ISSN 2278-3091
Volume 11, No.6, November - December 2022
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse081162022.pdf
https://doi.org/10.30534/ijatcse/2022/081162022

GIS-technology of Water Drainage System (WDS) Modernization in Ukrainian City with Rugged Terrain

Victor Belogurov[1], Galina Fafurdinova[2]
[1]Emergency Rescue Service of Kharkiv, Kharkiv, Ukraine, ID ORCID: http://orcid.org/0000-0002-3425-205X
v.belogurov@gmail.com
[2]*Student of* O.M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine
fafurdinova@rambler.ru

Received Date: October 21, 2022 Accepted Date: November 25, 2022 Published Date: December 06, 2022

ABSTRACT

GIS-technology of water-drainage-system modernization in Ukrainian city with rugged terrain, has been developed. The directions of modernization municipal sanitary sewer system for carrying waste are proposed. These are: the decentralization of the drainage system (1), the use of local treatment facilities (2) and of higher aquatic vegetation for additional treatment (3). The transition from a pressure network to a non-pressure network is proposed to be carried out by replacing the sewage pumping station (SPS) with a local treatment plant. If necessary to increase the self-cleaning capacity of small rivers that receive domestic wastewater and storm drains with surface runoff, cascades of simple dams from bio fouling materials can be created on them. The 3D mathematico-cartographical model of the city houscommunal services has been developed, which allows making decisions based on geostatistical analysis. The suitability of model is checked by the RR criterion.

Key words: Sanitary sewer, Geostatistical-Analyst Module of ArcGIS Software, RR-criterion of Model Suitability, Mathematico-Cartographic(MC) modeling of houscommunal services, WDS-line with Local-Treatment-Plant & bioremediation & regulated-drainage.

1. INTRODUCTION

Municipal environmental problems are a complex of interrelated economic, ecological and social problems. This article discusses the issues of solving this problem based on the achievements of science about network systems, computer research, modeling and computational experiments, as well as spatial analysis based on geographic information systems (GIS) and GIS technologies.

The objects of this paper are sanitary savage systems, urban engineering networks and nature river network in the suburban area playing the role of a water receiver for urban wastewater and surface runoff from the urban area.

The purpose of the article is the GIS-technology develops to help solving real environmental problems in the Ukrainian city, where these problems are especially acute.

2. LITERATURE REVIEW

2.1 Theory and Practices of Engineering Pipeline Systems

The article based on Diploma by Galina Fafurdinova [1] abbot spatial analysis of the distribution of emergency situations on the sewage networks of the Krasnoarmeysk city (Donets region, Ukraine) with Geostatistical Analyst module of ArcGIS Software from Esri.com (Redlands, Ca, USA).

Chekurin's[authorId=6602558772] pipeline gas dynamics theory is presented in the works [2-4, 6-8] variation method for solving inverse problems in [5], Chekurin–Postolaki's method of nondestructive testing [9-11], Chekurin–Khymko's numerical model [12], a new criterion - in [13]. The work [8] on thermoelasticity-thermodynamic approach was get in Encyclopedia of Thermal Stresses and monograph was published in Springer, Cham. The most complete review of the works of Chekurin V.F. given in article [23]. New to trade of V.F. Chekurin multicriterial tasks are described in article [14].

The works of researchers from Kharkiv, Ukraine are known: Dyadun S.V.- about water supple [15] and control to aggregates of pumping stations [16, 17]; Tevyashev A.N. et all about stochastic model for a water supply network [18, 19], Information and Measurement System [20-22].

2.2 Criteria base of MC- modeling and MGDH-algorithms by Academic Ivakhnenko[autorId=7005548495]

The main criterion for mathematical-cartographic modeling is the RR-criterion for the reliability of models, proposed by the author in 1990 [24]. In [25], the legitimacy of this criterion - the Belogurov's RR-criterion - was confirmed by the citation "The suitability of the model is ensured by RR-criterion

formulated in compliance with the fundamental Idea of Academician A. N. Kolmogorov“[26]. This criterion also allows you to check the correctness of the input data, for example, as it was done in the article [27].
The RR criterion has found wide application in the works of the cybernetics pioneer Academician A.G. Ivakhnenko [28] and his colleagues [29, 30] on the application of MGDH algorithms.

2.3 Hybrid-modeling school by E.V. Bodyanskiy (MGDH with Neuro-Fuzzy Kolmogorov's network)

Head of the school E.V. Bodyanskiy[authorId=13105377000] and other researchers works in NURE Kharkiv, Ukraine.

This group includes those works by E.V. Bodyansky [31-34], which are closely related to the GMDH as a basic component of the hybrid approach. Since the creator of MGUA - A.G. Ivakhnenko - always emphasizes the importance of the RR criterion for filtering (culling) unreliable models (which had RR> 1 during testing), then a hybrid approach based on GMDH is the big chance to success. If only the set of models that leaked through the hard sieve of the RR-criterion were not empty, what is quite possible for forecast in the financial sector.

In the works of O.G. Rudenko [35-37] is attracted by a variety of approaches, that in the last work [35] led to the task to maximize the new criteria of correntropy.

3. SEWERAGE SYSTEM DEVELOPMENT FOR RUGGED CITY

This section discusses two types of engineering networks: water supply system and sanitary sewer system (or wastewater discharge). The possibilities of stochastic water management system are considered. Stochastic models of the water supply network allow you to identify hidden leaks and calculate their quantitative parameters [1]. It allows not only solving the problems of water supply, but also to the approach to reducing surface runoff from urban areas. A stochastic approach can solve all municipal environmental problems for cities located in a flat locality; however, in the conditions of a significant difference in the heights of the drainage system require additional efforts.

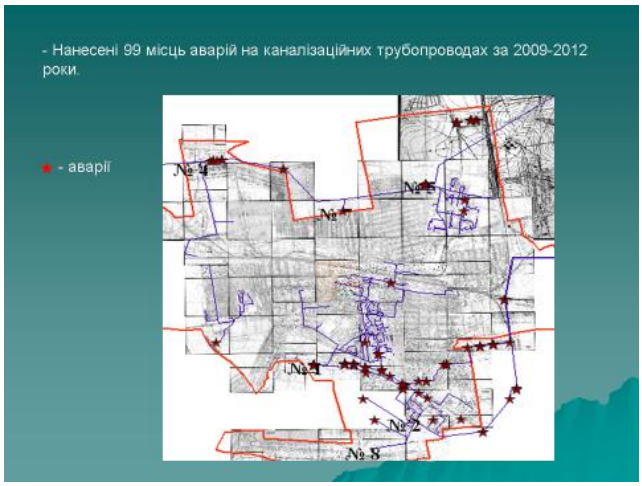


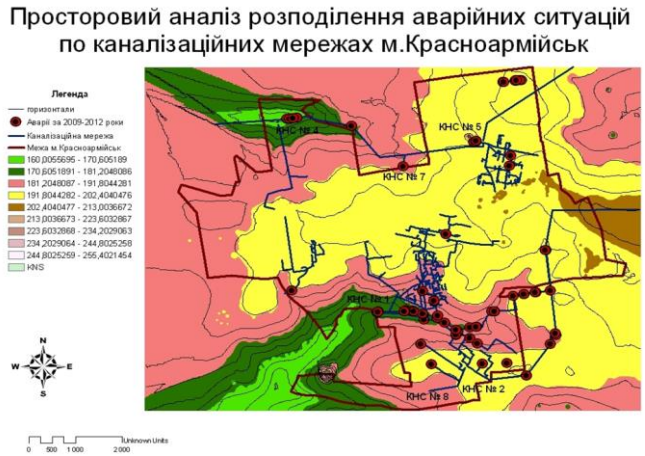
Figure 1: Geostatistical processing of cartographic and thematic data

Resulting map (Fig. 1) consists of layers: city boundaries M 1:2000, city boundaries of the CNS, river accidents, incident sites, numbers, statistics, description.

We offer innovative areas of modernization of engineering networks of urban wastewater. The basis for such modernization is invited to put 3 ideas. These are: decentralization of the sewer (drainage) system (1), the use of local wastewater treatment plants (LOS) (2) and the use of higher water vegetation (biotechnology) for the purification (3).

4. SPATIAL ANALYSIS OF EMERGENCIES IN THE KRASNOARMEYSK SEWERAGE NETWORK

In the diploma [1] it is carried out: Theoretical review of the possibilities of using GIS tools for spatial analysis of sewer network failures (1); Analysis of the distribution of emergencies on the territory (2); Analysis of the distribution of



emergencies in relation to the terrain (3). The resulting map is shown in Fig.2.

Figure 2: Resulting map for spatial analysis of the distribution of emergencies in sewerage networks of the city

In the course of the work [1], 95 (!!!) maps (usually no more than 10) at a scale of 1: 2000 and 9 maps at a scale of 1:10 000 were geo-anchored; as well as 6,507 (usually hundreds) elevation marks. It should be noted the creative approach and special care, scrupulousness and integrity of the thesis by Galina Fafurdinova, which she defended with a grade of "Excellent". Her work deserves to be replicated for other cities in Ukraine.

Spatial analysis of the distribution of emergencies in sewerage networks (Fig. 1) revealed that most accidents occur on sewer pipelines, which are served by KNS № 1. The calculation with GIS shows that the reconstruction of KNS № 1 will prevent more than 60% of accidents on pipelines.

5. CREATION OF A DECENTRALIZED-CONTROLLED WATER-PROTECTION TREATMENT COMPLEX

The idea of "decentralization" arose as a result of the analysis of the estimated graphic task, performed by students of the specialty "GIS and GIS-Technology" L for Lysichansk (Donetsk region, Ukraine). The "technical task" was developed on the modernization of the Lysichansk wastewater drainage system, which was already included in LTP and The Biotechnology, which was inspired by the ideas of bioremediation (Bioremediation). However, the "technical task" was not implemented "due to lack of funding".

Table 1: Values of pollutants

Wastewater treatment technology	Suspen-ded solids	BOD	COD	Ammonia	Surfactants	Phos-phates
Traditional	62,6	58,8	61,6	38,4	42,1	24,1
Bio-plato	76,5	92,0	83,3	51,4	64,6	33,0

The degree of purification has improved significantly (see data in Table 1). These data confirm the thesis that there is no alternative to the use of bio-Plato for wastewater treatment of residential and communal facilities in urban areas.

The main advantages of the bio-Plato technology are low cost, no need for electricity, ease of construction and the practical absence of the need to maintain operating personnel.

It is possible to reduce the accident rate of the drainage system if you install a local VOC treatment plant in the KNS building №1 instead of a pump and discharge wastewater from pipelines, for example due to bio plateau technology.

Basic result of sections 2-4. The created GIS technology can be used by any end user who knows how to develop mathematico-cartographic models (MC-models) with Geostatistical Analyst module of ArcGIS Software.

ArcSWAT technology [38] is suitable for integrated soil-water modeling. A special place is occupied by article [39], in which strict reviewers taught the author to seek and find nature-like technologies for solving any problem. Biotechnology is an indispensable component of success in solving real complex problems.

The implementation of our recommendations will ensure the absence of extremely high levels of water pollution in the Poltva River (which now occur regularly) with a given probability of the impossibility of an event KZ = 10 [40].

6. CONCLUSION AND RECOMENDATIONS

1. Considering that the solution to the problem of the city of Lviv has already been proposed earlier at the state level (funding was allocated, but the money did not reach the Lviv city), we now propose to first carry out only the modernization of the sewerage system in the Lviv same way as described in sections 2-4 for the city of Krasnoarmeysk (Donetsk region, Ukraine). Such work can be performed by a non-governmental organization (NGO) Emergency Rescue Service (ERS) of Kharkov, which owns GIS-technologies, has the necessary forces and means, as well as experience in performing engineering and technical work to solve Emergency environmental problems on the rivers of the Kharkov region (Ukraine).

2. The most acute municipal problem in Ukraine is the pollution of the Poltva River, where environmental emergencies regularly occur, caused by the discharge of wastewater of the Lviv.

3. Decentralized regulated sewerage and wastewater discharge of Lviv city with the use of higher aquatic vegetation for additional treatment of surface runoff will significantly improve the water quality in the Poltva River and prevent the resulting pollution of the adjacent sections of the Bug-Vistula basin in Belarus and Poland.

It should be noted the surprising results that were achieved by ResearchGate when searching for scientific publications citing the seemingly "long-forgotten" article by Belogurov V.P., 1990 [24]. The final list includes 3 works by Academician A.G. Ivakhnenko with authors Ivakhnenko G.A. [41], Müller (Germany) [42], Savchenko Ye.A., and Wunsh D.(USA) [28] and well-known researchers: Amalia Foka (Greece) [29], Pappas St.Sp., and Economou I. (Greece) [43], Pavel Kordic (Czech Republic) [44], Angel Marchev and Milena Piryankova (Bulgaria) [45].

Taking into account that 2023 marks the 110th anniversary of the birth of Academician A.G. Ivakhnenko, as well as a wide range of studies in many countries of the world associated with his name, to the organizers of the CSIT 2023 conference are recommended to dedicate to this event, for example, one of the sections of the conference that will take place in Ukraine, where the MATR of GMDH was born and worked all his life.

The importance of citing of Academician A.G.Ivakhnenko works in 1994-2002 requires additional citation of modern papers on this work topic. These include the latest "with GIS" papers from KhNUMG (Kharkiv, Ukraine) [46, 47].

And finally, special attention should be paid to the work by A.S. Chaudhuri [48], where reference [112] cites Belogurov's article [24], which is now well known in the world.

REFERENCES

1. Fafurdinova G.M. ***ДИПЛОМ за темою: Просторовий аналіз розподілення аварійних ситуацій на каналізаційних мережах міста Красноармійськ,*** Kharkiv, 2013 // ***Diploma by topic:Spatial analysis of the distribution of emergency situations on the sewage networks of the city of Krasnoarmiysk***, Kharkiv, Ukraine, 2013 (in ukrainian)

2. V. F. Chekurin. **A variational method for solving direct and inverse problems of the theory of elasticity for semiinfinite strip,** *Izv. Ross. Akad. Nauk. Mekh. Tverd. Tela*, No. 2, pp. 58–70 (1999); English translation: *Mech. Solids*, 34, No. 2, pp. 49–59 (1999).
3. V. F. Chekurin. **An approach to solving the stress state tomography problems of elastic solids with inconsistent strains,** *Izv. Ross. Akad. Nauk. Mekh. Tverd. Tela*, No. 6, pp. 38–48 (2000); English translation: *Mech. Solids*, 35, No. 6, pp. 29–37 (2000).
4. V. F. Chekurin. **Inverse problem of nondestructive control of the level of hardening of sheet glass,** *Izv. Ross. Akad. Nauk. Mekh. Tverd. Tela*, No. 3, pp. 86–97 (1998); English translation: *Mech. Solids*, 33, No. 3, pp.68–77 (1998).
5. V. F. Chekurin. **Variational method for the solution of the problems of tomography of the stressed state of solids,** *Fiz.-Khim. Mekh. Mater.*, 35, No. 5, pp. 23–32 (1999); English translation: *Mater. Sci.*, 35, No. 5, pp.623–633 (1999; https://doi.org/10.1007/ BF02359348).
6. Stel'makh O.B., Chekurin V.F. **Relaxation en surface de l'énergie et effet Benedix dans lessemiconducteurs.** *Fizika i tehnika poluprovodnikov* 22 (9), pp.1698-1699. (1988).
7. Chekurin V.F. **Thermoelasticity of semiconductors: the many-continuum thermodynamic approach.** *Encyclopedia of Thermal Stresses*, Springer, Berlin 11, pp.5844-5858. (2014).
8. Chekurin V., Kushnir R., Ponomarev Y., Prytula M., Khymko O. (2021) **A Model of a System for GasTransmission Pipeline Integrity Monitoring.** In: Bolzon G., Gabetta G., Nykyforchyn H. (eds) *Degradation Assessment and Failure Prevention of Pipeline Systems.* Lecture Notes in Civil Engineering, vol 102. Springer, Cham.
9. Chekurin V. F., Postolaki L. I. **A variational method for the solution of biharmonic problems for a rectangular domain.** *Journal of Mathematical Sciences*, 160 (3), pp.386–399. (2009).
10. Chekurin V. F., Postolaki L. I. **A variational method of homogeneous solutions for axisymmetric elasticity problems for cylinder.** *Mathematical Modeling and Computing*, 2(2), pp. 128–139. (2015).
11. Chekurin V., Postolaki L. **Application of the Least Squares Method in Axisymmetric Biharmonic Problems.** *Mathematical Problems in Engineering*, (2016). 2016, 345764.
12. Chekurin V., Khymko O. **Mathematical modeling of a small pressure disturbance in gas flow of a long pipeline.** *Mathematical Modeling and Computing*, 2017, 4(2), pp. 126–138.
13. Chekurin V., Khymko O. **Numerical modeling transient processes in a longgas pipeline.** *Math. Model. Comput.* 6(2) pp.220–238 (2019).
14. Dudykevych V., Prokopyshyn I., Chekurin V., Opirskyy I., L a k h Yu., Kret T., Ivanchenko Ye., Ivanchenko I. **A multicriterial analysis of the efficiency of conservative information securitysystems.** *Eastern-European Journal of Enterprise Technologies* ISSN 1729-3774 3/9 (99) 2019.
15. Dyadun S. **Information technologies to estimation the effectiveness of water supply systems control depending on the degree of model uncertainty.** *CEUR Workshop Proceedings*, 2020, 2740, pp. 137–145 (2020).
16. Kuznetsov V., Dyadun S., Esilevsky V. **The control to aggregates of pumping stations using a regulator based on a neural network with fuzzy logic** // *E3S Web of Conferences*, 2019, 102, 03007. – 2019.
17. Yesilevskyi V., Dyadun S., Kuznetsov V**. ISTM networks for anaerobic digester control** / *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, 2019(5), pp. 130–136. 2019.
18. Tevyashev A., Matviyenko O., Nikitenko G. **Construction of a stochastic model for a water supply network with hidden leaks and a method for detecting and calculating the leaks** // *Eastern-European Journal of Enterprise Technologies*, 6(4-102), 2019. Pp. 29–38.
19. Tevyashev A., Matviyenko O. **The mathematical model and the method of optimal stochastic control over the modes of the water main operation** // *Eastern-European Journal of Enterprise Technologies*, 6(4), 2015. Pp. 45–53.
20. Karpukhin A., Tevyashev A., Tkachenko V. **Designing of optimal infocommunication system** // *3rd International Scientific-Practical Conference Problems of Infocommunications Science and Technology*, PIC S and T 2016 - Proceedings, 2017. Pp. 5–7, 7905319.
21. Shostko I., Tevyashev A., Neofitnyi M., Ageyev D., Gulak S. **Information and Measurement System Based on Wireless Sensory** // *2018 International Scientific-Practical Conference on Problems of Infocommunications Science and Technology*, PIC S and T 2018 - Proceedings, 2019. Pp. 705–710, 8632084.
22. Tevyashev A., Shostko I., Neofitnyi M., Koliadin A. **Laser Opto-Electronic Airspace Monitoring System in the Visible and Infrared Ranges** // *2019 IEEE 5th International Conference Actual Problems of Unmanned Aerial Vehicles Developments*, APUAVD. - Proceedings, 2019, pp. 170–173. 894388.
23. Belogurov V.P., Kosolapov S.V. **In memory of V.F. Chekurin.** *Mathematical modeling and computing*, V.9, No.2, pp.303-310 (2022).
24. Belogurov V.P. **Criterion of model suitability for forecasting quantitative processes.** (1990) *Soviet journal of automation and information sciences*, English translation of *Avtomatyka* 23(3), pp. 21-25. (1990).
25. Belogurov V.P. **Risk zones assessment from tailings dam break with GIS.** *Eurasian Mining*. 2021. No. 2. Pp.74-81 (2021).
26. Kolmogorov A. N. **Theory of information transfer.** *Report. Plenary Session of the USSR Academy of Sciences*. Moscow:Izdatelstvo AN SSSR, 1956.
27. Bilogurov V.P., Nagorna G.A. **Model of background water quality for the regulation of skid standards** / *Eastern European Journal of Advanced*

Technologies. ISSN: 1729-3774. – 2011, V. 2, No. 6 (50), pp. 46–49. (2011).

28. Ivakhnenko A.G., Ivakhnenko G.A., Savchenko E.A. and Wunsh D. **Problems of Further Development of GMDH Algorithms: Part 2. Pattern Recognition and Image Analysis**, Vol. 12, No. 1, 2002, pp. 6–18.
29. Amalia Foka. ***Time Series Prediction Using Evolving Polynomial Neural Networks***. A dissertation submitted to the University of Manchester Institute of Science and Technology for the degree of MSc. 1999.
30. Liatsis P., Foka A., Goulermas J.Y., Mandic L. **Adaptive polynomial neural networks for times series forecasting.** *Proceedings Elmar - International Symposium Electronics in Marine*, 2007, pp. 35–39, 4418795 (2007).
31. Bodyanskiy Y., Boiko O., Zaychenko Y., Hamidov G., Zelikman A. **The Hybrid GMDH-Neo-fuzzy Neural Network in Forecasting Problems in Financial Sphere.** *2020 IEEE knd International Conference o) n System Analysis and Intelligent Computing, SAIC*.
32. Bodyanskiy Ye., Vynokurova O. and Teslenko N. **Cascade GMDH-wavelet-neuro-fuzzy network.** *Proc. 4th Int. Workshop on Inductive Modeling «IWIM 2011»*, pp. 22-30, 2011.
33. Bodyanskiy Ye., Teslenko N. and Grimm P. **Hybrid evolving neural network using kernel activation functions.** *Proc. 17th Zittau East-WestFuzzy Colloquium*, pp. 39-46, 2010.
34. Bodyanskiy Ye., Vynokurova O. and Pliss I. **Hybrid GMDH-neural network of computational intelligence.** *Proc. 3rd Int. Workshop on Inductive Modeling*, pp.100-107, 2009.
35. Rudenko O., Bezsonov O., Borysenko V., Borysenko T., Lyashenko S. **Developing a multi-step decurrent algorithm to maximize the criteria of correntropy.** *Eastern-European Journal of Enterprise Technologies*, 2021, 1(4), pp. 109-115. (2021).
36. Rudenko O.G., Bezsonov A.A., Liashenko A.S., Sunna R.A. **Approximation of Gaussian basis functions in the problem of adaptive control of nonlinear objects.** *Cybernetics and Systems Analysis*, 2011, 47(1), pp. 1–10.
37. Bezsonov O., Ilyunin O., Kaldybaeva B., Shamraev A., Zorenko V. **Resource and energy saving neural network-based control approach for continuous carbon steel pickling process.** *Journal of Sustainable Development of Energy, Water and Environment Systems*, 2019, 7(2), pp. 275–292 (2019).
38. Belogurov V.P., Tyurin A.V. **Modeling the ecological state of the Seversky Donets River using the ARCSWAT GIS technology** // *Eastern-European Journal of Advanced Technologies* ISSN 1729-3774, V.3, No.2(69), pp.19-22. 2014.
39. Belogurov V.P. **Development methodology generalized evaluation of environmental state regions.** *Eastern-European Journal of Enterprise Technologies*, 2014, 5(10), pp. 51–56.2014.
40. Belogurov V.P., Baklanova V.Yu. **Application of the pollution coefficient to assess the state of water bodies.** *Technological audit and production reserves.* 2015. Vol.1. No.4(21). pp. 17-19. URL: http: //elibrary.ru/item.asp?id=22967992.
41. Ivakhnenko A.G., Ivakhnenko G.A. **A comparison of discrete and continuous recognition systems.** *Pattern Recognition and Image Analysis*. 1996. Vol. 6. № 3 pp. 445-447.
42. Ivakhnenko A.G., Ivakhnenko G.A., and Müller J.-A. **Self-organization of Neural Networks with Active Neurons.** *Pattern Recognition and Image Analysis*, 1994, vol. 4, no. 2, pp. 185–196.
43. Pappas St.Sp., Ekonomou L. (2006). **Comparison of artificial intelligence methods for predicting the time series problem.** *Conf. Paper/H2020 FLEXITRANSTORE View project* (2006).
44. Pavel Kordík. **Fully Automated Knowledge Extraction using Group of Adaptive Models Evolution.** Thesis Czech Technical University in Prague. 2014 URL: http://www.researchgate.net/publication/223462932.
45. Marchev Angel, Piryankova Milena. **Evolution of the Concept of Self-Organization by the Founding Fathers of AI**. *(2022) 10th International Scientific Conference IEEE Evolution of the Concept of Self-Organization by the Founding Fathers of AI*. Page 1 978-1-6654-9777-0/22.
46. Kukhar M.A., Kasyanov V.V., Shuldiner J.V., Maliavin A.N., Voronkov O.A. **Formation of geoinformation provision elements of railway networks for logistic transportation management.** *IOP Conference Series: Materials Science and Engineering*, 2019, 708(1), 012012.
47. Pomortseva O., Kobzan S., Yevdokimov A., Kukhar M. (2020). **Use of geoinformation systems in environmental monitoring.** *E3S Web of Conferences*, 2020, 166, 01002.
48. Chaudhuri A.S. **A Review of Cybernetics in Modeling in Financial Engineering.** Fellow, 2006. Indian Institute of Advanced Study Rashtrapati Nivas Shimla 171 005. 2006, 78pp