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WATER QUALITY MONITORING IN VALEA JIULUI

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Abstract: *The paper presents the monitoring of the water quality in Valea Jiului, related to the Jiu river basin. In the increasingly alert conditions of urbanization and industrialization, contemporary civilization is characterized by a worrying process of deteriorating the ecological balance and pollution of water resources. Monitoring allows the achievement of four primary objectives in knowing the state of water quality, namely: monitoring, forecasting, warning and intervention. The paper presents the objectives of water quality monitoring, aspects related to the implementation of water monitoring programs.*
Keywords: *monitoring, water quality, Valea Jiului*

1. Introduction

Compared to the conditions of life in general and the development of human activities in particular, water is of double importance, namely as an environmental factor, respectively generating ecological systems and as a raw material for certain uses: use as a source of water drinking water, use as industrial water, use of recreational water, fish farming. In both cases, water must meet certain quality requirements; in particular it must be of appropriate quality. From a statistical-mathematical point of view, quality indicators are of the nature of continuous variables, i.e. of quantitative characteristics that can take any numerical value, within certain limits.

Natural waters also have the function of receiving wastewater laden with waste or losses resulting from human activities, which alters their initial quality. In the conditions of the contemporary society, characterized by the accelerated rhythm of the socio-economic development, there is a tendency of a dangerous accentuation of the process of pollution of water resources, being able to reach totally inappropriate situations.

Therefore, taking into account the two main characteristics – water-environmental factor and water-raw material, it is necessary to provide, for appropriate periods, an appropriate program of measures for the protection of water quality. But in order to draw up and implement such a program effectively, first of all it is necessary, as an absolutely necessary condition, to have as accurate and complete information as possible on the degree of pollution of natural waters and the regime of potential sources of pollution.

2. General data on Valea Jiului mining basin

2.1. Geographical location

Valea Jiului Basin is the most important coal basin (pit coal) in Romania, taking into account the reserve per unit area, the quality of coal and the experience gained in operation. The basin is geographically located in southwestern Romania, between 45°17'- 45°22' north latitude and 20°13'- 20°33' east longitude and located along Southern Carpathians, is the gateway to Retezat National Park and other Carpathian destinations, being surrounded by mountains belonging to Parâng group and Retezat group. It is morphologically constituted as a narrow and deep depression, one of the few found in Southern Carpathians. It has the shape of a triangular syncline, asymmetrical, oriented in the direction of ENE-WSW, with the peak in the west and the base in the east, with a length of 46km and a width between 2-9km, with the maximum at the confluence of Eastern Jiu with Western Jiu and covering 137.6 km^2 (fig.1).

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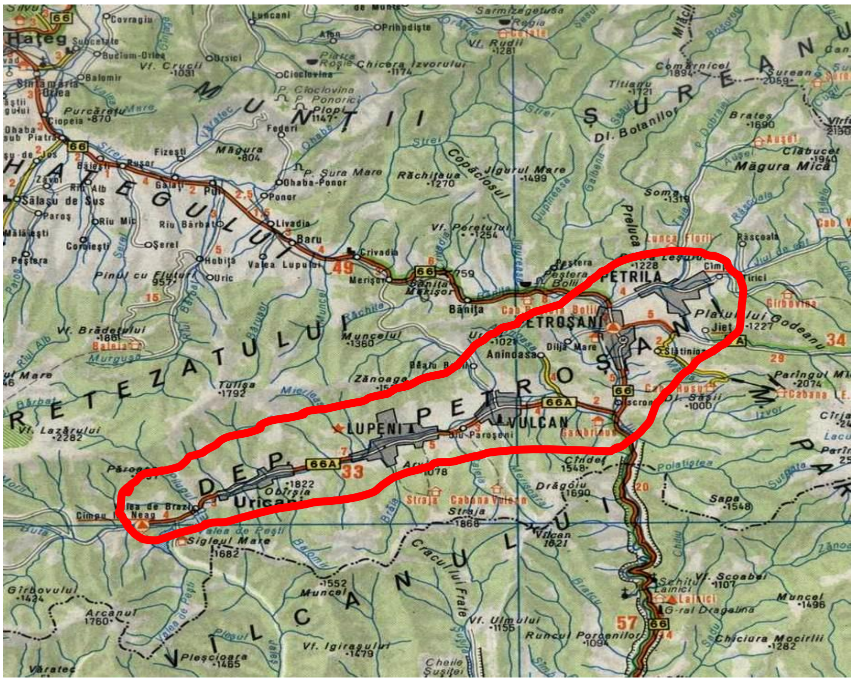

Figure 1. Geographical location of Valea Jiului mining basin [1]

Valea Jiului (fig. 2) runs along the two origins of Jiu, which practically divide the depression into two plateaus:

1. Petroșani Plateau, to the east, crossed by Eastern Jiu passing through the settlements of Cimpa, Lonea, Petroșani, Livezeni, to which Jieț and Bănița belong.

2. Vulcan plateau, to the west crossed by Western Jiu, which passes through the settlements of Câmpu lui Neag, Uricani, Bărbăteni, Lupeni, Paroșeni, Vulcan, Coroești, Iscroni, to which Crividia, Dealu Babii and Aninoasa belong.

The bottom of this depression is relatively high (556m at the confluence of the two Jiu rivers, 800m to the eastern and western edges) from three municipalities: Petroșani, Lupeni, Vulcan and three cities: Petrila, Uricani, Aninoasa with a total population of 120,734 inhabitants (2011 census). The connection to Transylvania is ensured by a railway line, thus forming a high intra-mountain depression that explains its relatively cold climate. Valea Jiului is a micro-region made up of Petroșani-Simeria and DN 66A, a road that is intended to be extended through connecting it with Băile Herculane and Oltenia by Petroșani-Tg.Jiu railway and DN 67A.

Access to the mining perimeters is provided by normal or narrow DNs and railways. It is considered that the transport infrastructure at the mining perimeters currently ensures the transport and traffic capacities to the mines in Valea Jiului.

Figure 2. Location and positioning of localities in Valea Jiului mining basin [1]

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2.2. Basin hydrography

Most of Petroșani Depression is drained by the rivers in the upper Jiu basin, the main hydrographic arteries, according to the size of the basin areas, being the Western Jiu, the Eastern Jiu and Jieț (fig. 3).

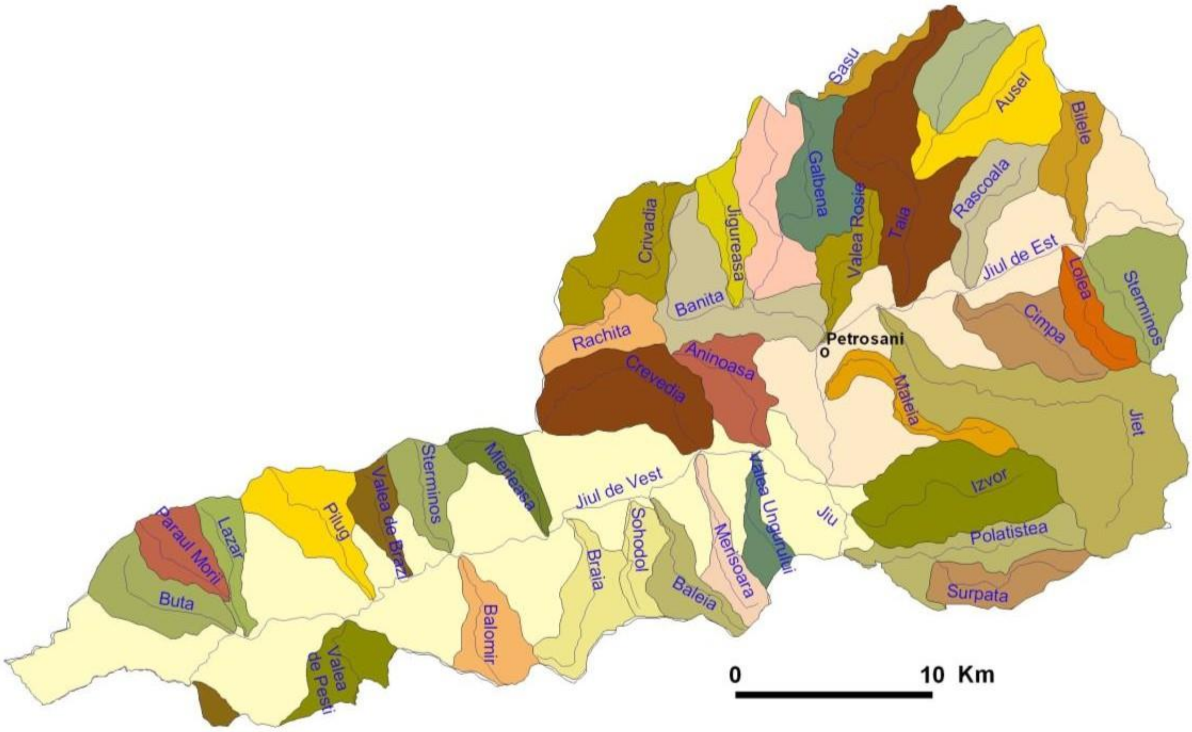

Figure 3. Hydrographic network and delimitation of river basins in Petroșani Depression [2]

The river basin is located in the southwestern part of Romania between 43°45'-45°30' north latitude and 22°34'- 24°10' east longitude.

The contour of the basin is limited to the:

- North, by the great heights of the mountains of Șurean, Parâng, Retezat, Cerna, which separate it from the basins of the tributaries of Mureș, Sebeș, Streiului and Cerna Mureș.
- West, from the high peaks of the hills and platforms to the neighborhoods of the settlement of Sărbătoarea and, further on, to the plain of the settlements of Sărbătoarea – Segarcea - Măceșu delimiting it from those of Cerna-Danube, Bahnei, Topolnița, Blahnișa and Desnățui.
- East, the boundary of Jiu basin follows a narrow ridge that separates it from that of Olt, until near Craiova. To the south, it enters the Romanian Plain, and the boundary of the basin follows a line that would unite the villages of Leu-Ghizdăvești-Bechet.
- South, the boundary is formed by the course of the Danube River.

Jiu is a first-order tributary of the Danube and joins it 692km upstream of the Black Sea. Springs in the Southern Carpathians have a length of 339km, an average slope of 5%, a sinuosity coefficient of 1.85, and a basin of 10,080km^2. The hydrographic network totals 3876km. The density of the hydrographic network is 0.38km/km^2.

The origin of *Western Jiu* is considered to be Soarbele brook, which springs from Retezat Mountains, near Curmăturii of the same name; in the mountains, it disappears on some calcareous parts, and downstream from Casa Câmpuşel and up to the confluence with Buta brook, it is locally called Scocu Mare.

After entering the depression, the stream resumes its name Jiu. Downstream of Vulcan, Western Jiu receives numerous tributaries, with springs in the mountain area. The valleys of these waters are generally parallel to each other, narrow, with steep slopes, due to the hard rocks they cross. Among the most important tributaries of Western Jiu let's mention, on the left: Valea Morii, Urseasca, Pilugu (Bilugu) - from Retezat, Sterminosu, Mierleasa (from the top of Tulișa), Crevedia and Aninoasa (from the top of Dealul Babii-Dealul Paltina). On the right, among the streams that descend from Vâlcan Mountains, there are: Rostovanu, Valea de Peşti, Balomiru, Tusului, Braia, Sohodol, Baleia, Merişoara, Pârâul Ungurului.

At Câmpu lui Neag, Western Jiu has an average slope of over 50 m/km, but this is gradually reduced and basins formed by lateral erosion appear, at Uricani, Bărbăteni, Lupeni, Jiu-Paroşeni, Vulcan and Iscroni.

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Eastern Jiu is formed by the union of several brooks that descend from Șureanu and Parâng mountains: Voievodu, Bilele, Sterminosu, Fetiţa, Cotu Ursului and Lolaia. After entering the depression, near Răscoala settlement, the slope of the Eastern Jiu decreases and several basins formed by lateral erosion are highlighted at Cimpa, Bironi, Petrila and in the north of Petroşani. Among the most important tributaries let's mention the following ones: on the right - Taia (with keys cut in limestone), Băniţa (with Jupâneasa, Jigurelu and Pârâul Babei), Dâlja; on the left - Cimpa, Cimpşoara, Jieţul, Maleia and Sălătruc, with springs in Parâng. Jieţul gathers its waters from the glacial circuses on the northern side of Parâng (Mija, Slăveiul, Roşiile), has a length of over 20km and an average flow of approx. 2m^3/s. Its slope is steep, over 75 m/km.

The Western Jiu and the Eastern Jiu join downstream of Iscroni and Livezeni, forming Jiu. Until the exit from the depression, it receives a few more tributaries, more important being those on the left side, with springs in Parâng (Izvoru and Polatiştea).

The water supply of the two Jiu is pluvio-nival, to which is added the underground supply (from karst and from the piedmont and terrace deposits). The average multiannual flow of the two rivers has values of 2-3m^3/s at their entry into the depression and 8-10m^3/s near the confluence. The solid flow is characterized by multiannual average values of 0.2-11kg/s in the sections at the entrance to the depression (Câmpu lui Neag and Lonea). In the 1980s and 1990s, the transit of alluvium was significantly altered in the sections located downstream of the coal preparation plants (Iscroni and Livezeni) compared to those that evolved in natural conditions, the ratio between the volume of alluvium transported in natural conditions and the influenced of the mining industry being on average 1/26. After the closure of Petrila and the refurbishment of Coroieşti (2003-2004), the values of the solid flow are close to those recorded in the natural regime.

In order to prevent floods, dams (over 40% of the length of the two Jiu) and regularizations were made in the region (on the Eastern Jiu, at Petrila - 9 km and Petroşani - 3 km; on the Western Jiu, at Dănuţoni - 2 km, Lupeni - 3.1 km, Coroieşti - 2 km and Paroşeni - 1.2 km).

Natural lakes are represented by those of glacial origin from Parâng, such as Mija, Roşiile, Zănoaga Stânii, Sliveiul or Lacul Lung. The lakes of anthropic origin were either created for water supply (Valea de Peşti, the dam on Baleia valley), or were formed in the perimeter of the mining fields, in former quarries (eg: at Câmpu lui Neag, Jieţ) or between tailings dumps (e.g. Petrila mining field).

Valea de Peşti reservoir is located on the brook of the same name, about 500m upstream of its discharge into Western Jiu. The reservoir was put into operation in 1973 and was created to meet the requirements for drinking and industrial water and flood mitigation. The dam has a height of 57m and a length of 250m, the total volume of the lake being 5.4 million m^3. The accumulation has a maximum depth of 56m and an area of 0.24km^2 [2].

Groundwater reflects the tectonics and the geological composition of the region, belonging to Câmpu lui Neag-Petrila fissure-type groundwater body, with an area of 149km^2. The resources are used to supply water to the population.

2.3. Climate

The climate is temperate-continental, with weak influences of the Mediterranean currents. The climate is harsh, but not excessive, winters are not cold, and summers are generally cool.

The average annual air temperature is 7.5°C, the average monthly temperature varies from a maximum in July of 17.2°C to a minimum in January of -3.8°C. Annually the number of days with temperatures above 0°C is 193 days, and below 0°C is 172 days, representing the average of the values registered at Petroșani and Parâng stations.

Rainfall is the main source of river supply in the basin. Depending on the exposure of the slopes, the amounts of precipitation and their annual distribution are different. Thus, the northern slopes benefit from higher amounts due to the western circulation, and the southern slopes of the mountains in the basin register reduced amounts of precipitation due to the phoenix circulation. Floods that cause floods are caused by rainfall exceeding 40-50mm at short intervals (three to four times a year).

In the cold season, precipitation in the form of snow, which will serve as a water reservoir for the period from early spring when its melting triggers large spring waters. The largest snow reserve accumulates in the mountainous area of the basin, while in the extra-Carpathian area its thickness and duration will gradually decrease towards the confluence.

The duration of the snow cover depends on the low amount and the maintenance of the air and soil temperature below 0°C, the snow remaining over 100 days a year in the mountainous area.

In summer, during clear nights with low local traffic, the development of radiative processes leads to the cooling of the air above the slopes, contributing to its displacement towards the lower part of the valley where it forms the "cold lake", the bottom of the depression throughout the night, and disappears after sunrise.

One aspect that influences the thermal inversion phenomenon is nebulosity.

In winter, the cloud layers invade the low forms, depression, allowing the establishment of a normal gradient at 800m altitude from the cloudy ceiling that favors the formation of a layer with reverse temperature. In the annual regime of relative humidity, the air is found, a main maximum in December (93%), when the air temperature is low, and the main minimum is recorded in March-April (77%).

The wind regime is normal, without excesses of intensity or duration, without danger to the forest vegetation, finding that when they intensify, in combination with the snow and the soil moistened by precipitation, as a result of the concentration of air currents due to the terrain produces isolated falls. During the summer, storms can occur, often accompanied by hail, being short-lived. In Petroșani depression, the predominant winds are the wind that blows from the northeast to the south and that causes the temperature to drop and the snow to blizzard, followed by the warm winds from the southeast.

2.4. Flora and fauna

The flora and fauna of Valea Jiului have elements that are part of it, a center of tourist attraction. The mountains are dominated by coniferous forests; among the most common are those of spruce, but also pine, bison (pinus cembra), juniper, yew. Oak and beech forests are common, home to many birds and are home to many animals, such as hares, wolves, foxes, wild boars, deer, bears, bearded eagles, a species found only in Retezat Mountains, the black goat.

The world of wild birds is also rich and varied. Suffice it to say: the nightingale, the woodpecker, the hazelnut, the tit, the quince, the blackbird, the jays, the sitars.

Valea Jiului has a rich fauna whose spread is favored by the presence of forests. However, anthropogenic interventions, through the exploitation of forests or deforestation in order to expand meadows and cultivated areas, the construction of forest roads, the location of mining operations, the storage of tailings, the construction of cottages and holiday homes, have partly restricted the area of some species.

3. Sources of water pollution in Valea Jiului

3.1. Mine

The mining activity, carried out over time in Valea Jiului, also involved the evacuation of water from the underground environment as well as the use of large amounts of water in the preparation processes. Until not many years ago, the discharge of wastewater from mining operations and the poor efficiency of wastewater treatment processes, wastewater from coal preparations, had as a direct effect, the loading of the natural emissary, Jiu River, with large amounts of mineral suspensions, substances organic and other pollutants (phenols, NH^{4+}).

Wastewater from coal mining and preparation is contaminated with both mineral suspensions and chemicals. Coal mining in underground operations is associated with significant local changes in the composition of the earth's crust, which significantly affects the regional hydrological regime, both quantitatively and by increasing the flow of surface water infiltrated into the lower seams of the lithosphere, especially qualitatively, by significant amounts of dissolved minerals that it entails in the accumulations of receiving water. Any mining operation consumes relatively clean water, from the dowry of the land, which it returns, loaded with harmful substances that harm the flora and fauna of rivers and lakes, while reducing water resources for domestic, agricultural and industrial consumption.

For this reason, it is necessary to know in detail the hydrological regime of each mine and to ensure the purification of drained water from rock formations intersected by mining works. The clay-coal suspensions discharged into Jiu together with the wastewater from these units had a very high gravitational stability, because from a granularity point of view, they fall into the colloidal and hemi- colloidal domain. Because of this, they remained in suspension and gave the water an unpleasant gray-brown color.

In recent years, there has been a decrease in pollution with solid suspensions, due, on the one hand, to the restriction of the activities responsible for this pollution and, on the other hand, to the refurbishment of some production units. The imposition of the legislation also meant the need for the adoption of technical and technological solutions from National Company of Pit Coal, materialized solutions, through the construction of its own treatment plants and connection of sewage pipes to the sewerage network of Valea Jiului through which these waters are directed, to the treatment plant from Dănuțoni, where a treatment is carried out, in

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accordance with the norms in force before the discharge into the emissary, as well as the refurbishment of Coroiești Preparation. The new technological flow ensures the recirculation of technological water in a proportion of about 80%.

At present, the problems related to the direct discharge into natural emissions of the water coming from the underground are still encountered in some of the auxiliary enclosures (for example the Eastern precinct of Livezeni mine), which were not connected to the location.

3.2. Agriculture and stock-breeding

Due to the configuration of the depression relief of Valea Jiului, it can be said that the agriculture of this area was and still is one of subsistence focused on obtaining the strict necessities of potatoes, corn, fruits and vegetables, being an activity of local importance. The significant occupation of the rural population, surrounded by Valea Jiului, is the raising of animals, respectively sheep and cattle. It can be seen that this sector of activity has a significant influence on water pollution. The main aspects of environmental pollution caused by the agriculture and stock-breeding can be:

- The uncontrolled storage of farmyard manure and the lack of arranged basins for collection of stable must from animals, belonging to many private households, have as negative effects their drainage in the running water, as well as the nitrate infestation of groundwater.
- Aggravation of the soil erosion phenomenon, on sloping lands, as a result of the practice of an inadequate system of agriculture, respectively poor organization of the territory, execution of soil works from hill to valley, crop rotations with a high share of weeds, absence of organic fertilization.

3.3. Building

Pollution of water with solid suspensions, these sediments are entrained by water and percolate in the subsoil, where it pollutes both the soil sector and the groundwater table below them. This type of pollutant will inevitably lead to an increase in water turbidity, especially in the case of consolidation works and foundations for pilots, or protection of slopes, surface washing, service spaces on construction sites, construction works carried out near the courses of water.

3.4. Tourism

It can have a negative impact on the environment through the intensive use of water and land by recreational facilities, the supply and use of energy resources, and the storage of waste. The continuous increase in the number of tourists and the development of tourism has led to the aggression of the environment through wastewater from tourist units, pollutants from transport (passing vehicles), and emissions of pollutants from thermal power plants.

3.5. Other activities

Water pollution from industrial sources can only occur if the treatment plants in these units do not work properly. These are installations for the neutralization of substances resulting from various technological processes (for example, the installations for the neutralization of wastewater from the galvanizing workshops of SC GEROM SA and UPSRUEM), wastewater from car washes, from various activities carried out by city households.

At present, all the companies and enterprises operating in Valea Jiului are connected to the centralized sewerage network, there are no problems related to the possibility of discharging sewage directly into the outflows.

A source of water pollution is rainwater discharged directly into the outfall. Rainwater washes the roadway and sidewalks, loading it with various physical and chemical pollutants. Thus, these waters take up significant amounts of dust, road waste, motor oils and fuel spilled from the tanks of vehicles that are discharged into natural emissions. Storage of wood waste, but also chemical pollution, it is known that some of the products resulting from the decomposition of this type of waste are phenols. The most important source of pollution of Jiu River and its tributaries is currently domestic and animal wastewater. In areas with farms along Jiu River and its tributaries, there is no ecosystem for collecting and treating water resulting from household uses and animal husbandry activities.

The direct discharge of domestic and animal wastewater leads to an increase in the concentration of organic substances, an increase in the chemical consumption of oxygen, a decrease in the concentration of dissolved oxygen and an increase in the concentrations of some organic pollutants (NH^{4+} and NO^{2-}).

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The deficiencies of the current sewerage system that serves Valea Jiului are not only manifested in the above mentioned regions, they are also present in the urban space. Thus, without exception in all component cities, there is no sewerage system in the so-called settlement areas. The situation is also valid for some residential neighborhoods, located on the outskirts of cities, residential quarters where domestic wastewater is discharged directly into the emissary (for example, in the Municipality of Lupeni - fig. 4, the towns of Aninoasa and Uricani).

Figure 4. Discharge of domestic wastewater from a residential quarter in Lupeni directly to the emissary [1]

Another factor that contributes to water pollution is the storage of household waste and other assimilated waste as well as waste from construction directly in the riverbeds and streams or in the immediate vicinity, on the banks, the latter being entrained during periods of excess rainfall and later constituting deposits of different sizes in the riverbed. In addition to direct physical pollution, this waste also gives an unpleasant appearance to the areas where it accumulates, contributing to the degradation of the landscape and thus to the decrease of the tourist potential.

Groundwater pollution is primarily related to the possibility of infiltration of soil pollutants or those resulting from the decomposition of household waste (stored in "landfills" that have nothing in common with controlled landfills that should exist).

It is also worth mentioning that for the urban region of Valea Jiului, for the drinking water supply of the population, volumes of water taken exclusively from surface sources are used. Groundwater is used for this purpose only in a part of the individual households located on the outskirts of the localities or in the belonging villages.

4. Methods for determining water quality

For all water quality indicators, standards for analytical methods are available, such as European Standards (EN) or standards issued by the International Organization for Standardization (ISO).

The following is a brief description of the most common methods for determining water quality [3].

a. *Titrimetric analytical methods* - are common laboratory methods in quantitative chemical analysis and are often used to determine the unknown concentrations of an analyte to be identified. Neutralization titrymetry, complexometry, precipitation, redox are applied in the laboratory. The indices to be determined are: total nitrogen, ammoniac nitrogen, calcium, chlorides, dissolved oxygen, chemical oxygen consumption, biochemical oxygen consumption.

b. *Gravimetric analysis methods* - are among the most accurate methods of determination. Their basic principle is to bring a component to be determined, existing in solution in the form of a practically insoluble (or precipitated) product, which must have a known and constant composition. The precipitate is filtered off

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from the rest of the components in the solution and purified by washing, and after appropriate heat treatment, weighed. From the resulting mass, calculate the quantity of the determined component. The indices that are determined are: ammoniac nitrogen and suspended matter.

c. *Methods of analysis by spectrometry,* which consist of the electromagnetic interaction with the substance that takes place along the entire spectrum composed of γ-rays, X-rays, ultraviolet, infrared, microwave and radio waves. Depending on the energy of the radiation, the interaction is manifested by absorption spectra, emission, scattering of electromagnetic waves, or changes in the properties of the substance. Spectroscopy is the experimental method that measures and interprets this interaction.

d. *UV-VIS spectrophotometry analysis methods* that use the range of visible wavelengths as well as adjacent fields, such as ultraviolet and infrared (10-7-10-6 m). The specificity of UV-VIS spectroscopy, compared to other types of spectroscopy, is that the vast majority of matter structures, which are larger than atoms, i.e. molecules, interact with the electromagnetic field of the UV-VIS domain, by resonance.

The identification of these interactions allows the establishment of the identity and molecular characters, especially of the organic and coordinating compounds, with conjugated cyclic polyene systems, which are distinguished by high selectivity. The following indices are determined by spectrophotometric methods: total iron, nitrates, nitrites, ammonium, and total phosphorus.

e. *Atomic absorption spectrometry analysis methods* are based on the absorption of energy at specific wavelengths by the atom in the ground energy state as a result of which it passes into the excited state.

Chemical atomization is applicable for the determination of ultra-micro quantities of mercury and volatile hydride elements (SeH_2, AsH_3, BiH_3, SnH_4). The method involves the use of reagents which convert the element to be analyzed into a volatile compound, usually a hydride, which is carried by an inert gas in a quartz tank heated to about 900°.

The indicators determined by these methods are: Na, K, Ca, Mg, Co, Ni, Cu, Zn, Cd, Pb, Hg; As, Ar, Sb, Se.

f. *The methods of analysis by atomic emission spectrometry* are based on the phenomenon of desorption (emission) of light energy. The principle of the method is to vaporize and excite the atoms of the sample to be analyzed.

The amount of water sample must be sufficient to ensure both laboratory tests and quality assurance requirements and quality control tests (QA/QC).

Of great importance for water storage are sampling tools, graduated bottles, different containers / bottles are used for different water samples (figure 5):

- Chemically resistant clear bottles (Pyrex glass) are used for the determination of organic compounds (a);
- Polyethylene containers are used for the determination of inorganic compounds (b);
- Special tubes, which are required for groundwater sampling (c), with peristaltic and submersible pumping tubes.

a. b. c.

Figure 5. Containers used for water sampling:
a. Pyrex glass; b. Polyethylene bottles; c. Special tubes

Sample preparation techniques are:

- Tests performed for the determination of heavy metal cations dissolved in water are pre-treated based on precipitation, ion exchange or chelation and extractive.
- Tests performed for the analysis of semi-volatile and non-volatile organic compounds are pre-treated based on the extraction of the liquid phase or the solid phase.

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5. General considerations for water quality monitoring

Water quality monitoring is a vital support for any water management program. Water monitoring is defined as an integrated activity of assessing the physical, chemical and biological characteristics of water in relation to human health and environmental conditions, related to a use, intended for water. In the design and implementation of water monitoring programs, it is vital to consider the differences in the space-time characteristics in parallel with the accessibility of the monitoring of each source.

In order to optimize the monitoring networks, three elements must be taken into account [1]:

a. *Monitoring information system*

In order to obtain the optimal information, it is necessary to take into account all the stages that the information goes through in the network (sampling, physic-chemical and biological analysis, database, process modeling, reporting and use of data for decision making.

b. *The actual optimization of the network*

It is carried out after analyzing how the existing network has responded to the need for information and identifying the reasons why the information obtained does not fully cover the need.

c. *Cost-effectiveness analysis*

The costs of monitoring activities are high, especially those of routine activities.

5.1. Water sources to be monitored

a. *Water from rivers* because it is most used for drinking water supply, is a receiver for wastewater discharge and because management plans and monitoring system are the most accessible.

b. *Wastewater* is water that has multiple uses, during which it is loaded with various pollutants and substantially changes its composition.

- *Domestic wastewater* is the drainage water, after it has been used for household needs in homes and units for public use and comes from discharges from food preparation, from washing clothes.
- *Industrial wastewater* is that which is discharged in a concentrated manner after its use in the technological processes of obtaining raw materials or finished products. May be:
    - cooling water, which forms the main proportion (volume) of industrial wastewater;
    - wash water, which ranks second in volume, occurs in a wide variety of industries and results from the use of feed water, for the entrainment and removal of unwanted materials;
    - process waters, are those that have served as a solvent or as a reaction medium in the process of processing raw materials, have a relatively low volume;
- *Urban wastewater* is the mixture of domestic wastewater by collecting it in a common sewer system.

c. *Rainwater* is rainwater or snowmelt, adding to this category, water used for street washing. Their volume is generally known, but it depends on a number of factors, as part of it evaporates, another part seeps into the soil and only the rest is collected through the sewer system.

5.2. Water quality indicators to be monitored

The groups of indicators to be monitored are (Table 1):

• Indicators that give information about oxygenation conditions: dissolved oxygen (OD) chemical oxygen demand (COD) and biochemical oxygen demand (BOD);

Table 1. Water quality indicators to be monitored

Indicator groups	Water quality indicators	U.M.
Conditions for oxygenation	dissolved oxygen (DO), chemical oxygen consumption (COD), biochemical oxygen consumption (BOD)	mgO_2/l
Nutritional conditions (contributes to eutrophication)	ammonium (NH_4^+), nitrates (NO_2^-), nitrites (NO_3^-), total nitrogen(N)	mgN/l
	orthophosphates (PO_4^{3-}), total phosphorus (P)	mgP/l
	chlorophyll A	µg/l
Salinization (general ions)	dry filtrate residues at 105^0C, chlorides (Cl^-), sulphates (SO_4^{2-}), Ca^{2+}, Mg^{2+}, Na^+	mg/l
Pollutants of natural origin	total Cr (Cr^{3+}, Cr^{6+}), Cu^{2+}, Zn^{2+}, As^{3+}, Ba^{2+}, Se^{4+}, Co^{3+}, Pb^{2+}, Cd^{2+}, total Fe (Fe^{2+}, Fe^{3+}), Hg^{2+}, total Mn (Mn^{2+}, Mn^{7+}), Ni^{2+}	µg/l
Other relevant indicators	phenols, anionic surfactants, absorbed organic halides (AOX)	µg/l

Note: *In addition to the water quality indicators set by the European Union rules, there are other categories of interest for water monitoring studies conducted in research projects.*

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• Indicators that give information about the presence of nutrients, which can contribute to the phenomenon of eutrophication: nutrients are classes of substances that contain nitrogen atoms (ammonia, nitrites, nitrates, organic nitrogen compounds), phosphorus atoms;
• Salinity indicators, which are given by the general content of anions and cations;
• Indicators of natural origin include mainly heavy metal cations;
• Indicators of organic origin are phenols, anionic surfactants and absorbed organic halides (AOX).

5.3. Water quality monitoring equipment

For water quality monitoring are used [1]:

a. *Automatic stations* capable of performing rapid analysis and transmitting data from the field to the center coordination of the local real-time environmental monitoring system.

Of these, the *WQMS (Water Quality Monitoring System)*, also used in Valea Jiului, is a system designed to automatically monitor up to 9 water quality parameters: temperature, conductivity, dissolved oxygen, pH, turbidity, redox potential and ammonium concentration (figure 6). The system is operated by software based on the Windows operating system called Global Logger II. The data can be transmitted to a central unit via a modem or stored in a data logger and subsequently downloaded. It is capable of recording a number of 40879 measurements and operates in the temperature range –40°C ÷ + 85°C.

b. *Portable field determination equipment* (Figures 7 and 8)

• pH meter / ion detector model 340i produced by WTW (Wissenschaftlich - Technische Werkstätten GmbH) (figure 7). The pH measurement is made with three decimals and with an accuracy of: ≤ 0.005 pH ± 1 digit; the accuracy of the redox potential measurement depends on the measurement scale used: ≤ 0.3 mV (-999.9… + 999.9 mV) respectively ≤1 mV (-1999… + 1999 mV); temperature measurement accuracy: ≤0.1 K ± 1 digit;

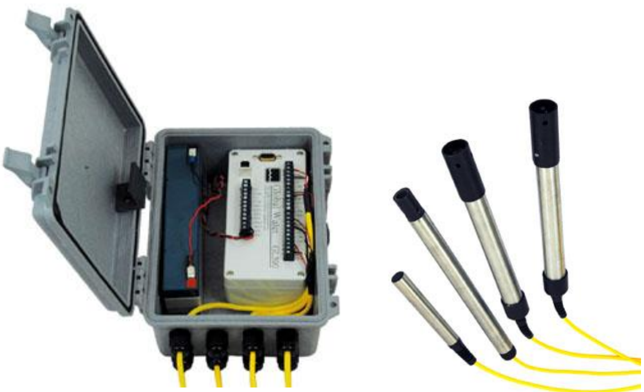

Figure 6. WQMS system in standard configuration [1]

Figure 7. pH meter/ion detector model 340i [1]

Figure 8. Potable apparatus for the determination of pH, redox potential, temperature, conductivity and dissolved oxygen

• pH meter model HI 9023 produced by Hanna Instruments for field determinations of the following parameters: pH, redox potential and temperature. Measuring ranges 0.00 - 14.00 for pH, 0 - 399.9 and 400– 1999 mV for redox potential and 0.0 - 100.0°C for temperature.

• Conductivity meter model HI 9033 produced by Hanna Instruments for field determinations of the electrical conductivity of water (or TDS, ie total dissolved salts). Measuring ranges 0.0 - 199.9 μS/cm, 0 - 1999 μS/cm, 0.00– 19.99 mS/cm, 0.0 - 199.9 mS/cm.

• Device for determining the dissolved oxygen content model HI 9142 produced by Hanna Instruments for field determinations of dissolved oxygen content in water samples. Measuring range 0.0 - 19.9 mg/dm^3.

It is specified that the portable devices presented are in the endowment of the environmental laboratory within the University of Petroșani.

c. *Laboratory equipment* for analyzing samples taken from established monitoring points.

For the determination of water quality parameters, which involve performing tests that cannot be performed with portable equipment, such as chemical and biochemical oxygen consumption, turbidity, or determination of ion concentrations (especially in the event of accidental pollution), chemical and physical methods of analysis set out in point 4 shall be used.

The first stage is the taking of samples from the established control points, while observing the existing methodologies and prescriptions, so that no contamination of the respective samples occurs. The same rules for preventing contamination or damage to the samples shall be taken into account during their transport to the analysis laboratory. The samples brought to the laboratory will be subjected to the analyses provided in the monitoring program or in special situations to the analyses specific to each case.

For this purpose, the equipment will consist of a turbidimeter and the equipment and substances specific to chemistry laboratories, necessary for performing chemical laboratory analyzes.

HPLC Chromatograph (figure 9), also equipped with the University of Petroșani, will be used for high-precision analysis and for which results are needed as quickly as possible. It is a high performance liquid chromatograph for liquid phase chemical analysis. The sensitivity of this chromatograph is 1:1000000 and depends on the quality of the detector. The chromatograph is equipped with a UV-VIS spectrophotometer (detector). This device determines the content of heavy metals, lanthanides, pesticides and organochlorine compounds in water, air and soil samples.

Figure 9. Chromatograph HPLC [1]

6. Water quality monitoring in Valea Jiului

6.1. Water quality and indicators to be monitored in Valea Jiului

As the surface waters of Valea Jiului, especially the waters of Eastern Jiu and those of Western Jiu, which are the main watercourses that cross this area, are used by the population, their quality indicators must be the basis for monitoring.

It should be noted that in the territory of Valea Jiului we cannot talk about the use of Jiu waters for the purpose of supplying drinking water to localities, uses in the food industry that require very strict quality conditions. Also, not being a suitable area for large-scale agriculture, the use of water for crop irrigation is almost non-existent (this is largely due to the precipitation regime in the area); it is limited to individual systems (consisting of low capacity pumps) and these are very small in number [1].

In terms of industrial uses, the main sources of water pollution, until the start of the closure of the mining activities, were the processes of extraction and processing of coal in the preparation plants to which is added the agent that uses the waters of Western Jiu. - Paroșeni Thermal Power Plant.

The trend of increasing concentrations of suspensions in the waters of Jiu has been recorded *since the 1970s* and has led to the disappearance of aquatic flora and fauna downstream of coal plants, removing the river from the tourist circuit, also making it impossible to use water in agricultural and industrial purposes.

In the years 1990-1991, the concentrations of suspensions are reduced, in the conditions of a decline of the mining activities (ex: miners' strikes from 1991); the resumption of mining in 1992 was reflected in a further increase in the number of suspensions discharged into Jiu. The ratio between the volume of alluvium transported in natural conditions and that influenced by mining activities had an average value of 1/26 [5].

At the beginning of the 1990s, measurements made in the sections Răscoala, Livezeni (on Eastern Jiu), Câmpu lui Neag and Iscroni (on Western Jiu) showed an increase in pollutant concentrations in surface waters (up to 2-4 times), downstream of the mining units. On Eastern Jiu, the average annual values (1989-1994) of pollutant concentrations indicated that the level of significant pollution was exceeded for the following indicators: suspensions, phosphates, chemical oxygen consumption and ammonia nitrogen in Livezeni section. In Iscroni section on Western Jiu, records for the same range indicated a stronger impact of mining activities on surface water quality, especially through the large amounts of suspensions discharged into Jiu. The presence of heavy metals (Cu, Pb, Zn, Cd) and cyanides was also reported. During the same period, the average annual concentrations of suspensions in discharged water from coal preparations exceeded more than 20 times the maximum permissible values, and the maximum concentrations exceeded 50000-100000 mg/l [5].

At the level of 2000, the amount of water discharged from the groundwater and discharged directly into the emissary varied between 1.6 and 6.8 m^3/t; solid suspensions were the main pollutant, reaching concentrations of 15000-17000 mg/l. Industrial waters resulting from the coal preparation process were the most important source of surface water pollution; their flow varies between 0.85 and 1.45 m^3/t of processed coal. The wastewater had a high content of ultra-fine clay material (the percentage of material below 10 microns represents 60% of the discharged suspensions), humic acids 3-5g/l, various suspensions ranging between 300-100 g/l and a weak acid pH 6-7.51. All these characteristics gave the waters extremely difficult clarifying properties [5].

In 2002, there were 13 sources of water pollution in the region, respectively 12 industrial ones (mines Lonea, Petrila, Livezeni, Aninoasa, Vulcan, Paroșeni, Lupeni, Bărbăteni, Uricani, Valea de Brazi, Coroiești and Lupeni preparations) and a source of domestic pollution (RAAVJ Petroșani). The waters from the mining operations in the east of the region were characterized by a high content of suspensions, phosphates and hydrogen sulfide. Chemical oxygen consumption (COD_{Cr}) also exceeded the potentially significant level of pollution by demonstrating the presence of residual lubricants and flotation reagents.

After the restructuring (e.g. the closure of Petrila), the situation has partially improved. As only three mining units are discharged into Eastern Jiu, the degree of pollution is lower due to dilution; thus, the waters of the Eastern Jiu fall into the second category of quality and are in the process of natural regeneration [5].

In the western region, the waters from the mining operations and the preparation plants were characterized by high concentrations of suspensions and phosphates, the values signaling a significant degree of pollution. The indicators ammonium, hydrogen sulfide and chemical oxygen consumption exceeded the alert thresholds (potentially significant pollution). As a result, until 2003, the waters of Western Jiu were much more polluted than those in the eastern basin, not even meeting the quality requirements for category III waters.

Starting with 2003-2004, in order to reduce the impact on the waters of the Western Jiu, a modernization and greening program was applied to Coroiești preparation, with obvious effects (significant reduction of the concentration of solid suspensions in the river waters. Annual average values of suspension concentrations decreased more than 800 times, from 38916 mg/l in 2002 to 7294.5 mg/l in 2003, 146 mg/l in 2004 and 46 mg/l in the first 6 months of 2005. The suspension has positively affected the natural biocenoses, which have begun to recover, for example, in October 2004, several fish species were observed on Western Jiu, upstream of the confluence with Eastern Jiu [5].

In 2006, the main industrial pollutants remained Lupeni preparation and mining units in the western basin, but the water quality of Western Jiu River has improved considerably. In the case of both major hydrographic arteries, some pollutants that come from the discharge of sewage (nitrogen, phosphates) in the perimeter of traditional settlements in the depression [6] exceed the values settled by the rules in force.

The mining activity carried out over time in Valea Jiului also involved the drainage of groundwater. Of the total water discharged, mine infiltration water generally represents 15–25%.

The evacuation of mine water is done through the system of canals along the entire length of the mining works, dimensioned according to the hydrological regime of the mine. Mine water is collected in one or more water lodges, usually located at the lower level, from where it is pumped to the surface with the help of pumping stations. Due to the tendency of sedimentation of the suspensions caused by the mine waters, both in the canals and in the water lodges, a periodic cleaning of them is required, with the evacuation of the deposited sediment.

For most mining companies, the treatment of mine water is done jointly with the wastewater from the preparation process (e.g. mines Petrila and Lupeni). To reduce water consumption, mine water flow schemes operate in a partially closed circuit.

Mine waters in Valea Jiului are not subject to neutralization, chemical or bacteriological treatment, as the content of chemicals dissolved in water does not exceed the permitted limits. As the treatment is carried out jointly with the washing water from the preparations, the presence of ions in the mine water improves the clarification conditions in the treatment plants.

From the multitude of data recorded, over time, of the indicators of water quality discharged into the emissary from some of the mines in Valea Jiului, Tables 2 and 3 show their average values determined in *2010 and 2013*, respectively [7].

Table 2. Average value of water quality indicators in 2010

No.	Indicator quality	U.M.	Maximum permissible limit	The determined average value of the water quality indicators Mine water/ Domestic water enters the treatment station						
				Lonea	Petrila	Livezeni	Vulcan	EPCVJ	Lupeni	Uricani
1.	pH	unit. pH	6,5-8,5	7,02/6,94	7,88/6,26	-/6,52	7,51/6,92	-/6,59	7,81/-	8,08/7,01
2.	Fixed residue	mg/l	2000	1923/127	1900/111	-/7,45	1633/186,5	-/124	984/-	1002/448
3.	Suspensions	mg/l	60	71,6/28	34/22,6	-/71,6	30,4/8,2	-/542,4	118,0/-	16,4/39,4
4.	Calcium	mg/l	300	-	-	-	46,4/-	-	16,0/-	31,2/-
5.	Magnesium	mg/l	100	-	-	-	16,09/-	-	42,11/-	20,57/-
6.	Ammonium	mg/l	2	-/0,66	0,66/0,96	-	-/1,14	-/9,88	-	-/1,31
7.	BOD_5	mg O_2/l	25	-/10,0	10/27,5	-/76,0	-/26	-/28,0	-	-/13,7
8.	COD	mg/l	125	218,96/138,1	138,04	-/99,96	95,2/59,5	-/38,3	71,4/-	127,56/57,1
9.	Sulphates	mg/l	600	75,0/26,5	622,5	-	432/55,9	-/120,0	172,5/-	200/124,0
10.	Chlorides	mg/l	500	35,45/31,91	50,34	-/31,2	24,46/18,08	-/21,27	19,50/-	34,03/33,68
11.	Nitrates	mg/l	2	-/<2	<2	-	-/<2	-/<2	-	-/<2

Table 3. Average value of water quality indicators in 2013

No.	Indicator quality	U.M	Maximum permissible limit	The determined value of the water quality indicators (min.-max.) Mine water/ Domestic water enters the treatment station	
				Lonea	Petrila (together at the entrance to the treatment station)
1.	pH	unit. pH	6,5-8,5	7,2-7,9/6,6-7,98	7,06-7,85
2.	Fixed residue	mg/l	2000	118-1897/253-1400	719-1331
3.	Suspensions	mg/l	60	11,2-182/4-10,8	29,2-140,8
4.	Ammonium	mg/l	2	-/6,0-59;	9,50-48,0
5.	BOD_5	mg/l	25	-/23-46	37,0-100

The quality conditions imposed by the technological processes that use water are mainly related to the hardness of the water (from this point of view there are no problems) and its turbidity which, after the closure of Lupeni Coal Preparation Plant, is no longer an impediment.

From an ecological point of view, the situation is slightly different because the main source of water pollution in the two Jiu is the discharge of domestic wastewater from areas not connected to the sewer system and a long period of time in which the mining industry affected the two emitters (Eastern and Western Jiu) by discharging insufficiently treated or untreated industrial wastewater has caused imbalances in the specific ecosystem whose restoration requires relatively long periods of time.

Thus, the effects of the discharge of untreated sewage can be synthesized by affecting the amount of dissolved oxygen, the chemical and biochemical oxygen demand and the concentration of organic matter and the products resulting from their decomposition (ammonium, nitrites and nitrates).

Taking into account the above, the water quality indicators that need to be monitored are: pH, suspensions, biochemical and chemical oxygen demand, nitrates, ammonium, sulphates, chlorides, calcium, magnesium contents. Of course, these indicators can be extended on a case-by-case basis.

6.2. Determining the frequency of measurements

Given the limited water uses of the two major watercourses in Valea Jiului as well as the high self-cleaning capacity characteristic of turbulent mountain rivers, a high monitoring frequency is not required as in the case of air.

In general, weekly data are sufficient for all cases.

To monitor the quality of the tributaries of the two Jiu, the rivers Bănița, Jieț and Taia, *Fl. Faur* [1] proposes to make monthly determinations, and for the streams Buta, Maleia, Sălătruc, Staicului, Aninoasa, Sohodol, Baleia, Căprișoara, Mohora, Morișoara, Valea Lupească, Valea Secănească, Valea Ungurului, Valea Lupului, Crividia, Plesnitoarea, Tusa, Braia, Merlaşu, Mierleasa as well as to determine the water quality from the lakes formed in the former quarries and between the branches of the tailings dumps to make four determinations annually (i.e. at intervals for three months).

6.3. Location of monitoring points and number of stations used

The main purpose of the local water quality monitoring system in Valea Jiului is to determine the influence that the activities carried out in the area have on their quality. Since the main watercourses are represented by the two Jiu, it goes without saying that attention will be directed to their monitoring.

Groundwater quality monitoring is performed monthly according to AGA no. 7/2018, by performing analyzes by an accredited laboratory, but also its own laboratory [5].

The comparison of the results of the analytical determinations with the limit values imposed by Law 458/2002 as amended and supplemented by Law 311/2004 shows that, at present, the maximum permitted limit values for quality indicators pH, ammonium, chlorides, sulphates, sulfides and hydrogen sulfide are not exceeded.

In terms of water quality of watercourses, the latest available data indicate that the breakdown by water resource category at the Jiu river basin level includes [6]:

• 9 natural water bodies from the category of rivers that have been classified in *good ecological status;*

• 1 artificial water body (Valea de Pești accumulation) whose potential has been included in a *good ecological potential.*

Within the Jiu river basin, belonging to Hunedoara county, natural water bodies (rivers) totaling 142 km were evaluated based on monitoring. Of the 142km, in terms of chemical condition, 130 km were monitored, which were in good chemical condition.

The dangerous substances from the watercourses on the territory of Hunedoara County, at the level of the Jiu river basin, were monitored in watercourses, through 12 monitoring points. Quality standards in Hunedoara County are not exceeded.

In the following, a solution for monitoring water quality in Valea Jiului, proposed by Eng. Fl. Faur, Ph. D, will be presented [1].

In order to determine the quality of these waters, it is proposed to place three automatic monitoring stations of WQMS type as follows (Figure 10):

- 1 WQMS system on Western Jiu, in Câmpu lui Neag area, i.e. upstream of the urban area;
- 1 WQMS system on Eastern Jiu, at the exit from Lonea area;
- 1 WQMS system will be located 200m downstream of the confluence point of the two Jiu rivers.

For the other monitoring points (weekly monitoring), located on the courses of the two rivers (Western and Eastern Jiu), portable devices will be used and samples will be taken for laboratory analyses. The same methodology will be applied for the monitoring points with the frequency of measurements established at one month and once every three months.

These points will be located at the border between the component localities of Valea Jiului and will follow the determination of the influence that each locality has on the water quality.

The test points of the waters of rivers Taia, Băniţa and Jieţ will be established at 200m upstream of the confluence point with the Eastern Jiu.

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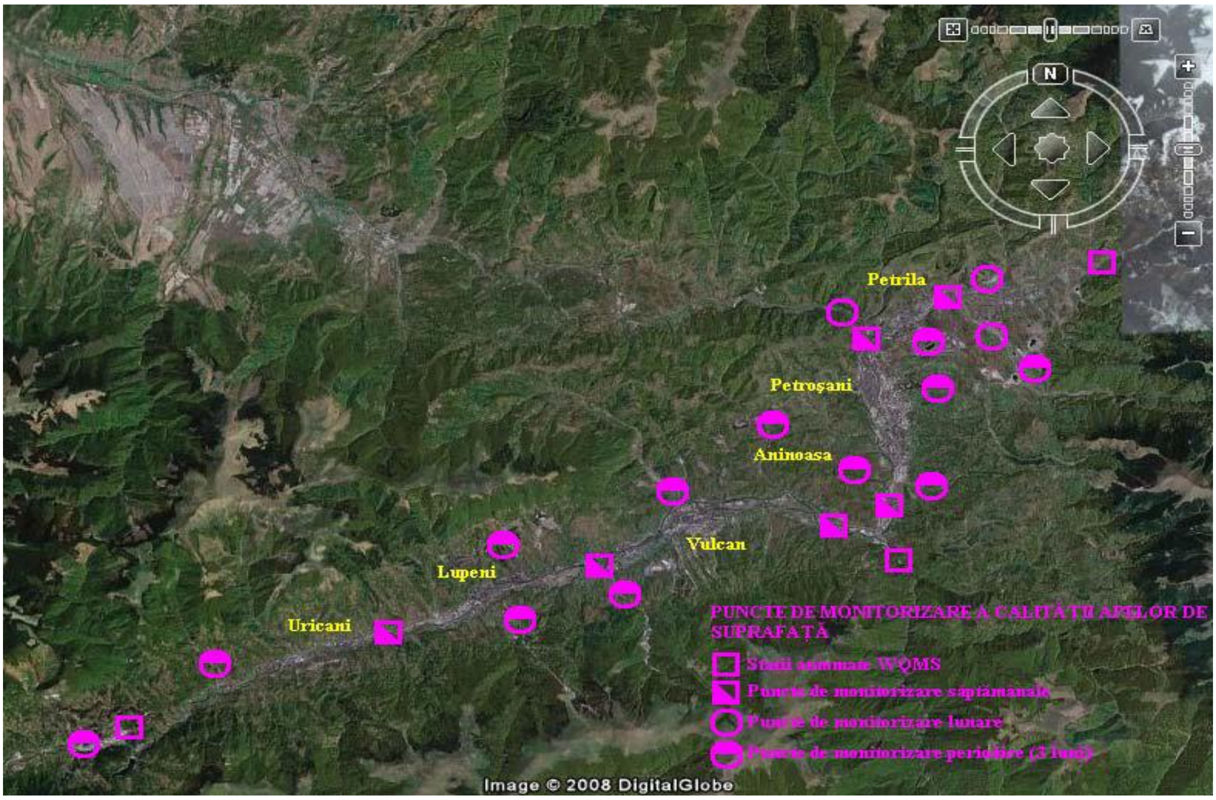

Figure 10. Location of equipment and intended points for water quality monitoring in Valea Jiului [1]

For streams in the study area, sampling points will be established at 100 m upstream of the confluence. In their case, it should be noted that in some periods of the year characterized by prolonged lack of rainfall, it may be impossible to prove their quality (some streams may dry out temporarily). For lakes in the area, the number of samples required to be taken from each will be determined by their size.

7. Conclusions

The quality of surface water, more precisely of the waters of Jiu River, has depended over time primarily on the activity of the energy sector in Valea Jiului basin, the mines and Paroșeni thermal power plant. To these is added household and animal wastewater from household uses.

With the restructuring of the mining sector, there is an improvement in the quality of Jiu water, mainly due to the considerable decrease in mineral suspensions.

The organization of environmental monitoring at the local level is the responsibility of the AJPMs and depends in particular on the financial resources available. From this point of view, the situation at the national level is not very good, the high costs of measuring and control equipment, the lack of laboratories equipped according to European standards, limit the possibility of building efficient local environmental monitoring systems.

The quality monitoring system for environmental components, designed for Valea Jiului, is one that aims to use state-of-the-art equipment to perform measurements and tries to reduce the likelihood of errors due to laboratory sampling.

This is one of the directions for the development of the national monitoring system. By setting up a network of local systems, it is possible to achieve a quality control of the environment, much more efficient and more complex, this fact also means more complex data and more useful information, for the national and international system, in which Romania is a partner.

References

[1] **Faur Fl.** 2009
The Elaboration of an Environmental Monitoring System in the Jiu Valley - doctoral thesis, Petroșani (in Romanian)

[2] **Costache A.** 2020
Vulnerability of Human Settlements and Social Risks in Petroșani Depression, Transversal Publishing House, Târgoviște (in Romanian)

vol. 28, issue 1 / 2022
pp. 50-65

[3] **Căldăraru F**. 2010
Methods for Measuring and Monitoring the Average Quality Parameters, Cavallioti Bucharest Publishing House (in Romanian)

[4] ******* 2020
Strategy for the Coal Transition of the Jiu Valley. Analysis of the Main Challenges and Opportunities in the Jiu Valley, PricewaterhouseCoopers Management Consultants SRL (PwC) (in Romanian)

[5] **Agency for Environmental Protection, Hunedoara** 2020
Data for water analysis (in Romanian)

[6] **Ionică (Udrea) M.M.** 2010
Reduction of Wastewater Pollution Resulting from the Mining Activities of Valea Jiului Basin in order to Rehabilitate Upper Jiu - doctoral thesis, Petroșani (in Romanian)

[7] **Băloi (Semen) A.N.** 2014
Study of Surface Water Quality in the Western part of Valea Jiului as a Result of the Restructuring of the Mining Industry in the Area, doctoral thesis Petroșani (in Romanian)