SUSTAINABLE MINING SYSTEM FOR ENVIRONMENT PROTECTION

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The development of the mining industry must be corelated with the costs of the affected land after the closed mines. An integrated system taking into account the entire parameters for environement protection is proposed.

1. Introduction

Due to its abundance and importance, coal has been extracted in different parts of the world for a long time, and it is still nowadays the object of one of the most important economic activities.

However, the nature of the mining activity produce multiple and various negative environmental effects, such as: using large field areas for the exploitation activity, piling, stocking useful mineral substances, industrial installations, access ways, etc., resulting in totally useless surfaces for other activities, for a long period of time; producing large and various quantities of polluting waste (solid, liquid, gaseous) with different poisonous quantities, as a result of the diversity of mined ore; the emission of greenhouse gases with negative effects on the atmosphere, flora and fauna in the area; chemical pollution of soil, which may affect for years to come its fertility; air pollution by gases resulted from the technologic process; suspension dust emanated from quarry blasting, from loading-unloading the waste and useful quantities, from pre-crushing the ore and specially from the technologic haulage; river beds pollution in the area of the mine, very serious because of the small flow and length of the rivers, making it very difficult to dilute harmful substances and naturally regenerate the river beds.

Considering the above mentioned facts, it results that the mining and capitalisation activity of coal have a negative impact on al environmental factors by occupying large areas of land and removing them from agriculture, reducing the emission of greenhouse gases in the atmosphere and loading the river beds with impurities.

2. Assessing the quality of environmental factors affected by coal exploitation

2.1. Soil quality analysis

In order to assess the quality of the soil affected by the mining activity, soil samples had to be collected all around the perimeter of the mine and the areas visibly affected from a physical and a chemical point of view.

In setting the sampling points, the activity of the point and the possibility of accidental pollution have been considered.

In order to take soil samples, all the sampling points have been marked on the situation plan of the area. The vegetation has been completely removed from the sampling area and samples from two different heights of the same sampling point have been collected, the surface of the soil (Ss) and 20 cm in depth than the surface of the soil (S_A).

The soil samples must be chemically analysed by the use of specific methods therefore the main chemical quality indexes being determined: hard metals (copper, cadmium, lead, zinc, nickel), sulphates, free cyanides, HAP (naphthalene, phenanthrene, anthracen, fluoranthen, pyrene, benzanthacene, chrysene, benzofluoranthene, benzopyrene, benzoperylene, indeno (1,2,3,) pyrene).

2.2. Air quality analysis

Air samples have to be collected in order to assess the quality of air affected by the mining or quarry, resulting therefore the main indexes: suspended dust and sedimental dust.

Thus, representative samples from four different sampling points must be collected determining therefore the quality index “sedimental dust”, monthly.

The values obtained following the analysis of the collected samples are compared to MAC = 17g/m^2/month (according to STAS 1257/1987).

2.3. Water quality analysis

For the assessment of the quality of water in the perimeter of a mine, technologic and waste water samples have been analysed and the chemical quality indexes have to be monitored.

In setting the sampling points, the type of waste water (waste or technologic) as well as the waste water outlet and the discharge from the perimeter, must be considered. The collection have to be made at the discharge point from the perimeter (for technologic waste water) using a surface sampler.

The specifically monitored and analysed chemical parameters are: pH, suspended solids, COD-Cr, BOD_5, ammonium, sulphurs, sulphates, phenols, petroleum products, total phosphorus, total cyanides, chlorine, filterable residues at 105° C, calcium, magnesium.

3. Impact size assessment

In order to appreciate the environmental impact of a mine or open pit mine, as well as to follow the evolution in time of the environmental pollution phenomenon, a global assessment method of the state of environmental health or pollution in a given moment was used, assessing the environmental factors: AIR, WATER, SOIL.

The Environmental Impact Assessment Method consist in following a series of synthetic appreciation steps, based on quality indexes which may reflect the state of assessed environmental factors, as well as representing them through a graphic method and determining the global pollution index.

Each assessed environmental factor will be characterised through a representative pollution index in order for the degree of pollution to be appreciated.

The quality of an environmental factor or element is within the limits admitted by the National Standards or Regulations, which estimate environmental effects of a certain activity. Therefore, the quality of the environmental factor is reported within the admitted limits resulting thus the **pollution index – Pi**.

Considering the maximum admissible limits in the norms and regulations, the pollution index (Pi) is determined as follows:

$$\text{Pi} = \frac{C_{\max}}{C_{admissible}} \qquad (1)$$

where:

C_{max} = is the maximum determined concentration of the pollutant – measured or determined;

$C_{admissible}$ = is the maximum admissible concentration according the norms in force;

If: Pi = 0 ÷ 1.0 – the environment is affected within admissible limits and the effects are either positive or negative without being harmful;
Pi > 1.0 – the environment in affected over admissible limits, the negative effects being assessed according to the degree of exceeding.

For a quantitative assessment of the impact, the quality of environmental factors expressed by the pollution index Ip, is comprised within a Productivity Factor Scale by assigning a factor to express the state of the environment in a given moment compared to the its initial state, as it may be seen in Table 1.

Table 1. Impact Index

Productivity Factor	**Pi Value**	**Effects on humans and the environment**
10	0	Environment unaffected by humans; natural environment
9	[0.0 – 0.2]	The environment is affected by the human activity without any quantifiable effects
8	[0.2 – 0.7]	The environment is affected within admissible limits – level 1. Alarming threshold: potential effects
7	[0.7 – 1.1]	The environment is affected within admissible limits – level 2. Intervention threshold: with significant effects
6	[1.1 – 2.0]	The environment is affected within admissible limits – level 1. The effects are accentuated
5	[2.0 – 4.0]	The environment is affected within admissible limits – level 2. The effects are harmful
4	[4.0 – 8.0]	The environment is affected within admissible limits – level 3. Harmful effects are accentuated.
3	[8.0 – 12.0]	The environment is degraded – level 1. Effects are lethal for average periods of exposure.
2	[12.0– 20.0]	The environment is degraded – level 2. Effects are lethal for short periods of exposure.
1	> 20.0	The environment is unsuited to life forms.

3.1. Tismana I environmental impact – Case study

3.1.1. Soil pollution index determination

The value and environmental impact during coal exploitation through resource dislodgement and change of pedogeneytic processes of the following indexes has been considered when setting the productivity factor for soil: sulphates, zinc, nickel.

$PI_{\text{sulphates P1S}} = \frac{98.31}{200} = 0.49$ Pf = 8 $PI_{\text{sulphates P1A}} = \frac{48.9}{200} = 0.24$ Pf = 8

$PI_{\text{sulphates P2S}} = \frac{97.92}{200} = 0.48$ Pf = 8 $PI_{\text{sulphates P2A}} = \frac{736.34}{200} = 3.68$ Pf = 5

$PI_{\text{sulphates P3S}} = \frac{196.5}{200} = 0.98$ Pf = 7 $PI_{\text{sulphates P3A}} = \frac{195.15}{200} = 0.97$ Pf = 7

Pf_{average} for the sulphates quality index is 7.

$PI_{Zinc\ P1S} = \frac{106.68}{100} = 1.06$ Pf = 7 $PI_{Zinc\ P1A} = \frac{136.65}{100} = 1.36$ Pf = 6

$PI_{Zinc\ P2S} = \frac{166.96}{100} = 1.66$ Pf = 6 $PI_{Zinc\ P2A} = \frac{48.5}{100} = 0.48$ Pf = 8

$PI_{Zinc\ P3S} = \frac{153.87}{100} = 1.53$ Pf = 6 $PI_{Zinc\ P3A} = \frac{183.41}{100} = 1.83$ Pf = 6

$Pf_{average}$ for the zinc quality index is 7.

$PI_{nickel\ P1S} = \frac{16.58}{20} = 0.82$ Pf = 7 $PI_{nickel\ P1A} = \frac{16.48}{20} = 0.824$ Pf = 7

$PI_{nickel\ P2S} = \frac{16.51}{20} = 0.825$ Pf = 7 $PI_{nickel\ P2A} = \frac{16.56}{20} = 0.828$ Pf = 7

$PI_{nickel\ P3S} = \frac{16.74}{20} = 0.83$ Pf = 7 $PI_{nickel\ P3A} = \frac{31.22}{20} = 1.56$ Pf = 6

$Pf_{average}$ for the nickel quality index is 7.

According to the Productivity Factor Scale presented in the table, the productivity factor for soil is **Pf_{soil} = 7.**

3.1.2. Air pollution index determination

The values of two quality indexes (suspended dust and sedimental dust) have been considered when setting the productivity factor for air.

$$PI_{sedimental\ dust\ P2} = \frac{16.61}{17} = 0.97 \text{ Pf} = 7$$

$$PI_{sedimental\ dust\ P3} = \frac{8.59}{17} = 0.50 \text{ Pf} = 8$$

$$PI_{sedimental\ dust\ P4} = \frac{23.7}{17} = 1.39 \text{ Pf} = 6$$

The $Pf_{average}$ for the sedimental dust quality index is 7.

$$PI_{suspended\ dust\ P1} = \frac{185.49}{50} = 3.70 \text{ Pf} = 5$$

$$PI_{suspended\ dust\ P2} = \frac{195.15}{50} = 3.91 \text{ Pf} = 5$$

The $Pf_{average}$ for suspended dust quality index is 5.

According to the productivity factor scale presented in Table 1, the productivity factor for air is **Pf_{air} = 6.**

3.1.3. Water pollution index determination

In order to assess the quality of surface waters the authors consider the provisions of Decision no. 352 of the 21st of April 2005 regarding the changing and amendment of the Governmental Decision no. 188/2002 for the approval of a series of norms and regulations regarding wastewater discharge conditions in the river beds.

The values of three quality indexes (suspended solids, COD-Cr, filtrate residues at 105°C) have been considered when setting the productivity factor for water.

$$PI_{\text{suspended solids P1}} = \frac{34}{60} = 0.56 \quad Pf = 8$$

$$PI_{\text{suspended solids P2}} = \frac{110}{60} = 1.83 \quad Pf = 6$$

$$PI_{\text{suspended solids P3}} = \frac{21}{60} = 0.35 \quad Pf = 8$$

The $Pf_{average}$ for suspended solids quality index is 7.

$$PI \text{ COD-Cr P1} = \frac{9.6}{125} = 0.07 \quad Pf = 9$$

$$PI \text{ COD-Cr P2} = \frac{9.6}{125} = 0.07 \quad Pf = 9$$

$$PI \text{ COD-Cr P3} = \frac{28.8}{125} = 0.23 \quad Pf = 8$$

The $Pf_{average}$ for the COD-Cr quality index is 9.

$$PI_{\text{filtered residue P1}} = \frac{1460}{2000} = 0.73 \quad Pf = 7$$

$$PI_{\text{filtered residue P2}} = \frac{1100}{2000} = 0.55 \quad Pf = 8$$

$$PI_{\text{filtered residue P3}} = \frac{840}{2000} = 0.42 \quad Pf = 8$$

The $Pf_{average}$ for the filtered residue 105°C quality index is 8.

According to the Productivity Factor Scale presented in Table 1, the environmental water factor is given a productivity factor of **Pf_{water} = 8.**

The productivity factors obtained for each environmental factors of the analysed area help to conceive a graphic representation of a diagram as a simulation of the synergic effect.

3.2. Global pollution index determination

The Global Pollution Index **(GPI)** of an ecosystem results from the relation between two surfaces (the ideal one and the real one):

$$Gpi = \frac{S_i}{S_r} \tag{2}$$

When there are no changes of the quality of environmental factors, therefore, when there is no pollution, this index is equal to 1, as for when the value of the index is greater than 1 then there are quality changes of the environment.

A scale regarding environmental quality has been conceived based on the value of the Global Pollution Index, presented in Table 2.

Table 2. The relation between the value of the Gpi and environmental quality

GPI Value	Effects of the activity on the environment
GPI = 1	Natural environment, unaffected by human activity
GPI = 1-2	The environment os affected by the human activity within admissible limits
GPI = 2-3	The environment is affected by the human activity leading to a state of discomfort of all life forms
GPI = 3-4	The environment is affected disturbing all life forms
GPI = 4-6	The environment is affected by the human activity becoming dangerous to all life forms
GPI > 6	The environment is degraded, unsuited to all life forms

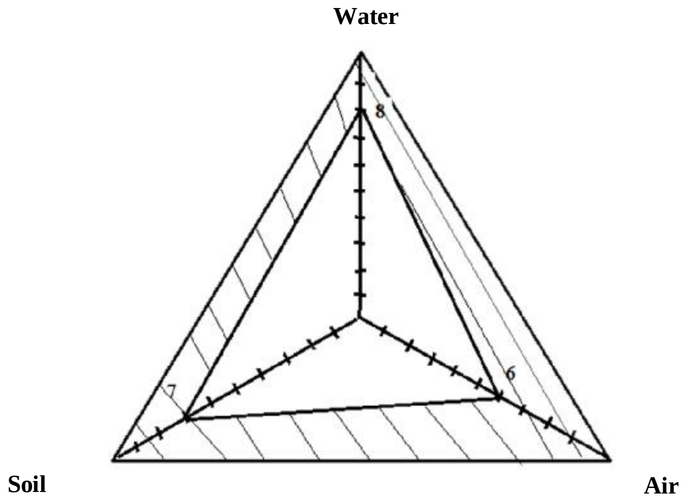
The productivity factor obtained for each environmental factor in the analysed area help the development of the graphic representation of a diagram, as a method of simulation of the synergic effect. The resulted geometric figure following the analysis of the three environmental factors is an equilateral triangle.

The ideal State (S_i) is graphically represented by a precise geometric figure with equal rays with a 10 unit productivity value. By uniting the points resulted in the positioning of the values expressing the real state (S_r) it results an irregular geometric figure with a smaller surface.

Graphically, the geometric figure illustrating the real state of the environment overlaps the figure illustrating the ideal state.

$$Gpi = \frac{S_i}{S_r} \tag{3}$$

$$S_i = \frac{10 \cdot 10}{2} + \frac{10 \cdot 10}{2} + \frac{10 \cdot 10}{2} = 150$$



$$S_r = \frac{7 \cdot 6}{2} + \frac{6 \cdot 8}{2} + \frac{8 \cdot 7}{2} = 73$$

$$I_{GP} = \frac{150}{73} = 2.05$$

The Global Pollution Index I_{GP} = 2.05 proving that the activity of Tismana I quarry affects the environment leading to a state of discomfort to all the life forms.

4. Conclusions

The scope of analysing the sustainable system for environmental protection is to:

- offer a global image of the state of health and quality of the environment in a given moment;

- allows the comparison of the state of an area in different moments in time, offering the possibility to follow both the quality of different environmental factors as well as global environmental quality of the studied area.

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