sustainability

MDPI

Article

# A Spatial Analytic Hierarchy Process for Identification of Water Pollution with GIS Software in an Eco-Economy Environment

**Razvan Serbu [1], Bogdan Marza [1] and Sorin Borza [2,*]**

[1] Faculty of Economic Science, University "Lucian Blaga" of Sibiu, 10 Victoriei Bd., Sibiu 550024, Romania; razvan.serbu@ulbsibiu.ro (R.S.); bogdan.marza@ulbsibiu.ro (B.M.)
[2] Faculty of Engineering, University "Lucian Blaga" of Sibiu, 10 Victoriei Bd., Sibiu 550024, Romania
* Correspondence: sorin.borza@ulbsibiu.ro; Tel.: +40-745-617-315

Academic Editors: Alexandru Ozunu and Dacinia Crina Petrescu
Received: 13 September 2016; Accepted: 10 November 2016; Published: 23 November 2016

**Abstract:** Water pollution has become a global problem and its impact on the health of the human population is growing day by day. This study aims to assess the pollution of the Cibin River (Romania) by a physicochemical analysis. Water samples have been collected from four locations along the Cibin River over a period of 12 months. At this time, there are several commonly used Multiple-Criteria Decision Analysis (MCDA) methods for the assessing the impact of pollutants on the environment. In this research, we used the Analytic Hierarchy Process (AHP) multi-criteria method to evaluate each sampling station's physicochemical parameters. The significant results place the river in the first (sampling stations 1, 2 and 3) and second (sampling stations 4) water quality classes. Another significant result of this work is that the research using GIS software allowed an integrated automatic data collection system and displays interactive results.

**Keywords:** environment; pollution; GIS; multi-criteria; method

## 1. Introduction

The state of the environment has continuously degraded due to industrial activities. Environmental pollution has increased because of the exploitation of natural resources due to unprecedented population growth, as well as for many other reasons. Nations of the world have committed to developing measures and preventive actions in order to slow, halt and, if possible, reverse this process that has proven to be disadvantageous and harmful [1]. Environmental impact assessment is a procedure that aims to analyze and evaluate the impacts of human activity on the environment. In this way, it supports the actions for the improvement of environmental quality and helps in the practical implementation of sustainable development [2]. This millennium will bring a continuous search for equilibrium, especially from the socio-economic and political points of view. We have discussed in other papers the continuous search for equilibrium between privacy and security, and now it is time to find a balance between ecology and economy [3]. The population of the Earth will have to face more and more challenges in balancing ecology and economy. We think that the future can be a bright one only if humanity takes into consideration eco-economy, sustainability, and, even more importantly, an eco-bio-economy.

In 2011, the academician Alexandru T. Bogdan tried to unify the two concepts of eco-economy after Lester Brown and bio-economy after Nicholas Georgescu Roegen and came up with a new paradigm "eco-bio-economy" [4] as an economy of the future meant to serve the lives of people through rational use of environment resources. In this perspective, the author presented in a graphical form the integrated ellipse of eco-bio-economy and the subsequent stations between concept, phrases and paradigms, which form the content of the concept of eco-bio-economy. In this vast and complex process, the principles of eco-economy must be expanded:

(1) Major contributions in ensuring the ecological balance by reducing the conflict between man and nature, and between the processes of economics and social development and natural resources.
(2) The settlement of patterns of evolution on solutions to avoid ecological crisis.
(3) Imposing environmental attitudes on the members of the society.
(4) Orientation of all eco-economic activities toward sustainable development as the only solution to promote bio-eco-economy [5].

In their book, Robert Kaplan and David Norton wrote, "If you can't measure something, you can't manage it". Since reality is pretty close to this paradigm, we will focus on presenting how we can practically measure an ecological impact on the environment [6].

As has always been known, water is an important part of the environment and the protection of surface and groundwater is of vital importance. Therefore, water quality assessment and tracking changes in water quality have become indispensable tools for future actions to be implemented.

In this context, we intend to determine the pollution in the Cibin River, which flows in a densely populated area through the middle of Sibiu city. We set out to study whether Cibin River stays within certain pollution classes according to Romanian legislation.

Quality control and continuous monitoring of surface waters, and assessing the data obtained, are remarkable goals in the Water Framework Directive, as developed by the European Union and the competent institutions of Romania [7].

There are several methods for performing the evaluation of the environmental impact of polluting factors. For example, the analytic network process (ANP) is a multicriteria methodology able to consider a wide range of quantitative and qualitative criteria, according to a complex model [8]. The integration of a Geographic Information System (GIS) and Analytic Hierarchy Process (AHP) greatly facilitates the decision-making process [9]. Analytic Network Process (ANP) methodology is currently used in territorial decision problems. ANP is a simple and understandable methodology, even for those who are not experts in the decision process, and it is suitable to be applied jointly with visual representations in real time during workshops [10]. Checklists, matrix or network techniques, GIS methods and quantitative methods can be used to assess the environmental impact and to reach a final conclusion. It should be stressed that there is no single best method.

The user must decide which methods to use in a project. Since there is increasing pressure to express environmental impact numerically, quantitative methods are considered to be beneficial methods, as they are able to compare different alternative decisions. The Multi-Criteria Decision Making (MCDM) methods Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity Systems (TOPSIS) can be successfully used to evaluate the different factors involved in the processes of the natural environment [11]. For the analysis of surface water, modeling techniques such as AQUTOX [12] can be used for conventional parameters such as dissolved oxygen, temperature, pH, total nitrogen, total phosphorus, and organic impurities to assess water quality. The quantitative methods for assessing the impact of environmental pollutants include the Battelle Columbus method [13], which should be considered when the unit of environmental impact is being defined based on the environmental quality and the importance of the environmental parameter unit. Quantitative methods define a numerical value that quantifies the state of the environment. There are many quantitative methods. These quantitative methods can be used for quality assessment in a complex environment and are able to assess the impact of human activities on the environment as well as develop mitigation plans for rehabilitating polluted environments. The main objective of this paper is to determine, using spatial analysis software developed by Geomedia Professional and the multi-criteria method AHP, the most and least polluted areas of the Cibin River.

In addition, the visual interface of GIS allows researchers to establish a clearer and smoother communication channel, which can greatly enhance the efficiency of problem-solving in many cases [14].

The method will be applied for the first measurement of the physical and chemical factors of the River Cibin and the surrounding geographical region. The link between parameters that define water quality can be analyzed using the Pearson moment [15] which creates a correlated analysis between these parameters. One objective of our project is to focus on just one element of the environment: water, more specifically the water surface and concrete results using a quantitative method of evaluation in accordance with the guidelines of the European Union Framework Directive [16].

The following parameters will be measured in accordance with Romanian Standards with the tools indicated in parentheses:

- pH (PHEHT NEOTEK PONSEL digital sensor: pH, Redox, Temperature, Datasheet);
- Dissolved oxygen content (NOETEK-sensor digital PONSEL: ODOT: Optical Dissolved Oxygen Data Sheet) standards oxygen saturation.

The analysis methods used to determine the physical and chemical quality indicators for water were as follows: dissolved oxygen—ISO 5814/99, pH—SR ISO 10523-97, $PO_4^-$—KIT Merck, $SO_4^-$—PS/LE 17, $NH_4^+$—SR ISO 7150-1/2001, $NO_3^-$—SR ISO 7890/2000, CCOCr—SR ISO 6060/96, CBO5—SR ISO 5815/95, solid suspension—STAS 6953/81, waste—STAS 9187/95.

The algorithm presented in this paper will contain the following steps:

(1) Classification of surface waters;
(2) Determining the type of surface water: river or lake;
(3) Determination of physico chemical;
(4) Analysis of physico chemical space measurement;
(5) Determination of chemical agents depending on the deviation from the rules in force;
(6) Classification of parameters using the AHP.

The work presented will determine the quality of water in various points in the geographic area considered, taking into account the specific factors of pollution in surface water. The algorithm is designed to be flexible and can be extended with additional assessment criteria, if necessary. The advantage of the method is that it provides certain important environmental parameters. The algorithm designed can be easily used for data processing. The paper algorithm will be introduced in GIS software. This will support the work of specialists carrying out reports on surface water areas studied, in accordance with national and EU environmental directives.

The global crisis is currently complex and multi dimensional one that affects every aspect of our life—health and living conditions, quality of the environment and social, economic and technological issues, etc. It is a vast crisis that has not been seen before in humanity. Human re-spirituality the sustainable basis of the large institutions, and it represents a redefining of human nature from the perspective of the fact a revolution of the means must always be subordinate to expectations. Only out of a harmony between means and expectations can we achieve the health of the common lives of all people, communities, organizations, families and institutions [17].

We tried to illustrate the utility of multi-criteria methods, in particular AHP, to assess water pollution. We implemented this method in software Geomedia Professional and we have tried to show the possibility of making an automatic processing and visualization of data on pollution in the River Cibin.

## 2. Materials and Methods

As we already mentioned, first we wanted to see in which category Cibin River fits in terms of water pollution, according to existing legislation. For this purpose, we analyzed the legislation on surface waters in Romania, we analyzed each pollutant from the same point of view. Then, based on measurements taken, we intend to highlight the usefulness of AHP multi-criteria method for evaluating chemical parameters. We exemplified in detail how this method is being applied and its implementation in GeoMedia Professional software.

The study results refer to a series of chemical parameters which refer to water quality in the Cibin River. They were compared with Order No. 161/2006 [16], which makes reference to the classification of waters according to their ecological status. Depending on this classification waters may be:

- Class I (one) very best in environmental terms;
- Class II (two) best of ecological terms;
- Class III (three) environments of ecological terms;
- Class IV (four) worst in ecological terms;
- Class V (five) very bad in ecological terms

Water samples were collected along different periods of the year.

The maximum allowances for drinking water were taken from Law 458/2002 [17], amended by Act No. 311/2004 [18]. Categories and technical requirements have been taken in order 1146/2002 [19].

Spatial data analysis was done using GIS software (Esri, Redlands, CA, USA), Geomedia Professional [20]. Digital maps made related areas were investigated and results obtained in accordance with rigorous laws, orders and standards.

Measuring points upstream of the dam at the mouth of the river are visible in Figures 1 and 2. All measuring points are visible in Figure 3.

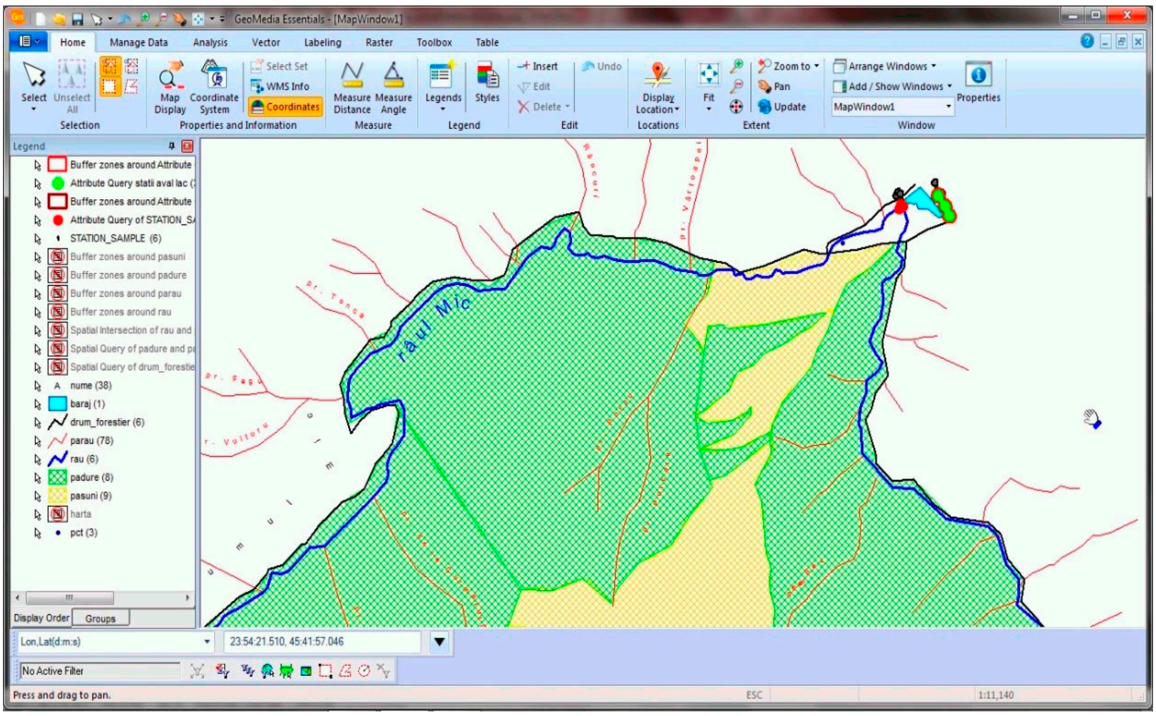


**Figure 1.** The map illustrating where we placed the first measuring point, in the mountainous area near the formation of River Cibin.

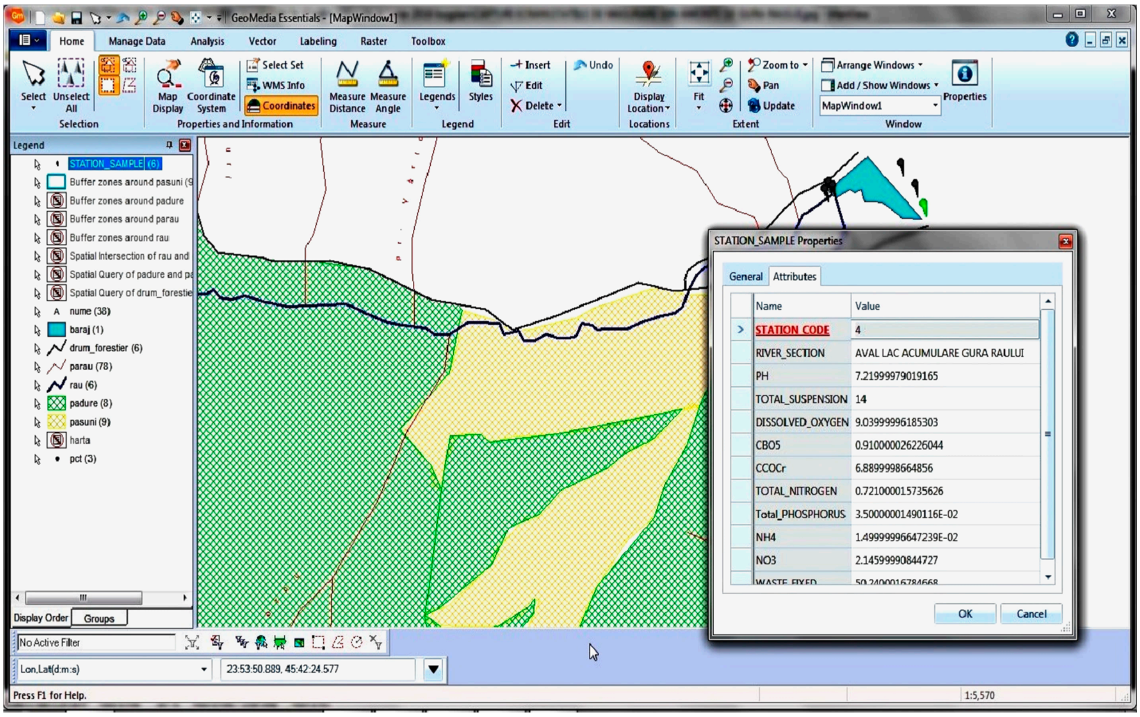


**Figure 2.** The table with the dates of the first measuring point in Geomedia Professional, example for implementation of the Analytic Hierarchy Process (AHP) methodology in the Geographic Information System (GIS).

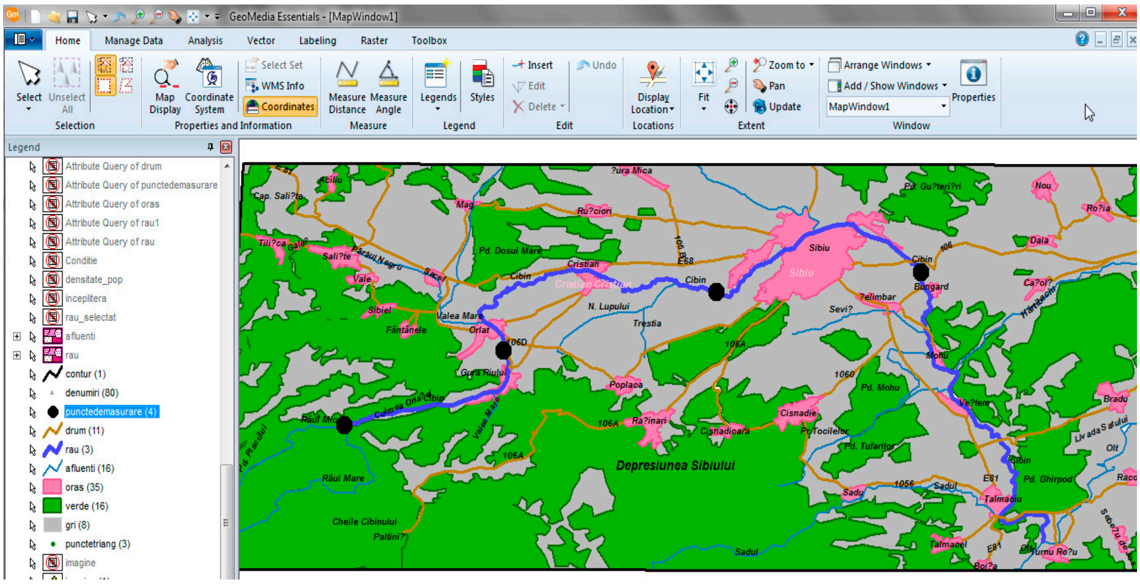


**Figure 3.** The map with all measuring points along Cibin River, on hills and mountainous area and in the plains.

For a better explanation of the map in Figure 3 and the paper in general, we found it necessary to present the real image in Figures 4–7, showing places where the measurements were performed.

Measurement station number one is presented in Figure 4.

**Figure 4.** The place where measurements were made for station 1.

Measurement station number two is presented in Figure 5.

**Figure 5.** The place where measurements were made for station 2.

Measurement station number three is presented in Figure 6.

**Figure 6.** The place where measurements were made for station 3.

Measurement station number four is presented in Figure 7.

**Figure 7.** The place where measurements were made for station 4.

In this paper we have mainly used the AHP method.

Multi-criteria analysis appeared in 1960 as a tool for taking decisions. Recently, it has become increasingly popular in project management, both in the ex-ante and ex-post evaluation of projects, as shown [21]. Multi-criteria analysis applies specifically where the approach via a single criterion is not sufficient (such as cost-benefit analysis), especially when significant social and environmental impacts cannot be assigned monetary values. The purpose of this tool is to structure and combine different evaluations that must be considered in the decision-making process when making decisions involves several alternatives and their treatment of each of these greatly influences the final decision.

Importantly, the multi-criteria analysis is used to record the reasoning and subjective views of stakeholders in relation to each issue. It is usually used to synthesize opinions to determine priority structures to analyze conflict situations or make recommendations or offer operational advice.

The AHP multi-criteria method was developed by Saaty [22,23] as a method of analyzing decisions based on a hierarchy of their component decisions. As noted in [24], this proved to be one of the methods applied the AMC and is mentioned in most textbooks and guides on AMC. This method is essentially an interactive one, where a decision maker or a group of decision makers communicate their preferences and analyst opinions can be debated or discussed and results can be evaluated. The method derives largely from theories about human behavior, including those relating to the process of thinking, logic, intuition, experience and learning theories. AHP also involves developing a cumulative linear model, but its format standard procedures are used to derive the weights and scores achieved by alternatives which are based respectively on the pair of criteria and comparison of options.

Therefore, the AHP is based on the construction of a series of matrices "paired comparisons" criteria for comparing with each other [22]. The aim of this approach is the ranking or weighting of each criterion describing the importance of the contribution of each of these criteria to target the overall problem. If the criteria are broken down into a number of sub-criteria comparisons, the pair is repeated for each one of the levels of this hierarchy. A comparison pair of $n$ criteria ($C_1$, ..., $C_n$) to reflect the importance or weight of each criterion in influencing the overall objective and involves the construction of a matrix $n$ (C) showing the dominance of a criterion in the left column of each of the criteria, as shown in Figure 8.

$$
C = \begin{array}{c|ccc}
 & C_1 & \cdots & C_n \\
\hline
C_1 & c_1/c_1 & \cdots & c_1/c_n \\
\vdots & \vdots & \ddots & \vdots \\
Cn & c_n/c_1 & \cdots & c_n/c_n
\end{array}
$$

**Figure 8.** The "paired comparisons" matrix.

For each record C, the ratio reflects the scale of weights assigned to each criterion priority basis. To make these determinations, Saaty developed a scale for intensity of importance of nine points (Table 1). It argues that scale is based on psychological experiments and is designed to correctly reflect the priorities of the comparisons between the two elements, at the same time as minimizing the difficulties that are involved [23].

**Table 1.** The Saaty table: the factors importance.

| Intensity Importance | Definition |
|---|---|
| 1 | Equal importance to both elements |
| 3 | Lesser importance of one item over another |
| 5 | Significant or critical importance of one item over another |
| 7 | Demonstrated the importance of one item to another |
| 9 | The absolute importance of one element over another |

The values of 2, 4, 6 and 8 are intermediate values that can be used to represent shades of law in addition to those five basic assessments. For the matrix C, each record in the cell is positive and diagonal elements (CJJ) are equal to 1, assuming that transitivity preferences prevail. For example, if $C_1$ is preferably on a scale of from 5 to $C_2$, then $C_2$ is preferred on a scale of 1/5 $C_1$, the mutual property CJJ = 1/CJJ is satisfied and estimates are provided only for cells that are above the diagonal.

Other examples used for multi-criteria methods in the literature are: TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). This is a technique to evaluate the performance of alternatives through the similarity with the ideal solution. According to this technique, the best alternative would be one that is closest to the positive-ideal solution and farthest from the negative-ideal solution. The positive-ideal solution is one that maximizes the benefit criteria and minimizes the cost criteria. The negative-ideal solution maximizes the cost criteria and minimizes the benefit criteria. In summary, the positive-ideal solution is composed of all best values attainable from the criteria, and the negative-ideal solution consists of all the worst values attainable from the criteria [25–27]. ELECTRE (Elimination and Choice Expressing Reality) is a very simple method and it should be applied only when all the criteria have been coded in numerical scales with identical ranges [28,29]. ANP (Analytic Network Process) is a multicriteria methodology that is able to consider a wide range of quantitative and qualitative criteria, according to a complex model [7,9]. PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) is a multi-criteria decision aid system that permits the building of an outranking between different alternatives [30].

The AHP method has been used in the literature, especially in recent years. In order to find a frequency of scientific papers on topics similar to this paper, the authors conducted a study [31], which took into account more than 2 million articles in 128 countries in the last 5 years, according to several keywords. The study highlighted the following information presented in Table 2.

**Table 2.** The keywords for AHP, GIS and water.

| Keyword | Number of Uses |
|---|---|
| water ahp decision making | 19 |
| AHP, GIS, Water | 17 |
| AHP GIS | 101 |
| GIS, AHP decision making | 26 |
| GIS ahp topsis decision making | 1 |
| GIS, AHP, TOPSIS | 4 |
| water pollution AHP GIS | 0 |

## 3. Results

### *3.1. The Physico-Chemical Parameters Measurements Made on Water Quality in the River Cibin*

The measurements presented in this paper were made in each and every month of the year. The graphic of the variation of physicochemical parameters is shown in Figure 9 and the measurements are presented in Table 3.

**Table 3.** All measurements of physicochemical parameters of Cibin River water.

| River Section | pH | Total Suspension | Dissolved Oxygen | CBO5 | CCOCr | Total Azote | Total Phosphorus | $NH_4$ | $NO_3$ | Fixed Residues |
|---|---|---|---|---|---|---|---|---|---|---|
| | | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L |
| Cibin downstream Sibiu | 6.97 | 26.0 | 10.96 | 5.6 | 36.0 | 3.838 | 0.101 | 2.59 | 4.16 | 201.75 |
| Cibin upstream Sibiu | 6.51 | 20.0 | 12.95 | 2.04 | 14.0 | 1.284 | 0.058 | 0.14 | 3.07 | 123.4 |
| Cibin downstream Sibiu | 6.52 | 22.0 | 11.65 | 5.72 | 30.0 | 5.062 | 0.247 | 4.72 | 3.77 | 232.4 |
| Cibin upstream Sibiu | 6.7 | 26.0 | 11.15 | 3.21 | 22.2 | 1.215 | 0.089 | 0.18 | 3.79 | 119.10 |
| Cibin downstream GR | 7.21 | 20.0 | 9.63 | 1.13 | 6.9 | 0.359 | 0.022 | 0.009 | 1.02 | 33.79 |
| Cibin downstream accumulation lake GR | 7.10 | 16.0 | 8.67 | 1.16 | 9.0 | 0.041 | 0.028 | 0.041 | 1.98 | 47.69 |
| Cibin downstream GR | 7.07 | 13.0 | 9.09 | 0.92 | 6.9 | 0.420 | 0.013 | 0.009 | 1.25 | 36.47 |
| Cibin downstream accumulation lake GR | 7.22 | 14.0 | 9.04 | 0.91 | 6.9 | 0.721 | 0.035 | 0.015 | 2.14 | 50.24 |
| Cibin upstream Sibiu | 7.16 | 17.0 | 8.64 | 1.39 | 8.06 | 3.916 | 0.098 | 0.041 | 3.91 | 108.23 |
| Cibin downstream Sibiu | 7.07 | 22.0 | 5.6 | 3.25 | 18.06 | 2.284 | 0.651 | 2.284 | 4.33 | 230.88 |
| Cibin downstream GR | 6.79 | 19.0 | 10.13 | 1.26 | 6.90 | 0.292 | 0.021 | 0.009 | 1.09 | 44.63 |
| Cibin aval accumulation lake GR | 6.97 | 16.0 | 10.10 | 1.38 | 7.87 | 0.689 | 0.023 | 0.009 | 1.84 | 56.36 |
| Cibin downstream Sb | 6.8 | 23.0 | 9.39 | 1.84 | 17.22 | 1.144 | 0.09 | 0.198 | 3.20 | 101.48 |
| Cibin upstream Sb | 6.83 | 19.0 | 7.39 | 4.25 | 25.0 | 3.470 | 0.525 | 1.547 | 5.92 | 214.5 |
| Cibin upstream Sb | 6.62 | 24.0 | 10.61 | 1.54 | 10.42 | 0.877 | 0.069 | 0.121 | 1.90 | 84.07 |
| Cibin downstream Sb | 6.64 | 27.0 | 9.64 | 4.67 | 22.82 | 2.578 | 0.298 | 0.716 | 5.75 | 150.0 |
| Cibin upstream Sb | 7.46 | 22 | 10.83 | 2.9 | 14.88 | 1.820 | 0.139 | 0.384 | 3.78 | 148.5 |
| Cibin downstream Sb | 8.15 | 26.0 | 10.0 | 4.36 | 19.84 | 2.898 | 0.202 | 0.501 | 6.15 | 243.83 |

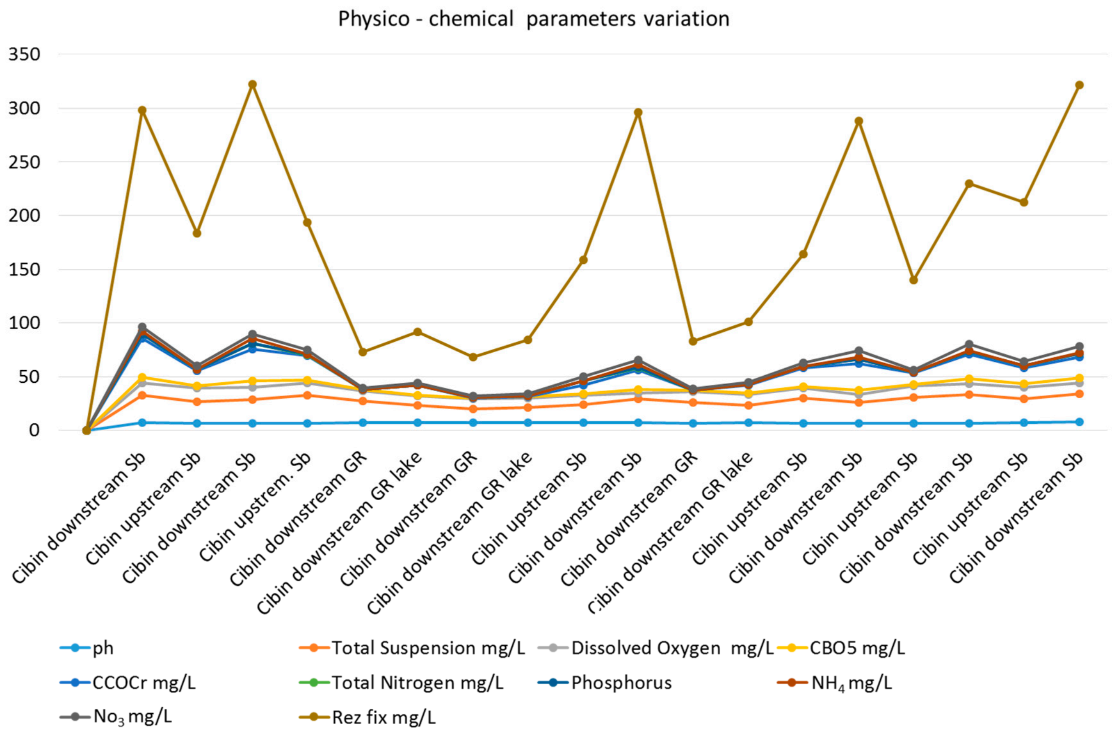


**Figure 9.** Physico—chemical parameters variation.

pH is an important factor that determines the suitability of water for various purposes, including toxicity to animals and plants [32]. The pH is around 7, being neutral in most of the water samples. Figure 10 shows that minimum values reach 6.51 and maximum values reach 8.15.

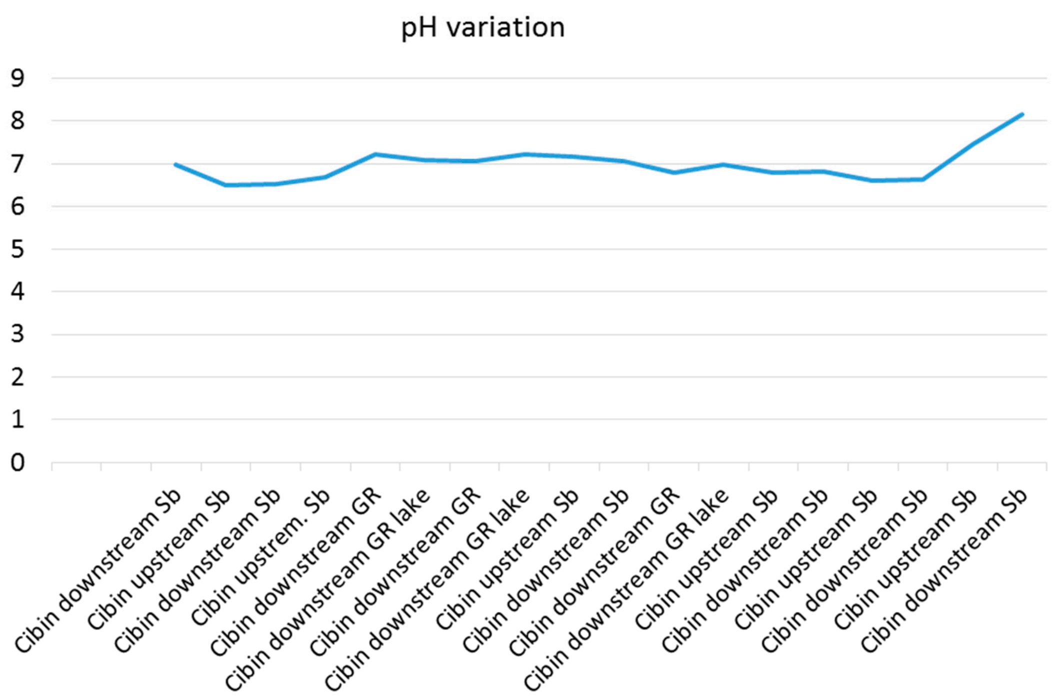


**Figure 10.** The pH variation.

The fluctuation of PH related to seasons is present in Figure 11.

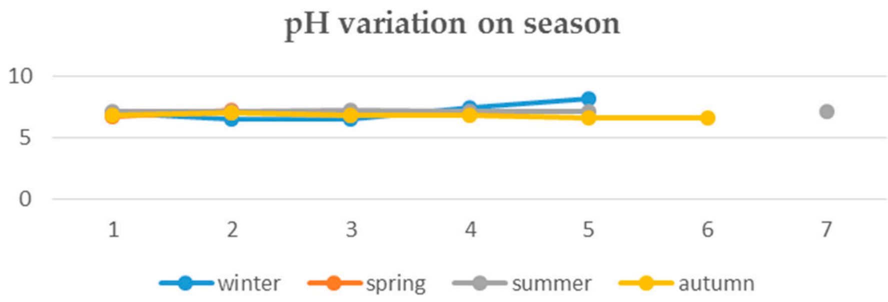


**Figure 11.** pH variation on season.

The medium pH value measured upstream of the accumulation lake from Cibin River is presented in Figure 12.

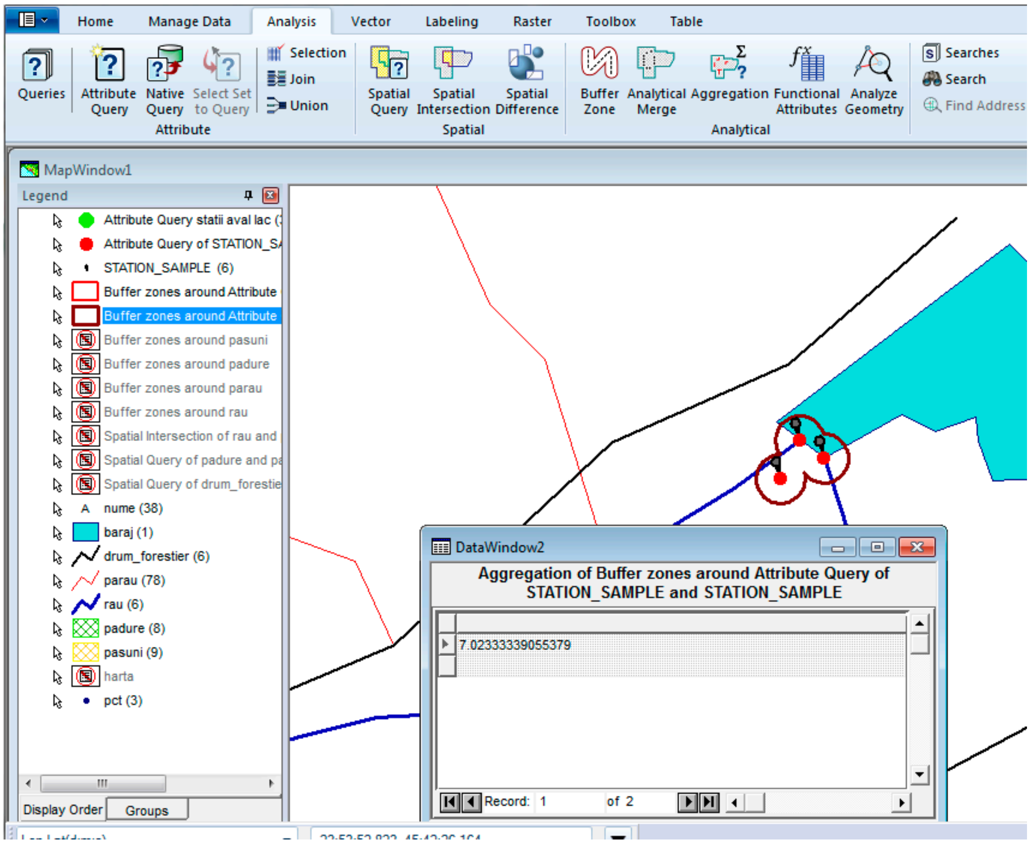


**Figure 12.** The medium value pH on station one.

The medium pH value measured downstream of the accumulation lake from Cibin River is presented in Figure 13.

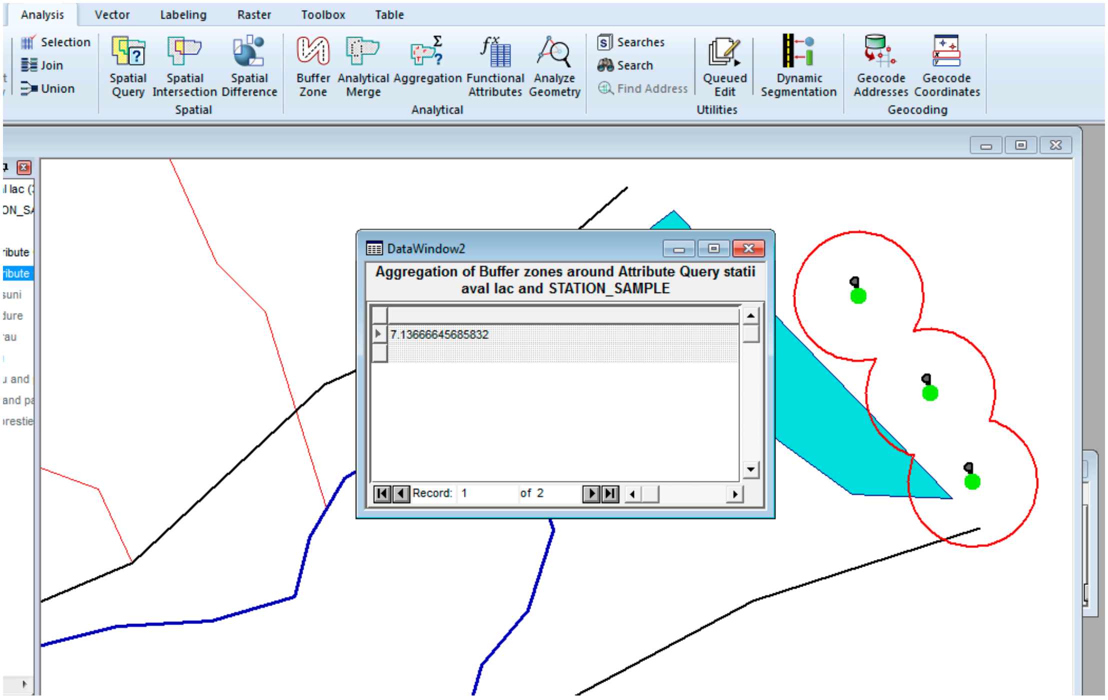


**Figure 13.** The medium value pH on station two.

The average of the values for all four seasons is presented in Table 4.

**Table 4.** The pH average values in different seasons.

| Winter Average_pH | Spring Average_pH | Summer Average_pH | Automn Average_pH |
|---|---|---|---|
| 7.122 | 6.955 | 7.124 | 6.775 |

The graphical representation of the average values for pH on seasons is shown in Figure 14.

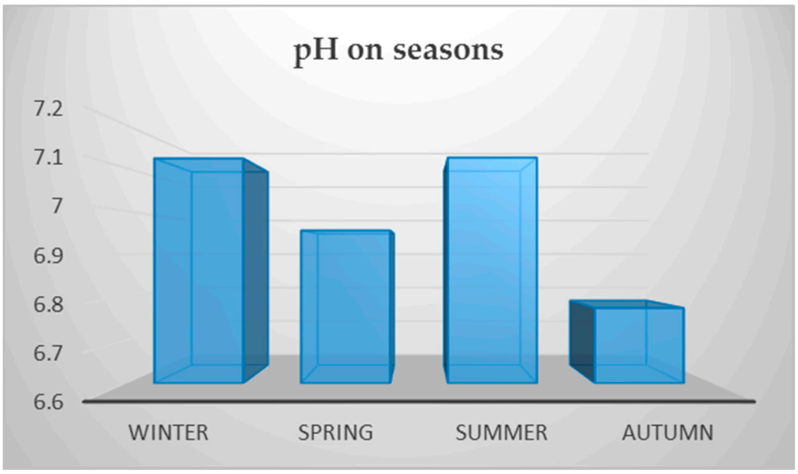


**Figure 14.** The average value of pH on seasons.

The suspended solids are the solids remaining in a water sample filtered through a 1.2 µm filter. According to the World Health Organization, the compounds and elements remaining after filtration are commonly calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate, silica and nitraten. A high amount of suspended solids affects the taste and odor of water, knowing that levels above 300 mg/L become noticeable to consumers. If the suspended solid increases, the river water becomes increasingly unacceptable.

The existence of suspended solids can reduce the clarity of the water, it can degrade the aquatic habitats and can increase the temperature. These are all negative effects that should not happen, and that are decreasing the photosynthesis activity and will result in a higher mortality for aquatic animals.

The variation of residue values for a season are presented in Figure 15.

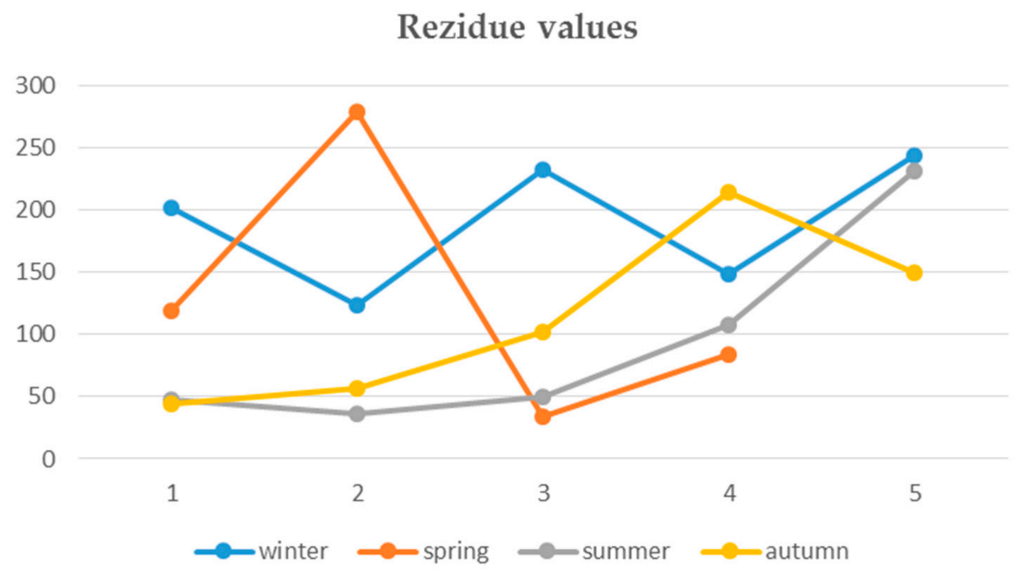


**Figure 15.** The variation of residue values on season.

The variation of total suspension on season are presented in Figure 16.

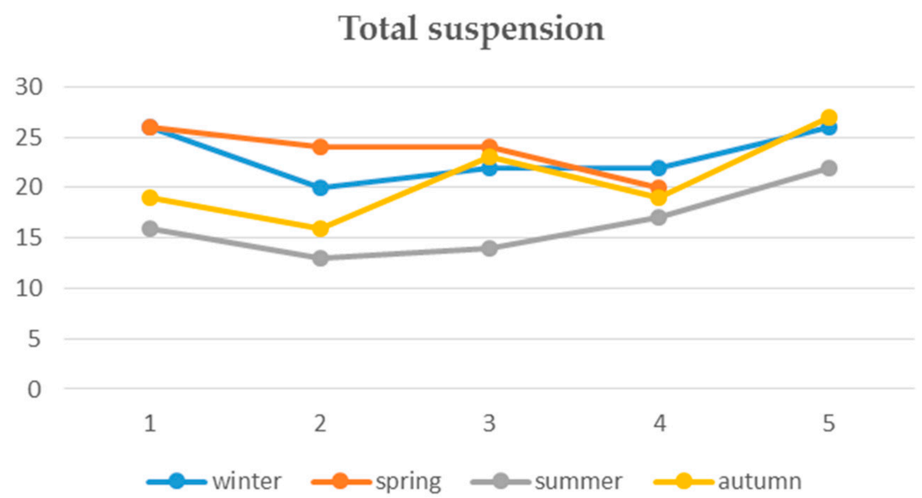


**Figure 16.** The variation of total suspension on season.

A special characteristic of the Cibin River is the fact that the suspensions are found in low amounts ranging between 13 and 26 mg/L, which strengthens the decision of the Cibin River insertion in the 1st class of quality. The variability of the suspension is an indication of the hygene of river banks both for the source and for the points of collection (the variations is within 30%–40%). Once the snow melts, in the spring, a series of natural elements engage in the sources, this is why they appear in a higher volume in the first two monitoring months (March and April). The values registered in October, November and December are the consequences of human pollution. During the winter period, with low irradiance conditions, primary nutrients including $NH_4$ accumulate due to continuing inputs and low phytoplankton nutrient uptake activity. During spring, increases in seasonal and irradiance create conditions for phytoplankton growth and $NH_4$ concentrations decrease due to dilution by spring runoff [33].

Nitrates are very important elements in determining the biological potential of a surface water. Overall growth and high concentration of nitrate and phosphate in lakes lead to eutrophication which increases the amount organic mass in stagnant water. Phosphates and nitrates occur mainly during the rainy season due to the ejection of agriculture. They can be used as nutrients by algae or other aquatic plants [32]. In Figure 17 we present the variation in values for nitrate measurement stations throughout the four seasons.

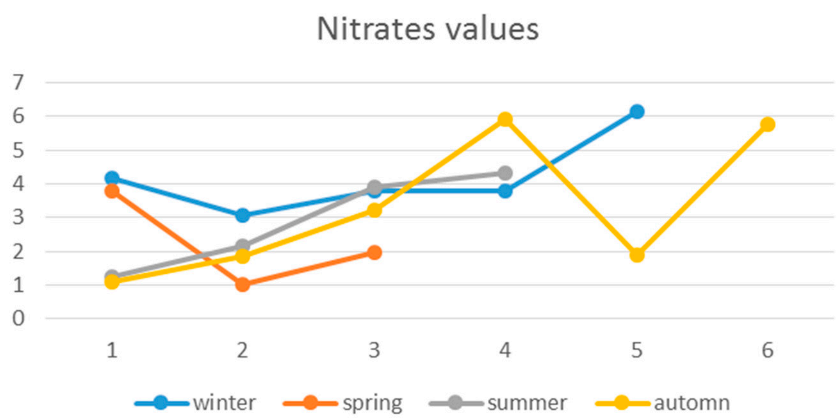


**Figure 17.** Nitrates Values during four seasons.

Benchmarks for nitrate proposed by international organizations:

- Directive 98/83/EC Annex IB—50 mg/L
- WHO guidelines in 2005—50 mg/L
- Ministry of Health Canada—45 mg/L
- US Environmental Protection Agency—45 mg/L
- National legislation—45 mg/L, 50 mg/L

Nitrate concentration varies between the upper river and the area around Sibiu. The minimum amount is about 1 mg/L, while the maximum value is measured at 6 mg/L. The maximum value was recorded in fall.

In Figure 18, we calculated the average amount of nitrates in measuring stations in the upper river with GIS software.

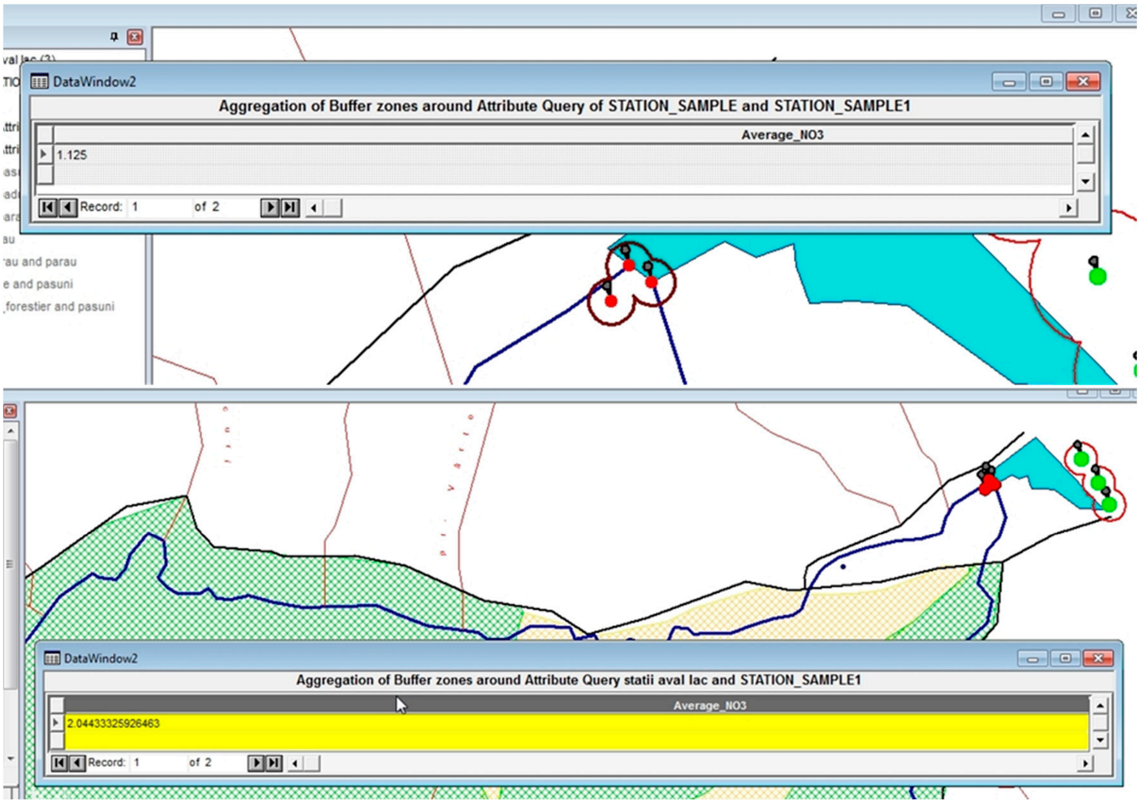


**Figure 18.** The average values nitrates calculated in GIS software.

The average value of nitrates in all measuring stations is = 3.284556.

Next, for each pollutant we kept the same calculation procedure as that used for pH, nitrates, and waste.

After the physico-chemical analysis of all factors are taken into account, Cibin River water can be classified as first class for stations 1 and 2 and as second grade quality in stations 3 and 4. Raul Mare and Raul Mic in which Cibin River forms have very good water quality during the spring and fall. In the upper area, people picnic in the summer so that the human factor is increasing, which generates increasing pollution, especially of nitrates, nitrites and residues present in the water. A higher degree of pollution of the Cibin River, into and out of the city of Sibiu, especially nitrate residues, BOD5 and COD, lead to framing the River Cibin in second class water quality.

*3.2. Results Obtained by Applying the AHP Method for the Determination Most Polluted and Least Polluted Measurement Point*

Using the multi-criteria AHP method we further intend to determine which of the measuring stations is less polluted according to values measured and depending on the physico-chemical measure. Mean values of Physico-Chemical factors, for each measuring station are shown in the Table 5.

**Table 5.** The values for physico-chemical factors in all measurement stations.

| Physico-Chemical Factors Measurement | Cibin Downstream Sb | Cibin Upstream Sb | Cibin Downstream Gura Raului | Cibin Upstream Gura Raului |
|---|---|---|---|---|
| pH | 5.923333 | 6.875 | 7.023333333 | 7.096666667 |
| Total suspension | 23.66667 | 22 | 17.33333333 | 15.33333333 |
| Dissolved oxygen | 9.206667 | 10.595 | 9.616666667 | 9.27 |
| CBO5 | 4.641667 | 2.15333333 | 1.103333333 | 1.15 |
| CCOCr | 25.28667 | 14.4733333 | 6.9 | 7.923333333 |
| Azote | 3.355 | 1.70933333 | 0.357 | 0.483666667 |
| Phosphorus | 0.337333 | 0.0905 | 0.018666667 | 0.028666667 |
| $NH_4$ | 2.060833 | 0.17883333 | 0.009 | 0.021666667 |
| $NO_3$ | 5.0175 | 3.27883333 | 1.125 | 1.989666667 |
| Waste | 212.2267 | 114.13 | 38.29666667 | 51.43 |

Next we present the calculation in the AHP method for the determination of the most polluted and least polluted physical and chemical parameters according to Table 5. We present the calculation of the weights for pH, CBO5, CCOCr and Total Phosphorus.

### 3.2.1. AHP Methodology Calculation for pH Parameter

Whether it is tap water or fountain water, the water that we shower with or swimming pool water, its pH is important. This unit actually expresses the acidity of the water, on a scale from 0 to 14. A pH between 6.5 was found only in September and is tolerated by the human body. However, there are different needs internally and externally.

For a pH from 0 to 7, water may be considered acid if pH 7 water is considered to be neutral, and above this level we can speak of alkaline water. The index does not measure water toxicity, instead it needs to be understood in relation to the human body. Other substances, such as drinks (juice, and alcohol) or cosmetic products (soaps, toothpaste, shampoos, etc.) have specific pH. For example, most commercial drinking water has pH 7, beer has a pH around 5 and juices between 5 and 6. The blood and our cells should be slightly alkaline, they have a pH of 7.35 and 7.5, but they are also influenced by body water extracted from the food we eat. Thus, drinking water serves to compensate for eating food that is too acidic, which can disrupt our metabolism. This is especially true if the kidneys are not healthy because they have the important task of adjusting the acidity or alkalinity of the blood (urine has values that can vary between 4.8 and 8). External healthy skin normally has a pH between 4.5 and 6, which is slightly acidic, and therefore a number of cosmetic products have the same level of pH. When we wash or a bathe, we should respect these parameters.

Ideally, the pH of the water we consume and we wash should be between 6.5 and 9 and it is good to know that the tap values can differ from one region to another. In regions with calcareous soil, subsurface water, for example, is more alkaline. Water that is pH neutral and slightly alkaline water is better to drink (especially for those who eat slightly acidic food).

As mentioned above, interpretation was done for Table 6 and the normalized matrix, Table 7.

The CR index must be less than 0.01. This is true for all physical and chemical factors taken into account.

**Table 6.** The "paired comparisons" matrix for pH.

| pH | Cibin Downstream Sb | Cibin Upstream Sb | Cibin Downstream Gura Raului | Cibin Upstream Gura Raului |
|---|---|---|---|---|
| Cibin downstream Sb | 1 | 0.5 | 0.333333 | 0.333333 |
| Cibin upstream Sb | 2 | 1 | 0.666667 | 0.666667 |
| Cibin downstream GR | 3 | 1.5 | 1 | 1 |
| Cibin upstream GR | 3 | 1.5 | 1 | 1 |

**Table 7.** The normalized matrix for pH.

| pH | Cibin Downstream Sb | Cibin Upstream Sb | Cibin Downstream Gura Raului | Cibin Upstream Gura Raului | Sum | W | P. Vector | Lambda | Max | CI | CR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cibin downstream Sb | 0.111 | 0.111 | 0.111 | 0.111 | 0.444 | 0.111 | 0.4444 | 4 | 4 | 0 | 0 |
| Cibin upstream Sb | 0.2222 | 0.2222 | 0.222 | 0.222 | 0.888 | 0.222 | 0.8888 | 4 | | | |
| Cibin downstream GR | 0.3333 | 0.3333 | 0.333 | 0.333 | 1.333 | 0.333 | 1.333 | 4 | | | |
| Cibin upstream GR | 0.3333 | 0.3333 | 0.333 | 0.333 | 1.333 | 0.333 | 1.3333 | 4 | | | |

3.2.2. AHP Methodology Calculation for CBO5

This index is a measure of the contamination of organic waste water and the amount of oxygen (mg/table) required for oxidative degradation by microorganisms of organic substances contained in one litter of water at 20 °C for 5 days (BOD5). It can determine the consumption of oxygen in 24 h (CBO24) immediate biochemical oxygen demand (CBIO) and consumption within 20 days (CBO20).

The maximum value allowed for CBO5 is 25 [34] in Romania.

A multi-criteria value using the AHP weights is presented in Tables 8 and 9.

**Table 8.** The "paired comparisons" matrix for CBO5, biochemical oxygen demand in five days.

| CBO5 | Cibin Downstream Sb | Cibin Upstream Sb | Cibin Downstream Gura Raului | Cibin Upstream Gura Raului |
|---|---|---|---|---|
| Cibin downstream Sb | 1 | 0.333333 | 0.142857 | 0.142857 |
| Cibin upstream Sb | 3 | 1 | 0.333333 | 0.333333 |
| Cibin downstream Gura Raului | 7 | 3 | 1 | 1 |
| Cibin upstream Gura Raului | 7 | 3 | 1 | 1 |

3.2.3. AHP Methodology Calculation for CCOCr Parameter

Chemical oxygen demand COD (potassium dichromate method) is the mass concentration of oxygen equivalent to the amount of potassium dichromate oxidation in acidic consumed dissolved organic matter and matter present in wastewater.

The maximum value in Romania allowed is 125 CBOCr according to [35].

The eable by Saaty and muticriteria values using the AHP weights are presented in Tables 10 and 11.

3.2.4. AHP Methodology Calculation for Total Phosphorus, *N* Parameter

The admissible value in Romania is 1.0 mg/dm$^3$ according to [36]. The table by Saaty and muticriteria values using the AHP weights value of total phosphorus, are presented in Tables 12 and 13.

In the same way we calculate with AHP method the weight for Total Nitrogen, Ammonia Nitrogen, Nitrogen, Fixed residue.

Finally, we obtain the weights for all parameters. The results of calculations using AHP method for all parameters are shown in Table 14. We get the rankings of water pollution in the Cibin River depending on the physico-chemical parameters from Table 5.

The weight parameters variation is presented in Figure 19.

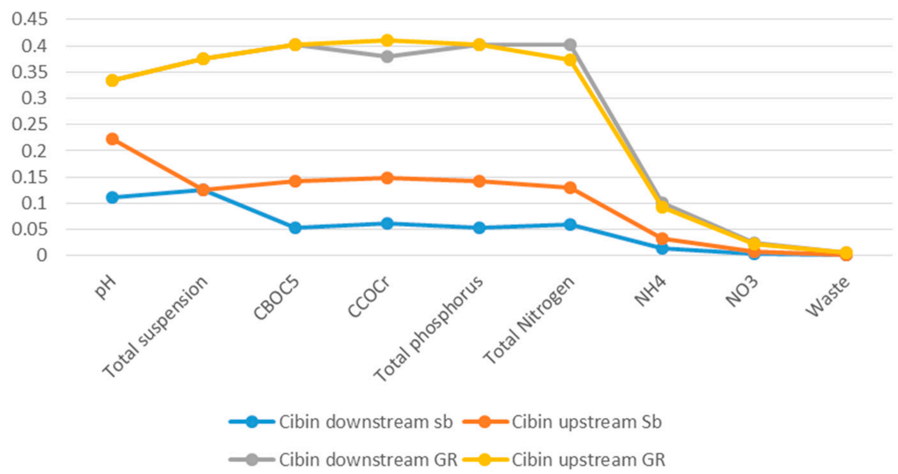


**Figure 19.** The weight parameters variation.

**Table 9.** The weight of CBO5.

| CBO5 | Cibin Downstream Sb | Cibin Upstream Sb | Cibin Downstream Gura Raului | Cibin Upstream Gura Raului | Sum | W | P. Vector | Lamda | Max | CI | CR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cibin downstream Sb | 0.05555 | 0.045455 | 0.05769 | 0.057692 | 0.2163 | 0.054099 | 0.2164 | 4.0015 | 4.0125 | 0.004193 | 0.004712 |
| Cibin upstream Sb | 0.16666 | 0.136364 | 0.13461 | 0.134615 | 0.5722 | 0.143065 | 0.5729 | 4.0049 | | | |
| Cibin downstream Gura Raului | 0.38888 | 0.409091 | 0.40384 | 0.403846 | 1.6056 | 0.401418 | 1.6107 | 4.0125 | | | |
| Cibin upstream Gura Raului | 0.38888 | 0.409091 | 0.40384 | 0.403846 | 1.6056 | 0.401418 | 1.6107 | 4.0125 | | | |

**Table 10.** The "paired comparisons" matrix for CCOCr, Chemical oxygen demand (potassium dichromate method).

| CCOCr | Cibin Downstream Sb | Cibin Upstream Sb | Cibin Downstream Gura Raului | Cibin Upstream Gura Raului |
|---|---|---|---|---|
| Cibin downstream Sb | 1 | 0.333333 | 0.2 | 0.142857 |
| Cibin upstream Sb | 3 | 1 | 0.333333 | 0.333333 |
| Cibin downstream Gura Raului | 5 | 3 | 1 | 1 |
| Cibin upstream Gura Raului | 7 | 3 | 1 | 1 |

**Table 11.** The weight for CCOCr.

| CCOCr | Cibin Downstream Sb | Cibin Upstream Sb | Cibin Downstream Gura Raului | Cibin Upstream Gura Raului | Sum | W | P. Vector | Lamda | Max | CI | CR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cibin downstream Sb | 0.0625 | 0.045455 | 0.078947 | 0.057692 | 0.2445 | 0.0611 | 0.245085 | 4.0080 | 4.0511 | 0.0097 | 0.0099 |
| Cibin upstream Sb | 0.1875 | 0.136364 | 0.131579 | 0.134615 | 0.5900 | 0.1475 | 0.594739 | 4.0317 | | | |
| Cibin downstream Gura Raului | 0.3125 | 0.409091 | 0.394737 | 0.403846 | 1.5201 | 0.3800 | 1.539623 | 4.0511 | | | |
| Cibin upstream Gura Raului | 0.4375 | 0.409091 | 0.394737 | 0.403846 | 1.6451 | 0.4112 | 1.66192 | 4.0407 | | | |

**Table 12.** The "paired comparisons" matrix for total phosphorus.

| Total Phosphorus | Cibin Downstream Sb | Cibin Upstream Sb | Cibin Downstream Gura Raului | Cibin Upstream Gura Raului |
|---|---|---|---|---|
| Cibin downstream Sb | 1 | 0.333333 | 0.142857 | 0.142857 |
| Cibin upstream Sb | 3 | 1 | 0.333333 | 0.333333 |
| Cibin downstream Gura Raului | 7 | 3 | 1 | 1 |
| Cibin upstream Gura Raului | 7 | 3 | 1 | 1 |

**Table 13.** The weight for total phosphorus.

| Total Phosphorus | Cibin Downstream Sb | Cibin Upstream Sb | Cibin Downstream Gura Raului | Cibin Upstream Gura Raului | Sum | W | P. Vector | Lamda | Max | CI | CR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cibin downstream Sb | 0.055556 | 0.045455 | 0.057692 | 0.057692 | 0.216395 | 0.054099 | 0.216478 | 4.001539 | 4.012582 | 0.0041939 | 0.004712 |
| Cibin upstream Sb | 0.166667 | 0.136364 | 0.134615 | 0.134615 | 0.572261 | 0.143065 | 0.572973 | 4.004979 | | | |
| Cibin downstream Gura Raului | 0.388889 | 0.409091 | 0.403846 | 0.403846 | 1.605672 | 0.401418 | 1.610723 | 4.012582 | | | |
| Cibin upstream Gura Raului | 0.388889 | 0.409091 | 0.403846 | 0.403846 | 1.605672 | 0.401418 | 1.610723 | 4.012582 | | | |

**Table 14.** The measuring points ranking, depending on physico-chemical parameters consider.

| | pH | Total Suspensions | CBOC5 | CCOCr | Total Phosphorus | Total Nitrogen | $NH_4$ | $NO_3$ | Waste | Geomethric Mean of Weight | Rank of Our Researches |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cibin downstream Sb | 0.1111 | 0.125 | 0.0541 | 0.06115 | 0.0541 | 0.05987 | 0.014967 | 0.00374 | 0.00093544 | 0.02706620 | **4** |
| Cibin upstream Sb | 0.2222 | 0.125 | 0.14307 | 0.14751 | 0.14307 | 0.1296 | 0.032401 | 0.0081 | 0.00202506 | 0.05640292 | **3** |
| Cibin downstream GR | 0.3333 | 0.375 | 0.40142 | 0.38004 | 0.40142 | 0.40142 | 0.100355 | 0.02509 | 0.00627216 | 0.15393216 | **1** |
| Cibin upstream GR | 0.3333 | 0.375 | 0.40142 | 0.41129 | 0.40142 | 0.37364 | 0.09341 | 0.02335 | 0.00583813 | 0.15041841 | **2** |

Map research results are presented in Figure 20.

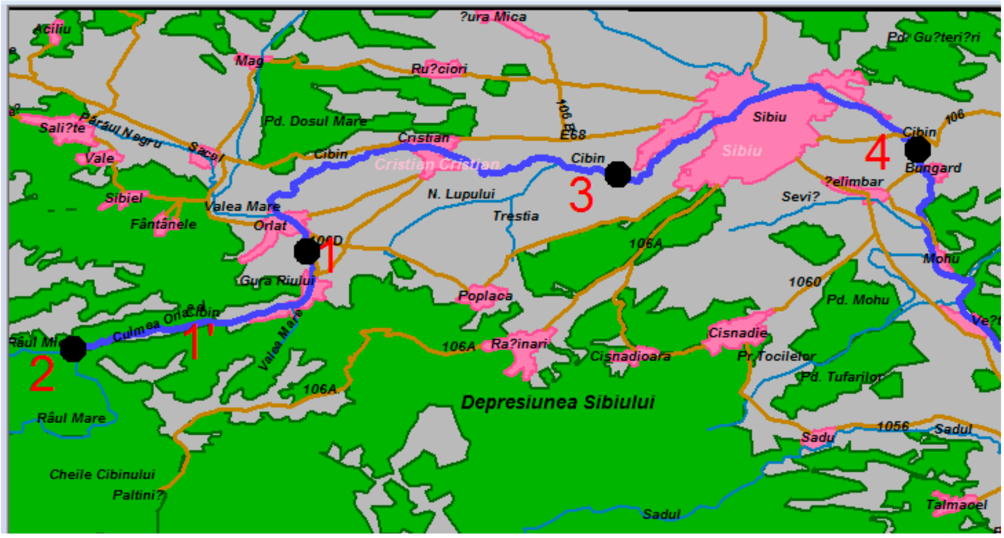


**Figure 20.** The results of our research.

Our research results, as a result of applying the method AHP, are as follows:

- The least polluted water is the number two measuring points, in the mountain area of CIBIN, Cibin River, Cibin downstream of the GR point. It is interesting to note that this point is found by the village mouth, and by the lake. The water is cleaner than that upstream of the lake. Although it was expected that the least polluted water would be found at the point of measuring number one, application of the AHP method led to a different result than that suggested by human assumption;
- As expected, Cibin River water is most polluted by the city of Sibiu, which has 200,000 inhabitants.

Research conducted in this paper led to the result that Cibin River is among the least polluted in Romania.

AHP calculation methodology can be implemented in GIS software.

Another result of this work is that the AHP method, the calculation, can be implemented in software Geomedia Professional. This is very important because in the future we can view the status of pollution of a river at any point where measurements are made. This can be done practically in real time multi-criteria evaluation of existing measurement points on a particular river.

## 4. Discussion

The research that we have conducted has revealed that Cibin River is a river where water quality is pretty good, relatively less polluted than other rivers. The AHP multi-criteria method led to predictable results in this case. It can be used successfully in more complex cases in which physico chemical analysis has very different values. The AHP method allows for the evaluation of several observation points regardless of the number of parameters and their complexity can give accurate results on environmental pollution.

As seen in Table 2, a search for the keywords water pollution, AHP, GIS found no articles that studied all three entities simultaneously. This is one more original aspect of this paper. By conventional means, determining water quality of the River Cibin is one of the objectives of the work and research has determined that the River Cibin has very good water quality and is among the least polluted rivers in Romania. The AHP multi-criteria method resulted in the viewpoint that pollution depends on physico chemical factors.

The precise situation of the observation points is shown in Figure 21.

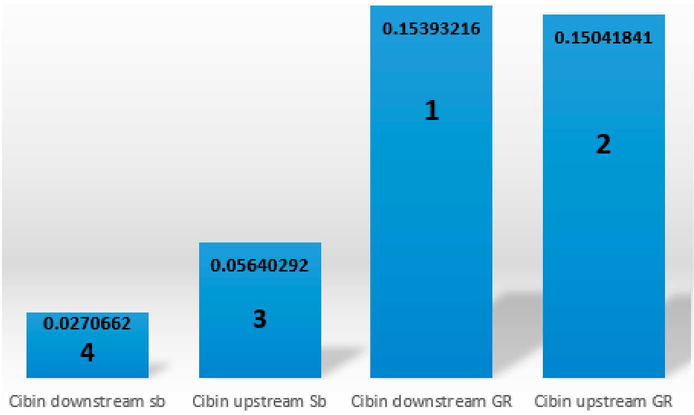


**Figure 21.** The rank of observation points.

GIS software allows us to highlight in real time and with a visual representation, the pollution in each observation point. The AHP multi-criteria method functions can be calculated on GIS software, Geomedia Professional. This is particularly important because it allows for the evaluation of interactive observation points.

Starting from the research presented in this paper we can provide a system for measuring data, taking them into a database. The database is attached to GIS software by calculation methods that are implemented for multi-criteria that can therefore interactively present pollution at any point depending on each parameter considered, and globally according to results provided by the multi-criteria method or methods considered.

From the physical point of view, such a system can be achieved as follows:

- For data acquisition, sensors are used to measure parameters. They are connected through computer motherboards acquisitions.
- Labview software virtual appliance allows us to obtain the results of measurements performed in the field. The results are stored in a database attached to this software. This can be Access, SQL Server, Oracle, etc.
- GIS software, takes this database, performs calculations and creates intelligent interactive maps showing the results.

The proposal for the integrated system is visible in Figure 22.

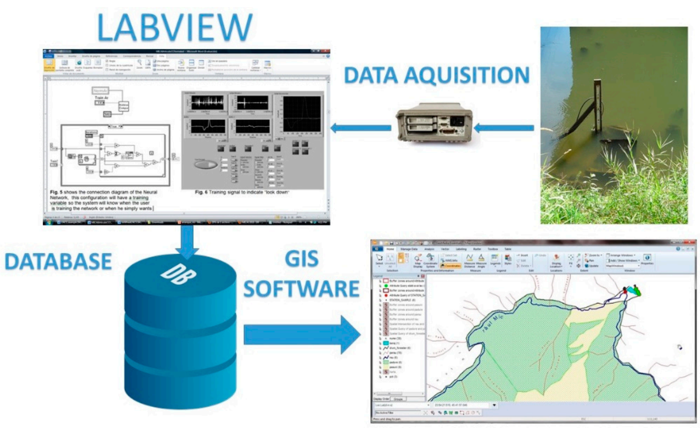


**Figure 22.** The Integrated System for acquisition, processing and interactive visualization data.

Human development is ecologically sustainable in relation to the environment if the interventions and affects are imposed by human activities. Whether they are economic, technological, social or cultural does not alter the intrinsic rates of change of Nature or the ecosystems in ways unmanageable by Nature or irreversible from the point of view of future generations.

## 5. Conclusions

Studying the measurements that are observed by the measuring station downstream from the dam to the mouth has the best results in terms of pollution. In this area, the Cibin River is the least polluted. In the first part of the paper it was noted that the upper area of the Cibin River can be classified as Class 1 Classification pollution of surface waters made in Romania. Notably, although there was a change along Cibin River, the water quality remained very good.

The AHP multi-criteria method and software used have led to the same result. Cibin River has the most polluted water downstream from Sibiu and the cleanest water downstream of the dam at the mouth. Multi-criteria methods can be used in complex cases to determine the physical and chemical pollution of the Cibin River.

Multi-criteria methods, in particular the AHP methods, are particularly useful tools in research work, allowing for complex interpretation of research results.

Developing a new model of development of human society requires the adaptation of old concepts, especially economic ones, and their connection to the specific environmental management and the contemporary crisis. This paper analyzed the basic components of the concept of sustainable development: environmental protection, enabling measurements that can highlight the importance of the development of mechanisms, criteria, tools and models that can put the economy in alert mode in finding new ways of achieving ecologic development.

The research can be extended taking into account different parameters to those of a physico chemical nature. As we have shown in Table 2, literature that simultaneously deals with issues of multi-criteria methods and GIS software (AHP, TOPSIS and GIS) is scarce. Moreover, this work is among the few that treats water pollution problems of multi-criteria analysis using GIS techniques. Besides physico chemical parameters, you may take into account other parameters of a different nature. In this case we can further apply the TOPSIS method. We may consider as factors:

- medical nature such as bacteria, microorganisms;
- noise;
- number of residents.

In this way, the pollution in each observation point can be determined in a complex manner.

The present paper is a first step in the proposed integrated system. The paper showed that the AHP multi-criteria method can be calculated in a GIS software and showed the applicability of multi-criteria methods in assessing surface water pollution, according to several parameters. In the future, research will be focused on implementing this system. Calculations for multi-criteria methods can be achieved either by their own function's software data acquisition and GIS software, either by the program or in a programming language.

**Author Contributions:** Razvan Serbu conceived of and designed the research. Bogdan Marza performed the data processes. Sorin Borza wrote the paper. All authors revised the research design and extensively updated the paper. All authors read and approved the final manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Robu, B. *Environmental Impact and Risk Assessment for Industrial Activities*; EcoZone Press: Iasi, Romania, 2005. (In Romanian)
2. Toro, J.; Requena, I.; Duarte, O.; Zamorano, M. A qualitative method proposal to improve environmental impact assessment. *EIA* **2013**, *43*, 9–20. [CrossRef]
3. Serbu, R.; Marza, B.; Borza, S. Bio-Eco-Analysis for Risk Factors using GIS Software. *Int. J. Comput. Commun. Control* **2013**, *8*, 305–312. [CrossRef]

4. Bogdan, C.D. *Eco-Bio-Diplomaţie, un nou Concept Pentru o Dezvoltare Durabilă Inteligentă, într-o Lume Globalizată, în Context Eco-Bio-Economie*; Editura Academiei Oamenilor de Ştiinţă din România: Bucharest, Romania, 2012. (In Romanian)
5. Petrescu, I. Human Capital in Eco-Economy and Sustainable Development of Romania. *Rev. Gen. Manag.* **2013**, *18*, 5–19.
6. Kaplan, R.S.; Norton, D.P. *Strategy Maps: Converting Intangible Assets into Tangible Outcomes*; Harvard Business School Press: Brighton, MA, USA, 2004.
7. Water Framework Directive. *Directive of the European Parliament and of the Council 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy*; PE-CONS 3639/1/00 REV 1; European Union: Luxembourg, 2000.
8. Saaty, T.L. *The Analytic Network Process*; RWS Publications: Pittsburgh, PA, USA, 2001.
9. Stojković, S.; Đurđić, S.; Anđelković, G. Application of multi-criteria analysis and GIS in ecotourism development (Case study: Serbian Danube region). *Glasnik Srpskog Geografskog Društva* **2015**, *95*, 51–66. [CrossRef]
10. Lami, I.; Absante, F.; Bottero, M.; Pensa, S. Integrating multicriteria evaluation and data visualization as a problem structuring approach to support territorial transformation projects. *EURO J. Decis. Process.* **2014**, *2*, 281–312. [CrossRef]
11. Herva, M.; Roca, E. Review of combined approaches and multi-criteria analysis for corporate environmental evaluation. *J. Clean. Prod.* **2013**, *39*, 355–371. [CrossRef]
12. Akkoyunlu, A.; Karaashan, Y. Assessment of improvement scenario for water quality in Mogan Lake by using the AQUATOX Model. *Envrion. Sci. Pollut. Res.* **2015**, *22*, 14349–14357. [CrossRef] [PubMed]
13. Dee, N.; Baker, J.; Drobny, N.; Duke, K.; Whitman, I.; Fahringer, D. An Environmental Evaluation System for Water Resource Planning. *Water Resour. Res.* **1973**, *9*, 523–536. [CrossRef]
14. Zhan, X.; Wang, Z.; Lin, J. GIS Based Measurement and Regulatory Zoning of Urban Ecological Vulnerability. *Sustainability* **2015**, *7*, 9924–9942. [CrossRef]
15. Mustapha, A.; Aris, A.Z.; Juahir, H.; Ramali, M.F.; Kura, N.U. River water quality assessment using environmentric techniques: Case study of Jakara River Basin. *Environ. Sci. Pollut. Res.* **2013**, *20*, 5630–5644. [CrossRef] [PubMed]
16. ORDIN nr. 161 din 16 Februarie 2006. Available online: http://www.rowater.ro/dacrisuri/Documente%20Repository/Legislatie/gospodarirea%20apelor/ORD.%20161_16.02.2006.pdf (accessed on 21 April 2016). (In Romanian)
17. LEGE nr. 458 din 8 Iulie 2002 Privind Calitatea Apei Potabile REPUBLICARE*. Available online: http://www.ludus.ro/portal/mures/ludus/portal.nsf/1CEAE085D41C323AC2257E14002DD2CA/\protect\T1\textdollarFILE/L458-2002.pdf (accessed on 13 April 2016). (In Romanian)
18. LEGE nr. 311 din 28 Iunie 2004. Available online: http://www.rowater.ro/dacrisuri/Documente%20Repository/Legislatie/gospodarirea%20apelor/LEGE%20311_28.06.2004.pdf (accessed on 16 April 2016). (In Romanian)
19. Laws News. Available online: http://www.legex.ro/Ordin-1146-2002-33930.aspx (accessed on 16 April 2016).
20. Borza, S. *Realizarea Aplicatiilor GIS Folosind Geomedia Professional*; University "Lucian Blaga": Sibiu, Romania, 2011.
21. Beria, P.; Maltese, I.; Mariotti, I. Comparing Cost Benefit and Multi-Criteria Analysis: The Evaluation of Neighbourhoods Sustainable Mobility. Available online: http://ww2.unime.it/sefisast/SEFISAST/Conference_Paper_files/BERIA_MALTESE_MARIOTTI.pdf (accessed on 9 October 2016).
22. Saaty, T.L. Marketing application of the analytic hierarchy process. *Manag. Sci.* **1980**, *26*, 641–658.
23. Saaty, T.L. What is the Analytic Hierarchy Process? In *Mathematical Models for Decision Support*; NATO ASI Series; Springer: Berlin/Heidelberg, Germany, 1988; Volume 48, pp. 109–121.
24. Goldbach, S.G.; Lefleur, S. Cost-Benefit Analysis and Alternative Approaches from the Centre for Logistics and Goodds (CLG) Study of Evaluation Techniques. 2004. Available online: http://www.systemicplanning.dk/Cost-Benefit%20Analysis%20_CBA_%20and%20alternative%20approaches%20from%20the%20Centre%20for%20Logistics%20and%20Goodds%20_CLG_%20study%20of%20evaluation%20techniques,%202004.pdf (accessed on 13 April 2016).
25. Hwang, C.L.; Yoon, K. *Multiple Attribute Decision Making: Methods and Applications*; Springer: New York, NY, USA, 1981.

26. Yoon, K. A reconciliation among discrete compromise situations. *J. Oper. Res. Soc.* **1987**, *38*, 277–286. [CrossRef]
27. Hwang, C.L.; Lai, Y.J.; Liu, T.Y. A new approach for multiple objective decision making. *Comput. Oper. Res.* **1993**, *20*, 889–899. [CrossRef]
28. Roy, B. Classement et choix en présence de points de vue multiples (la méthode ELECTRE). *La Revue d'Informatique et de Recherche Opérationelle (RIRO)* **1968**, *2*, 57–75.
29. Chapter 1. Electre Methods. Available online: http://l11.lamsade.dauphine.fr/dea103/ens/bouyssou/Outranking_Mousseau.pdf (accessed on 10 October 2016).
30. Preference Ranking Organization Method of Enrichment Evaluation (Promethee). Available online: http://www.ijesi.org/papers/Vol%202(11)/Version-1/F021101028034.pdf (accessed on 11 October 2016).
31. Directory of Open Access Journals. Available online: https://doaj.org/ (accessed on 12 October 2016).
32. Venkatesharaju, K.; Ravikumar, P.; Somashekar, R.K.; Prakash, K.L. Physicochemical and bacteriological investigation on the river stretch in Karn. *Kathmandu Univ. J. Sci. Eng. Technol.* **2010**, *6*, 50–59.
33. Peterson, D.H.; Smith, R.E.; Hager, S.W.; Harmon, D.D.; Herndon, R.E.; Schemel, L.E. Interannual variability in dissolved inorganic nutrients in northern San Francisco Bay estuary. *Hydrobiologia* **1985**, *129*, 37–58. [CrossRef]
34. Standardization Association in Romania. Available online: http://magazin.asro.ro/index.php?pag=3&lg=1&cls=2&dom=13&gr=060&sgr=25 (accessed on 10 April 2016).
35. HOTĂRÂRE nr. 352 din 21 Aprilie 2005 Privind Modificarea şi Completarea Hotărârii Guvernului nr. 188/2002 Pentru Aprobarea Unor Norme Privind Condiţiile de Descărcare în Mediul Acvatic a Apelor uzate. Available online: http://www.gnm.ro/otherdocs/nsbhrtjqp.pdf (accessed on 17 April 2016). (In Romanian)
36. Panaitescu, P. Wastewater Treatment Technologies Applied in Conformity with the European Environmental Policies. Available online: http://www.utgjiu.ro/revista/ec/pdf/2014-04.Special/26_Casen%20Panaitescu%201.pdf (accessed on 15 April 2016).