THE NEED TO REHABILITATE THE SEWERAGE NETWORKS

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Abstract

All cities in Romania have a sewerage network. The construction of these networks began at the end of the 19th century. As such, a significant part of these networks is very old and have past the original intended lifespan. The gradual expansion of the settlement forced the expansion of the sewerage network (wastewater treatment started being taken into account much later). In Romania there are about 340 towns and over 25 are over one hundred thousand inhabitants; the wastewater network was built in the combined procedure, only one network to evacuate several types of waste water (domestic, rain, industrial, etc). One issue is that the rain water flowrate could be over 50 times greater than the domestic waste water flowrate and therefore from time to time the pressure from the network forces a part of the unsanitary water out into the streets (one litre of this water contains millions of microorganisms). The cities continue to develop, the traffic becomes more and more intensive (it is estimated that around 7.5 million cars are in the country today) and the consequences of having unsanitary water on the streets threatening population's health is an important cause of concern (with potential catastrophic consequences). A preventive solution would be to conduct periodical sewerage network rehabilitation works.

Until recently the network design was supposed to be done for a rain with a frequency of 1/1. Starting with 2013 the legislation requires the networks to be designed for a 1/10 frequency. This means that the flowrate has doubled and since the network was not originally designed to handle this much water the streets are prone to be flooded.

At the same time, according to the European Directive, rainwater must be kept at source for rational use. All these elements also lead to the necessity of rehabilitation of the sewerage network, whether it is in a separate or in a combined process. The paper aims to contribute to addressing these technical issues, which are amplified by the need for a substantial investment.

Keywords

Sewerage rehabilitation, design rain frequency, combined sewerage.

1. INTRODUCTION

In Romania the sewage networks are over 100 years old. At first the sewer network was run in a unitary process. Over time, three major problems arose: 1) the localities have developed and in most cases the network's graph has become uneconomic; 2) the pipeline material has aged and succumbs to the mechanical stresses; this leads to repeated repairs that are expensive and are done under stress and in a rush due to the service interruption time; if we take into account the provisions of HG. 2139/2004, which states that the normal operating period is 24-36 years, this means that all the networks built before 1980 should be reviewed/rehabilitated/replaced [1]; 3) the damage caused by the heavy rainfall has increased with the increase in the city's building endowment; therefore, the calculated rainfall frequency had to change; however, this change leads to an increase in the storm water flow and thus to the floods on the streets, floods that become mixed with wastewater and hence the danger of developing large-scale diseases. Usually, the calculation frequency for the localities was 1/1 (a rain of which the intensity was exceeded each year). Starting in 2013, when the NP. 133 standard came into force [2], the frequency of rainfall in the sewerage network for large localities (over 100,000 inhabitants) became 1/10. A brief estimate shows that the wastewater flow (sewage and rainfall) can reach the double value from the initial dimensioning flow (the collectors of the sewerage network in the unitary process are dimensioned "at full capacity" - degree of filling 1.0); what happens to the extra flow that does not "enter" into the sewer? It should be checked whether the current drains are still adequate under the new conditions.

2. LARGE RAINFALL RISKS ON THE LOCALITIES

Romania has 340 localities categorised as a “city” out of which 25 have over 100,000 inhabitants. These localities are historic cities or industrial cities with important social, cultural and industrial facilities. When water from precipitations falling on the inhabited areas exceeds the sewage transport capacity (dimensioned at 1/1 rainfall frequency, with small exceptions on restricted areas) the excess water remains on the ground and creates: 1) difficulties in traffic (at peak hours is so difficult because of the lack of roads and the lack of parking spaces; it is estimated that in the country there are about 7.5-8 million cars, the vast majority of them being in the cities); 2) blockages the sub-crossings at which pumping stations are under-dimensioned or have nowhere to pump water; 3) flooding to the underground spaces of the public buildings (some of which are of historical or of high importance, such as the metro line in Bucharest); 4) flooding of important installations (gallery for the heating network, drinking water supply valve manhols, underground pumping stations (water, sewerage, etc.), petrol warehouses, etc.; 5) flooding of underground garages; 6) illness of the inhabitants through the diseases that can develop due to the wastewater from the sewage.

The most impressive case is that of Chicago city [3]; around midl 19th century a heavy rainfall (15 cm of water on the streets) washed the city, but also the sewage. The water flew through channels into Lake Michigan that is located on the bank of Chicago city. The lake was the city’s drinking water supply but since the water treatment (chlorination) only started later in the 1930s, about 175.000 inhabitants became sick with infected water diseases such as typhoid fever, diarrhoea, cholera, etc. After the unfortunate event, severe measures were put in place to achieve a 1/100 rainwater retention system in underground tunnels (211 km of tunnels with a diameter of 3-10 m, located at a depth of 50-100 m, with a total volume over 1.5 million cubic meters); after the rain passes the stored water is pumped into the treatment plant; the total discharge of purified water is done into an adjacent basin of the Mississippi River. The work is in operation for a city with more than 5.5 million inhabitants. Today there are a lot of similar works but not of the same magnitude.

In our country, the most unfortunate events were recorded in the 1970s when, for example, the whole central area of Bucharest was flooded.

To reduce the high impact on localities, a first solution has already emerged. This consists in the creation of retention basins that temporarily accumulate the excess water which can then be returned into the sewerage network by pumping or through gravitational methods. The second solution consists of building a new network that will take over the excess water. The combinations between the two can be also applied depending on the real situation of the network. Of course, in the case of a network that operates in a separate process, the problem is more complicated.

3. SIZING THE PROBLEM

Solving the problem has several aspects that are all more or less difficult to solve:

- The network length which should be rehabilitated is extensive; an estimation made during the development of GP 127/2014 [4] shows that from around 22,000 km of existing network length at least 2,000 km should be rehabilitated; the cost may be significant;

• The significant flow rate increase (about 2 times) leads to the need to increase the diameter of the collectors on all the streets; since the network is in a unitary process, the restoration of all collectors is causing trouble for the users during the rehabilitation process; disrupting the water supply service during the maintenance works is very difficult as the network is branched;

• Dilution of sewage water and occurrence of some difficulties in the operation of the wastewater treatment plant;

• Branched network allows with great difficulty the deviation of wastewater during rehabilitation (needing additional works);

• Lack of underground space under the carriageway for the placement of new works;

• Severe stalling of traffic during the execution of new works.

For the evacuation of an additional water flow there are basically two options/two solution types:

a) the creation of a new network, thus doubling the existing network's capacity - a very difficult solution due to the unavailability of the underground space in the existing localities (underground carriageways); this would allow the separation of the two networks and the possibility of creating a network as separate process, with the advantage of a better functioning wastewater treatment plant, and of evacuation of the rain water in the river (cleaner water if the streets are also clean). The achievement of a sewerage system in a separate process is also the goal of the European Directive regarding the better management of meteoric water falling on the territory of the locality (water collection and use for multiple other purposes hence avoiding the use of drinking water). In this solution, it is also possible to pass part of the collected rainwater into the "old" sewer and then into the "new" sewer when the dilution degree is the proper one; the same can be done when the collector is parallel to a water stream;

b) maintaining the existing network, remedying the defects resulting from the long operation and creating retention basin (in convenient/suitable places) reservoirs that retain the "peak of the rain" and the stored water is resubmitted (usually by pumping) into the sewage so as not to produce pressurization of some sections or difficulties in the operation of the treatment plant; seems a simpler option but is not easy to apply.

A combined solution between the first two (new collectors where possible, retention basins where it is rational) is also a possibility.

Caution: When choosing one of the solutions, it is advisable to take into account the fact that, in the unitary process, rainwater "periodically" washes the sewage, ensuring a better operation. In the past 20 years, household wastewater flow has declined steadily due to a lower consumption of specific drinking water (reaching 100 l/pers.*day) due to rising tariffs, metering, reduction of the industrial activity, etc.

Rehabilitation of the sewerage network, a complex, complicated, long-lasting and costly investment provides a great advantage: sewerage interventions will be less frequent, they will not be done under the time constraints and the service quality will increase significantly.

4. ILLUSTRATIVE EXAMPLE

To illustrate the complications that interfere when sizing the problem, a numerical example is given.

Base data: a locality with 120,000 inhabitants; city area is 1,500 ha; average population density 80 places/ha; the length of the sewerage network is 240 km; length of main collector and secondary collectors 28 km; the average leakage coefficient F = 0,6; general collector slope I = 0,003; specific drinking water consumption (Maximum time) q = 172 l/pers.*day; the network is categorised as 'old' - over 40 years – made out of concrete tubes; calculation rainfall at initial dimensioning f = 1/1; IDF curves according to STAS 9470/73; there are no new IDF curves for the city; in the case of Bucharest, from the comparison of the data of the IDF curves in STAS 9470 and the new curves made in 2013 there can be deduced an increase in the intensity of the rainfall calculation of about 30%.

The town's network dimensioning at rainfall f = 1/1, given in Table 1, was made according to SR 1846.

Table 1. Option 1 - Old network, large collectors' size

Section	L [m]	N [pers.* 1000]	S [ha]	Q_m [l/s]	I [%]	Q_{met}, [m³/ s]	T_p [min]	Q_t [m³/s]	Dn (e) [mm]	V_{pl} [m/s]	i [l/s*ha]
1-2	1500	5	62,5	10	3	3,08	17,5	3,08	1400	2,0	130
2-3	1000	14	175	28	3	10,4	25	10,43	2000	3,0	110
3-4	1000	28	350	56	3	17,0	30	17,06	2500	3,0	90
4-5	1000	38	475	76	3	21,8	36	21,88	3000	3,0	85
5-6	1000	62	775	123	3	29,3	41	29,42	3500	3,0	70
6-7	1000	86	1075	171	3	40,6	46	40,77	4000	3,0	70
7-8	1000	110	1375	219	3	48,3	52	48,52	4000	3,0	65
8- SE	1000	120	1500	238	3	48,3	58	48,52	4000	3,0	55

Note: Sizing was made in full section; Qt = Qm + Qmet; IDF curves after STAS 9470/73.

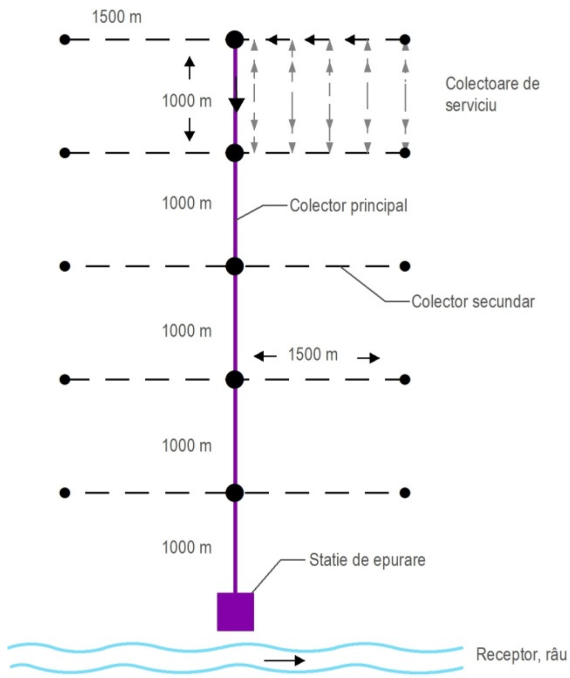

Figure 1: The general scheme of the existing network

Resizing the network at 1/10 rainfall frequency calculation; **Option 1** to build a new network is given in Table 2; the result show much larger diameters than existing ones. In order to use the capacity of the existing network, a new network has been dimensioned but only for the transportation of the flow difference (Δ_Q); resulting in a network with the diameters Dn (1), **Option 2.**

Table 2. Option 2 - Parameters for building a new network

Section	**L [m]**	**S [ha]**	**I [‰]**	**i [l/s*ha]**	**Q_P [m^3/s]**	**Dn [mm]**	**Δ_Q [m3/s]**	**Dn (1)**
1-2	1500	62,5	3	240	8,1	2000	5,0	1600
2-3	1000	175	3	200	18,9	3000	8,5	2000
3-4	1000	350	3	160	30,2	3500	13,2	2500
4-5	1000	475	3	150	38,4	3500	16,6	2500
5-6	1000	775	3	130	54,4	4000	25,1	3000
6-7	1000	1075	3	125	75,6	4500	34,8	3000
7-8	1000	1375	3	120	89,1	5000	40,5	3500
8-SE	1000	1500	3	110	89,1	5000	48,5	4000

Note: Dn (1) is the additional diameter required in the new concrete network; $\Delta_Q = Q_m - Q_t$.

Calculations for the retention basins volume, **Option 3**, is given in Table 3. The solution contains the old network (Table 1) and the retention basins. All workspaces (in all variants) will be resized to see what additional features are needed.

Table 3. Option 3 – Old rehabilitated network plus retention basins

Node	**Q_m F =1/10 [m^3/s]**	**$Q_{collector}$ [m^3/s]**	**Δ_Q [m^3/s]**	**Basin capacity [m^3]**
2	8,1	3,0b	5,0	5560
3	18,9	10,4	8,5	6880
4	30,2	17,06	13,2	10400
5	38,4	21,88	16,6	13000
6	54,4	29,43	25	20700
7	75,6	40,77	34,8	28800
8	89,1	48,42	40,5	33100
9	89,1	48,52	40,5	33100

The recalculation of the existing old network (as shown in Table 1) with large collectors due to large meteoric water flows, has low flows to household wastewater when it does not rain, leading to low flow velocities for the unitary network and therefore the need for its current washing.

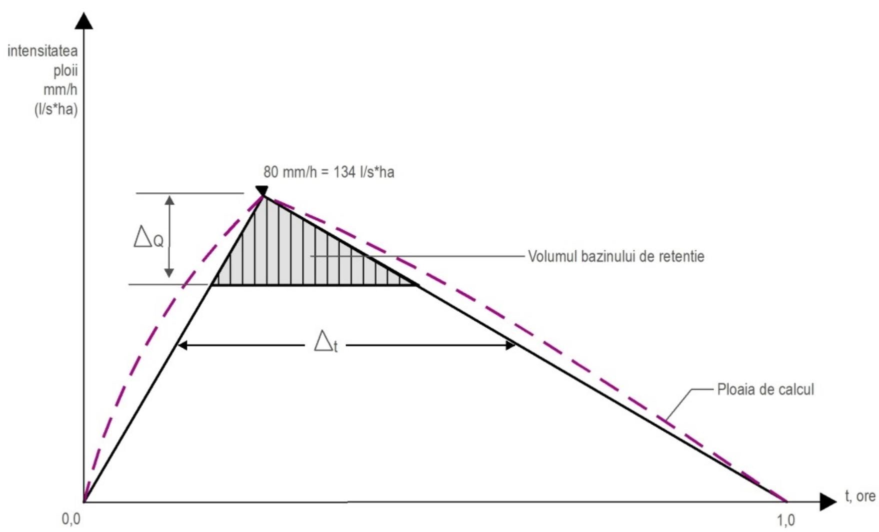

Figure 2: Rain calculation and retention basin volume calculation scheme

Checking the network in the event of a change in the rainfall frequency in order to align with the new Normative [2], shows that the network is totally undersized; to deal with the new conditions the network should either be totally replaced (option 1) for the flow difference (Δ_Q) or create a second new network, parallel to the existing one (option 2) which has the advantage that it can be executed more easily than the network in option 1.

The provision of retention basins with overflowing water after the rainfall, option 3, leads to the volumes in Table 3. The sizes of the pumping stations are not specified as their size is directly influenced by the drainage time of the basins; the drainage time must be correlated with the capacity of the downstream collectors and with the operation of the wastewater treatment plant (where the technological process should not be damaged).

An investment cost assessment was made and the options were compared. For Option 1 – a new network was estimated to cost approximately 65 million Euros. Option 2 – a new additional network to run in parallel with the old one was estimated at 49 million Euros. The cost of the basins (without the pumping stations) amounts to 75 million Euros. It turns out that the option 2 is cheaper and therefore it can be easier to achieve option 3 because the street traffic disruption is much lower. Obviously, it depends on the availability of space for retention basins and keeping them under periodic maintenance and in proper peak condition (washing after each use).

The costs necessary for the rehabilitation of small collectors which bring the wastewater to the collectors described in the tables are not included in the above estimates.

5. CONCLUSIONS

The need to increase the transport capacity of the wastewater sewerage network in large localities with more than 100 thousand inhabitants results from the requirement of the standards [2] as well as from the high costs related to the repair of the faults in the collectors with a long lifespan.

The solution to the problem can be found in the balance of costs between the two situations: the network remains as it is and the flood damage is being paid or the network is rehabilitated and results in an investment and exploitation cost; solutions are closely related to the local situation (land topography and network graph). The costs involved vary with the duration of the work.

A new network must be combined with measures in the territory to meet the requirements of the European Directive on the management of rainwater at the place of production (watering, washing, infiltration, settlement zones, etc.).

The direct discharge of rain water from the sewerage network into the receiving river, at the end or in the course, shall be done in compliance with its quality conditions. Compliance with the requirements of the river basin management plan is mandatory.

It is also necessary to periodically rebuild the IDF curves to highlight the influence of climate change.

6. REFERENCES

[1] HG. 2139/2004 - for the approval of the Catalogue on the classification and the durations of normal operation of the fixed assets; with changes in 2015 and 2016.
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[4] GP. 127/2014; Guide to rehabilitation of pipelines for water transport.