Study on the impact of sewer pipes on the environment
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Abstract. The present paper has as objective a study on the impact of sewer pipes on the environment. At the beginning of the paper there is a brief study on the causes that produce quality deterioration of sewer pipes. Following, there is a characterization of the existing sewer pipe types. At the end of the paper there will be indicated the effects of direct and indirect rehabilitation of the sewage network and will be proposed strategies to improve their performance.

Key Words: wastewater, pipe, impact, environment.

Introduction. Systematic construction of pipelines and ducts began at the end of the 19th century in Romania, in a number of cities there were built water supply systems and sewage networks and after 1910 they started building wastewater treatment plants. At the beginning, development was relatively modest because no tubes were produced in the country, the energy was slightly developed, water treatment was done by simple means (without disinfection, rinse in decanter without reagents, slow filtration).

Issues related to surface and groundwater quality come mainly from untreated wastewater discharged into watercourses, totaling 79% of all the wastewater produced in Romania (POS Mediu, www.posmediu.ro).

Romania set its target to collect, by 2015, 60% of the discharged waters, by implementing the environmental Acquis. Another commitment relates to connecting up to 70% of citizens to water and sewer networks by 2015 (MMSC, www.mmediu.ro).

Also, the quality of rivers in Romania will be significantly improved by investing in the reduction of point contamination sources that increase the risk of eutrophication of natural receivers and the risk of disease in the population. The quality of surface waters is influenced by discharges of wastewater, when they are not pretreated or treated improperly before being discharged in the receiver. Annual statistics on the main water sources in Romania, respectively The Water Quality Synthesis in Romania, elaborated annually by the “Romanian Waters” National Administration, between 2007 and 2011 (ANAR 2012) have estimated that the total volume of wastewater originating from human agglomerations which was discharged in natural receivers sufficiently treated, has increased with 43.925 million m³/year (14.6%).

Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment supplemented and amended by Commission Directive 98/15/EC on February 27, 1998, is the legal basis of Community legislation on wastewater (http://eur-lex.europa.eu) This Directive was transposed into Romanian legislation by Government Directive no. 188/28.02.2002 for approving the rules on conditions for discharge of wastewater into the aquatic environment, which was supplemented and amended by GD no. 352/21.04.2005. Thus, there were included requirements for compliance with transition periods negotiated for collecting systems and treatment plants, and also with the sensitive area status for Romania.

The final transition period for implementation of the Directive was set on 31st of December 2018, with intermediate times for collection and treatment of urban wastewater. In order to implement and comply with provisions of Council Directive 91/271/EEC concerning urban wastewater treatment, Romania obtained transition periods for:

a. Collection of urban wastewater (art. 3 of the Directive), as follows:
   - by 31st of December 2018, compliance with the Directive will be achieved in human agglomeration with less than 10000 l.e;

b. Urban wastewater treatment and their discharge – art. 4 (1, a, b) and art. 5 (2):
- by 31st of December 2015, compliance with the Directive will be achieved in human agglomeration with more than 10000 l.e;
- by 31st of December 2018, compliance with the Directive will be achieved in human agglomeration with less than 10000 l.e;

Strong development was achieved after the First World War and mostly after the Second World War; the current stage started in the 90s should conclude this matter by year 2018. There is to be supplied with water about 40% of the population, sewer networks must be completed for about 60% of the population and wastewater treatment at high standards for about 70% of the volume of wastewater.

**Material and Method.** An important issue is that the length of the sewer network is much lower than necessary. There is no village where all people are connected to the sewer. This leads indirectly to their poor behavior towards operation of the network.

**Operating status of sewage networks.** According to the National Statistics Institute, from 2012 the population of Cluj County is largely connected to the sewage network at a rate of 89.90% (www.insse.ro).

Networks in larger municipalities are made in the unitary mode, this means that when high rainfall “sewage does not cope” or “sewage is discharged” are two of the most heard phrases. There can be multiple causes (Bica 2013):
- sizing was performed at a calculated rain frequency that today is no longer right for that certain village;
- rainfall has changed much; it rains in excess in short amounts of time (as for example in Dobrogea rains on average 400 mm/year, or about 1 mm/day; in 2013, for example, it rained more than 100 mm in 2 hours; sewers cannot drain all of the water from high rainfall, standing water causing great trouble in small areas – blocking traffic, flooding homes, collapsing roads etc.);
- “discharge” of the sewer has “the advantage that it washes the sewer” but brings household wastewater on the street, in green spaces, in homes; household wastewater has microorganism concentrations in the millions per liter; illness can develop at a larger scale; water on slopes or on the sloping part of the village is accumulated in the flat part and hence the major floods; even if this repeats often, no corrective actions are taken;
- drains are blocked by floaters brought by the water (from uncontrolled deposits, unsavaged streets, outside the village etc.);
- collectors have blocked sections due to large elements introduced (through the manhole) into the network by locals (out of ignorance, greed, bad will, negligence etc.) and chemicals or dangerous substances discharged into the sewer;
- lack of an adequate washing technology, especially on the sections where it is known that the self-cleaning speed is not achieved (collectors have low slopes and flows for large periods of time);
- sections where hydraulic jumps occur at high flow and downstream flowing is blocked;
- lack of ditches against the flow of water from slopes;
- systematic lack of retention basins etc.

Concurrently, you can also notice the noise and risk represented by manhole lids (placed usually on the axis of the street) due to the difference in elevation or improper execution, and also the lack of these lids as a result of vandalism.

Water pollution caused by human agglomerations is mainly due to the following factors (ANAR 2012):
- **Low rate of population connected to wastewater collection and treatment systems.** Public services of water supply, sewers and treatment have an important role to improve the quality of life. Due to the low rate of connection of people to wastewater collection and treatment systems, the pollution of rivers occurs by discharging household wastewaters through drains directly into the river and polluting groundwater by wastewater infiltration into the soil.
Malfunction of the existing wastewater treatment plants. Wastewater treatment plants are the main tools for treatment of polluted waters, but if they fail to operate properly, it leads to pollution of surface waters with organic substances, nutrients and toxic substances.

Improper waste management. Development of urban areas requires a greater deal of attention also in terms of collecting household waste by building ecologic waste landfills and elimination of uncontrolled waste storage, often found alongside rivers and lakes.

Development of urban areas and insufficient protection of water resources. Water underpinning for making potable water are regulated by law, in terms of water quality and water source protection. Lack of protection areas is a danger of water contamination.

Types of tubes used for making pipes and drains. In the domain of pipe and drain/collector making were used various types of materials; it started with stone and wood, continued with prefabricated elements of wood (staves), stone (masonry) and brick (embroidered with lime and then cement), with lead and copper and in more recent years (about 200 years) with the use of iron, at first as cast iron and then also steel. In the 20th century the plastics and composite materials industry was developed. The diversity of materials became quite large and an important qualitative step was made: tubes were produced industrially and mounted on the site obtaining hundreds of kilometers long pipes with a good behavior in time. Today, the range of materials is much diverse and there are composite materials that ensure simultaneously the three basic conditions needed by a pipe or collector: good mechanical strength, resistance to chemical aggression and minimum wall roughness, meaning water flow with little energy consumption. There are several types of materials that are used (Bica 2013; SREN 1916/05; SREN 14801/08; SREN 13508-1/04; SREN 13566/04; SREN ISO 13844/01; SREN 1401-1/03; SREN 13508/2011):

- Grey cast iron/pressure cast iron/second casting iron. This material was used until the 70s for making sewer pipes. It is estimated that the country has thousands of kilometers of pipes made from grey cast iron and most of these will have to be remediated. Their lifespan is approximately 100 years. Length of tubes is 4-6 m.

- Carbon steel. The technology for producing steel advanced leading to replacement of grey cast iron with steel pipes, a more economic material, and more mechanically resistant. The downside was that it was less resistant to corrosion. Its lifespan is 30-40 years. Length of tubes is 6-12 m (Figure 1).

- Asbestos cement. It started replacing some of the cast iron and steel pipes in the 70s – 90s. It is a composite material made from asbestos fiber and cement grout (about 70%); the mixture is wrapped on mold cylinders and grip is controlled at a hot temperature. After hardening, it’s lathed at the ends for mangling and obtaining of a section normal to the axle. Joining is made with asbestos cement collar and rubber gasket. It is a material resistant to corrosion, mechanically resistant up to pressure of 6-10 bars. Lifespan is about 50 years. Length of tubes is 4-6 m (Figure 2).

- Prestressed concrete. It started being used in the 60s as a material for culverts; the longest culvers in the country are made from PREMO pipes. Made of reinforced concrete and prestressed with special steel wire, it has a good mechanical resistance, normally up to 10 bars and in special conditions up to 20 bars. Lifespan is 30-40 years. Length of tubes is 4-6 m (Figure 3).

- Pipes made of plastic tubes. Development of plastics industry has led to the development in the production of pipes. There are many sorts, from simple wall tubes to reinforced plastic tubes. They are produced by extrusion at diameters of 50-2400 mm; work pressure is maximum 10 bars; they are resistant to corrosion and widely used in rehabilitation technology. Lifespan is about 50 years. Length of tubes is 6-12 m (Figure 4).

- Pipes made of FRP tubes. Fiberglass Reinforced Polymers (FRP) or also with sand filler (GRPSF) are quite widely used nowadays even if they were brought to us relatively late (after 1995). It is a composite material (polyester, fiberglass and sand);
tubes are produced in two technologies, by coiling (large diameters) and by guniting in centrifuged form. They are produced in the country. Joining is done with a gasket. Lifespan is about 50 years. Length of tubes is 6-8 m (Figure 5).

- **Ductile (nodular) cast iron, 3rd casting cast iron.** Although it was developed 30 years ago, in Romania it started being used only after year 2000. This was due to the fact that it is expensive and imported. There are still modest achievements in distribution networks and at first for adducts. It is produced a corrosion resistant tube, with good mechanical strength and good binding; the tube has thin walls because the material is better and is cast by centrifugation; protection is carried out with special mortar cement or accepted polymeric resins and with a layer of Zn and polymer on the outside; it is a robust material, it can resist up to 30 bars. Lifespan is over 100 years. Length of tubes is 6 m (Figure 6).

![Figure 1. Steel tube (Bica 2013).](image1)  ![Figure 2. Asbestos cement pipe (www.bzi.ro).](image2)  ![Figure 3. Prestressed concrete pipe (www.prefab.ro).](image3)  ![Figure 4. Plastic tube pipes (www.spatiulconstruit.ro).](image4)  ![Figure 5. FRP tubes (www.ecosat.ro).](image5)  ![Figure 6. Ductile cast iron pipes (Bica 2013).](image6)

**Causes that produce quality deterioration in pipes and drains.** Under the influence of natural and artificial factors in general all materials that pipes are made of deteriorate, age thus reducing the technological performances of constructions in which tubes are embedded: adducts and distribution networks, sewer collectors, discharge pipes. One can distinguish some of these effects:

- increase of water loss in pipes and drains and water quality deterioration;
- loss of energy with lost water or with conservation of technologic parameters;
- interruption of service operation to repair the damage, that brings more costs;
- increased operating costs by repeating repairs at small intervals;
- decrease in the safety of operation in case of disaster (fires, floods etc.);
- deterioration of underground constructions by increasing soil aggression, groundwater level rise etc.;
- accelerated deterioration of transport routes under which these pipes and drains are located.

Reliability of pipes and drains decreases in the following cases:

- operation at variable flows and pressures (slow or fast variable);
- operation at high and variable external loads; load from ground heaviness, load from traffic, loads from dynamic earth stresses;
- temperature variation of transported liquid/water;
- soil aggression from the outside and water aggression on the inside; corrosion destroys the tube's wall with or without deposition of corrosion products;
- reduced transport capacity by increasing roughness due to corrosion or depositions on tubes’ walls;
- changing in the structure of the material, in time;
- deposition of amorphous or aggressive substances that reduce the active section and thereby of water speed; to maintain the required flow, the pressure must be increased in the section;
- mechanical stress during and beyond when there are executed underground repairs at other networks;
- exceptional stresses from natural (earthquakes) or artificial (world wars) causes.
Causes of accelerated deterioration of pipes may be due to a poor design, the use of improper materials, negligent execution, improper operation or disadvantageous combination of all these.

Another important thing is that water introduced into the network must not be aggressive or must not become aggressive towards the pipeline during operation.

**Discussion.** Operation, the longer part in the life of a construction, depends on the quality of the design and execution, but also on how working conditions are met. Water quality parameters must be monitored at prescribed intervals and at greater intervals an assessment on the general behavior must be performed: performance indicators must be monitored continuously. It is important to highlight the ongoing repair costs and reports of noncompliance in operation (smell in the street resulting from fermentation of deposits due to low speed of water flow with suspensions, how the sewage is cleaned etc.). Preventive repairs must be introduced in operating procedures in the operating management.

There are several pollution sources which may affect the soil, subsoil or groundwater following completion and maintenance of sewer pipes. These may include the aspects below.

**Sources of water and groundwater pollution, the effect of pollutants.** Surface water/groundwater pollution following completion of sewer networks (Cole & Marney 2012; ANAR 2012; JASPERS 2010; Nakayama et al 2007; Tee et al 2014; Zhen et al 2014; Nagataa et al 2011; Easa & Abou-Rayan 2010):

**In the construction phase** may occur:
- increase in the pollution level of the receiver of wastewater due to discharge of non-treated or partially treated water from the wastewater treating plant;
- local changes of drainage conditions, due to underground constructions or pipe installation operations;
- acceleration of erosion phenomena due to removal of vegetation on sites, and also due to excavation operations using heavy machinery and/or improper construction methods or soil protection measures. These phenomena can result, in sloping areas, to soil instability, landslides and ground entrainment in the beds of water surface bodies, with a possible effect of their pollution (e.g. increased turbidity);
- reduction or obstruction of the water flow section by entraining soil or rock displacement from the river or creek’s bed, due to accentuation of some erosion processes;
- degradation of the stability of banks by placement or operation of construction equipment in their vicinity;
- contamination of surface water bodies through leaks of polluting products (accidental spills of wastewater, fuel, lubricants etc.);
- contamination of groundwater by infiltration of accidental spills of wastewater, fuel, lubricants etc.; improper removal of construction wastes.
In the operating phase may occur:
- qualitative and quantitative changes expected (positive or negative) in the natural receiver determined by taking treated wastewater from the wastewater treating plant and, in case of combined networks, discharges out of the sewer network;
  - issues to be considered include:
    ● additional loadings of pollutants,
    ● additional hydraulic load,
    ● concentration of pollutants in treated wastewater,
    ● reduction of loads (kg/day, tons/year) and concentrations (mg/l) of pollutants considering specific qualitative parameters of treated wastewater discharged into the receiver;
  - impact assessment will consider the modifications in the connection rate and the treating process of wastewaters; average flow of wastewaters discharged and flow of the natural receiver for weather without precipitations;
  - potential contamination of the receiver with hazardous substances due to leakage/draining of waters on industrial sites (including rainwaters);
  - contamination of surface waters and groundwater caused by leakage from pipes due to damage in the sewer network;
  - sewerage network dysfunctions including failures, leakage, blockages that lead to spills and may cause pollution of groundwater surface waters;
  - pollution of the receiver of treated wastewaters in the circumstances of significant damages at the wastewater treating plant and due to discharge of untreated wastewater;
  - groundwater contamination due to damage to the integrity of sludge drying beds (infiltration into groundwater).

Sources of soil pollution, the effect of pollutants. There are several cases that could lead to pollution of soil/subsoil, in the two phases of development of sewer networks, as follows (Easa & Abou-Rayan 2010; Das & Das 2003; Loomis & Warner 1990; Foster et al 2005; Foster 1994; www.newslincolncounty):

In the construction phase:
- soil degradation due to removal of topsoil;
- temporary land employment change;
- temporary increase of soil erosion on working sites where excavations are carried out – e.g. on routes of pipelines, retention/discharge basins for rainwaters etc., which can lead, in sloping areas, to soil instability and landslides;
- erosion caused by removal of vegetation, earthwork and the use of heavy machinery and equipment during construction activities carried out in the riverbeds or in their vicinity;
- pollution of soil by accidental spillage of fuels, lubricants and chemical substances, by spreading of grout from concrete preparation platforms or from locations where concrete is used;
- soil contamination by infiltration of various leaks that may result from improper storage or handling of wastes or construction materials;
- leakage of wastewater from existing sewer networks, produced during rehabilitation works.

In the operating phase:
- final land employment change;
- erosion phenomena, soil instability and landslides (in sloping areas), caused by rainwater drain into surface waters; effects may be exacerbated in the period up until restoration of vegetation;
- contamination of soil by infiltration of various leaks/accidental losses of polluting products (oils, reagents).
The most common causes of damage to sewer pipes are (Bica 2013):

1. **Internal corrosion of metal tubes.** Damage to the pipe wall and reduction of mechanical resistance up to their collapse. Under favorable conditions, parts of the tube can be expelled (Figure 7).

2. **Expulsion of joint elements.** It is a common phenomenon for cast iron, prestressed concrete and asbestos cement tubes. It is the most common fault in PREMO concrete tubes; due to constructive reasons or behavior in time (field dampening, variable exterior charges etc.) the gasket gets in a non-symmetrical position in the joint and is expelled at overpressures; remediation is costly (Figure 8).

3. **Prestressed reinforcement corrosion.** It is a common damage resulting in explosion of the tube and total pressure loss (Figure 9).

4. **Biochemical corrosion of tubes in the sewer network.** It occurs where biodegradable material deposits happen regularly, because the washing of sewage is not done. The deposits begin to ferment and H₂SO₄ is produced; in dampening conditions in the collector, the acid reacts with CaOH from the upper wall of the tube until total destruction; the result is collapse of the tube (Figure 10). Periodic cleaning is very important, especially in sections where no good washing/self-cleaning speed can be provided.

5. **Clogging of the pipe/drain with biologic vegetal material.** Often the pipes and drains are made in the vicinity of trees. In time, due to the lack of water and the occurrence of cracks in the pipe/drain (usually around joints) tree roots enter into the pipe, widen the hole through biological pressure and develop a water absorption structure which can be impressive. The effect is reduction of flow up to total blockage of water flow (Figure 11).

6. **Internal incrustation.** Incrustation reduces the transport capacity (especially by reducing the active section of the pipe/drain). In sewer collectors repeated depositions, due to biologic stabilization and lack of network cleaning, lead to cementation of the material up to total complete obstruction of the section (Figure 12).
7. Total or partial obstruction with large bodies. A number of materials are introduced into the sewers through manhole lids: construction materials, chemicals, metallic scrap, dead animals etc.; due to their size, they reduce the transport capacity and accelerate the corrosion phenomenon (Figure 13).

Figure 13. Materials that block sewer pipes (Bica 2013).

Conclusions. In order to improve, it is needed to implement certain procedures of operation, inspection, maintenance and monitoring, considering measures that need to be taken. If these already exists, they must be reviewed to optimize performance of sewer pipes.

Wastewaters are waters which by their rich content in various substances in a suspension or dissolved form and of various bacteria, present serious danger for public health.

Infiltration of these waters into the soil can lead to infection of groundwater, rendering them improper for drinking water supply.

Also, discharge if wastewater directly into watercourses muddles their water and decreases its quality, causing death in the aquatic fauna (fish) and making it impossible to use them as sources of water or for recreation.

Their stagnation in various ponds or puddles produces smelly gas emanations, making the area insanitary. By their content in pathogen germs they are an important source of spread of a series of diseases, especially gastro-intestinal (cholera, abdominal typhus, dysentery).

Drains and pipes that compose the exterior sewer networks must meet a number of quality conditions, required by the characteristics of the wastewaters they transport, structure and configuration of the terrain they are mounted on etc.

In Romania it is imperative to carry out works to change and expand the sewer network, given that more than 71% of wastewater is not treated or is insufficiently treated. Moreover, pipe sewer lifespan in many sewer networks has been exceeded for a long time, leading to breakage or cracking of the pipes producing soil and groundwater pollution.

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