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BIG AGGLOMERATIONS DELINEATION IN THE CONTEXT OF COMPLIANCE WITH THE REQUIREMENTS OF THE URBAN WASTEWATER TREATMENT DIRECTIVE-STUDY CASE CRAIOVA AGGLOMERATION

DELIMITAREA AGLOMERĂRILOR UMANE ÎN CONTEXTUL CONFORMĂRII CU CERINȚELE DIRECTIVEI PRIVIND EPURAREA APELOR UZATE URBANE - STUDIU DE CAZ AGLOMERAREA URBANĂ CRAIOVA

Sanda-Adina MARIAN[1], Liana-Daniela DUDĂU[2], Alina-Mariana CODIȚĂ[3], Olivia CIOBOIU[4]

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Abstract: This study investigates the delineation of human agglomerations within the framework of ensuring compliance with the Urban Wastewater Treatment Directive. Focusing on the case study of Craiova agglomeration, the analysis examines the critical parameters that define urban areas requiring enhanced wastewater treatment infrastructure. By assessing demographic, geographic, and administrative boundaries, the study identifies key factors that influence the classification of urban settlements as eligible for directive-specific sanitation improvements. The research employs a mixed-method approach, incorporating both qualitative and quantitative analyses. Spatial data mapping and field observations underscore the challenges faced by urban planning authorities in delineating boundaries consistent with EU regulatory standards. These challenges include rapid urbanization, variable population densities, and resource allocation disparities, which complicate the effective management of wastewater treatment systems. Methodical evaluation of human agglomerations, based on standardized metrics, can facilitate improved implementation of wastewater treatment policies. The results further suggest that local governments need to adopt integrative planning strategies that consider the evolving dynamics of urban growth. Ultimately, this study contributes to a better understanding of urban boundary setting and provides recommendations for policy adjustments to ensure sustainable urban wastewater management practices.

Key-words: *Urban Wastewater Treatment Directive, people equivalents, aquatic ecosystem*
Cuvinte cheie: *directiva privind epurarea apelor uzate urbane, locuitori echivalenți, ecosistem acvatic*

[1] Jiu Water Basin Administration, 54 Nicolae Romanescu Street, 200738, Craiova, Dolj, Romania, e-mail: adinamarian2020@gmail.com (correspondent author);
[2] Jiu Water Basin Administration, 54 Nicolae Romanescu Street, 200738, Craiova, Dolj, Romania;
[3] University of Craiova, Faculty of Mecanics, Department of Applied Mecanics and Civil Construction, Romania
[4] Oltenia Museum, Natural Sciences Section, Craiova, Dolj, Romania.

1. INTRODUCTION

The delineation of human agglomerations plays a critical role in ensuring compliance with the Urban Wastewater Treatment Directive. As urban centers continue to evolve in response to rapid population growth and industrial development, defining the boundaries of these agglomerations has become both a challenging and pertinent issue (Montero et al., 2021). The Urban Wastewater Treatment Directive (91/271/CEE) has been instrumental in guiding member states toward ensuring that wastewater is treated to a level that protects human health and the environment. However, the successful implementation of these guidelines requires accurate and contextual classification of urban areas that are subject to these regulations. In many instances, the ambiguous nature of urban expansion complicates efforts to demarcate areas that need infrastructural upgrades and environmental protection measures (Guastella et al., 2019). The challenge lies in striking a balance between administrative convenience and the dynamic reality of urban growth.

This article focuses on the case study of the Craiova agglomeration, exploring how effective boundary delineation can facilitate improved sanitation, resource allocation, and management of urban wastewater treatment systems in line with European Union regulatory requirements. This study examines spatial planning strategies and regulatory frameworks that support the delimitation process. By scrutinizing demographic trends, land use data, and administrative boundaries, the research provides insights into the practical implications of policy enforcement within urban settings (Yang et al., 2019; Săgeată et al., 2025).

The case of Craiova illustrates how tailored boundary-setting measures can address both current needs and future urban expansion (Șoșea, 2013). Ultimately, establishing clear, scientifically backed parameters for defining urban agglomerations not only enhances compliance with wastewater treatment standards but also contributes to sustainable urban development and environmental conservation.

2. DATA AND METHODS

This study employs a comprehensive mixed-method approach to delineate the boundaries of human agglomerations, with a particular focus on Craiova agglomeration, in compliance with the Urban Wastewater Treatment Directive (Strano et al., 2021; Soares, 2020). The methodology is structured into several phases: data collection, spatial analysis, policy review, and field validation. Each phase is supported by both quantitative and qualitative methods to ensure a robust framework capable of addressing both physical and regulatory dimensions.

2.1. Data Collection

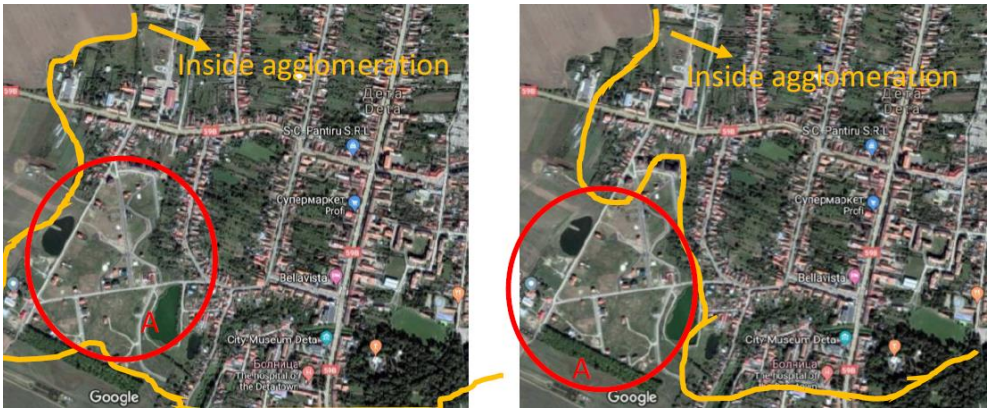
Primary data sources include recent census reports (NIS, 2020), land use databases, and satellite images. Secondary data is gathered through literature reviews of previous studies on urbanization and wastewater management directives. The gathered data is homogenized and geo-referenced, allowing for the creation of a detailed digital map for agglomerations that illustrates the integration of multiple datasets into a comprehensive digital system.

2.2. Spatial Analysis

Geographic Information System (GIS) tools are employed to perform spatial analyses. Using high-resolution satellite images, the study identifies urban growth patterns, population densities, and infrastructural layouts. These maps (Fig. 1) highlight urban sprawl, pinpointing areas where population clustering is the most pronounced. Additionally, spatial interpolation techniques are used to estimate population variables in regions with incomplete data. Boundary delineation is further refined with overlay analyses comparing current administrative borders with emerging urban footprints, ensuring that the proposed limits accurately reflect the dynamic nature of urban development.

Historically, urban developments have been formed in most cases from densely populated central areas and peripheries with a lower density. The continuing urbanization trend leads to a growing need and interest in including urban sprawl indicators in monitoring systems for sustainable development, environmental status, biodiversity, and landscape quality (EEA, 2018).

While central areas in most of the cases are more suitable for centralized collection systems, for the peripheries it is not always easy to decide whether they are "sufficiently concentrated" (Steurer & Bayr, 2020). Two options for definition of agglomeration boundaries could be considered, respectively excluding or including areas with lower density as shown in the Fig. 1 below.



Option 1: Agglomeration boundary Option2: Agglomeration boundary

Fig. 1 Options for agglomerations delineation

Although the first option may fulfil the expectations of citizens about not being "left out", including lower density areas may result in higher investment and operating cost if demands for centralized systems are misunderstood, *e.g.* if there is an expectation for piped collection covering the whole agglomeration area. Option two appears as more favorable since it provides the advantage of being as "sufficiently concentrated" according to the Urban Waste Water Directive.

2.3. Policy Review

To contextualize the spatial findings within the regulatory framework, an in-depth review of the Urban Wastewater Treatment Directive is undertaken. The study examines the Directive's criteria concerning urban agglomeration sizes, wastewater volumes, and pollution thresholds. Documents and policy briefs from the European Commission, in conjunction with national guidelines, are analyzed to bridge the technical parameters with urban planning requirements. If the settlement grows in this direction, in a certain time it will become "sufficiently concentrated" and agglomeration boundaries should be reconsidered. If in a certain time the settlement will grow in one direction and become "sufficiently concentrated" the agglomeration boundaries should be reconsidered.

The integration of Geographic Information Systems (GIS) within a decision-support framework significantly en-hances urban sprawl monitoring and management in European cities, leading to improved land-use planning outcomes (Kalogiannidis et. al., 2025; Vardopoulos et al., 2023).

2.4. Field Validation

While remote sensing and secondary data provide a comprehensive overview, field visits and interviews with local planning authorities complement the collected data. Field validation involves site inspections to confirm infrastructural features and urban condition assessments. These qualitative insights ensure that the weight of local administrative experience is factored into the boundary delineation process.

Overall, the conjunction of GIS mapping, satellite imagery, demographic analysis, and policy reviews provides a multidimensional perspective on urban limits. This integrative approach not only ensures the technical soundness of the research but also enhances the practical applicability of the findings. The methodology section is designed to provide transparency and reproducibility, ensuring that future research can build upon this framework in both local and broader European contexts. The combination of advanced mapping techniques and methodical field validation represents a modern approach to addressing urban planning challenges in line with environmental directives (Marek et al., 2017). This detailed methodology provides a robust basis for delineation urban agglomerations, ensuring that the data and techniques used are both rigorous and aligned with the directive's requirements.

3. RESULTS AND DISCUSSIONS

The analysis of the Craiova agglomeration revealed several critical factors affecting both the delineation of the urban area and its wastewater management practices. The spatial assessment, underpinned by detailed map (Fig. 2), showed that the population density and land-use patterns form an irregular yet identifiable urban cluster. These patterns have direct implications on organic loading and the subsequent planning of wastewater treatment facilities.

Following the application of the methodology, Craiova agglomeration included the municipality of Craiova and the villages: Cernele, Popoveni, Șimnicu de Jos, Făcăi, Izvorul Rece, Cernelele de Sus, totaling 257,101 people equivalents.

The results from the quantitative analyses indicate that Craiova agglomeration exhibits a medium organic load concentration. Sources of organic pollutants were primarily identified from domestic, commercial, and light industrial discharges. Laboratory testing of wastewater samples consistently recorded biochemical oxygen demand (BOD) levels that do not surpass the normative thresholds prescribed by the Urban Wastewater Treatment Directive.

Field validation and in-depth inspections of the primary wastewater treatment facility in Craiova have shown that advanced tertiary treatment processes have been implemented to address these higher organic loads. The treatment plant utilizes a multi-stage process consisting of primary sedimentation, activated sludge systems, and advanced oxidation processes, which has contributed to a substantial reduction of BOD and Total Nitrogen and Total Phosphorus levels (Kardos et al., 2025). Performance monitoring reports indicate that the plant operates within the required efficiency margins mandated by the Wastewater Directive, achieving over 90% reduction in organic load under optimal operating conditions.

The wastewater treatment plant (WWTP) plays a crucial role in environmental conservation, along with well-established operational strategies. It can allow the removal of several pollutants from wastewater, such as organic matter, nitrogen and phosphorus, avoiding their negative impact on the environment. (Bassin et al., 2021; Smol et al., 2020).

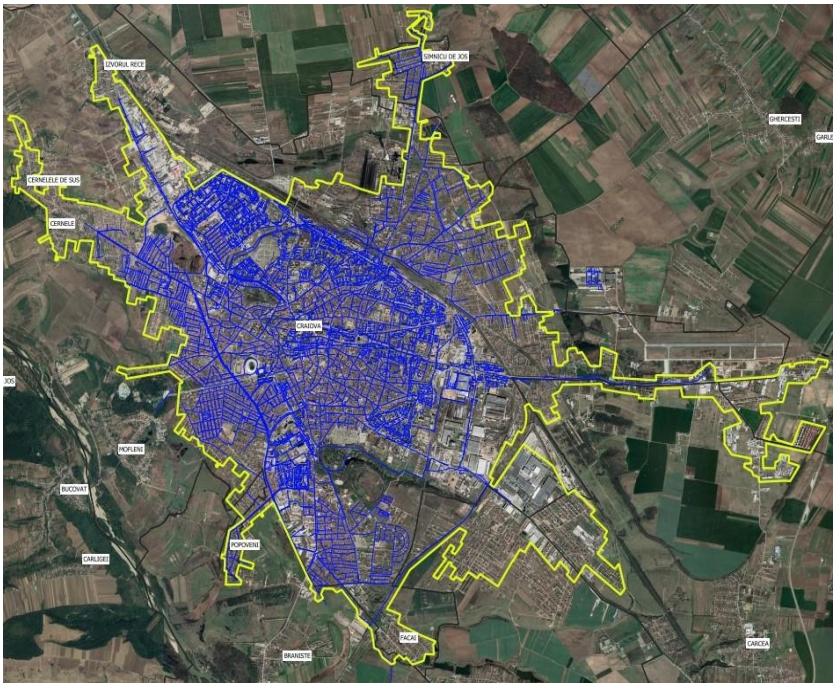


Fig. 2 Craiova agglomeration
Source: Jiu Water Basin Administration

After the commissioning of the treatment plant in 2011 was observed a decrease in the values of quality indicators discharged into surface waters (Table 1).

Several challenges remain, however. Although overall compliance with the directive is maintained, intermittent episodes of elevated organic load sometimes lead to transient exceedances of prescribed thresholds. The study discusses these variations in context, recognizing that fluctuating inflows, unexpected industrial discharges, and seasonal demographic changes may all compound the organic load (Fig. 3).

Table 1 Wastewater discharge from Craiova human agglomeration before and after the operation of the waste water treatment plant (WWTP)

Pollution indicator	Samples/ year	Concentration limit value (H.G. 352/2005)	Average concentration (mg/l) (2010)-without WWTP	Chemical load (t/year) (2010)-without WWTP	Average concentration (mg/l) (2024)-with WWTP	Chemical load (t/year) (2024)-with WWTP
TSS*	12	35	68.417	3,079.77	4.016	82.705
BOD	12	20	40.275	1,812.97	13.341	274.713
Total Nitrogen	12	10	17.31	779.2	4.682	96.424
Total Phosphorus	12	1	2.051	92.303	0.074	1.536

* total suspended solids
** biochemical oxygen demand

Source: Jiu Water Basin Administration

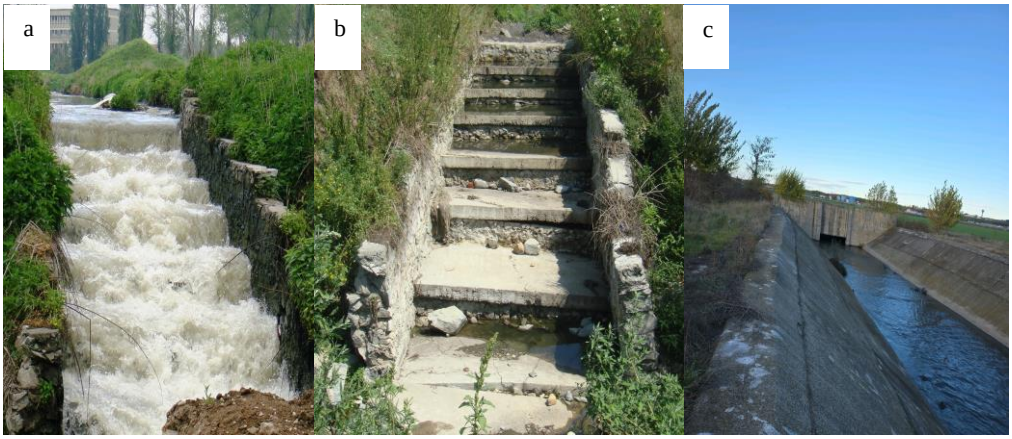


Fig. 3 Wastewater discharge points from Craiova agglomeration (a), (b) Craiovița channel - before WWTP and (c) the Jiu River, Işalnita-Malu Mare sector - after WWTP

Further discussion focuses on the dynamic relationship between urban growth and infrastructure capacity. Craiova wastewater treatment plant's adaptive measures such as the installation of remote monitoring sensors and real-time process adjustments demonstrate a proactive approach. These adaptations are

critical for maintaining compliance as the city's boundaries expand and the organic load intensifies. Moreover, ongoing policy reviews and updated engineering practices contribute to the continuous improvement of wastewater treatment efficiency. While Craiova agglomeration meets to a great extent the requirements of the Wastewater Treatment Directive, the study emphasizes the need for constant monitoring and infrastructure updates to mitigate the impacts of future urban expansion and potential increases in organic loading. Future research should focus on predictive modeling to better anticipate areas of risk and guide investments in upgrading urban wastewater treatment facilities.

4. CONCLUSIONS

The comprehensive analysis carried out in this study underscores the importance of precise delimitation of urban agglomerations, particularly for ensuring compliance with the Urban Wastewater Treatment Directive. The case study of the Craiova agglomeration has revealed several key insights that contribute to both academic understanding and practical urban management.

Firstly, the spatial delimitation of Craiova region has proved crucial in identifying areas of concentrated urban growth. Detailed maps developed from satellite imagery and census data have illustrated that the expansion of the urban area is not homogenous; rather, it is characterized by episodic, peripheral developments. This non-uniform expansion underlines the need for continuous, updated mapping to accurately reflect the evolving urban landscape. Recognizing these growth patterns is essential for local policymakers to allocate resources efficiently and plan for infrastructural enhancements.

The assessment of the organic load within the agglomeration has provided important indicators of environmental pressure on the urban wastewater treatment infrastructure. The organic load levels, particularly in areas with dense population clusters, call for an intensified focus on upgrading treatment processes. The study found that although the existing wastewater treatment plant meets several requirements stipulated in the directive, certain operational aspects need further optimization. These findings suggest that improvements in the treatment process could result in enhanced environmental outcomes and better compliance with EU standards (Popa et al., 2012).

Urban wastewater has a major and predominantly negative influence on aquatic ecosystems, leading to a series of physical, chemical, and biological changes. The consequences of improper discharge of this water can seriously affect the health of ecosystems and livelihoods that depend on water.

Finally, the study emphasizes the synergistic role of technological advancements and policy refinement. The integration of advanced spatial analysis tools with traditional environmental assessments has proven effective in pinpointing critical areas where targeted interventions are required. Additionally, the results highlight the importance of adopting a flexible regulatory framework that can adapt to the dynamic nature of urban growth and its associated environmental challenges.

Craiova agglomeration serves as a valuable example of how modern data collection, mapping techniques, and environmental assessments can guide sustainable urban development. The lessons learned from this study are not only applicable to Craiova, but also offer broader implications for other urban regions aiming to balance rapid growth with environmental compliance and public health safeguards.

In today's rapidly urbanizing world, the management of human settlements is crucial, particularly regarding wastewater treatment as mandated by the European Wastewater Directive. In this context, the Romanian environmental protection authorities have put into operation an online reporting platform that serves as an invaluable tool in ensuring compliance with these regulations (https://epurare-ape-uzate-urbane.rowater.ro).

The platform enhances transparency by allowing stakeholders—government agencies, municipalities, and citizens to access real-time data about wastewater management practices. This transparency fosters trust and accountability, as communities can see how their local authorities are performing in meeting compliance standards.

The platform is also used for data collection and reporting processes and facilitates timely updates and the submission of necessary documentation, ensuring that municipalities can swiftly address any compliance issues. This efficiency can lead to better allocation of resources and, ultimately, improve wastewater treatment infrastructure. Not in the least, the platform can serve as educational tools, raising awareness about the importance of proper wastewater management among citizens. By providing easy access to information about local practices and compliance statuses, communities are empowered to engage and influence their local governments.

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