RESEARCH OF WATER LOSSES IN THE PIPE NETWORK OF THE SPRINKLER IRRIGATION PLOT

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Abstract

The paper presents the results of research on water losses from the pipe network of irrigation plots still in the exploitation phase in Romania. These plotters have a long service life, considering their creation about 40-50 years ago. The advanced degree of wear and tear of network components, especially pipes and hydrants, led to the occurrence and maintenance of water losses. The assessment of water losses is done directly on site by measurements on the pipe network. The simulation of water losses is carried out by using appropriate calculation programs in this field (Epanet and its extensions, Hydra, AutoCad, ArcMap), with the use of databases created in Excel and Word. The simulation requires a complex data base collected from the field, from the design documentation and from the network operation process. The input data required in the analysis program are represented by sets of word, excel, .xlș and .dxf files and so on. The results obtained by simulation are exported in tables, graphs, curves of variation of hydraulic parameters and other.

Key words: flows, hydrants, pipes, pressure, simulation, water losses

In Romania, a small number of components of the irrigation systems made before 1989 are currently in operation. These systems show intense processes of degradation of the constructive structure and the installations that serve the exploitation process (Luca M. *et al*, 2016). The irrigation system is structured from irrigation sectors or plots. The predominant watering method used to irrigate agricultural crops is sprinkling. The watering equipment used before 1990 was also used after this year (self-moving watering pipes, with pivot, drum with hose), but in the last period of time, high-performance equipment was purchased.

During the operating periods of the irrigation systems, water losses from the network of canals and pipes are permanently present. Water losses influence the hydraulic efficiency of the system components, but also the operating expenses in a negative way. Water losses have been present since the establishment of the irrigation system, and their value is variable over time.

Current climate changes, with a high frequency of droughts, have led to a reduction in the sources and volumes of water available for irrigation (Chirica S. *et al*, 2019). The droughts recorded in the years 2007, 2020 and 2022 in the eastern part of Romania had an extremely negative impact on the state of crops, a fact that demonstrated once again the need for irrigation systems in Romania. In this context, more importance should be given to water losses from irrigation systems (Chirica S. *et al*, 2018).

Water losses are differentiated in size and in the structure of the irrigation system. On the components under state administration (water intake, basic pumping and repumping stations, discharge pipes and adduction and distribution channels, and so on) a large volume of water losses is recorded (Cismaru C., 2004; Luca M. *et al*, 2019; Nicolaescu I. *et al*, 2005; Sticea S.A. *et al*, 2020). Within the irrigation plots, which are privately owned or leased, water losses were relatively limited by the execution of rehabilitation and modernization works).

The phenomenon of water losses from the pipes of the drinking water distribution networks is more studied on a national (Chirica S., 2019; Manescu A., 2010) and international level, a situation determined by the period of continuous operation of these networks (Boulos P.F., Aboujaoude A.S., 2011; van Zyl J.E., 2014; GIZ 2011; Lambert A.O.,Thornton J., 2006).

The purpose of the paper is to present some studies and researches on how to evaluate the water losses present in the pipe networks of the irrigation plots currently in operation in Romania. The paper mainly refers to the first scenarios needed in the simulation of water losses in old irrigation plots.

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MATERIAL AND METHOD

For the research of water losses, the PPS 11 Lunca Banului irrigation plot located in the "Albița - Falciu Complex Irrigation and Drainage Development" in Vaslui County was selected *(figure 1).* The research area belongs to the arid climatic zone of Romania.

The PPS 11 irrigation plot has an irrigated area of 1,173 ha. The structural components of the irrigation plot are the following: the PPS 11 pressurization station, the pipe network (main, secondary, tertiary), irrigation hydrants, constructions on the pipe network (homes, massive anchors).

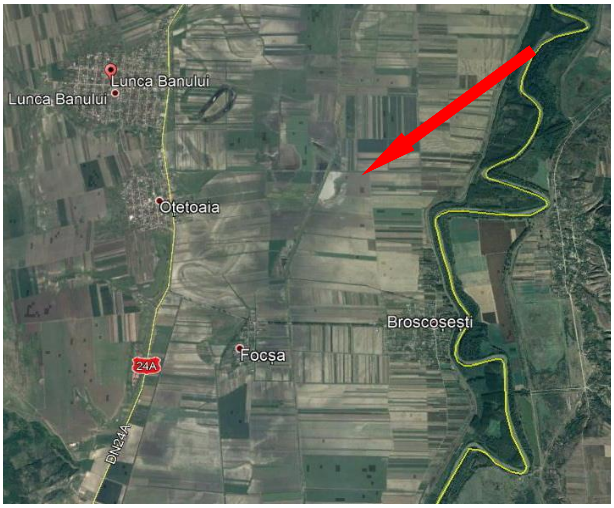


Figure 1 **Location of the study and research area - Plot PPS 11 Lunca Banului, Albita - Falciu Complex Irrigation and Drainage Development**.

Water for irrigation is taken from the Prut River with the PRS Bumbata pumping station and pumped into the AC adduction channel. The pipe network of the irrigation plot is of the branched type. Pipes are made of steel pipe, asbestos-cement pipes and PVC pipes. The watering method is sprinkler and is applied with classic watering equipment powered by hydrants located on the tertiary pipes.

The „Albita – Falciu Complex Irrigation and Drainage Development" was designed by I.S.P.F. Bucharest in 1977 and was executed in the period 1977 - 1978. The irrigation plots were in permanent operation in the period 1979 - 1989. The operation of the irrigation plots was interrupted after 1990, and some entered conservation. In 2007, 11 OWUI (Organization of Water Users for Irrigation), were established, which currently administer about 53% of the irrigated area. The Lunca Banului irrigation plot originally had an area of 1853 ha, and at the current stage, about 1173 ha is irrigated through the reconfiguration of the area.

The field research was carried out in several stages, which included data collection, topographic studies, technical expertise, analysis of the structural and functional state of the irrigation plot components with influence on water losses, the study of rehabilitation documentation and technical modernization etc. Some of the design documentation was not accessible. For each irrigation plot, the initial topographic plans were used, as well as those updated on the date of the research. The research in the field took photographic reliefs and video images.

Data processing was carried out according to the methodologies indicated for each program used in the simulation. The primary data collected were processed and stored in databases such as Excel, Word, and graphics and so on.

SYNTHETIC ELEMENTS OF WATER LOSS SIMULATION MODELS

Physical water losses occur in all components of a water transport and distribution network (Chirica S., 2019, Mănescu A., 2010):

- supply pipes;
- main, secondary and branch pipes from the distribution network;
- the pipes in the hydraulic installation of the pumping and repumping stations;
- the network of pipes and hydrants,
- the hydraulic installation in the dormitories on the route of the pipelines and so on.

According to GIZ (2011), water losses in a network of water supply pipes can be classified according to the way of presentation:

- visible (reported) water losses, which come from the damage of the pipes / tubes and the joints that make up the pipe networks; losses of this type appear on the surface of the land and are easy to locate;
- hidden (unreported) water losses, which do not appear on the surface of the land, a situation that requires the use of special equipment for detection; losses of this type can generate flows greater than 250 l/h at a pressure of 50 mcA;
- ground water losses, where flows are considered lower than 250 l/h at a pressure of 50 mcA; they appear in the form of drops and cannot be detected using acoustic methods.

The pipeline networks for the transport and distribution of water present during their operation three characteristic stages in which water losses are highlighted (Kropp I. and Herz R., 2005):

- the run-in period of the network, when there are many breakdowns due to design errors, tube manufacturing defects and technological execution errors;
- the stage of operation at normal parameters, when breakdowns show a low frequency of occurrence, and the degradation of pipes and the formation of water losses are caused by special events (exceptional forces, landslides, earthquakes, subsidence and so on);
- the stage of accentuated structural degradation of the network, highlighted by the exponential increase in the number of breakdowns as the normal duration of operation of the pipes

and couplings is exceeded.

The analytical expression of the relationship between the emission times and the values of the water flows that are lost, depending on the size and type of damage (reported, unreported and background) can be presented by the following equation (GIZ, 2011):

(1) $$V_p = (C + L + R) \cdot Q ,$$

where: Vp is the volume of lost water, m^3; C, L, R - awareness, localization and remediation times, days; Q - lost water flow, m^3/day.

The parameters that define the operation of the existing emitters on a pipe include a series of characteristics of the assembly made up of the emitter - the medium transited by the volume of water emitted - fluid. The function that describes the flow rate of an emitter present on a pipeline located in a certain area has the form (Eq. 2) (Chirica S., 2019):

(2) $$Q_E = f(P_{gm}, P_{he}, P_{ht}, P_{gt}, P_{fc}),$$

where P_{gm} are the geometric parameters of the emitter, P_{he} – hydraulic parameters of the emitter, P_{ht} – hydraulic parameters of the land, P_g – geotechnical parameters of the land and P_{fc} – physical-chemical parameters of the land.

Broadcaster formed on pipes made of various materials (steel, cast iron, plastic materials, reinforced concrete, etc.) can have different shapes and sizes from pores/holes, to microcracks and cracks, cracks, etc. The flow through each form of emitter is characterized by a specific equation.

The consumption in a pressure-based simulation model is made up of the water demand from the nodes and the water losses recorded in the system. The flows available for consumption (q_i^{avl}) can be expressed through the relationship (Chirica S., 2019):

(3) $$q_i^{avl}(P_i) = q_i^{req} \times \begin{cases} 1, & P_i \geq P_i^{ref}, \\ \left(\frac{P_i - P_i^{min}}{P_i^{ref} - P_i^{min}}\right)^{\alpha}, & P_i^{min} < P_i < P_i^{ref}, \\ 0, & P_i \leq P_i^{min}, \end{cases}$$

where P_i is the pressure in node i, P_i^{ref} - the service pressure value that satisfies the water requirement, q_i^{req}, P_i^{min} - the minimum pressure value, below which the system cannot supply water to consumers, α - exponent describing the pressure-requirement relationship (determined experimentally).

Calculation programs developed by using various software are used for the sizing and checking of water-carrying pipe networks. Among these programs can be listed (Chirica S., 2017, van Zyl J. E., 2014): Epanet, Hydra-Canalis, Urbano Hydra, Mike Urban, etc. A series of modules can be added to these programs to determine various parameters of the pipe network, such as water losses.

The simulation models for the pipe networks that structure the irrigation plots must consider a series of peculiarities in the formation of water losses. The physical water losses occurring in all the components of the plot are located in: the hydraulic installation in the pumping station, the network of pipes and hydrants and the hydraulic installation in the dormitories/distribution nodes.

Water losses from an irrigation system are presented as percentage values in the specialized literature (Stăncescu L. *et. al*, 1984, Cazacu E. *et al*, 1982). For an irrigation plot with pressurized pipes, the types of losses presented above can be considered, but to which must be added unavoidable / planned losses in the exploitation process (e.g. emptying of the pipe network).

In sprinkler irrigation plots with pipe networks, water losses are allowed according to the values imposed by the operating rules (Cazacu E. *et al*, 1982, Stăncescu L. *et. al*, 1984, Sticea S.A. *et al*, 2019). The allowed value of water losses is specified depending on the place of their production. Admissible values (percentages) for water losses from the total volume of water transported in the irrigation plot have the value of about 5% in the pipe network and about 10% in field irrigation (Stăncescu L. *et. al*, 1984).

The analysis of water losses will be consistent with the mode and duration of operation of the irrigation systems in Romania's climatic conditions. They work in the spring, summer and autumn, and during the winter they go into conservation and repair. When the exploitation process is stopped, regardless of the season, the pipe network is emptied, a situation that causes a planned loss of water.

RESULTS AND DISCUSSIONS

The simulation of water losses for the irrigation plot was carried out in several stages. In the first stage, the design data of the PPS 11 Lunca Banului irrigation plot were taken *(figure 2)*. To these were added the data taken from the field regarding the current constructive and functional state of the irrigation plot. The topographical data of the plot were updated by carrying out a study on the actual topography of the pipeline network. Through the transition from cooperative ownership (existing before 1990) to private ownership and through the establishment of OWUI Lunca Banului, changes occurred in the size of the plot surface, its geometric shape and the structure of the pipe network. All this required updating the plot features. All data were processed and stored in databases accessible to the simulation programs.

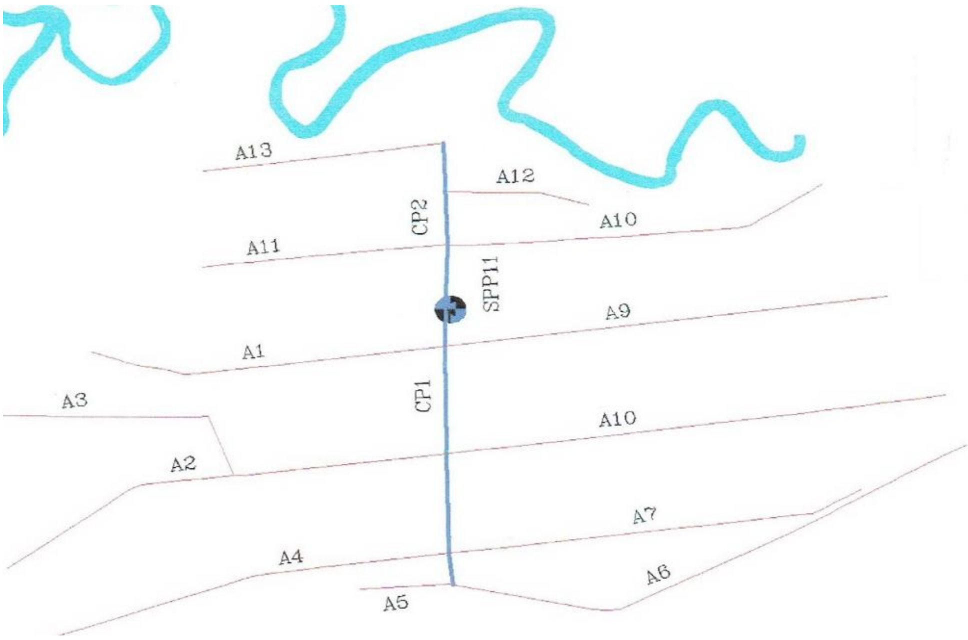


Figure 2. **The initial scheme of the pipeline network at the PPS 11 Lunca Banului Irrigation Plot**

The data pre-processing step creates the framework on which the work scenarios will be simulated. In this phase, the previously processed data are customized so that they reflect the requirements of the study model (van Zyl J.E., 2014). Pre-processing of the initial data consists of a set of operations, namely the calculation of flow rates in the nodes of the network, the determination of the position of the piezometric line, the assessment of the roughness of the pipes according to the duration of operation, the recalculation of the diameters of the pipes. By knowing these data parameters of the hydraulic simulation model are established.

In the second stage, the simulation of the operation of the pipeline network was carried out in the initial version of design and execution with the existing materials at that time.

In the third stage, the simulation of the operation of the pipeline network was carried out in the current version of the equipment and structuring of the surface of the irrigation plot. The modification of the topography of the network and of the net irrigated surface was taken into account, in which case the program input parameters were recalculated. Plot flow and supply pressure were calculated considering new values for watering rates, hydromodule, yields, pipe materials, etc. (Cismaru C., 2004, Luca M. *et al*, 2019, Luca M. *et al*, 2021).

In the fourth stage, the simulation of the operation of the network was carried out on variants of structuring and equipping with watering equipment in order to evaluate water losses.

The hydraulic-mathematical model for simulating water losses from a pipeline network requires the following input data: 1 – data regarding the characteristics of the network; 2 – data from measurements (flow and supply pressure, variation of water demand at network nodes); 3 – data extracted from the water loss monitoring documents held by the beneficiary. The analyzed irrigation plots generally do not have a monitoring system and a database on water losses.

The necessary contour conditions in the water loss simulation model are the following: 1 – the PPS flow that feeds the irrigation plot; 2 - flow rates at the derivation nodes on the pipeline network; 3 - the flow rates at the irrigation hydrants in operation; 4 - the value of the pressures in the pipe network and the way of variation. The contour conditions differ depending on how the irrigation sectors are used, a situation that requires the enlargement of the analysis scenarios. If in a water supply system the entire pipe network is permanently in operation, in an irrigation plot the network is in operation in sectors, according to the watering rotation schedule.

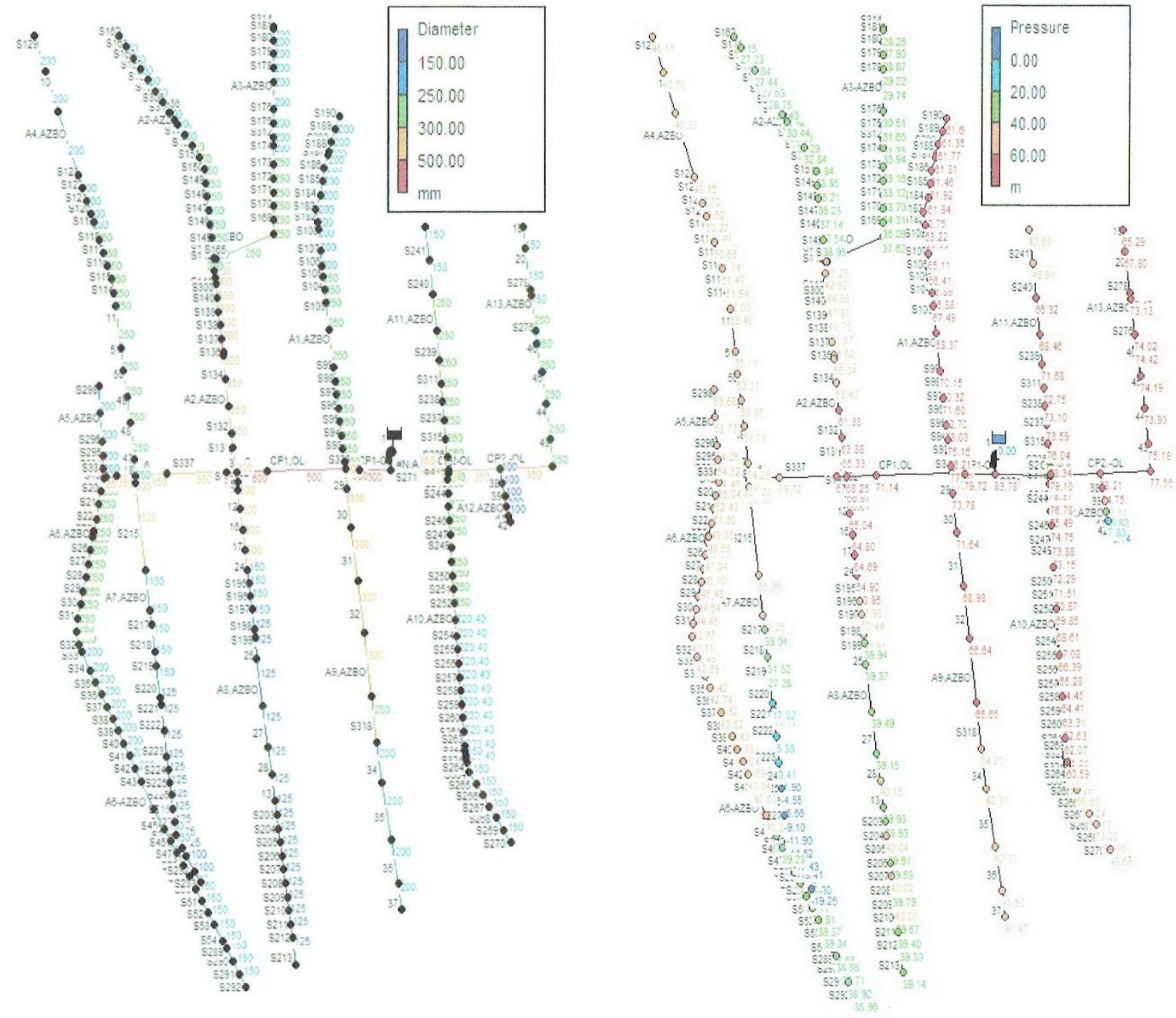
The calibration of the hydraulic - mathematical model is carried out on the basis of the measurements made in the field and the data obtained from the monitoring systems. No visible water losses were recorded during the field survey. Thus, the simulation model considered the existence of hidden (background) water losses. Thus, the calibration was based on the assumption of ground water losses distributed over the entire length of the pipe network.

Scenario I of the pipeline network simulation in the initial design version of the PPS 11 Lunca Banului irrigation plot considered the design data of the existing pipelines in the field (*table 1*). The initial pipeline network of the plot was structured from the following components: a - the main pipeline CP1 which fed the tertiary pipelines A1 – A9; b - main pipeline CP2 that feeds tertiary pipelines A10 – A13; c – tertiary pipes A1 – A13 equipped with irrigation hydrants; d - irrigation hydrants Dn 100 mm; e - fireplaces with hydraulic installations for derivation, ventilation, emptying, control and protection against hydraulic shock.

The input data to the program were the following: parameters of pipes made of steel and asbestos cement with Pn10, respectively length, inner diameter and equivalent roughness. Also, the value of the inlet flow rate Qs = 0.887 mc/s and the supply pressure Ps = 6.80 bar at the pressurization station.

Table 1. **Pipe network parameters**

Pipe	L (m)	Material	Pn (bari)
CP 1	1704	Oțel	10
CP 2	928	Oțel	10
A1	1889	Asbestos, PVC	6
A2	2476	Asbestos, PVC	6
A3	1462	Asbestos, PVC	6
A4	2410	Asbestos, PVC	6
A5	480	Asbestos, PVC	6
A6	2961	Asbestos, PVC	6
A7	2207	Asbestos, PVC	6
A8	2626	Asbestos, PVC	6
A9	2330	Asbestos, PVC	6
A10	2010	Asbestos, PVC	6
A11	1292	Asbestos, PVC	6
A12	771	Asbestos, PVC	6
A13	1274	Asbestos, PVC	6



a b

Figure 3**. Results obtained in Scenario I of the simulation of the pipeline network at the PPS 11 Lunca Banului Irrigation Plot: the distribution of the diameters on the calculation sections of the network: b – the pressure values on the calculation sections of the network.**

Output data from the simulation program, the flow in the calculation sections/nodes and the pressure in the nodes, the velocity and the head loss on each calculation section and on the entire pipe network were tabulated. The variation of the geometric and hydraulic parameters of the pipeline network, resulting from the simulation, was presented in the form of pipeline network diagrams.

The research is in the preliminary stage of data collection. Also, work is being done on the first stage of the simulation of the irrigation plot for the initial structuring option. The simulations are currently done for stage II where the irrigation plot is restructured as surface and pipe network parameters. The first set of data obtained refers to the current characteristics of the pipeline network (*figure 3*). This stage required the restoration of the parameters of the irrigation regime and the reconfiguration of the pumping station with the calculation of the operating point parameters (Q_{PPS}, P_{PPS}) (Luca M. *et al*, 2021).

The modernization of the PPS 11 Lunca Banului irrigation plot required a constructive and functional restructuring of the pumping station and the pipeline network. Bringing the pipe network of the irrigation plot up to the current technical level requires a series of modernization works.

CONCLUSIONS

The infrastructure of the irrigation systems currently in operation in Romania is the least rehabilitated and modernized component after 1990. About 40-50% of the water introduced into the irrigation system is lost through this infrastructure.

The current organization scheme of irrigation plots must be restructured to correlate with the type of ownership of agricultural land, the shape of the irrigated surface, the net irrigated area. Functional parameters of the irrigation plots must be recalculated to correlate with the conditions imposed by the current climate characteristics, and especially by the prolonged presence of droughts in the eastern part of Romania.

Water losses in the pipe network of an irrigation plot can be simulated by using Hydra and Epanet programs together with additional programming modules and on variants of exploitation scenarios according to the age and structural condition of the pipes.

Realizing the simulations for the current plots requires the creation of a new database regarding the topographical component, the toponomy of the pipe network, the culture plan, the watering norms and the equivalent hydromodule, the watering equipment that can be used, values and types of monitored losses, etc.

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