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Original Article

Environmental Impact Assessment of Tailing Dumps (Case Study: Lupeni Coal Mine, Jiului Valley)

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Abstract

The aim of this study was to provide an assessment of the environmental impact that the tailing dumps from Lupeni coal mine (Jiului Valley) have on the local environment. To achieve this goal, several field trips were organized during which observations on the area were noted and biological samples were collected (soil samples). The study was based also on laboratory and computer studies during which biological samples were analyzed and the results were processed to determine the degree of impact. The current study focused primarily on assessing the quality of the terrestrial biotic environments, by identifying the main groups of invertebrates and plant species that inhabit the anthropogenic soils and on the recent observations made on field in the affected area. The results of some preliminary studies on the stability of the waste dumps and on the quality of the aquatic biotic environments were also considered. Based on all information gathered this way, a rapid impact assessment matrix (RIAM - Pastakia and Jensen, 1998) was applied. The matrix results (scores) have highlighted the differences between the various areals of the tailings deposit and the importance of the environmental reconversion of the affected terrains. The study showed that the tailing dumps have a negative impact on the environmental components, but also, in some cases, have a slightly positive impact, particularly if the consequence of their formation has effects that could be exploited for some leisure or touristic purposes. Outcomes of this study provide viable information that can be used for local environmental restoration.

Keywords: tailing dump, Lupeni, coal mine, rapid impact assessment matrix, biotic environment

1. Introduction

The mining activity is one of the main sources of environmental pollution both because of the actual extraction of ore and as a result of its preparation. Damage to the environmental components due to various activities of this industry leads to an ecological disequilibrium, thus affecting the existence of all living organisms [2, 7, 10]. Therefore, finding proper ways to prevent and decrease the impact of mining on the local environment is a priority issue in this industry.

The coal mining operation in Lupeni area began in 1884 and it soon became one of the most productive sectors within regional and national context. Thus, Lupeni coal mine is currently among the few still operating mines in the coal basin of Jiului Valley.

The extracted coal was used for energy in power plants nearby (Paroşeni, Mintia) or for the steel industry (Hunedoara) [15].

The environmental problems caused by coal mining in this area occurred both on water (i.e. major pollution of the Jiu river that had as a consequences the disappearance for a certain period of time of the aquatic fauna of the river) and air (i.e. fine particle pollution resulted from coal

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preparation, from its storage along with the tailings resulting from mining and from burning in Paroşeni thermal plant) or soil (i.e. due to the storage of various substances on its surface and waste dumps), having major effects also on the human health [3].

As in any mining operation, the management of the waste generated within E.M. Lupeni raised and raises environmental issues.

Tailings resulting from mining and primary processing of coal are stored in tailing dumps, in a hilly area north of Lupeni town at about 2 km away (fig. 1).

The choice of location it was intended to affect an area as small as possible, with low economic importance.

Tailings transportation is done by funicular and storage was done on three branches (noted by R1, R2, R3) constructed in only one step.

Now only the southern branch is currently still active and the other two are closed.

Their sizes vary between 900 m - branch R1 and 1,200 m - branch R3, and heights between 40 and 70 m. The total area occupied by the tailings is about 34 ha [14].

Due to its configuration, the deposit has presented several phenomena of instability in time, but the material is stable at the moment. The waste dumps have impact on the landscape (being visible both from the town and from the slope opposite to the one on which they are located), morphology and hydrology (due to the lifting of the tailing dumps, lakes were formed at their base by blocking water courses or by rain water accumulation).

The tailings also amended the state of ecosystems so new ecosystems appeared, which, however, are poorly developed. These ecosystems have a high potential to maintain biotic communities and they offer premises for using of local environment as a recreational area.

Figure 1. The geographical location of tailing dumps from Lupeni coal mine, Hunedoara County (Google^{TM} Earth Pro, 2007)

This study is a part of an extensive study aimed to: identifying what impacts the tailing dumps have on the environment, assessing the quality of aquatic and terrestrial biotic environments, matrix assessment of impacts based on the quality of the biotic environments analyzed and proposing rehabilitation methods for the dumps.

2. Methodology

2.1. Methodology for soil samples and analysis

Soil sampling for both biological and physical-chemical analysis was made in four sampling points located as follows: three points located on R2 branch: sample number 1 (P1) - in a wooded area of the heap, sample number 2 (P2) - in an area with grassy vegetation and the sample number 3 (P3) - in an area devoid of vegetation and point blank (M), located in a wooded area between R2 and R3 branches.

Determination of pH was done in accordance with ISO 10390 : 2005. From each sampling point 50 g of clean soil was weighted on the analytical balance over which was added distilled water achieving a 1 : 4 dilution and constantly mixed for two hours. Finally, the solution was filtered and the results were read using Multi 250i multiparameter.

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Humus was determined using a qualitative method: the soil was dry for 24 hours at 105°C, after that was sifted and weighed 12 grams of soil from each sampling point over which were added three pills of solid NaOH and 10 - 20 mL of distilled water. After 2 hours of constant shaking the mixture was brought to a final volume of 100 ml with distilled water and left to rest for 24 hours after which the results was read according to table 1. The soil samples needed to determine these two parameters were taken once at the end of April, 2011.

Table 1.Qualitative interpretation based on quantity of humus staining resulting from the reaction

Scale	0	1	2	3	4
Amount of humus	Without	Low	Medium	High	Very high
Staining	-	straw yellow	dark yellow	brown yellow	brown

In order to determine the quality of the terrestrial biotic environments, biological samples were taken using Barber traps, in two different dates (August and September 2010) [8, 13].

Each sample consisted of 5 sub samples (4 located at the corners of a square with a 5 m edge and one at the intersection of its diagonals) as shown in figures 2a and 2b.

Figure 2. Sample distribution: (2a) sketch of a sampling point; (2b) placing of a sampling point in an area devoid of vegetation of the tailing dumps; (2c) Barber trap situated in the blank area

Traps were made from plastic bottles with a height of 15 cm (fig. 2c). A small amount of water mixed with ethylic alcohol was placed in each trap. Each trap was covered (fig. 2c) to avoid clogging or rainfall penetration. Traps were left in the field 5 - 6 days, then the biological material was collected in 50 mL Falcon conical tubes, washed under running water, preserved in absolute ethylic alcohol and read using binocular magnifying glass. For each sample three readings were made.

2.2. Methodology for environmental impact assesment (RIAM)

The results of the biological samples together with the field data obtained and the previous information about this site have been processed to complete a rapid impact assessment matrix (RIAM - Rapid Impact Assessment Matrix). This matrix was designed after the model offered by Pastakia and Jensen in 1998. It is a useful tool for organizing, analyzing and presenting the results of the environmental impact assessment.

RIAM was originally developed to compare alternatives in a project, but it can be successfully used to compare different plans and programs in terms of the impact on the environment [6, 9]. This matrix can be adjusted according to the various criteria that the evaluator wants to achieve, considering that the evaluation scale offered by Pastakia is variable [4].

At first, the environmental components, selected from Leopold's matrix (1971), were identified and divided into three main categories: (a) physical and chemical components (12 components), (b) biological and ecological components (10 components) and (c) socio-economic and cultural components (14 components).

These environmental components were analyzed based on some evaluation criteria presented in table 2. The first two evaluation criteria (A1 and A2) can individually change the obtained environmental score, while the following three (B1, B2, B3) can not change the obtained environmental score [12]. Each evaluation criteria has an evaluation scale that will represent the scores obtained by the environmental component.

Unlike the matrix provided by Pastakia and Jensen (1988), we have chosen for the evaluation criterion A1 (importance of the environmental condition/factor) to change the rating scale by taking into account the importance of the local impact from the site and continuing to the national level. For criterion B1 (permanence), we considered a permanent impact as it affects the environmental component for more than 15 years.

Criterion B2 (reversibility) was taken into account by the fact that when an impact is reversible over a period of 15 years can change the importance to the environmental component that affects him.

A cumulative impact was considered when it is influenced by factors other than the actual tailings dumps storage (e.g. handling equipment on the heap, cultural and educational level of population, economic situation, weather conditions etc.).

Based on these grades, an environmental score was calculated (SE) separately for each component using the following formulas [11]:

$$(A1) \times (A2) = (At) \quad (1)$$

$$(B1) + (B2) + (B3) = (Bt) \quad (2)$$

$$(At) \times (Bt) = (SE) \quad (3)$$

Table 2. Description of the environmental impact evaluation criteria and of the evaluation scale (adapted after Pastakia, Jensen, 1998)

Evaluation criteria	Scale	Description
A1 The importance of environmental condition or factor	4	Important for national interests
	3	Important for regional interests
	2	Important only for the locality
	1	Important only for the location/site
	0	No importance
A2 Magnitude of environmental change or effect	+3	Major important benefit
	+2	Significant improvement of the status quo
	+1	Improvement of the status quo
	0	Lack of change in the status quo
	-1	Negative change of the status quo
	-2	Disadvantages or significant negative changes
	-3	Major disadvantages or negative changes
B1 Permanence	1	No changes
	2	Temporary
	3	Permanent
B2 Reversibility	1	No changes
	2	Reversible
	3	Irreversible
B3 Cumulativity	1	No changes
	2	Non-cumulative/unique
	3	Cumulative/synergism of impact

Depending on the score obtained, the environmental components were placed in a category of impact (table 3). The environmental score and the category of impact were calculated both for each category of environmental components and for the whole studied area.

Table 3.Classification and description of impact categories based on environmental scores [9]

Environmental score	Category of impact	Description of category
Over +101	+E	Major positive changes/impacts
+76 to +100	+D	Significant positive changes/impacts
+51 to +75	+C	Moderate positive changes/impacts
+26 to +50	+B	Positive changes/impacts
+1 to +25	+A	Changes/impacts slightly positive
0	N	Lack of change in the status quo/inapplicable
-1 to –25	-A	Slightly negative changes/impacts
-26 to –50	-B	Negative changes/impacts
-51 to –75	-C	Moderate negative changes/impacts
-76 to –100	-D	Significant negative changes/impacts
Under -101	-E	Major negative changes/impacts

3. Results and discussions

3.1. Results of the soil analysis

Analysis outcomes showed slightly alkaline pH of soil from the dump higher in areas deprived of vegetation. It is noted that the presence of vegetation influences the values of this parameter. The amount of humus in the samples taken from the tailings dumps storage area is reduced compared with control sample, varying the type and abundance of vegetation installed on the landfill. Thus, it is missing in areas deprived of vegetation and is slightly higher in the area covered with tree vegetation compared with the area covered with herbaceous vegetation (table 4).

Table 4.Determination of pH and the amount of humus for soil samples taken from the tailings dumps from Lupeni mine (M-natural area, blank sample, P1- sampling point on the tailing dumps with tree vegetation, P2 - sampling point on the tailing dumps with herbaceous vegetation, P3- sampling point on the tailing dumps devoid of vegetation)

Sample points	M	P1	P2	P3
pH	6,5	7,47	7,44	8,01
Values for determining the amount of humus	4 (large quantity)	1 (small amount)	1 (small amount)	0 (absence)

After analyzing the biological samples, species from following taxonomic groups were identified as shown in table 5: Insecta, Arachnida, Myriapoda and Crustacea. Other species were also caught in the traps: reptiles - in the traps placed on the tailing dumps - amphibians and small mammals (shrev) – in the traps associated with the blank sample. It can be observed that the biomass changes according to the location of the sampling point. Thus, most individuals (both numerically and in terms of diversity) are found in areas covered by tree vegetation (where mature individuals of Betulaceae family and developed grass level predominate), while in areas devoid of vegetation (for sample number 3) they are present in very small numbers and represent a small number of taxonomic groups. This variation of the biomass can be viewed in figs. 3 and 4.

All species determined into the soil samples have high ecological importance for the local environment. Thus, insects and their larvae help the process of pedogenesis by shredding organic matter and deploying it.

Some of the sampled individuals are detritophages (tipulids, colembols, crustaceans), their presence help to discompose organic matter.

Carabids are important due to their abundance (numbers within population) because they enrich the soil with organic waste containing nitrogen from the chitin, components of their body, at the same time they help biological control of phytophagous insects. The presence of the phitofags (representatives of the orders: Hymenoptera, Thysanoptera, Diptera, Coleoptera) is not a strong point for the tailing dumps, because, in order to rehabilitate in a natural way, in first phase, the development of any plant species is important, meanwhile these invertebrate species may impede or condition the development of certain plant species [1, 8]. However their number is limited by the entomophagous species that are most abundant on tailing dumps (fig. 5).

Table 5.Distribution of the number of individuals, grouped by taxonomic groups, depending on the date of sampling and the sampling points (M-natural area, blank sample, P1- sampling point on the tailing dumps with tree vegetation, P2 - sampling point on the tailing dumps with herbaceous vegetation, P3- sampling point on the tailing dumps devoid of vegetation)

Taxonomic group	Number of individuals in each sampling point by the two dates of sampling							
	August 2010				September 2010			
	M	P1	P2	P3	M	P1	P2	P3
Insecta Class								
Ord. HYMENOPTERA								
Fam. Formicidae	282	60	125	6	61	13	69	3
Fam. Braconidae, Chalcidoidea, Ichneumonidae, Proctotrupidae	7	4	0	0	8	17	3	1
Ord. COLLEMBOLA	45	2	7	0	28	14	6	0
Ord. THYSANOPTERA	0	0	0	1	0	0	0	0
Ord. DIPTERA								
Sord. Brachycera	7	32	0	0	0	2	1	0
Sord. Nematocera Fam. Culicidae Fam. Tipulidae	2	3	0	0	0	1	3	0
Ord. MECOPTERA Fam. Panorpidae	2	14	0	0	0	0	0	0
Ord. COLEOPTERA								
Fam. Carabidae	6	0	0	0	7	2	0	0
Fam. Staphylinidae	0	2	1	0	0	0	0	0
Fam. Crysomelidae	1	0	0	0	0	0	2	0
Fam. Elateridae	0	0	0	1	1	1	0	0
Ord. HETEROPTERA	0	3	0	0	0	1	0	0
Ord. HOMOPTERA Cicadinae - Aphidinae	2	0	0	1	0	0	2	0
Ord. LEPIDOPTERA	1	0	0	0	0	0	0	0
Arachnida Class								
Ord. ARANEAE	16	3	0	0	9	4	9	2
Myriapoda Class								
Subcl. Chilopoda	1	2	0	0	4	3	0	0
Crustacea Class								
Ord. ISOPODA	33	2	5	0	6	0	1	0

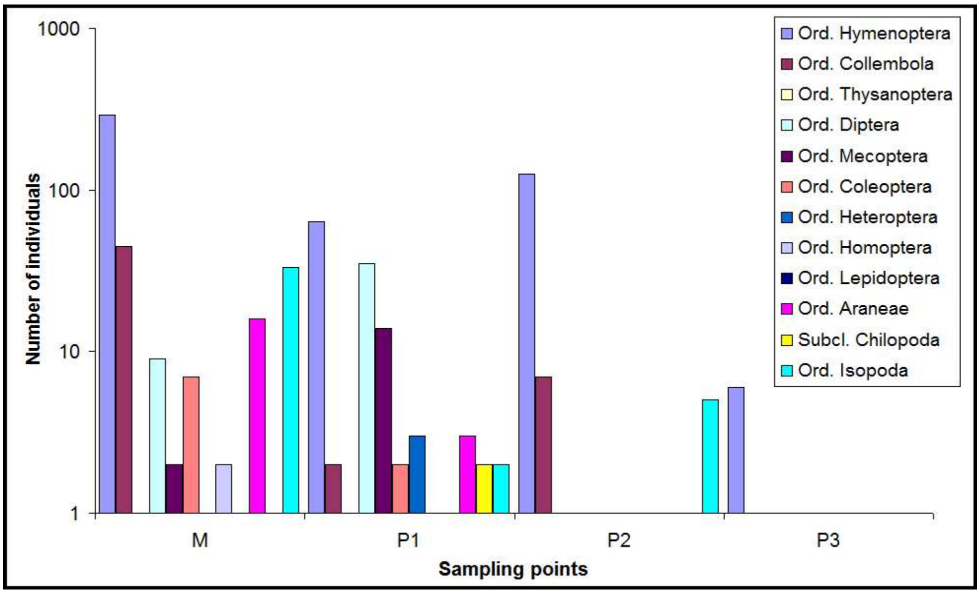

Figure 3. Structure and abundance of epigeal arthropodes sampled in August 2010 according to the four sampling points - logarithmic representation (M - natural area, blank sample, P1- sampling point on the tailing dumps with tree vegetation, P2 - sampling point on the tailing dumps with herbaceous vegetation, P3 - sampling point on the tailing dumps devoid of vegetation)

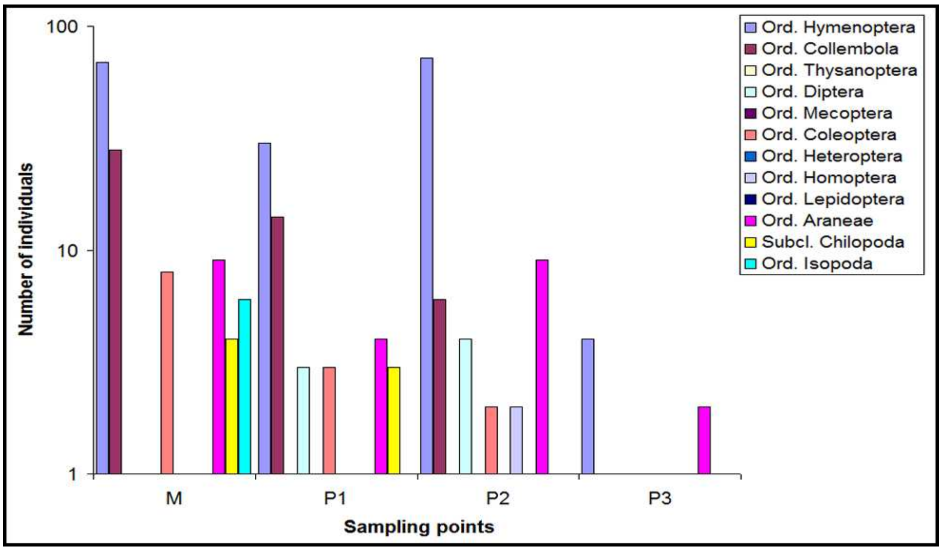

Figure 4. Structure and abundance of epigeal arthropodes sampled in September 2010 according to the four sampling points - logarithmic representation (M - natural area, blank sample, P1- sampling point on the tailing dumps with tree vegetation, P2 - sampling point on the tailing dumps with herbaceous vegetation, P3 - sampling point on the tailing dumps devoid of vegetation)

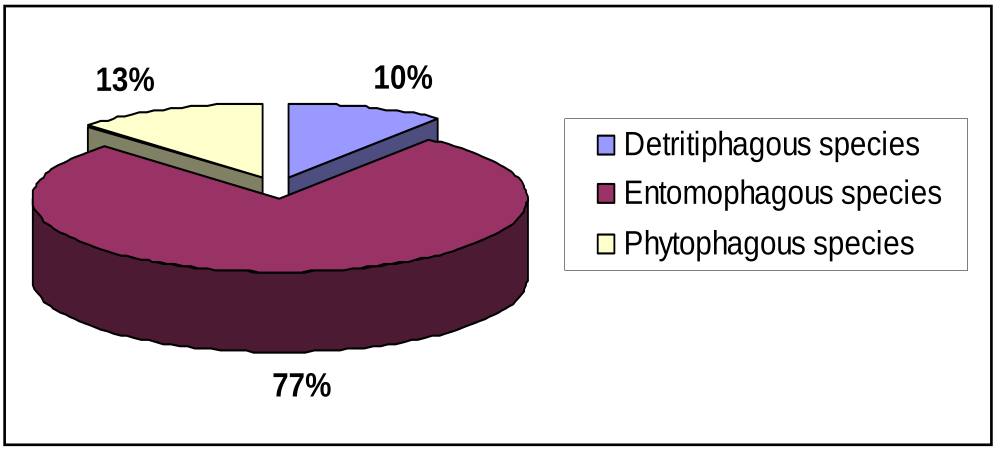

Figure 5. Proportional distribution of detritiphagous, entomophagous and phytophagous species, on the tailing dumps belowing to Lupeni mine during sampling

Also, during the sampling, differences in the soil layer were observed: in the area covered with trees, the anthropogenic soil had a thickness of about 5 cm, in the area covered with grass vegetation the soil layer did not exceed 1 cm, while in the area devoid of vegetation there was no soil, the few plant specimens being fixed directly in the sterile rock.

Correlating the number and variety of individuals with the environment they have been collected from indicates the importance of recovering with vegetation the terrains degraded due to human activity.

Thus, the higher the vegetation is developed, the deeper is the layer of soil formed and the more diverse is the biomass of invertebrates that will help to maintain the ecosystem. In ecosystems having advanced stages of succession small mammals will also occur, as the example of the forest ecosystem, in this study, were the blank sample was taken from.

3.2. Results of matrix assessment

Achievement evaluation matrix took into account the results of aquatic environments (ponds) form the studied area. They had values of pH and TDS's located within the legal limits allowed.

Bioindicator species determined in samples of water taken from the waste dumps lakes have belonged especially from following phylum's Protozoa, Annelids and subphylum's Crustaceans, Uniramia, most are species representative water class-B oligo-mezosaprobe [5].

The assessment matrix (RIAM) for our studied area is presented below (table 6).

Table 6. RIAM used for environmental assessment of Lupeni tailing dumps

Environmental Components	A1	A2	B1	B2	B3	SE	CI
Physical and Chemical Components							
Affected soil surface	1	-2	3	3	3	-18	-A
Soil quality	1	-1	3	2	3	-8	-A
Morphology	1	-2	3	3	3	-18	-A
Areas affected by water	1	-1	3	3	2	-8	-A
Water quality	1	-1	2	2	3	-7	-A
Air quality	1	-1	2	2	3	-7	-A
Microclimate and topoclimate	1	-1	3	3	3	-9	-A
Flooding	1	-1	2	2	1	-5	-A
Erosion	1	-1	3	2	3	-8	-A
Sedimentation	1	-1	1	1	1	-3	-A
Compaction	1	-1	3	3	3	-9	-A
Land stability (landslides)	2	-1	3	2	3	-16	-A
Environmental Score						-116	-E
Biological and Ecological Components							
Tree vegetation	1	-1	3	2	2	-7	-A
Herbaceous vegetation	2	-1	3	2	2	-14	-A
Microflora	1	0	1	1	1	0	N
Aquatic plants	1	+1	3	3	2	+8	+A
Terrestrial animals and reptiles	1	-1	2	2	2	-6	-A
Fish and shellfish	2	+1	3	3	2	+16	+A
Bentos	1	0	1	1	1	0	N
Insects	1	+1	3	3	3	+9	+A
Terrestrial microfauna	1	+1	2	2	1	+5	+A
Aquatic microfauna	1	+1	2	2	1	+5	+A
Environmental Score						+16	+A
Socio-Economic and Cultural Components							
Land use	2	+1	3	2	3	+16	+A
Open spaces and wilderness	2	-1	3	2	2	-14	-A
Wetlands	2	+2	3	3	2	+32	+B
Wooded areas	1	-1	3	2	2	-7	-A
Human interests and lifestyle	2	+1	2	2	3	+14	+A
Aesthetics and landscape quality	2	-2	3	2	3	-32	-B
Human health and safety	2	-1	1	1	1	-6	-A
Fishing	2	+1	3	2	3	+16	+A
Camping	2	+1	3	2	3	+16	+A
Unemployment rate	2	+1	2	2	1	+10	+A
Recreation and leisure	2	+1	3	2	3	+16	+A
Landfill site	1	-1	2	2	3	-7	-A
Buildings and structures	1	0	2	2	1	0	N
Accessibility	1	0	2	1	1	0	N
Environmental Score						+54	+C
Total Environmental Score						-46	-B

The assessment matrix analyzing reveals that the greatest impact occurs on the environmental physical and chemical components. Their status is degraded and amplified due to the storage of tailing and weather conditions. A part of this impact is reversible in consditions in which it can be mitigated in a relatively short period of time. Even if these components have had only slightly negative changes their cumulative score indicating some major adverse environmental changes.

Environmental biological and ecological components have an overall positive score which indicated that they have changed slightly positive. This is explained by the development of new aquatic ecosystems that have conducted to the emergence of new botic species. Dump bodies, even if initially were affected by physical and chemical components, have now a good biological state and offer an increased capacity to maintain life forms at local level. Socio-economic components suffer a negative impact on their natural potential but we can talk about a positive impact given by the fact that people prefer to use the land for recreational and leisure activities. In the lack of an organized form of tourism in this area, we can observe a new perspective of land use and a new function of area: pseudoturistic one.

All effects of these impacts reflect the relationship between the environment and local communities and it can be influenced by educational and cultural level of the community and local decision makers. We consider that local authorities can capitalize and exploit the positive impact of recreational activities on this area.

Anyway, the total score indicates significant environmental changes generated by deposition of tailings dumps in this area.

4. Conclusions

Mining activities have had a strong impact on the environmental components of area. Despite this fact, our biological, water and soil analysis showed a good quality of terrestrial and aquatic biotic environments.

This is only due to the relatively high capacity of the tailing dumps to support life forms. In the absence of environmental rehabilitation measures, the capacity of area to be reintegrated into the natural circuit is advantaged by its location in a hilly area (surrounded by extensive forests) and its physical, chemical and biological conditions.

Laboratory results were completed by field observations and thus we have obtained a more detailed image of the area.

By combining of qualitative and quantitative methods we realized a careful assessment and this fact reducing the degree of subjectivity involved by matrix completion.

In a short perspective, we will try to developing investigations by improving of data and information related to soil quality and to detailing the environmental components analyzed and assessed.

We hope that the results obtained from our analysis and assessment to be parts of an integrated solution for the local environmental planning.

We consider that this planning must to be oriented to the restoration of tailing dumps, capitalization of new biotic environments and, if is possible, transformation of site into a recreational area.

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