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THE IMPACT OF WASTE ON PUBLIC HEALTH AS A DRIVER OF HEALTH CARE MANAGEMENT

Modern waste management systems are predominantly evaluated through environmental and economic criteria, while public health indicators remain insufficiently integrated despite their critical role in assessing system effectiveness. Inefficient waste disposal and treatment increase the risks of infectious, respiratory, oncological diseases and negatively affect mental well-being, as confirmed by WHO and World Bank data. This study substantiates the need for a medical-ecological paradigm in waste management based on the One Health concept and Health Impact Assessment (HIA). Using comparative analysis of international practices and global health indicators, the paper demonstrates a strong correlation between pollution-related mortality, economic development, and waste management quality. The results justify integrating public health indicators into waste management optimization models, particularly for countries undergoing environmental policy reforms such as Ukraine.

Keywords: *waste management, public health, medical-ecological approach, One Health, Health Impact Assessment (HIA), circular economy, sustainable development, public health indicators, waste management system.*

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ВПЛИВ ВІДХОДІВ НА ГРОМАДСЬКЕ ЗДОРОВ'Я ЯК ЧИННИК УПРАВЛІННЯ В СФЕРІ ОХОРОНИ ЗДОРОВ'Я

У статті розглянуто актуальну проблему обмеженого урахування показників громадського здоров'я в сучасних системах управління відходами, які традиційно орієнтовані переважно на екологічні та економічні критерії. Обґрунтовано, що неефективне поводження з відходами спричиняє зростання ризиків респіраторних, інфекційних та онкологічних захворювань, погіршення психоемоційного стану населення та формування додаткового тягаря хвороб, пов'язаних із забрудненням довкілля. На основі аналізу статистичних даних Всесвітньої організації охорони здоров'я, Світового банку та OECD показано, що рівень смертності, зумовленої забрудненням повітря, води та інфраструк-

турними дефіцитами у сфері поводження з відходами, тісно корелює з економічним розвитком країн і якістю екологічного менеджменту. Проведено кореляційний аналіз між рівнем доходів країн та смертністю від забруднення повітря, який засвідчив наявність дуже сильного прямого зв'язку між зазначеними показниками. У статті узагальнено зарубіжний досвід інтеграції медико-екологічних підходів до управління відходами на основі концепцій One Health та Health Impact Assessment, зокрема в практиках Нідерландів, Швеції, Канади, Японії та США. Доведено, що включення показників громадського здоров'я до процедур екологічної експертизи забезпечує перехід від реактивних до превентивних управлінських рішень і сприяє зниженню довгострокових соціально-економічних витрат. Обґрунтовано необхідність переходу України від лінійної моделі поводження з відходами до інтегрованої медико-екологічної парадигми управління. Запропоновано структурно-логічну модель оптимізації системи управління відходами з урахуванням екологічних, економічних та соціально-санітарних індикаторів, у якій показники громадського здоров'я розглядаються як ключовий критерій ефективності управлінських рішень в умовах сталого розвитку та євроінтеграції. Запропонована модель може бути використана як аналітичний інструмент для формування державної екологічної політики та обґрунтування управлінських рішень на національному й регіональному рівнях.

Ключові слова: *управління відходами, громадське здоров'я, медико-екологічний підхід, One Health (Єдине здоров'я), оцінка впливу на здоров'я (Health Impact Assessment, HIA), циркулярна економіка, сталий розвиток, індикатори громадського здоров'я, система управління відходами.*

Statement of the problem. Modern waste management systems worldwide and in Ukraine are predominantly shaped by environmental and economic efficiency criteria, while public health indicators remain secondary or only fragmentarily integrated into managerial decision-making processes. Such an approach does not allow for a comprehensive assessment of the actual social consequences of waste management systems, particularly their impact on morbidity, mortality, and overall quality of life.

The growing volumes of municipal solid and industrial waste, driven by urbanization, industrialization, and increasing consumption, intensify environmental pressures and generate additional risks to public health. Inefficient waste treatment and disposal lead to air, water, and soil pollution, which is associated with higher rates of respiratory, infectious, and oncological diseases, as well as adverse effects on the population's psycho-emotional well-being. International studies by the World Health Organization, the World Bank, and the OECD confirm a strong relationship between the quality of waste management, levels of economic development, and public health outcomes.

In the European Union, North America, and Asia, a gradual shift from a purely environmental approach toward a medical-ecological paradigm of waste management can be observed, based on the principles of One Health and the application of Health Impact Assessment (HIA). Integrating public health indicators into environmental assessment systems enables a transition from reactive responses to pollution consequences toward preventive risk management and the optimization of healthcare expenditures.

In Ukraine, the waste management system remains fragmented, with landfilling dominating as the primary waste treatment method and a lack of systematic linkage between environmental monitoring and public health data. Despite the existence of strategic documents aimed at aligning with European standards, in practice there is still an absence of a unified analytical framework that integrates environmental, economic, and medical-sanitary indicators. This limits the ability to comprehensively assess the effectiveness of managerial decisions and increases socio-economic risks.

Thus, a pressing scientific problem lies in the absence of an integrated structural and logical model of waste management that systematically incorporates public health indicators as a key criterion of effectiveness. Addressing this gap is a necessary prerequisite for improving environmental policy quality, ensuring sustainable development, and facilitating Ukraine's adaptation to international and European standards in the field of waste management.

Analysis of recent research and publications. In contemporary scientific research, waste management is predominantly addressed through approaches focused on environmental safety and economic efficiency, including the minimization of landfilling, the development of recycling, and the implementation of circular economy principles, as emphasized in analytical reports by the World Bank Group [1; 2]. At the same time, a number of studies emphasize that public health indicators remain insufficiently integrated into waste management performance assessment systems, despite their crucial role in reflecting the real social consequences of environmental decisions, as highlighted by experts from the WHO Regional Office for Europe [3; 4].

Analytical reports by the World Health Organization and the World Bank indicate that inefficient waste management leads to increased risks of infectious, respiratory, and oncological diseases, as well as adverse effects on the psycho-emotional well-being of the population, particularly in urbanized regions [3; 4]. According to World Bank estimates [1; 2], global annual municipal solid waste generation exceeds 2 billion tonnes and continues to grow, significantly increasing environmental pressures and associated health risks.

Studies conducted by WHO Europe emphasize that the transition to a circular economy in the field of waste management produces not only environmental benefits but also substantial health and economic effects, particularly through reducing the burden of diseases associated with air, water, and soil pollution [3; 4]. At the same time, the application of Health Impact Assessment (HIA) is highlighted as an effective tool for preventive risk management.

In the scientific literature of the European Union, considerable attention is devoted to the waste management hierarchy and the 3R concept (Reduce, Reuse, Recycle), enshrined in Directive 2008/98/EC [7; 8]. However, researchers including Kagström (2013) and contributors to the European Journal of Public Health note that traditional waste management models only partially account for the impact of pollution on public health, particularly through air and water contamination and psycho-emotional stress in areas surrounding landfill sites [8].

International experience from the Netherlands, Sweden, Canada, Japan, and the United States demonstrates a gradual shift from a purely environmental approach toward a medical-ecological paradigm of waste management based on the One Health concept and the systematic application of HIA, as shown in studies published in the European Journal of Public Health, as well as in works by Kagström, Health Canada, Suzuki, and Tanaka [7–11]. In particular, in Sweden and the Netherlands, HIA is a mandatory component of environmental impact assessments, while in Canada and the United States spatial approaches are actively used to analyze risks to populations living near waste management facilities [8; 9; 11]. Japanese studies, particularly those by Tanaka (2015), additionally emphasize the psycho-emotional consequences of waste management practices, thereby expanding the traditional boundaries of environmental analysis [10].

In Ukrainian scientific publications, waste management issues are mainly examined through the lens of environmental safety, institutional frameworks, and the achievement of sustainable development goals, as demonstrated in works by Roman [5]. Certain regional studies conducted by Kravchenko, Zhukov, and Chasovska reveal a direct relationship between inefficient waste disposal practices and increased population morbidity, particularly respiratory and infectious diseases [6]. However, most existing studies remain fragmented and do not propose comprehensive models for integrating environmental, economic, and medical-sanitary indicators.

International statistical studies by the World Bank confirm a strong relationship between countries' levels of economic development, the quality of environmental management, and mortality indicators associated with air and water pollution and inadequate sanitation [12–14]. At the same time, the scientific literature lacks sufficiently developed structural and logical models for optimizing waste management systems that would systematically incorporate these indicators into managerial decision-making processes.

The purpose of this study is to develop a scientifically grounded approach to optimizing the waste management system through the integration of public health indicators and the development of a structural and logical model aimed at enhancing environmental policy effectiveness, reducing risks to population health, and ensuring sustainable development.

The main material of the study. In Ukraine, a persistent accumulation of industrial waste is observed, which perpetuates reliance on traditional disposal methods and generates heightened risks for aquatic and soil ecosystems [5]. Regional studies confirm that inefficient waste management has already resulted in adverse public health outcomes, particularly manifested in increased incidence of respiratory and infectious diseases [6]. In this context, the need to transition to waste management models that, alongside economic and environmental efficiency, incorporate public health indicators becomes increasingly pressing, which is especially relevant for Ukraine in the context of European integration. Classical approaches to waste management are grounded in the 3R concept (Reduce, Reuse, Recycle) and the waste hierarchy enshrined in Directive 2008/98/EC, which prioritizes waste prevention, followed by reuse and recycling. Although these models aim to minimize environmental impacts and achieve economic efficiency, they only partially account for the effects of waste on population health through air, water, and soil pollution, as well as the psycho-emotional burden experienced in areas surrounding landfill sites. In the countries of Northern Europe, as well as in Canada, Japan, and the United States, a medico-environmental approach to waste management is being progressively implemented, based on the One Health concept and the systematic application of Health Impact Assessment (HIA). The practice of integrating medical, sanitary, and social indicators into environmental assessment processes demonstrates that such an approach facilitates a shift from reactive responses to preventive risk management for both environmental quality and public health, thereby substantiating the feasibility and relevance of its adaptation in Ukraine (Table 1).

International practice demonstrates diverse models for integrating Health Impact Assessment (HIA) into waste management systems. In Sweden and the Netherlands, HIA is applied systematically at the national level, whereas Canada and the United States primarily focus on spatial monitoring of public health risks in areas surrounding landfills and waste treatment facilities. Japan represents an innovative approach by incorporating psycho-emotional indicators into waste management frameworks, thereby broadening the interpretation of environmental impacts through the lens of population well-being.

A comparative analysis of these practices indicates that the integration of health and sanitary indicators into waste management systems not only enhances environmental performance but also yields long-term reductions in healthcare expenditures by decreasing the burden of pollution-related diseases. Such an approach appears particularly promising for Ukraine in the context of environmental policy reform and harmonization with European Union standards.

In Ukraine, the waste management system remains fragmented and predominantly disposal-oriented, with more than 90% of municipal solid waste being landfilled or dumped. In most regions, the lack of integration between environmental monitoring systems and public health surveillance hampers the identification of causal relationships between environmental pollution and morbidity levels.

Although the National Waste Management Strategy to 2030 envisages alignment with European standards, its effective implementation requires the establishment of an integrated environmental and health data system, the introduction of health risk indices in the planning of waste management facilities, and the development of quality-of-life indicators linked to environmental conditions.

Accordingly, Ukraine needs to shift from a linear waste management model toward an integrated medico-environmental system, in which public health indicators constitute a key criterion for assessing the effectiveness of managerial decisions.

The inclusion of public health indicators is essential, as they reflect the tangible social consequences of environmental risks and the overall effectiveness of state environmental policy. In this regard, the use of internationally recognized indicators provided by the World Bank (World Bank Open Data) [12], which are directly related to environmental quality and living conditions, is particularly appropriate.

Table 1

Integration of the One Health and Health Impact Assessment approaches into waste management systems in developed countries

No.	Country	Features of integrating the One Health / HIA approaches	Key health- and waste-related statistical indicators	Analytical relevance for the study
1	The Netherlands, [7]	Implementation of an intersectoral One Health approach through national environmental risk control programs. Health indicators are integrated into the environmental monitoring system.	Approximately 4% of the national burden of disease is attributable to environmental factors (over 175,000 DALYs from outdoor pollution and 25,000 DALYs from indoor pollution).	Demonstrates a high level of integration of environmental and health indicators within the national monitoring system.
2	Sweden, [8]	Mandatory consideration of health indicators within Environmental Impact Assessment (EIA) has been applied since the 1980s; since the 2000s, the Health Impact Assessment methodology has been actively developed.	Legislation requires the inclusion of human health impacts in all EIA reports; examples of integration include municipal waste recycling and bioenergy projects.	Serves as a European benchmark for an integrated approach to assessing the health impacts of waste management; may serve as a model for Ukraine.
3	Canada, [9]	Active application of HIA in waste management and risk governance. The link between environmental quality and public health is reflected in national Canadian Environmental Sustainability Indicators reports.	Annually: 10,000–25,000 deaths and 78,000–194,000 hospitalizations associated with exposure to environmental factors (air, water, waste).	Demonstrates the economic benefits of preventive, environmentally oriented policies; relevant for substantiating the implementation of HIA in Ukraine.
4	Japan, [10]	Systematic implementation of the One Health approach in urban planning and waste management. Advanced quantitative methods are used to assess the impact of waste handling on the physical and psycho-emotional health of workers.	Elevated stress levels and reduced heart rate variability have been identified among waste management workers. In addition, Tokyo's waste footprint exceeds the city's own consumption volume by a factor of 2.4.	Illustrates an innovative approach to assessing not only environmental but also socio-psychological impacts of waste management systems.
5	United States, [10]	Well-established practice of Environmental Health Assessments (EHA) and HIA at the municipal level, particularly within EPA programs. Health impacts of landfills, waste incineration, and hazardous waste are systematically assessed.	EPA studies (2020) indicate a 12–18% increase in respiratory disease prevalence among populations residing within a 3 km radius of landfill sites.	Confirms the necessity of spatial health risk analysis in planning waste management facilities.

Source: developed by the authors based on an analysis of the literature sources [7]–[10]

One of the key indicators is the mortality rate attributed to household and ambient air pollution (age-standardized per 100,000 population), which captures mortality associated with indoor and outdoor air pollution and correlates closely with concentrations of fine particulate matter ($PM_{2.5}$) and other airborne toxicants. Air pollution represents one of the leading environmental health risks; according to the World Health Organization, combined exposure to ambient and household air pollution accounts for approximately 7 million premature deaths annually, primarily due to cardiovascular and respiratory diseases.

The scaling of this indicator enables cross-country comparisons of the environmental health burden, ranging from very low levels characteristic of countries with stringent environmental standards to critically high levels observed in states with weak environmental regulation and heavy reliance on solid fuels. Spatial analysis reveals pronounced global inequalities: the lowest mortality rates are recorded in North America, Western Europe, and Oceania, while the highest rates occur in sub-Saharan Africa and parts of South Asia. Aggregate indicators by income group are presented in Table 2.

Data from the World Bank classification for 2019 (Table 2) indicate a clear relationship between air pollution–attributable mortality and the level of countries' economic development. The lowest values of this indicator are observed in high-income countries (7–25), reflecting effective resource management systems, robust environmental policies, and well-developed healthcare systems. Countries with upper-middle-income status exhibit moderate values (30–80), consistent with transitional pathways toward more sustainable development models.

In contrast, countries with middle- and lower-income levels show a substantial increase in the indicator (exceeding 100), pointing to structural deficiencies in waste management, limited effectiveness of environmental regulation, and heightened environmental vulnerability. Ukraine (78.9) is positioned at the boundary between the middle- and upper-middle-income groups, indicating a moderate level of management effectiveness and underscoring the need for further improvements in sanitation, environmental policy, and public health.

The highest values (>200) are recorded in the least developed countries, reflecting a profound crisis in environmental governance and the critical impact of pollution on population health. Overall, higher income levels are associated with lower environmentally attributable mortality, whereas the opposite trend is observed in low-income countries.

Correlation analysis between income level (1 = high, 6 = low) and air pollution–related mortality confirms

Table 2

Intermediate mortality indicators attributable to household and ambient air pollution (mortality rate attributed to household and ambient air pollution, per 100,000 population, 2019)

	Country	Indicator value	Value range and indicator characteristics
1	Finland	7,4	< 28.90. High-income countries demonstrate the lowest mortality rates, reflecting effective environmental policies, emission control, and well-developed healthcare systems.
2	Norway	7,9	
3	Canada	8,1	
4	Sweden	8,1	
5	Iceland	8,2	
6	Australia	9,8	
7	Portugal	10	
8	France	10	
9	Spain	10,1	
10	The Bahamas	10,4	
…	…	…	
42	Brazil	28,9	28.90 – 62.90. Moderate mortality level; influenced by urbanization and industrial emissions under partially effective state regulation.
43	Argentina	29,7	
44	Slovak Republic	30,3	
45	Croatia	31,3	
45	Colombia	31,3	
…	…	…	
76	Bulgaria	62,9	62.90 – 115.20. Elevated level; typical of countries with active industrial development and insufficient environmental regulation.
77	Morocco	66,6	
..	…	…	
90	Ukraine	**78,9**	
91	Kazakhstan	83,4	
…	…	…	
114	Montenegro	15,2	115.20 – 174.00. High mortality level; reflects substantial pollution pressure, poor air quality, and weak monitoring and sanitary control systems.
115	Fiji	118,7	
116	Kyrgyz Republic	124,9	
…	…	…	
	Least Developed Countries (UN classification)	176	> 174.00. The highest mortality level, indicating a critical state of environmental safety and limited access to healthcare, which amplifies the health impacts of air pollution.
	Heavily Indebted Poor Countries	181,9	
	Small Island Developing States (Pacific)	194,7	
	High-income countries	24,4	Differentiation of mortality levels across countries by income group [12]
	Upper-middle-income countries	78,3	
	Middle-income countries	114,1	
	Low- and middle-income countries	121,2	
	Lower-middle-income countries	148	
	Low-income countries	195,9	

Source: compiled by the authors based on World Bank data [12]

this relationship: the Pearson correlation coefficient equals 0.97, indicating a very strong positive correlation (Figure 1).

The decline in national income levels correlates with increased mortality from household and ambient air pollution, confirming the influence of a country's economic capacity on waste management quality, environmental conditions, and public health indicators. In highly developed countries (Finland, Canada, Sweden), mortality ranges from 7–10 per 100,000 population, whereas in low-income countries it exceeds 190 per 100,000. Mortality attributed to air pollution serves as a key medico-ecological indicator for optimizing waste management systems.

Another important indicator is $PM_{2.5}$ pollution, population exposed to levels exceeding WHO guidelines (%), which reflects the proportion of the population exposed to air pollution above WHO limits. Data from 2017 demonstrate global disparities: the lowest values (<28.9%) are observed in North America, Western and Northern Europe, and Australia; medium to high values (62.9–174%) are typical for South and West Asia and North Africa; critical levels (>174%) occur in Sub-Saharan Africa and South Asia. Ukraine falls into the high exposure category (115.2–174%), driven by industrial emissions, transport, use of solid fuels, and insufficient air purification systems.

Mortality rate attributed to unsafe water, unsafe sanitation, and lack of hygiene reflects deaths caused by poor water quality, inadequate sanitation, and insufficient waste management infrastructure. Data from 2019 indicate a correlation between income level and mortality: low mortality (<28.9 per 100,000) is characteristic of most countries in North America, Europe, and East Asia, while high rates (>115.2) are observed in Tropical Africa. In Ukraine, mortality due to water and sanitation remains relatively low (<28.9).

Solid waste generation characterizes the scale of waste production. In Ukraine, it amounts to approximately 250–300 kg per capita per year, corresponding to the global average for middle-income countries. Gaps in waste collection coverage may lead to underestimation of actual volumes.

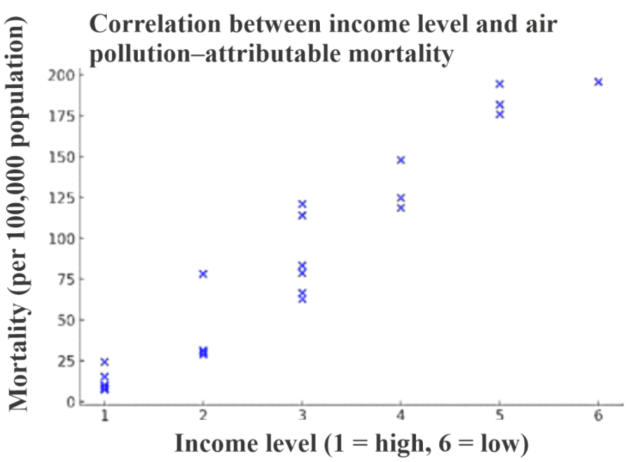

Fig. 1. Correlation between income level and air pollution–attributable mortality

Source: developed by the authors based on World Bank data [12]

Thus, high mortality associated with air and water pollution and ineffective waste management closely correlates with economic development levels and the quality of environmental management. Contemporary waste management approaches increasingly integrate environmental, economic, and public health aspects. These include: the sanitary-hygienic approach (risk factor control, monitoring), the ecosystem approach (One Health/Planetary Health), the eco-economic approach (Circular Economy), the spatial-analytical approach (GIS, HIA), and the integrated approach (ISWM).

Analysis indicates that existing models do not ensure full integration of environmental, social, economic, and medico-sanitary aspects. Key issues include limited preventive measures, weak integration of social and behavioral factors, absence of dynamic health risk monitoring, insufficient use of digital technologies, and inadequate adaptation to local conditions.

Therefore, it is advisable to develop a structured-logical model for optimizing waste management systems, integrating environmental, public health, economic, and socio-organizational aspects, ensuring scientific validity, preventive focus, and effectiveness of management decisions (Fig. 2).

The structural-logical model for optimizing the waste management system with consideration of public health indicators represents a comprehensive approach to integrating environmental, economic, social, and medico-sanitary aspects of managerial decision-making. The model is based on a phased analysis and includes an analytical block for assessing waste flows, environmental risks, and impacts on population health; the formation of an integrated indicator database; mathematical and spatial-analytical modeling; the development of management scenarios; as well as performance monitoring and a feedback mechanism.

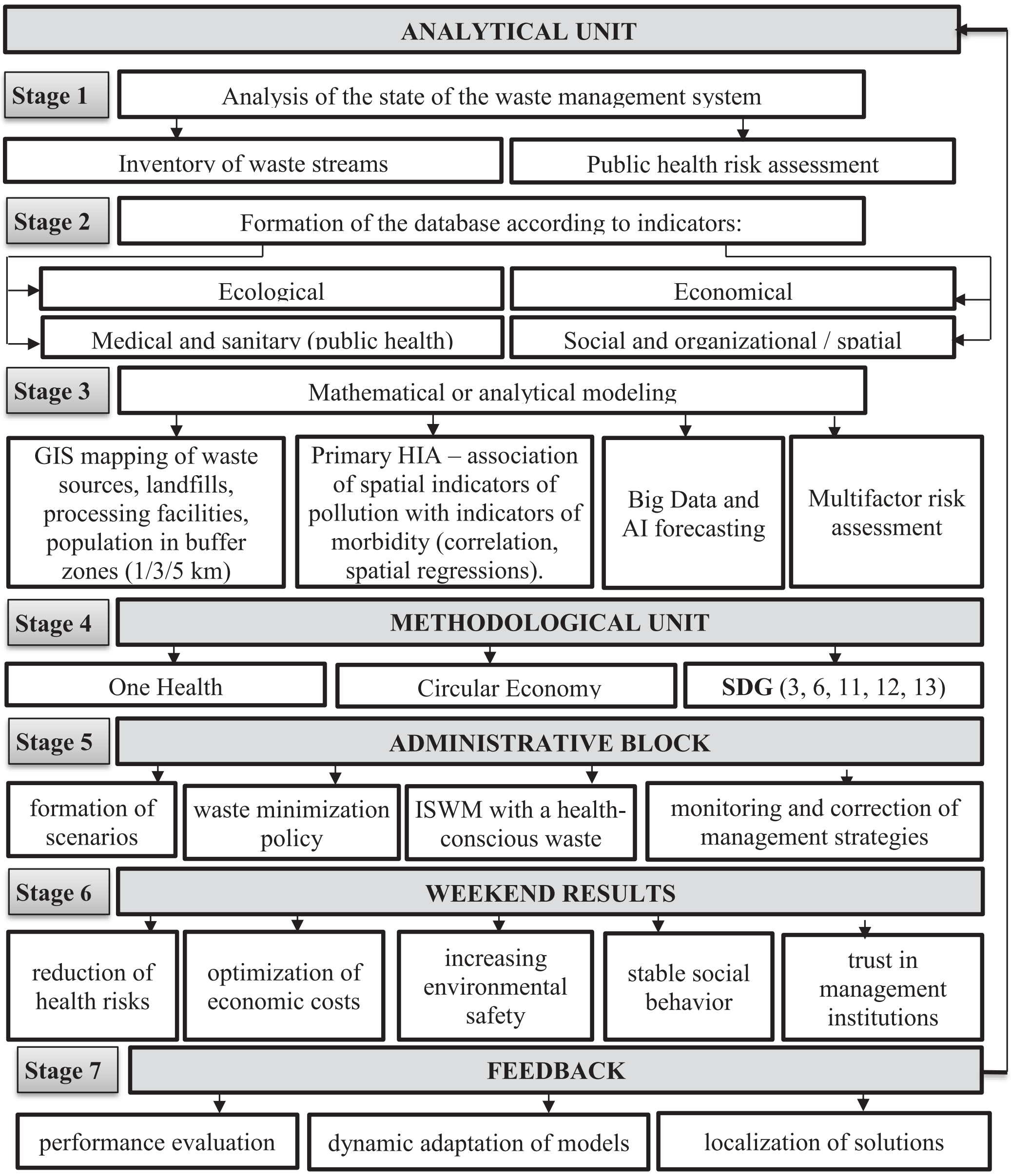

Fig. 2. Structural and logical diagram of the optimization of the waste management system taking into account public health indicators

Source: developed by the authors based on an analysis of the literature sources [7]–[10]

The analytical foundation of the model is built on a system of indicators encompassing environmental, economic, medico-ecological, and socio-organizational parameters. Key indicators include the volume of waste generation and recycling, landfill disposal rates, pollutant concentrations ($PM_{2.5}$, PM_{10}, NO_x, SO_2), mortality and morbidity rates associated with air and water pollution, expenditures on waste management and healthcare, accessibility of waste collection services, and spatial characteristics of infrastructure location. This indicator system enables a comprehensive assessment of the impact of waste management on the environment and public health.

The mathematical and analytical modeling stage incorporates GIS mapping, analysis of spatial correlations between pollution sources and health indicators, and the application of Big Data and artificial intelligence tools to forecast multifactorial risks. The methodological framework of the model is aligned with international concepts such as One Health, the Circular Economy, and the Sustainable Development Goals (SDGs 3, 6, 11, 12, and 13), ensuring consistency with contemporary European and global approaches.

The management block provides for the development of optimization scenarios, the implementation of the Integrated Solid Waste Management approach with due consideration of public health impacts, and continuous monitoring of policy effectiveness. Implementation of the model contributes to reducing public health risks, optimizing economic costs, enhancing environmental safety, and strengthening the resilience of the management system.

Comparative analysis indicates that Ukraine's waste management system is characterized by fragmented data and insufficient integration of public health indicators, which increases environmental and socio-economic risks. In contrast, EU and OECD countries apply comprehensive structural-logical models, digital monitoring tools, and incentive-based mechanisms. Therefore, it is advisable to introduce a unified information system, adapt European standards, integrate health risk assessment across all stages of waste management, and actively engage the public and business sector in system implementation.

Conclusions. The study confirms that waste management effectiveness should be assessed using public health indicators alongside environmental and economic criteria, as they best reflect the social impacts of environmental risks. WHO, World Bank, and national data reveal a strong link between waste management quality, economic development, and population morbidity and mortality. High-income countries demonstrate lower pollution-related mortality due to integrated waste management models, circular economy practices, and the use of Health Impact Assessment and the One Health approach, while countries such as Ukraine face higher exposure to environmental risks. A strong correlation between income level and mortality from air pollution highlights the role of economic capacity in effective environmental policy. Accordingly, air pollution–related mortality, $PM_{2.5}$ exposure, and mortality from unsafe water and sanitation are identified as key medico-environmental indicators. International practice shows a shift toward an integrated medico-environmental waste management paradigm supported by digital monitoring tools. For Ukraine, transitioning from a linear to an integrated medico-environmental model is essential to reduce environmental and public health risks and improve quality of life.

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