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PhD STUDENT

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RESEARCHES REGARDING THE EVOLUTION, MAGNITUDE AND COMPLEXITY OF THE IMPACT GENERATED BY THE ECONOMIC ACTIVITIES ON THE EAST JIU RIVER

- SUMMARY -

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„The thing the ecologically illiterate don't realize about an ecosystem," Kynes said, "is that it's a system. A system! A system maintains a certain fluid stability that can be destroyed by a misstep in just one niche. A system has order, a flowing from point to point. If something dams that flow, order collapses. The untrained might miss that collapse until it was too late.

That's why the highest function of ecology is

the understanding of consequences"

Frank Herbert, Dune

[1]*Pardot Kynes, First Planetologist of Arrakis*

CONTENT

INTRODUCTION

Water is an abiotic environment factor, which conditions the maintenance and development of life on Earth, being present in all layers (reservoirs) of the Earth: atmosphere, biosphere, hydrosphere and lithosphere. The most precious category of waters is represented by fresh, liquid waters, which represent only 0.036% of the total water existing on Earth (1,385 million km^3). On continents, freshwater sources are unevenly distributed, so about 30% on the land surface has permanent difficulties in providing water.

Human beings and the environment conditions are inseparable entities, the existence of humans on Earth being environmentally dependent, and environmental factors (air, water, soil) can change over time as a result of anthropogenic interventions. Thus, pollution occurs, implicit and inevitable aspect of contemporary society, in which some products or services resulting from economic activities become residues that can disturb functioning and evolution of ecosystems, depending on their nature and quantity.

Environmental pollution (alteration, degradation, deterioration of environmental factors' quality under the influence of polluting substances) is a consequence of production industries using imperfect technologies, which remain, still, wasteful with raw materials and energy, and removal of pollution is a problem of correcting the errors that cause it.

Vulnerability of water bodies should be considered as a relative, anisotropic and dimensionless property, which depends in particular on the degree of exposure to anthropogenic pressures. Given the high vulnerability of freshwater resources, international conferences and debates are organised, on the sustainable development of society, the management and use of water resources so that they are kept healthy, productive, safe, secure and resilient.

The United Nations Conference on the Environment in Stockholm in June 1972 recognized for the first time, from an international legislative point of view, the interdependence of social, technological, economic and environmental issues. Based on this truth, the concept and strategy of sustainable development were, in which ecology plays the role of a true foundation.

The importance of sustainable development is accentuated and developed by the intermingling of ideas and by numerous struggles won over time by the environment, at international conferences organised on environmental issues: the Bern Convention (1979), the Rio de Janeiro Conference (1992), the Johannesburg Conference (2002), the United Nations (UN) conference in Paris (2015).

Alarm signals regarding global drinking water resources come from the United Nations, which particularly addresses multilateral forums and major world partners, announcing the danger of a possible global crisis of drinking water. UN warns, in worldwide, regional conferences and negotiations, about a potential loss of potable water up to 40% by the end of 2030, in the context where the need for water resources is expecting to increase up to 55% in 2050.

Also, because of global population growth, by 2050, agriculture must produce 60% more food worldwide than at present, and in developing countries, production must double. From an industrial point of view, it is estimated that from 2000 to 2050, the increase in water demand would be up to 400%. To this end, strategies have been developed at global and European Union (EU) levels to stimulate sustainable and inclusive blue growth, thus introducing aspects of the blue economy (natural resources, energy, trade, development and security) into foreign policies. Regional strategies have also been developed to address common challenges and capitalise on current opportunities, working closely with civil society and the public and private sectors.

Pollution of natural water resources creates synergistic effects, which are manifested on local aquatic ecosystems and extend continuously in time and space, generating cumulative effects on other surface and underground water bodies with which they interact or have continuity.

Synergistic effects caused by natural water pollution can directly affect biological diversity, defined as the abundance of living entities in water resources. The biological diversity is represented by all species of plants, animals and microorganisms, genes they contain, interactions and complexity of interactions that the aquatic ecosystems form in the biological environment.

The aquatic environment, represented by all aquatic ecosystems, developed over millions of years, began to be affected and sometimes destroyed by anthropic activities. A large number of species suffer a rapid decline, some being close to the point where their extinction begins, as a direct result of destruction of habitats, overfishing, predators or competitors deliberately introduced by humans. One of the main enemies of biodiversity is poverty, and the degree of biodiversity protection can be improved by raising the standard of living and fighting against the underdevelopment of modern society. Moreover, the pollution of the aquatic environment can have a disproportionate and adverse effect on the poor, indigenous and marginalised populations, because of the general state of health, higher potential exposures and the reduced resilience to social, environmental and economic risk.

The level of understanding and knowledge of ecological decisions by the public is relatively low, and executive decision-making is at risk through the misunderstanding of environmental issues, without knowledge of essential data and functions of terrestrial and aquatic ecosystems. Many "legends" regarding the tasks of terrestrial and marine

ecosystems developed over the years, both in the general public sector and among environmental specialists. The functions of forests related to the aquatic environment are a clear example, assuming that forests are beneficial to marine ecosystems and nevertheless, for water resources, and based on direct observations, it has been proved that they are strictly related to soil degradation through massive deforestation and soil conservation and rehabilitation through afforestation.

Through logical correlation of terrestrial ecosystems, urbanised areas and aquatic ecosystems, a united image must be developed. Such a model might be essential, as a basis for conducting an in-depth dialogue between stakeholders, environmentalists and water managers. Shortly, as much as possible emphasis should be placed on information campaigns, public involvement and education in the attempt to disseminate the knowledge obtained.

Most anthropic activities consume and pollute water resources, and flowing waters are the most exposed. Their vulnerability is higher in the case of rivers and their tributaries in the mountain areas, with smaller dimensions and flows, which shelter ecosystems sensitive to any form of pollution. To identify protection measures for water resources and aquatic and riparian biodiversity, it is necessary to know and analyse the impact exerted by different anthropic actions, as well as to determine their extension (in time and space), complexity and magnitude.

PURPOSE OF THE THESIS AND RESEARCH METHODOLOGY

The hydrosphere is an essential factor for the existence of life and the development of modern human society; therefore, protection of freshwater resources and implicitly of aquatic ecosystems is, in the context of contemporary economic development, a challenge for both the present and future generations.

The novelty of the topic studied is the global approach to the concept of sustainable development (Agenda 2030), adopted at the General Meeting of the United Nations (UN) in New York in 2015. The 2030 Agenda directions of action are oriented towards ensuring availability, sustainable management of water resources and water quality conditions for all users, as well as towards protection of the aquatic environment and implicitly water resources.

Primary purpose of the PhD thesis is to analyse the impact generated by economic activities in the eastern part of Jiu Valley, to establish the spatial-temporal extension of the impact they generate, as well as to determine magnitude and complexity of the impact generated by pollution of the aquatic environment on the local aquatic ecosystems and population.

The main objectives set for solving the research on the chosen topic are:

- Detailed knowledge of the East Jiu River basin;
- Research on the fish species present in the river basin;
- Study of the mechanisms generating pollutants in the river basin;
- Characterization of waters from the physical-chemical and ecological point of view and their monitoring;
- Analysis of the impact generated by each economic activity;
- Analysis of pollutants' dispersion in the East Jiu River basin;
- Impact assessment;
- Establishing technical solutions for water body protection.

In order to achieve the set objectives, the research uses hydrogeological research methods based on stationary observations, with a specific frequency, in the hydrometric stations placed along the East Jiu River basin. The samples taken with a quarterly rate in the sampling sections were analysed in the laboratory, in order to collect experimental and observation data. Based on in situ analysis of the hydrographic basin and on interpretation of results obtained from samples taken, the quality of the aquatic environment was described and protective measures of the Eastern Jiu River were developed.

The longitudinal statistical methods were used to simulate pollutants' dispersion in the aquatic environment, to estimate the extent of the impact in the East Jiu River basin.

Analytical tools were used to validate the computational model, which confers more accuracy and rigor in scientific research.

Cross-sectional analyses were used to analyse the impact generated by each economic activity carried out in eastern Jiu Valley.

Estimating the degree of complexity and magnitude of the impact generated by anthropic activities implied, in an early stage, the use of the Delphi method of consulting field specialists, followed by reference to hypotheses based on analyses and complex interpretations of the studied bibliography.

All research methods used to carry out the doctoral thesis entitled "Research regarding the evolution, magnitude and complexity of the impact generated by economic activities on the East Jiu River" are materialized by a top-down approach, typology based on abiotic descriptive parameters, factors supposed to be in indirect relation with different biological communities (cause-effect relationship) and with degradation of water quality.

SUMMARY

Permanent development of modern society, based on the consumption of goods and services, leads to the increase of the obligation of economic agents to face the demands of the market by increasing the degree of local and regional industrialization. The newly established economic activities generate additional negative pressures on the environment and surface waters generating an increase in the degree of pollution which is manifested by the vulnerability of aquatic ecosystems to stress factors (xenobiotics).

Fundamental scientific research for the elaboration of the doctoral thesis "Research on the evolution, magnitude and complexity of the impact generated by the economic activities on the Eastern Jiu" was carried out at the University of Petroşani, INCD INSEMEX Petroşani and TU Bergakademie Freiberg. The multidisciplinary approach of the concepts regarding the particular elements of the impact on the water bodies in the eastern part of the Jiu Valley allows the applicability at the local and regional level of the methodologies in accordance with the objectives and requirements of sustainable development for a more sustainable future.

The first chapters of the doctoral thesis present information about the particularities of the watershed of the East Jiu River (climate, soil, subsoil, groundwater, flora and fauna). The initial objectives of the research carried out in the field were aimed at identifying the economic activities in the east of the Jiu Valley that generate an impact on the environment (especially the mining industry, but also the exploitation and processing of wood, agriculture and local animal husbandry and waste storage) as well as establishing a program of quarterly monitoring of the hydrographic basin in accordance with the Water Framework Directive 2000/60/EC, program established according to the location and the impact generated by the economic activities on the Eastern Jiu.

Theoretical research was materialized by choosing standardized analytical methods for the analysis of water quality indicators in the laboratory in order to ensure the validity of the results obtained. Based on the field observations and the information obtained following the process of developing and verifying the monitoring program, the appropriate methodologies were selected for the assessment of the physical-chemical and ecological quality of water.

The assessment of water quality in the 16 sampling sections established in the monitoring program was carried out according to the national regulations regarding the classification of surface water quality in order to establish the ecological state of water bodies (order 161/2006) but also by the analytical method of the index of water quality (ICA) which allows the classification of water into quality categories. Quality categories indicating the degree of pollution (instantaneous) of the water body, possible restrictions and uses of the water for the fields of use (PWS, FAWL, Industry and Recreation).

Research on the ecological assessment of aquatic ecosystems (ichthyofauna) was carried out in a first stage by the in-situ identification of Salmonidae and *Cyprinidae* species present in the watershed of the East Jiu River followed by the identification of areas vulnerable to potential pollution from the activities economic identified.

Evaluation of the quality of the ecosystems was carried out by quantifying the degree of sensitivity, the optimal conditions for development and reproduction of the Salmonidae and *Cyprinidae* species identified. The limits of the optimal conditions for the development and reproduction of the species were established from the bibliographic references studied regarding the ecotoxicological research carried out by exposing the aquatic ecosystems to external physical and chemical stimuli. The analysis of the impact generated by the economic activities in the east of the Jiu Valley was carried out by the method of impact networks followed by in-depth posteriori research about the local pluviometric regime, the quality of soils and shallow groundwater. From the point of view of the impact generated by tailings dumps on soils, quantitative assessments of the content of heavy metals and the oxidation and reduction capacity of tailings material deposits were made. The assessment of the heavy metal content was carried out according to the alert and intervention thresholds regulated by order 756/1997 and by establishing the heavy metal enrichment factor calculated by reference to a control sample.

Evaluation of the impact generated by the activities of exploitation and processing of wood mass, micro-agriculture and local animal husbandry as well as the uncontrolled storage of household waste highlights the significant negative contribution brought to maintaining water quality within higher quality limits/classes. In this case, it is recommended that the performance of these activities have minimal interaction with fresh water bodies and their performance must be carried out in an ecological way aligned with the requirements.

The magnitude and complexity of impacts, generated by economic activities, was studied by using a complex system based on fuzzy logic, designed based on the interactions between natural and artificial systems, between the physico-chemical indicators of water and the ecosystem. The complex system based on fuzzy logic was realized by composing the membership functions for the input (water quality indicators) and output (impact components) variables, these being interfered by sets of rules that make up the black box of the fuzzy system.

Each subsystem composed for each water quality indicator, interfered with each impact component, makes up a fuzzy subsystem that obtains the system outputs (impact components). In this case, 10 respectively 6 fuzzy subsystems were grouped, the impact components being weighted by using the Simulink programming language. Validation and testing of complex fuzzy systems was done on random data to observe what are the limitations of the system, what happens if in a water sample I have a very high

concentration of a certain pollutant, what is the maximum range of the outputs what are the points strengths and weaknesses of complex systems etc.

The research is completed by applying the proposed methodology for evaluating the magnitude, extent and complexity of the impact generated by the economic activities in the east of the Jiu Valley for the water quality determined on 15.08.2018. Following the research carried out, technical measures can be developed to reduce the impact generated by the economic activities located in the east of the Jiu Valley without significantly changing the hydrodynamics of the hydrographic basin.

As a result of the research carried out during the research internships, methods, techniques and tools were designed and finalized with the help of which the quality of water and aquatic ecosystems can be evaluated, as well as the impact generated at a given moment and/or continuously by human activity on the river Jiu.

Keywords: surface waters, CFD, sustainable development, aquatic ecosystems, GIS, ichthyofauna, water quality index (WQI), impact, fuzzy logic, environment, mining, pollution

CONCLUSIONS AND PERSONAL CONTRIBUTIONS

Based on diversified bibliographic references and analytical and experimental observations, the paper "Research on evolution, magnitude and complexity of the impact generated by economic activities on the East Jiu River" presents complex methods for evaluating water quality, as well as complex methodologies for evaluating the impact on water bodies. Considered to be an essential natural resource, water is the primary source for development of all biological processes in nature, it is of particular importance for the existence of life and for performing all human activities. Therefore, knowledge and understanding of the aquatic environment, but also of processes that take place in a natural or controlled manner, represent a significant component in the implementation and development of methods and strategies to reduce or eliminate the impact mentioned above.

The stages preceding the complex study of pollution phenomena in order to carry out research on the impact of economic activities on the East Jiu River, were represented by the description of structural and morphological characteristics of the basin, through which, vulnerabilities and invulnerabilities of the basin to the oxidoreductive action of chemical compounds, were examined.

Research on aquatic, terrestrial-riverine ecosystems and those that interact or can actively interact with the East Jiu River outlines the overall picture of species' habitats, their place in the ecosystem and the role of each biocenosis in the ecosystem. Distribution of species in the eastern part of the Jiu Valley is mainly conditioned by biotope but also by inter- and intra-specific relationships, that can intensify dynamics of ecosystem movement.

Regarding pressures caused to the environment, in Eastern Jiu Valley, several economic activities have been identified, that continuously and permanently interact with the East Jiu, among which:

- mining activities carried out on 3 sites (Lonea mining and the Jieț mining field, Petrila mining and Livezeni mining) with related tailings dumps;
- wood exploitation and processing activities carried out on sites with multiple uses;
- agricultural and zootechnical activities carried out in micro-farms managed by locals of Jiu Valley;
- activities of local residents, involving improper storage of waste.

Of these, mining industry generates the most significant impact on the hydrographic basin of the Eastern Jiu, both in terms of magnitude, complexity, recurrence, probability of occurrence, but also in terms of area of influence (occupied surface). The impact resulting from the processes of extracting and processing coal generates waters

loaded with heavy metals salts, organic products, nutrients, suspended particles (clay, coal dust) and in exceptional cases radioactive waste.

Currently, the mining activity in Eastern Jiu Valley is carried out only in Livezeni mining, Lonea mining and in the Jieț mining field. Petrila mining has been closed since 2015, currently undergoing extensive patrimony conservation, ecological and landscape reintegration processes.

The strategy followed to materialize the impact study on the East Jiu River basin involved, in a simplified way, the quantification of natural pollution of watercourses as well as pollution from economic activities carried out. The quantification was carried out on the basis of experimental research of water quality indicators relevant to each economic activity, established following a monitoring program, taking into account national and international legislative regulations.

The monitoring program of the East River and its tributaries, developed in accordance with the Water Framework Directive, was structured in quarterly monitoring of water quality indicators, in sampling sections, carried out between 07.03.2017 ÷ 15.03.2019. In this sense, 16 sampling points (monitoring sections) were chosen, which were located, in cascade, upstream and downstream of each economic activity or human settlement, organized so that the pollution dynamics would have an observable, comparative and delimiting character.

Reference conditions of the hydrographic basin were established as being the pollution of the hydrographic basin generated by geological formations and possible connections of the East Jiu River with underground water bodies. These have been quantified as "natural pollution" in an area/region where economic activities and interaction between humans and the water body are minimal. For this, section S1 located on the Jieț River, upstream of household activities, was established as a reference sample (witness), because it is a strategic point of water capture in order to ensure drinking water needs of Petrila city, it is classified as a sanitary protection zone and is an area protected from economic-industrial and household activities.

Physical and chemical water quality indicators, monitored in the 16 sections, are: temperature, pH, OD, CBO_5, Ammonium, Nitrates, Nitrates, Total Phosphorus, Total Phosphates, Dry filterable residue at 105℃, Sodium, Sulphates, Arsenic, Mercury, Chromium, Copper, Lead and phenols. The morphological ones are represented by water flow, river continuity, river width variation and riparian area structure.

In order to evaluate watercourses' degree of pollution, in each monitoring section (S1 ÷S16), methods that give the best results were researched, chosen and developed based on the interconnection of results obtained from physical-chemical, hydro-morphological and ecological analyses. Thus, for actual assessment of water quality, the ICA method was used, with the possibility of interpretation according to the obtained ICA intervals and interpretation for the fields of use (PWS, FAWL, Industry and Leisure).

Legislative assessment of results obtained (in the sampling sections) was carried out by framing in quality classes regulated by Order 161 of 2006. Ecological assessment of aquatic ecosystems (ichthyofauna) was carried out according to Directive 2006/44/EC and according to biographical references studied.

Assessment of water quality in the hydrographic basin of the Eastern Jiu by the ICA method, carried out in the 16 monitoring sections, classified the water of the Eastern Jiu and its tributaries into medium and good water quality classes. Results obtained for each section were correlated with the precipitation regime, taking notice of improvement trends of water quality in months with significant precipitation, with more pronounced hydrodynamic manifestations in the autumn-winter season. Comparative analysis carried out for results of water quality indicators and quality classes regulated by Order 161 from 2006 indicates a significant degree of pollution for Maleia and Slătioara rivers, which also have physical-chemical indicators included in quality classes 4 and, respectively, 5.

The ecological assessment of the studied watercourses was performed through research on the influences of physical-chemical factors on ichthyofauna in the hydrographic basin of the Eastern Jiu. Requirements of aquatic ecosystems, as well as effects manifested by pollutants on ecosystems belonging to the Salmonidae and *Cyprinidae* families were studied. Requirements of the *Salmonidae* and *Cyprinidae* ecosystems were studied, described and evaluated for pollutants such as suspended matter, pH, O_2, CBO_5, Nitrites, Nitrates and Phenols under conditions of normal reproduction, growth and development of species. In the case of the East Jiu River and its tributaries, the species present in the basin are not significantly affected by economic activities in the region. The ecological quality of water is lower in the lower part of the working basin which is mainly due to the input of pollutants from tributaries and natural processes.

In the studied basin, ecosystems belonging to the Salmonidae family show a higher degree of sensitivity to external stimuli (xenobiotics) compared to ecosystems belonging to the Cyprinidae family, which present a much higher degree of acceptability and adaptability to external stimuli. In this sense, Salmonidae populations present a higher risk of abandoning their usual habitat in favour of less polluted areas, a fact that can cause major imbalances at niche level, because the presence of a high and diversified population of species in the ecosystem makes higher in number and more complex niches. Research on aquatic ecosystems clarifies how life increases the capacity of the aquatic environment to support life, it facilitates getting the necessary food and adds extra energy to the system, due to chemical interactions between different organisms and microorganisms.

The impact caused by mining activities in Eastern Jiu Valley is as a result of activities involving storage of waste material on surface land, with major implications on water and soil. Thus, regarding the qualitative and qualitative analysis for major and minor elements of waste dumps belonging to Petrila mining and Livezeni mining,

research carried out for all studied metals shows a high enrichment factor compared to the control sample.

In the case of the Lonea 1 tailings dump, a high enrichment factor was assessed for titanium, manganese and vanadium, and for the Jieț dump, a high enrichment factor was assessed for copper, vanadium, manganese, barium, zinc, titanium and a very high exceedance of the blank sample in the case of cadmium. The oxidation-reduction capacity of tailings dumps from Eastern Jiu Valley indicates a very acidic to moderately acidic pH in lower layers of the tailings dumps, and in the upper layers a weak to moderately acidic pH with alkalinization tendencies in some areas, as a result of migration/accumulation of H+ and H_3O^+ ions in the lower layers under the influence of the local udometric regime.

Research carried out on shallow groundwater indicates low conductivity, neutral pH, low presence of metals in the water, which, in turn, indicates good water quality. In this case, we can claim that the dumps in Eastern Jiu Valley have a high capacity to transfer contaminants to the unsaturated area, which requires the implementation of ecological rehabilitation measures for the areas within the intervention thresholds, according to order 756/1997.

Wood exploitation and processing activities, micro-agriculture and local animal husbandry as well as uncontrolled storage of household waste have a significant negative contribution to maintaining water quality within higher quality limits/classes. That is why it is recommended that these activities have minimal interaction with fresh water bodies and that they are carried out in an ecological manner, aligned with requirements of sustainable development's objectives.

Evolution of the impact caused by contaminants mainly depends on nature and concentration of pollutant, water flow, the ability to oxidize or reduce, chemical reactivity as well as on pollutant's diffusion and dispersion in water.

Thus, the hydrographic basin of the East Jiu River is characterized by advantageous hydrodynamic parameters when it comes to intensification of reaeration processes that reduce the oxidation rate of dissolved oxygen. High flow rate but also high re-aeration capacity of the first two sectors of the East Jiu River, indicate a high natural purification capacity. In the lower part of sector three, the river's flow speed is significantly reduced, intensifying sediments' deposition on the bottom of the bed, which increases the oxidation rate of dissolved oxygen and reduces the self-purification capacity of the East Jiu River.

Oxygen consumption evolution and self-purification capacity of the river are also influenced by the nitrification processes of the ammonium ion which is oxidized into nitrite and nitrate ions. In river sectors where the flow velocity is lower, nitrification processes perform negative pH corrections (acidifications) and denitrification of nitrate to nitrite reduces biochemical oxygen consumption and performs positive pH corrections (alkalizations). Nitrosative oxidative stress caused to aquatic ecosystems by

transformations of nitrites and nitrates has implications on cell functions, being considered a triggering factor of chronic and acute diseases in fish populations.

The supply of sulphates, phenols and heavy metals from economic activities reduce the self-purification potential of the river as a result of oxidation processes carried out for transforming organic compounds. Regarding the contaminants' spread evolution, they are decomposed according to the degradation constant of each compound in relation to time, which can vary according to distance from the pollution source.

Analysis of the evolution of the impact caused by contaminants indicates a tendency of their accumulation in the benthos and bioaccumulation downstream of the East Jiu River. In the East Jiu River basin, major effects of contaminants on the integrity of ecosystems are mainly of anthropogenic origin, causing migration of species and death of very sensitive ecosystems.

Accidental pollution is stated as a random event that may happen (but does happen) because of the important feature that things that have never happened will happen. Functional and morphological configuration of the hydrographic basin, inventory of species and information on pollutants' behaviour in aquatic environment are useful tools in exceptional cases of accidental pollution, because we can choose the best measures to reduce contamination in the lower areas of the Jiu River.

Fuzzy logic was used in the composition of membership functions (input - output) for 4 interference systems that mediate the variables based on well-established rules. Research conducted on random data showed that only two of them offer uniform solutions in the entire impact area studied.

The described concept, used to evaluate the impact components on 15.08.2018, gives us an objective picture of the processes occurring in the East Jiu River, so we can conclude that in the monitored sections the Direction and Magnitude of the impact is **"neutral - small positive",** the impact complexity varies from **very small to small** up to **small to moderate**, i.e., in the hydrographical basin of the East Jiu River it is possible that 20 to 60 species may be affected by pollution, an impact may occur rarely or in some cases **once in a while** and **regularly** (16 -20 rare events).

In the East Jiu River, the average spatial dimension has a local extension and with a recurrence of the impact encountered in few and in some cases relatively similar events being recorded that may reappear at that time.

Evaluation of impact components (direction, magnitude, complexity, probability of occurrence, recurrence and spatial dimension) by using complex systems, as a result of averaging fuzzy membership functions (input – output) allows a high degree of observation of the impact generated by economic activities on Eastern Jiu. Adopting a favourable vision of the impact produced by these activities leads to effective management of effects and to implementation of the best decisions in a very short time.

The hydrographic basin of the East Jiu River is characterized by a medium impact of economic activities on aquatic ecosystems; therefore, improvement of fish populations is recommended. Research carried out on water bodies, shows that the morphology, chemistry and overall ecosystems manifest in the sense of regeneration of the water body system - aquatic ecosystems.

PERSONAL CONTRIBUTIONS

Answers found for the main objectives pursued within the research carried out in the hydrographic basin of the East Jiu and by applying technical and analytical perspectives in the applied scientific approach, led to concretization of the following contributions:

- General research on local climate, geology and geomorphology of the region, soils, hydrology and hydrogeology of underground water bodies;
- Identification, spatial structure and analysis of ecosystems present in the hydrographic basin of the East Jiu River;
- Determination of impact sources on water quality of the East Jiu River and, implicitly, the aquatic and terrestrial riparian ecosystems (mining industry, wood processing, uncontrolled waste storage, agriculture and local animal husbandry);
- Identification of quality elements and relevant physical-chemical parameters in terms of pollution/impact sources identified in the eastern area of the Jiu Valley;
- Establishing the control sections for the hydrographic basin of the East Jiu River and developing the monitoring program, in accordance with the Water Framework Directive 60 EC 2000;
- Identification and selection of reference methods for analysing water quality indicators as well as conditions for sampling and transporting water assays to the laboratory;
- Reaching targets and objectives established in the operational and supervisory program;
- Research and description of methods used to assess water quality of the East Jiu River (the water quality index method, national and international regulations as well as the methodology for interpreting results obtained for the water use areas - Source of drinking water, ichthyofauna and aquatic flora, industry, leisure);
- Evaluation of water quality in the hydrographic basin of the East Jiu, using the quality index method and creating synoptic diagrams by superimposing the results obtained using the water quality index method in the control sections of the East Jiu and the monthly amount of precipitation (liquid and solid) in Eastern Jiu Valley;
- Complex analysis of timely evolution of water quality, evaluated with the help of the water quality index for each analysed control section;
- Description of physical-chemical indicators of the East Jiu water, according to order 161/2006 in each analysed control section;
- Description of hydro-morphological elements of tributaries and the East Jiu River;

- Identification of priority species present in the hydrographic basin of the East Jiu River and study of their distribution in the areas vulnerable to impact;
- Research on requirements of the *Salmonidae* and *Ciprinidae* ichthyofauna for certain water quality indicators (suspended matter, pH, over-under gas saturation, dissolved oxygen, CBO, phenols, nitrites, nitrates);
- Study of synergistic effects on the ichthyofauna in the hydrographic basin of the East Jiu River by analysing the minimum and maximum limits as well as the optimal intervals of growth and development of *Salmonidae* and *Ciprinidae* populations;
- Description of the ecological state of the Eastern Jiu water, according to requirements of the ichthyofauna of the *Salmonidae* and *Ciprinidae* families in relation to water quality indicators;
- Complex analysis of general impact caused by the mining industry on Eastern Jiu using the method of impact networks;
- Analysis of general impact caused by the tailing dumps located in Eastern Jiu Valley using the method of impact networks;
- Studies on effective infiltration, pH and degree of enrichment in micro and macro elements of tailings dumps, mobility degree of micro and macro elements in the body of tailings dumps;
- Research on the impact of tailings dumps and mining operations in Eastern Jiu Valley on groundwater;
- Analysis of the impact generated by exploitation and processing of wood, local micro-agriculture and non-compliant waste storage;
- Research on the possibility of analysing the degree of expansion and evolution of the impact caused by economic activities through the use of CFD techniques;
- Mathematical modelling of the East Jiu River in 3 interconnected computational domains, according to the degree of uniformity of the river's hydrodynamic parameters;
- The study of hydraulic resistances of the East Jiu River flow, depending on nature of the bed;
- Organising the computational domain, energetic and parametric modelling of the East Jiu River;
- Research on the study of turbulence coefficients (Peclet No., Exx, Eyx, Exy, Eyy) for the East Jiu River;
- Validation of the computational model through sensitivity analyses of the East Jiu River, according to the river's flow speed, through graphic representation of scatter and residual diagrams, as well as estimation of the uncertainty degree of results obtained;

- Drawing up dispersion maps for studied pollutants (arsenic, phenols and sulphates), as well as study of the extent and evolution of the impact caused by arsenic, phenols and sulphates on ecosystems belonging to the East Jiu River;
- Study of evolution and expansion of the impact caused by organic pollution of the East Jiu River;
- Estimation of oxygenation and deoxygenation coefficients for confluence sectors studied in the analysis of the organic pollution degree of the East Jiu River;
- Drawing up evolution diagrams for oxygen deficit and for degradation of organic substances in critical sections by using the Streeter-Phelps equation;
- Organizing membership functions (fuzzification) based on quality classes regulated by Order 161 of 2006;
- Building logical meaning by defining the concepts of impact on water bodies (magnitude, direction, complexity, recurrence, probability of occurrence and spatial dimension) as a component of fuzzy thinking by which they respond to input data;
- Building inductive and deductive reasoning for objective composition of the knowledge base by correlating input and output variables in the black box;
- Testing fuzzy interference systems and applying the methodology (complex system) developed on randomly determined data to observe the character, behavior and limitations of the achieved interference systems;
- Choosing fuzzy interference systems that best meet computational requirements and implementing them for a measurement campaign carried out in the East Jiu's hydrographic basin;
- Justification of the practical utility of the fuzzy interference system in monitoring a water course and suggesting possible future developments of the system.

In the 21st century, the extensive and complex implementation of the evolutionary imperative "secure as many resources as possible" is increasingly complex because the environment is a "system" that can sometimes be irreversibly degraded and all these "resources" come, but what at what cost and what price must humanity pay in the end…

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