THE ASSESSEMENT OF THE RISK INDUCED BY CLIMATIC CHANGES ON WASTEWATER SYSTEMS FROM CLUJ COUNTY AND THE ASSOCIATED ADAPTATION MEASURES

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ABSTRACT. – The assessement of the risk induced by climatic changes on wastewater systems from Cluj county and the associated adaptation measures. Water is an essential element for life and for natural processes. Therefore, it is very important to assess the major threats early and to adopt the most appropriate adaptation measures to climate change. The risk assessment was based on the guidelines developed by DG Climate of the European Commission in *"Guidelines for Project Managers: Making Sustainable Investments Climate Resilient.* By analyzing the results it was observed that the main impacts/hazards to which wastewater systems have low resilience in the future are associated with the increasing frequency and intensity of floods and extreme rainfalls. Nevertheless, the adaptation of waste water systems will be easier in the future by taking into account and applying the most appropriate risk mitigation measures.

Key words: climate change, wastewater, adaptation measures, risk assessment

1. INTRODUCTION

1.1. Context

Water is an essential element for life and for natural processes. Our existence and economic activities are entirely dependent on this valuble resource. Good water management is of particular importance given that water at a global level is a limited source, so it is treated as a very important resource that needs to be protected. Human activities and climate change exert significant pressure on water resources. Therefore, it is very important to assess the major threats early and to adopt the most appropriate adaptation measures to climate change (Climate Change and Impacts on Water Supply Project, 2012, GASC, 2008).

The global warming process and its impact on the climate system are considered extensively in the 5th Climate Change Assessment Report prepared by

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the Intergovernmental Panel on Climate Change (IPCC, 2013), being justified by increase of the average global temperature compared to the pre-industrial age, the rise in sea and ocean levels and the warming of the Planetary Ocean, the accelerated retreat of the glaciers and the diminishing of the snow layers, the increase of the intensity and the frequency of some extreme meteorological phenomena, etc. In the period between 1880 and 2012, the average global temperature increased by 0.85ºC. Each of the past 3 decades has been successively warmer than any decade since 1850. In the northern hemisphere, the 1983-2012 period was most likely the warmest 30-year period of the last 1400 years, considering an average degree of confidence. Average precipitations increased in the northern hemisphere, at medium latitudes, with a high degree of confidence, after 1951. Changes in the dynamics of phenomena and extreme events were also observed after the 1950s. For Europe, an increase in the frequency and the intensity of heavy rainfall was observed (IPCC, 2013).

These extreme events result in both loss of life and significant economic losses and global climate models indicate that the frequency and intensity of these events will increase.

In the context of climate change, which anticipates increases in air temperature in the future, special attention should be paid to extreme temperatures and especially to heat waves. These may have adverse effects on water quality (by decreasing dilution and total dissolved oxygen and increasing the concentration of pollutants). All this can have repercussions on wastewater treatment, by increasing the concentration of pollutants. One of the problems is the increase in the final specific costs of wastewater as a result of the increase in water treatment costs. Another problem may be related to the social discomfort induced by the fermentation gases in the sewerage pipes.

High intensity rainfalls in cities where the sewer system is not separated from the rainfall drainage system may result in exceedances of the projected capacity of the sewerage networks, leading to urban flooding and overcapacity of sewage treatment plants with negative effects on the chemical and bacteriological properties of tributaries (Adapting Urban Water Systems to Climate Change, A Handbook for Decision Makers at Local Level, 2011). Due to an increase in rainfall intensities, a rise in the frequency of urban floods is expected in the future, which can cause physical damage to the structures of the wastewater system.

Taking into account the above mentioned arguments, adapting to climate change will be a key point in Romania's national climate change policy and in the country's overall development. Therefore, it is necessary for the Romanian decision-makers to focus on the major issues of climate change and to continue to develop and update policies to mitigate their effects (National Strategy for Climate Change 2013-2020, River Basin Management Plan (RBMP), Water Basin Administration (WBA) Someş-Tisa, 2016-2021).

On the other hand, it is widely accepted at a scientific level that projections of the climatic parameters (especially precipitation) have their degree of uncertainty, derived from a series of factors:

- interruptions in regional meteorological and climatic data series;
- deficiencies in understanding the natural system;
- the fact that climate predictions are based on models that do not take into account all factors associated with the climate system;
- limitations associated with emission scenarios that can only estimate future greenhouse gas emission levels (Adapting urban water systems to climate change, A handbook for decision makers at local level, 2011).

In addition, the projected climate change effects should not be seen as gradually emerging, linearly, but as average forecasts, with a relative constancy of parameters including periods with rapid changes.

1.2. A short description of Cluj County wastewater systems

In Cluj County, the agglomerations served by sewage treatment plants and associated sewage systems are shown below:

- Cluj Cluster, has a unitary sewerage system of 85%. It includes 5 localities: Cluj-Napoca, Baciu, Gilău, Florești (Florești and Luna de Sus), with an average wastewater discharged (Quz) of 111,000 m³/day;
- The Dej agglomeration (Dej, Ocna Dej) has a mixed sewerage system, being predominantly unitary in the downtown area of Dej town and separate in the areas with block quarters with an average discharge of daily wastewater of 4570 m³;
- The Gherla agglomeration (Gherla and associated cities) has a separate sewerage system, the daily waste water discharge being 3819 m³;
- Huedin agglomeration (Huedin); Quz = 2199 m³/day; 40% unitary sewerage system;
- Aghireșu agglomeration (Aghireșu-Fabrici and Aghireșu); Quz = 232 m³/day (2014); separate sewerage system;
- Apahida agglomeration (Apahida and part of Sânicoară); Quz = 679 m³/day (2014); unitary sewerage system (source: Someș Water Company S.A.).

2. METHODOLOGY

The objective of a risk assessment is to properly identify and manage significant risks. The methodology in this paper was based on the guidelines developed by Directorate-General Climate Action of the European Commission in *"Guidelines for Project Managers: Making Sustainable Investments Climate Resilient"*.

According to the Guideline recommendations, a number of primary climate drivers and secondary effects (eg. floods, landslides) in relation to which the wastewater system components (eg. sewage treatment systems and processes, waste water, energy, treated water, sludge, waste, sewerage network) are highly vulnerable and are considered in the risk assessment process.

Then, climate variables and derivates were associated with subsequent impacts/associated hazards.

The risk assessment works by assessing the likelihoods (probability of an event to occurr) and severities (the consequence associated with that event) of the impacts associated with the climate variable hazards. For each relevant hazard, scores were assigned using five classes for severity (insignificant, minor, moderate, major, catastrophic) (Table 1) and five probability classes (rare, unlikely, moderate, likely, almost certain) (Table 2), which combined will result in the level of risk exemplified in the form of a matrix.

Table 1. The probability classification classes

Probabilitaty	1	2	3	4	5
	Rare	Unlikely	Moderate	Likely	Almost certain
Significance	Highly unlikely to appear	Given current practices and procedures, this incident is unlikely to occur	Incident has occurred in a similar country / setting	Incident is likely to occur	Incident is very likely to occur, possibly several times
	5% chance of occurring per year	20% chance of occurring per year	50% chance of occurring per year	80% chance of occurring per year	95% chance of occurring per year

Table 2. The severity classification classes

Severity classes	1	2	3	4	5
	Insignifican t	Minor	Moderate	Major	Catastrophic
Significan ce	Impact can be absorbed through normal activity	An adverse event which can be absorbed through business continuity actions	A serious event which requires additional emergency business continuity actions	A critical event which requires extraordinary / emergency business continuity actions	Disaster with potential to lead to shut down or collapse of the asset / network

Data related to the current and future exposure at local or regional level were provided by the documents elaborated by experts belonging to recognized national institutions in the field, and if they were not available, they relied on other sources of such data/information at European level (eg. the European Climate Adaptation Platform, http://climateadapt.eea.europa.eu/map-viewer).

3. RESULTS

3.1. Hazards associated with climatic variables and risk assessement

The impacts/hazards associated with primary climate drivers and secondary effects are shown in the table below.

Table 3. Forms of impact associated with climatic variables

Climatic variable and secondary effects	Actual and future exposure (2050 energy strategy)	Possible impacts/hazards over wastewater systems
Increase in average and extreme temperatures	Current increasing trend with a level of statistical significance (Bojariu et al., 2015) An increase with 1.55-1.95°C for the average annual temperature and 1.65-2.25°C for the summer average temperature are expected for the 2050s (ADER, 2014)	Decreased wastewater quality by increasing evaporation and increasing pollutant concentration with negative impact on wastewater treatment costs
Extreme rainfall and urban floods	Current increasing trend for extreme rainfalls and urban flood frequency and intensity, especially in summer and autumn in the region (Bojariu et al., 2015) An increase by about 5% for rainfall amounts ≥20 mm is expected (Pollner et al., 2008, Bojariu et al., 2015)	Exceeding the drainage capacity of the sewerage system and of the wastewater treatment plant, even removing them from operation; this induces urban flooding and increasing the risk of disease and adverse effects on the quality of the environmental components (soil, surface water, groundwater, and ecosystems). Physical damage / destruction of some system components.
Maximum wind speed. Storms	Current increasing trend of summer storms Predictors of increasing the frequency and intensity of storms as a result of temperature increase and implicitly thermo-convective potential	Temporary disconnection of the power plant supply. Physical damage to structures (eg. roofs, coatings, everhead lines).
River floods and inundations	There are no significant increasing trends at present, but they are highlighted in the future predictions (*http://climate-adapt.eea.europa.eu)*	Exceeding the drainage capacity of the sewerage system and of the wastewater treatment plant, even removing them from operation; this induces urban flooding and increasing the risk of disease and

		adverse effects on the quality of the environmental components (soil, surface water, groundwater, and ecosystems). Physical damage / destruction of some system components.
Landslides	No relevant trends	Physical damage / destruction of system components with negative effects on the quality of environmental components (soil, surface water, groundwaters, ecosystems).

The risk assessment was performed for the components of the systems with medium and high vulnerability to climatic hazard/variables and the results are presented in Table 4 and exemplified in the risk assessment matrix (Table 5).

Table 4. Risk assessement

Climatic or derivative variable and the associated impact		Risk score		
		Probability (P)	Severity (S)	P x S
Increase of average and extreme temperatures	1.1. Decreased waste water quality by increasing evaporation and decreasing dilution, with a negative impact on the treatment cost of wastewater.	3	3	9
Increase of extreme rainfalls' frequency and intensity	1.2. Exceeding the drainage capacity of the sewerage system and of the wastewater treatment plant, even removing them from operation; that induces urban flooding and increasing the risk of disease and adverse effects on the quality of the environmental components (soil, surface water, groundwaters, and ecosystems).	4	5	20
	1.3. Physical damage / destruction of some system components.	3	5	15
Maximum wind speed. Storms	1.4. Temporary interruption of power supply of the power plant	4	2	8
River floods and inundations	1.5. Exceeding the drainage capacity of the sewerage system and of the wastewater treatment plant, even removing them from operation; that induces urban	3	5	15

Climatic or derivative variable and the associated impact		Risk score		
		Probability (P)	Severity (S)	P x S
	flooding and increasing the risk of disease and adverse effects on the quality of the environmental components (soil, surface water, groundwaters, and ecosystems).			
	1.6. Physical damage / destruction of some system components.	3	5	15
Landslides	1.7. Physical damage / destruction of some system components	2	5	10
	1.8. Negative effects on the quality of environmental components (soil, surface waters, underground waters, ecosystems).	2	4	8

Table. 5. Risk classification in the risk assessment matrix

			Probability				
			Rare	Unlikely	Moderate	Probable	Almost certain
			[1]	[2]	[3]	[4]	[5]
Severity	Insignificant	[1]					
	Minor	[2]				**1.4.**	
	Moderate	[3]			**1.1.**		
	Major	[4]		**1.8.**			
	Catastrophic	[5]		**1.7.**	**1.3., 1.5., 1.6.**	**1.2.**	

Risk level

- Residual
- Low
- Moderate
- High
- Extreme

Analyzing the results, it can be said that the main hazards to which systems have low resilience in the current and future perspective are associated with river floods and extreme rainfalls, whereas the adaptation measures proposed in the following section will address these impacts.

3.2. Adaptation measures to the effects of climatic changes on wastewater systems

In order to ensure water security in the future, it is necessary to invest in the transport, treatment and reuse of wastewater, as well as in policies and regulations as well as in information and ability to ellaborate a plan to adapt to climatic variability. A fully secure world in terms of water will need investment in three major area: better and more accessible *Information*, stronger and more adaptable *Institutions* and a natural and artificial *Infrastructure* to store, transport and treat water (Sadoff and Muller, 2009). An effective combination of structural measures (hard-measures) involving engineering construction, and soft, non-structural measures, involving education and information of the population, planning, regulations, collaboration and institutional decisions. The soft-measures are preferable to the structural ones because they are cheaper, with a reduced ecological impact and a more effective impact in many cases compared to structural measures.

Of course, some of the proposed adaptation measures can not be implemented by project owners, but through closer collaboration with all decision-makers, they can be included in local, county and regional strategic planning.

Significatently identified risk factors and their classification by risk levels are presented in *Table 4* of *Section 3.1.*

Adaptation measures to the effects of climate change are correlated, where possible, with those in national and regional specific plans and strategies (Table 6).

Table 6. Major hazards associated with climatic changes and proposed adaptation measures

No.	Hazards associated with climatic changes	Adaptation measures	Observations
1.	Exceeding the drainage capacity of the sewerage system and of the wastewater treatment plant, even removing them from operation; that induces rban flooding and increasing the risk of disease and adverse effects on the quality of the environmental components (soil, surface water, groundwaters, and ecosystems). Physical damage / destruction of components of wastewater systems as a result of river floods and inundations	Building new flood-control reservoirs	A number of specific engineering works are foreseen in the Flood Risk Management Plans (FRMPs), 2015, of the Someş-Tisa and Crișuri Water Basin Administrations (WBAs), which propose the construction of 3 new flood-control reservoirs on the small rivers (Aghireş- Nădaș River - 2.5 mil.m³, Ac. Ciumăfaia- Valea Borşa River - 5.1 mil. m³, Ac. Călata-Călata River - 2.1 mil. m³).
		Increased drainage capacity of the river channel	Some works are forseen in the FRMPs of the Someş-Tisa, Crişuri and Mureş WBAs: local works of recalibration of the river channel
		Structural works (supporting walls, channel stabilization structures)	Works included in FRMPs of the Someş-Tisa, Crişuri and Mureş WBAs on Somes, Someşul Mic, Borsa, Sic, Fizeş, Ocna, Crişul Repede, Călata and Iara watercourses.
		Increase the safety of reservoirs	Works included in FRMP of the Someş-Tisa for the Gilau reservoir
		Better planning of land use at the basin level by increasing afforestation in order to reduce the flood-risk, increasing groundwater infiltration and, implicitly, decreasing the surface runoff.	Works forseen in the in the FRMPs of the Someş-Tisa, Crişuri and Mureş WBAs (improvement of forests management in flood-prone areas - over 200 ha in the study area)
		Strengthening and elevating of old structures (embankments) in order to cope with updated discharge return periods	Such local works are planned along the large water courses, ie Someş and Someşul Mic

No.	Hazards associated with climatic changes	Adaptation measures	Observations
		Construction of the main components of wastewater systems (eg water treatment plants) in non-flood-prone areas. Performing flood risk assessment studies in the locations of problematic sites and adopting appropriate prevention and protection measures.	The owner's responsability
2.	Exceeding the drainage capacity of the sewerage system and of the wastewater treatment plant, even removing them from operation; that induces urban flooding and increasing the risk of disease and adverse effects on the quality of the environmental components (soil, surface water, groundwaters, and ecosystems). Physical damage / destruction of some system components due to urban flood and flash-floods	Development of the sewage network	Sewerage network expansion works will be carried out in Cluj-Napoca, Apahida, Gherla, Dej, Cuzdrioara, Sic, Huedin, Zalău, Jibou, Șimleu Silvaniei, Cehu Silvaniei, Hereclean, Sărmăşag, Bobota new sewerage network), (source: Somes Water Company SA)
		Reducing the risk of urban floods by discharging sewers through separate rainwater management (divisor system) wherever possible.	The owner's responsability
		Risk reduction for urban floods by replacing concrete pipes that are more rugged and more exposed to more efficient hydraulic pipe fracturing	The owner's responsability
		Changes in the use of urban areas by increasing green areas, applying porous pavements instead of asphalt and concrete in order to reduce surface runoff and increase infiltration.	It is recommended more effective collaboration with local, county and regional institutions is required in order to include these measures in specific plans and strategies
		Updating existing standards so that they can respond effectively to the cost-benefit ratio of rainfall imputs used in designing wastewater network structures	
		Maintenance and periodic cleaning of rainwater collecting and transport surfaces and	

No.	Hazards associated with climatic changes	Adaptation measures	Observations
		structures (rills, runnels)	
		Educating and engaging the public on wastewater processes in order to avoid the sewerage pipes blocking with wastes	

It is also necessary to take into account a number of other measures, considered as general measures for adaptation, in the case of wastewater systems:

- tighther and more efficient collaboration between beneficiaries and relevant institutions (ANAR, APM, etc.), by involving them in the updating and adaptation of the river basin planning and management schemes to the predicted climate changes;
- closer collaboration between beneficiaries and relevant institutions (city halls, county councils) to ensure that the proposed adaptation measures are also found in local, county and regional strategic planning;
- increasing the institutional capacity of the beneficiaries in the elaboration and implementation of projects and attracting funds.

4. CONCLUSIONS

Today's water security investments should be seen as an explicit part of a coherent long-term adaptation strategy that will build a more resilient world in the future. However, anticipated impact patterns due to the projected future hazards/climate change may differ in a more or less substantial way than the real ones. This assertion is based, on one hand, on the relatively high degree of uncertainty of future projections, on the availability of water resources, and on the other hand, on the uncertainties associated with the evolution of the variables associated with the anthropic factor.

The waste water system is unequivocally exposed to climate change. According to projections and predictions, an increase in temperatures and evapotranspiration is expected in the region, especially in the summer, less pronounced compared to southern Romania, an increase in days with heavy rainfall, rainfall intensity, floods and flooding, a decrease of snow layer duration and thickness.

This translates into a series of disturbances in the relationship between the atmosphere and the hydrosphere, which can have negative repercussions on the wastewater system.

Analyzing the results we can say that the main impacts/hazards to which systems have low resilience in the future perspective are associated with increasing frequency and intensity of floods and extreme rainfall.

By adopting measures to mitigate the adverse impacts associated with climate change, the adaptation of waste water systems will be easier by taking into account and applying the most appropriate risk mitigation measures, with emphasis on non-structural measures, respectively on an adaptive, robust and flexible management that can be adjusted and can evolve according to new climate circumstances.

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