal’, Mykolaiv City Communal Company, a study of the effectiveness of search devices APGK-015/2 and Universal-911M (Ukraine) in comparison with universal locator of cables and pipelines Radiodetection RD 8000 (England), Geophone Water Hjint Xmic (England), sound impulsor SEBA KMT RSP 3 (Germany). In the process of operation of the leak detectors, the practical capabilities of the devices under different conditions were tested.

On cast iron and polyethylene pipelines with route tracking at the maximum distance. The study was conducted on a complex part of the

water pipeline at a depth of 2.2 m in sandy soil and a large number of polyethylene and steel branches of different diameters and lengths. The maximum signal detection range along the route of the cast iron water pipeline by Radiodetection RD 8000 is 187 m, by APGK-015/2 and Universal-911M10 – 1000 m. On the polyethylene pipeline of the diameter of 32 mm and 50 mm the maximum signal detection range by SEBA KMT RSP 3 was 40 m, by APGK 015/2 – 70 m.

In the search in the side branches of water supply networks made of polyethylene of small diameters with a shock generator installed not only in the well where visible branches are, but also with a shock generator installed in other wells at the distance of 50-100 m from the survey site. The use of a shock generator in other wells is either necessary for the search for unauthorized branches on the main route of the water supply. The search for side branches was performed by the acoustic method along the route of the cast iron pipeline with branches made of polyethylene and cast iron pipes. APGK-015/2 perceived a branch at the signal level of 40–50% of the initial one, SEBA KMT RSP 3 did not perceive. The difficulty of searching on cast iron water supply networks is that there is no integrity of the pipe, it consists of chains, so the acoustic resonance signal of the pipe is propagated by water, and it is much smaller than if there was a steel or polyethylene pipe. Search for a leak on a polyethylene pipe of a small diameter of 20 mm on a simulator, at a depth of 1.2 m. At the end of the pipe there are three holes with a diameter of 4 mm. With use of APGK-015/2 the noise signal level at the source increases by 5–10 times compared to the background noise, SEBA KMT RSP 3 does not perceive a leakage.

Based on the results of comparing the practical capabilities of these devices, for further research we selected search device APGK-015/2, designed for (Fig. 2):

- search for the route of polyethylene, steel, cast iron, asbestos-cement and ceramic pipelines by acoustic method using a shock generator;
- search of the route of steel pipelines (gas pipelines, water pipelines, heating networks, oil pipelines, product pipelines and power cables) by induction method in passive mode without tone pulse generator;
- search for unauthorized branches of different materials (polyethylene, steel) on water mains, in sewerages by acoustic method;



Figure 2. Overview of APGK-015/2 with shock generator

- search for unauthorized connections to power cables by acoustic method;
- search for leaks in the leak detector mode by the acoustic method in relation to the noise of liquid leaking from the damaged pipeline while the site of the leak may be flooded with water, as well as gas noise in the pipeline;
- search for leakiness in closing of the valves and taps with liquids, air or gas.

Searching for a route of polyethylene and steel pipelines by acoustic method using APGK-015/2 search device is based on the following principle: the acoustic shock generator is installed on the pipeline and fastened by belts. The mechanism of the generator is driven by a small hammer, which effects single shocks on the wall of the pipeline. The pipeline is a resonator, and the sound is transmitted along it over a certain distance. The range of the sound distribution depends on the diameter of the pipe, the material of the pipeline, the presence of liquid, soil density and depth of the pipeline laying. The operator, moving with the acoustic receiver along the route, with the help of the acoustic sensor listens to the sound of the shock on the ground. Above the pipeline the sound of the shock will be the loudest, thus accuracy of the definition of an axis will be +10 cm. The acoustic search method allows to determine the route of a polyethylene or steel pipeline at a distance of several tens to several hundreds meters at a depth of 5–6 m. The range of the propagation of the acoustic signal depends on the diameter of the pipeline. The larger the diameter, the longer distance of the possible search for the pipeline route by the acoustic method. The acoustic sensor is installed across the pipeline with a step of 10–15 cm. Above the route of the pipeline, you can

hear the shock of the highest volume level. On rough terrain (grass, leaves, snow) the acoustic sensor cannot have close contact with the ground. In this case, we use rods sunk into the ground, that eliminates errors in determining the route of the pipeline. The sensor is installed in turn on each of the rods. The highest signal level will correspond to the pipeline route.

The frequency of the shock signal propagating along the pipe depends on the diameter of the polyethylene or steel pipe, the presence of liquid in it. Frequency tuning is performed using a block of narrowband filters. The filter unit of APGK-015/2 device has 12 narrowband frequencies of adjustment to the frequency of the shock signal propagating over the pipeline. This function makes its operation more selective and protected from street noise. During the operation of the shock generator, parasitic ground vibrations occur in the form of low-frequency shocks, similar to ones we hear over the pipeline. These shocks propagate through the ground and create an obstacle to the useful signal near the pipeline. There is a so-termed dead zone, where a strong signal of the shock on the ground interferes and covers the useful signal transmitted through the pipeline. 12 rejector filters are designated for tuning away from interfering shocks on the ground and also for protection against street noises and noises of passing cars. The receiver is an amplifier of the acoustic sensor signal and has two types of indication – sound (on headphones) and 10-bit LED indicator.

Connecting a boom to the receiver allows you to use it as a line locator in a wide frequency band. By the tuning on the industrial interference frequency of 50 Hz or on the signal of the cathodic protection station 100 Hz, you can check

the presence of communications in this area by induction method on the magnetic antenna. This is important when excavating, so not to damage other communications. The presence of an electric antenna allows you to determine the communications by the electrical component of the electromagnetic field. In the mode of the leak detector by the acoustic method using receiver APGK-015/2 and the acoustic sensor we listen to above ground noises which arise in a place of the burst of pipelines filled water or other liquids. The high sensitivity of the equipment allows you to hear not only the place of the pipeline burst, but also the movement of water through the pipeline. The accuracy of detecting the location of the leak is 0.5 m. The study of the use of APGK-015/2 device was conducted for two years. The results of the device using in 2018-2019 are shown in Figures 3–4.

During the first half of 2018, 63 hidden emergency leaks and 99 unauthorized tapplings were detected. The using APGK-015/2 device made it possible to establish the main reasons and magnitude of water losses in the city of Mykolayiv: leaks from the water mains (between pumping stations and boost pumps); leaks from city blocks networks, leaks in basements and unauthorized connections; undecount of water consumption by the residents with apartment meters and excessive water consumption by residents without meters.

On the basis of the analysis of the received results of application of the device, ‘Mykolaivvodokanal’, City Communal Company, effected calculations of the total cost of the saved water. Water losses in the volume of 1005.95 m³ at leakage have been estimated (number of the holes is 22, bursts in the form of cracks on pipes with a diameter of 100 mm – 41). The calculation was effected taking into account the estimated time of liquidation of the burst in accordance with the requirements of regulatory and technical documents. In reality, the searching for the location of the pipeline breakage can take from 1 to 3 days. On average, the water leakage until the moment of location of the burst can last for 48 hours. Thus, the actual water consumption increases to 48,295.6 m³. According to the current tariffs for 1 m³ of water, water lost as a result of the accidents amounted to UAH 495,410.26.

Water losses associated with unauthorized water suction from the network are estimated in accordance with the ‘Methodology for calculating water losses by companies providing centralized water supply services’, approved per Order of the Ministry of Regional Development, Construction and Housing No. 180 dd. 25.06.2014 at the level of 12 m³/thousand m³. The volume of the water losses that meets the established standard will be 584,415.36 m³. According to the current tariffs, the cost of water lost due to unauthorized water

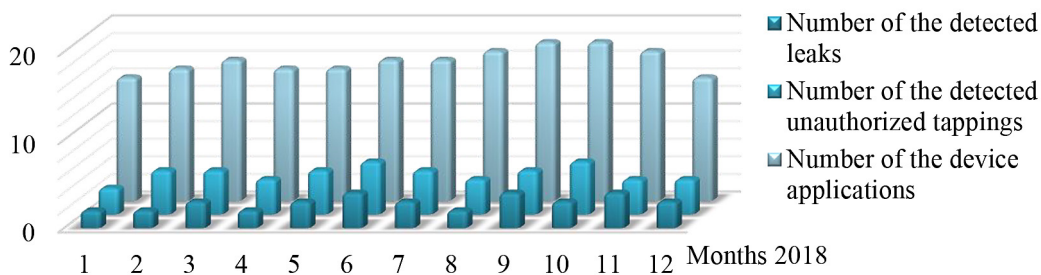


Figure 3. Results of using APGK-015/2 search device by ‘Mykolaivvodokanal’, Communal company, in 2018

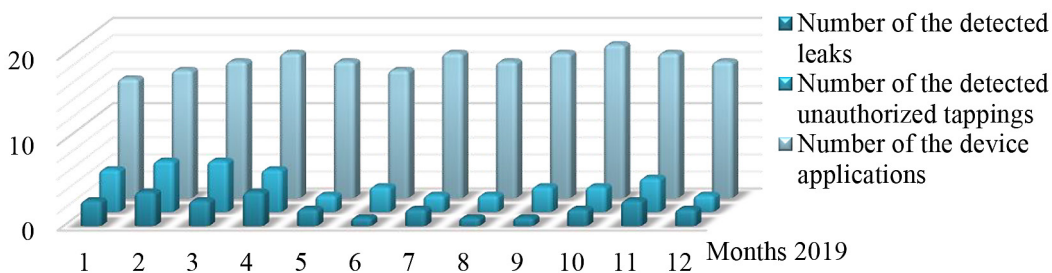


Figure 4. Results of using APGK-015/2 search device by ‘Mykolaivvodokanal’, Communal company, in 2019

suction is UAH 5,996,101.60 [Methodology for calculating water losses by companies providing centralized water supply services, 2014]. The total cost of the water saved as a result of using APGK-015/2 search device by ‘Mykolaivvodokanal’, City Communal Company, during 2018-2019 amounts to: 6,491,511.85 UAH.

CONCLUSION

The main reasons for water losses in the water supply networks of Ukrainian settlements are: leaks from the water mains (between pumping stations and boost pumps); leaks from city blocks networks, leaks in basements and unauthorized connections; undercount of water consumption by residents with apartment meters and excessive water consumption by residents without meters.

A comprehensive approach to solving the issue of detecting water leaks from water supply pipelines of the settlements of Ukraine with the use of special equipment provides an opportunity to increase up to 100% prompt detection of the accident areas, to reduce operating costs of the water supply sector. Comparative tests showed much better practical results and higher technical characteristics of the leak detector APGK-015/2. The estimated total cost of the water saved as a result of using APGK-015/2 search device by ‘Mykolaivvodokanal’, Communal company, during 2018–2019 amounts to: 6,491,511 UAH.

REFERENCES

1. Findings of the National Energy and Utilities Regulatory Commission in 2018. Database: ‘NEURC’, https://www.nerc.gov.ua/data/filearch/Catalog3/Report_NEURC_2018-ENG.pdf [Accessed: 14.09.2020].
2. Halysh V., Trus I., Gomelya M., Trembus I., Pasalskiy B., Chykun N., Trokhymenko G. 2020, Remeshevska I. Utilization of modified biosorbents based on walnut shells in the processes of wastewater treatment from heavy metal ions. *Journal of Ecological Engineering*, 21(4), 128–133.
3. Khymko O., Hryniv O., Prytula N., Prytula M. Algorithmic method for diagnosing gas leaks in sections of main gas pipelines (in Ukrainian). *Scientific Bulletin of Ivano-Frankivsk National Technical University of Oil and Gas. Computer Science and IT*, 826, 404-412, <http://ena.lp.edu.ua:8080/bitstream/ntb/31342/1/55-404-412.pdf>, [Accessed: 11.08.2020].
4. Kolesnytskyi O.K., Losiev O.A., Maznytsia A.S. 2014. Simulation of the method for search of leaks of underground pipelines on the basis of adhesive neural networks (in Ukrainian). *Measuring and computing devices in technological processes*. Khmelnytskyi National University, 1, <http://kolesnytskyi.vk.vntu.edu.ua/file/7f5e348bb18463db190f0b52c9a9a992.pdf> [Accessed: 14.08.2020].
5. Krylova I. 2018. Analysis of the modern scenario of water supply and wastewater sector in Ukraine (in Ukrainian). *Investytsiyi: Praktyka ta Dosvid*, 23, 118–125, DOI: 10.32702/2306-6814.2018.23.118.
6. Latyshev L.N., Nasyrova Z.R. 2006. System for detecting unauthorized tapings in the main oil pipeline (in Ukrainian). *Oil and Gas Business*, pp. 10, <http://www.ogbus.ru/authors/Latyshev/Latyshev1.pdf>, [Accessed: 14.08.2020].
7. ‘Methodology for calculating water losses by companies providing centralized water supply services’, approved per Order of the Ministry of Regional Development, Construction and Housing, 180, 25.06.2014 (in Ukrainian), http://search.ligazakon.ua/l_doc2.nsf/link1/RE25840.html [Accessed: 10.09.2020].
8. National report on drinking water quality and drinking water supply in Ukraine in 2018. Database ‘Ministry of Regional Development of Ukraine’ (in Ukrainian), <https://www.minregion.gov.ua/wp-content/uploads/2019/11/Proekt-Nats.-dop.-za-2018.pdf> [Accessed: 04.05.2020].
9. Nasonkina N.H., Maslak V.N., Holikova Yu.A. Water losses from water supply networks and ways to reduce them (in Ukrainian). *Modern Industrial and Civil Engineering*, 3(1), 2007 (in Ukrainian) pp. 5365, http://donnasa.ru/publish_house/journals/spgs/2007-1/06_nasonkina_maslak_golikova.pdf, [Accessed: 14.09.2020].
10. Popovych O.V., Karpash M.O. 2014. Analysis of acoustic methods of identification and determination of parameters of defects of metal structures (in Ukrainian). *Prospecting and Development of Oil and Gas Fields*. Ivano-Frankivsk, 2(51) (in Ukrainian), <http://library.nung.edu.ua/rozv%D1%96dka-ta-rozrobka-naftovikh-%D1%96-gazovikh-rodov-ishch.html>, [Accessed: 4.09.2020].
11. Shtaiar L.O. 2010. Acoustic method and pipeline leak control system for leaks: author’s abstract of Ph.D. thesis in Engineering Science: 05.11.13. Ivano-Frankivsk National Technical University of Oil and Gas. Ivano-Frankivsk, pp. 20, <http://elar.nung.edu.ua/handle/123456789/4410> [Accessed: 14.09.2020].
12. Vashchyshak I.R., Vashchyshak S.P., Yavorskyi A.V. 2020. Contactless detection of leaks in the ductless underground heating networks (in Ukrainian). *Prospecting and Development of Oil and Gas Fields*, 2. 125-132, <http://rrngr.nung.edu.ua/index.php/rrngr/article/view/403>, [Accessed: 4.09.2020].

13. Water supply networks of Ukraine: deterioration, service life, unsafe condition. ‘Ukraine the Communal’, Information Agency (in Ukrainian) <http://statistic.jkg-portal.com.ua/ua/statistic/vodoprovdmerezh-ukrajini-znoshenst-termni-jekspluataci-avarjnst/> [Accessed: 14.09.2020].
14. Zamikhovskyi L.M., Shtaier L.O. 2007. Method for detecting leaks from the pipeline with one-way access to transportation (in Ukrainian). Oil and Gas Power Industry. Ivano-Frankivsk, 2(3), <http://library.nung.edu.ua/naftogazova-energetika.html> [Accessed: 7.08.2020]
15. Zapukhliak N.M., Marchuk O.M., Zapukhliak V.B., Lukashevych I.I. 2012. Problems and prospects for detecting leaks from pipelines (in Ukrainian). Scientific Bulletin of Ivano-Frankivsk National Technical University of Oil and Gas, 2, <http://elar.nung.edu.ua/bitstream/123456789/2416/1/3215p.pdf>, [Accessed: 6.08.2020].