A SYSTEMIC ANALYSIS MODEL FOR THE ENVIRONMENT COMPONENTS IN METAL MINING AREAS

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ABSTRACT: *The impact that mining activities and capitalization of nonferrous metal ores have on the environmental conditions cannot be addressed sequentially, but only as a whole, thus leading to a system-type approach of the phenomenon. From this perspective, the entire objective reality of a hydrographic basin, taken as a whole, is considered to be a vast system that behaves like an entity and whose dynamics is controlled by the laws that govern the functionality and stability of systems.*

Key words: *system; geosystem; environment components; systemic analysis; inputs – outputs;*

1. Update on the theoretical analysis system and systems theory

The introduction of the "system" concept within the scientific analysis of processes and phenomena has led to a holistic and somehow simplified rendition of reality, that could not always be perceived through the ordinary means of investigation in its vast complexity, but only partially or in a confusing and fragmented manner.

Systemic analysis has multiple origins. It was used initially, with success, in comparative linguistics where F. de Saussure applied it in a structural analysis of phrase syntax [1]. Gradually, especially in the humanities, systemic analysis has become a general paradigm in scientific research and in epistemology.

The novelty that this paradigm brings is that it makes a clear distinction between two types of systems: cumulative systems, composed of similar but at the same time distinct elements that are placed in the system only through certain common characteristics and integrative systems [2, 3]. These systems subordinate their components, meaning that the component which is integrated within a system is different from the component that is isolated or integrated in another system.

The properties of integrative systems are considered to be emergent, in the sense that the properties of a system are not merely the sum of the properties characterizing its components, but they result from interaction. Therefore, these are properties of a collective and interaction explains the processes occurring within a system.

Systemic analysis has also revealed under - and over- ordination relations between systems, and the need to study internal interactions as well as the interdependence of related systems.

In short, the system can be defined as an organized group of entities whose mutual connections are made up of relations conditioning actual or potential actions, and whose behavior is a summary of the resulting properties of each entity and interactions between entities incorporated in the system.

The notion of system must be viewed in very broad sense, as all material bodies, plants, animals, the Earth and the universe are material bodies with a structure and a grouping of components in different ways and mutual interactions. Each of them could make up a system of its own.

System unity and its properties are

ensured by the existence of connections between its components. Each component can be also seen as a separate system, composed of a series of elements linked by connections and subject to complicated interactions that contribute to the maintenance of system individuality, thus making it indivisible.

In this perspective, the overall image of nature is originated in the existence in the universe of material systems consisting of sets of elements, subject to interactions between causes and effects, and provided with laws of permanent dynamics.

Any system is characterized, at any time, by a series of measures defining, at the time, the particular state of that system. Systems can maintain or change their status depending on specific programs, on their own structure or under the impulse of external or internal stimuli.

System analysis can detect subsystems that are gradually simpler or smaller, up to a certain limit, beyond which it can be concluded that a further division of a system no longer brings additional information, in which case it is considered that the element of a system has been reached.

On the other hand, the system, conceived as an ensemble consisting of subsystems, is in turn, part of a higher or superior system.

The series of all systems, from the smallest and up to the highest contains a number of progressive systems.

2. Comparative analysis of “input-output” components in the Ampoi Valley Geosystem

Actions and reactions taking place between the system and its external environment, and that are generated by the system states, vary depending on time. In this regard, one can define inputs in the system, namely how the environment influences the system, and outputs, namely the system influencing the environment, according to its own states. From all the input in a system, a separate category is that of uncontrolled input, considered as intrusions of the environment into the system.

The main feature of any system, and particularly of integrative systems, is to ensure stability, which takes place by the so-called adjustments. These are internal actions aimed at maintaining system functions. The adjustment mechanism ensures the quality and quantity of outputs through an appropriate dosage of the inputs. An adjustment mechanism can be represented as in figure no. 1, which shows that any deviation from the size of output (ΔY), R regulator may intervene, in a retroactive way, to generate an adjustment measure (ΔX), designed to bring outputs at the proper level [4].

To show how the systemic approach to environmental conditions works in mining

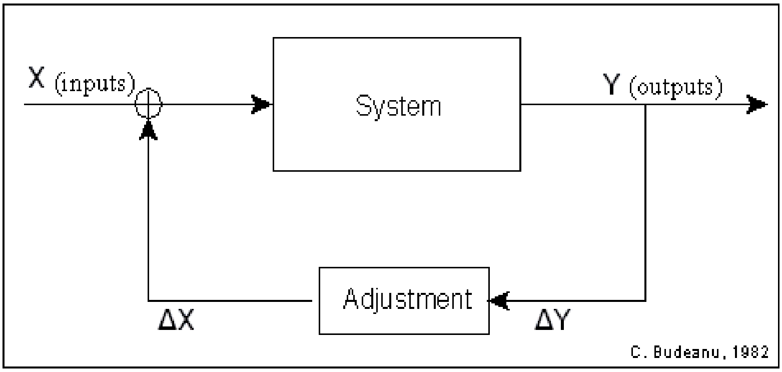

Fig. 1 Diagram of system self-adjustment

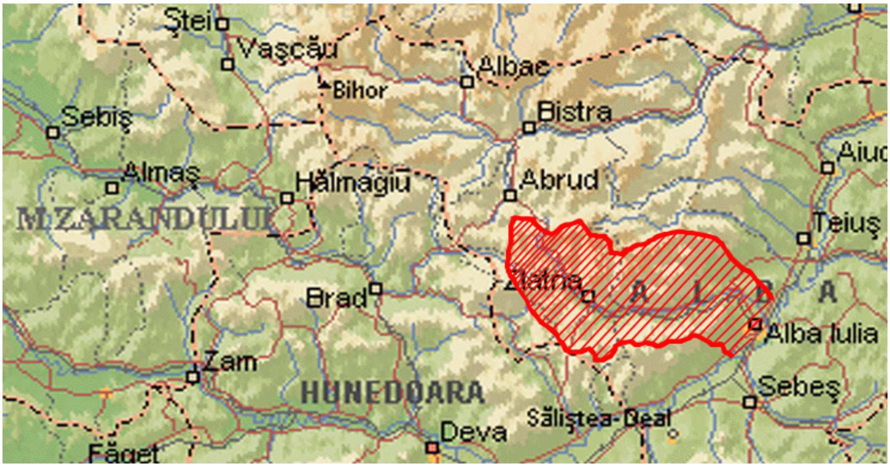

Fig. 2 Hydrographic basin of the Ampoi River

areas, we have undertaken a case study for the hydrographic basin of the Ampoi River, surrounding the town of Zlatna (Fig.2). Two factories were based here, which processed non-ferrous ores extracted from the mines in the Zlatna-Stănija Metal-processing District [2].

Seen from the perspective of systemic analysis, the entire hydrographic basin of the river Ampoi can be considered as a complex geosystem, consisting of non-biotic subsystems or components (atmospheric air, surface waters and groundwater, soil layer, geological structures, relief) as well as of biotic components (fauna, flora), which adds to an essential component, the anthropic one.

The latter is responsible for most uncontrolled inputs into the system and, implicitly, for the triggering of the most important environment disturbance.

3. The primary components of Ampoi Valley geosystem

The Ampoi valley geosystem fits conceptually within the category of natural integrative systems, as it is a stable system, or at least able to maintain its stability and integrity, as long as the inputs do not have a strong disruptive character. If one takes into account only the natural inputs (the movement of air masses, variations of temperature, precipitations, road groundwater and surface water etc.), although they sometimes have a disturbing nature, then the components and the system's internal adjustments have succeeded, in time, to maintain system stability.

With the start into operation of the deposit of Zlatna-Stănija district, the system starts to be affected by a nonspecific input (unnatural), since the processing of these ores is done in the town of Zlatna, situated near the central hydrographic basin of the Ampoi River (Fig. 2).

During the eighteenth and nineteenth centuries and the first half of the twentieth century, due to the low activity of the mineral processing factory, the internal adjustments of the geosystem have managed to maintain its stability, and the inputs were situated below the level of tolerability.

Problems began to appear with the introduction of fast-processing also highly polluting installations, which had been designed and engineered solely according to economic profitability principles.

In order to have a more complete picture of disruptive inputs, we have to start from the analysis of inputs and outputs of the subsystem that is the mineral ore processing factory from Zlatna [5]. Ores which were processed in this factory came from the deposits of the Zlatna-Stănija district, whose mineral composition is rendered in Table 1.

Table 1. Mineral composition of ores in the Zlatna -Stănija district deposits

Mineral	Chemical formula	Frequency (%)		
		minimum	maximum	average
Pyrite	FeS_2	0,5	9,0	1,8
Chalcopyrite	$CuFeS_2$	0,1	2,5	1,1
Marcasite	FeS_2	0	0,3	sporadic
Ilmenite	$FeTiO_3$	0	5,0	1,1
Rutile	TiO_2	0,5	4,0	1,5
Magnetite	Fe_3O_4	0	3	0,6
Pirotin	FeS	sporadic	2,0	0,5
Blend	ZnS	0	0,5	0,1
Molybdenite	MoS_2	0	0,2	0,1
Galena	PbS	0	0,4	0,2

Table 2. Microelement content in the ore from Zlatna-Stănija district

Element	Frequency (ppm)	
	minimum	maximum
Copper (Cu)	530	14.500
Gallium (Ga)	2	27
Nickel (Ni)	5	230
Molybdenum (Mo)	3	40
Cobalt (Co)	2	37
Chromium (Cr)	8	220
Manganese (Mn)	22	780
Titanium (Ti)	240	3000
Vanadium (V)	14	85
Tungsten (W)	11	670

By simply reading the chemical formulas of minerals from paragenesis, one can draw up an inventory of minerals that enter into the preparation plant, including: iron, copper, titanium, zinc, molybdenum, lead and sulfur. It is known that paragenetic minerals almost always contain a very small amount of minor elements. Therefore, during field work and exploration phases of deposits spectral and semi-quantitative analyses were run for the following elements: copper, gallium, nickel, molybdenum, cobalt, chromium, manganese, titanium, tungsten and vanadium. Results of these tests indicate, almost invariably, the presence of micro-elements. The minimum and maximum contents are presented in tab 2.

In the next phase of analysis, it is necessary to become familiar with the technology of preparation and especially with the characteristics and performance of installations used. The short synthesis of technology flows is shown in Figure no. 3 [6].

A summary of the data presented indicates differences between input and

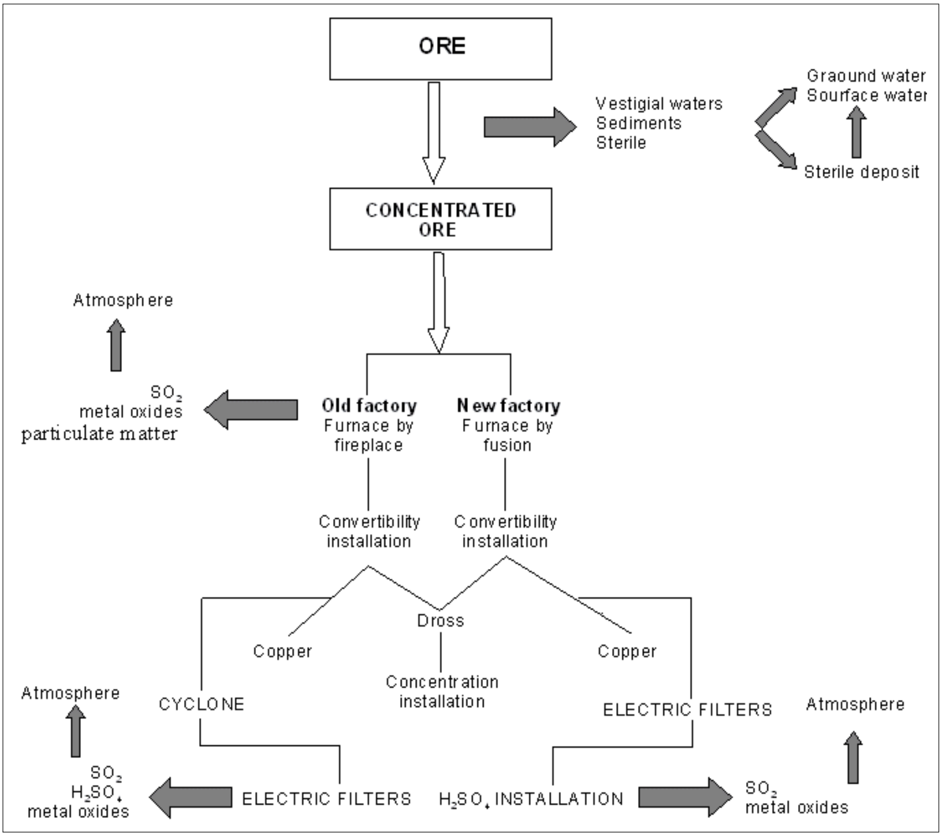

Fig. 3. Chart of polluting emissions found in the environment

output from the subsystem "ore processing factory", which is in fact "the intruding input", to the other subsystems. The situation of the main pollutants and the technology operations which allow them to spill out into the environment is presented as such [7]:

- dust and particle matter are present during handling operations and during the technological processes taking place at high temperatures;
- sulfur dioxide and sulfuric acid vapor, present mostly in the waste gases from the final phase of sulfuric acid manufacturing, are evacuated directly into the atmosphere when the presence of sulfur dioxide does not exceed the concentration of 7%, the minimum limit to be used in the manufacture of sulfuric acid;
- metal composites, in particular oxides of lead and zinc resulted in different phases of metallurgical processes but also in the operations of handling and packaging of products of oxidation [8];
- solid wastes, recovered in the form of slag or mud and stored in ponds or dumping sites, and which constitute a permanent source of pollution of all environmental components (air pollution by dust carried away from the storage areas, surface water and groundwater pollution, and here, implicitly, the pollution of biotic components).

Using this model, we made a study of all the subsystems that form the Ampoi valley geosystem: primary components (air, water), derived components (soil, vegetation, fauna), anthropic (buildings, communication channels) and of the health of people living in Zlatna.

Conclusions

Problems related to the impact of pollution on each element of the environment are quite well known and theoretically grounded. However, a separate analysis of the environment components has not lead to a true development of strategies to reduce pollution, which originated in the mineral ore processing factory, and then continuing with the technology preparation, resulting in a combined effect on all components of the environment.

Applying the systemic analysis, we have recovered minerals which are processed in the Zlatna plant, especially copper, and to some extent lead and zinc. Given the composition of ores, which come mostly from the surrounding area and from the Almaş -Stănija district, a range of important compounds and minor elements does not recover in the technological processes, but retrieves all the waste products (gases, powders, sludges, slags, industrial water).

Waste products affect, first and foremost, the primary components of the environment: atmospheric air and water, from the surface and the underground, then the retrieval and derivative components of the environment;

For the whole area examined, the distribution and pollutants concentration indicates a complex pollution of the atmosphere, containing gas (SO2, CO2, CO, NO), aerosols with high concentrations of heavy metals (Pb, Cd, Zn, Cu, As, Sb), powders of SiO_2 and possible other yet unidentified substances. All these are pollutants have synergistic effects, tending to concentrate and accumulate in the environment components.

The pollution of the atmosphere spreads on an area of about 47,000 ha, the distance of dissipation reaching about 10 km upstream and 40 km downstream.

The forest area affected by the phenomenon of drying because of this pollution is over 32 km^2 the areas most affected by pollution are located in the directions of a general movement air masses: E-SE and W-NW.

The effects of water pollution are: the direct impact on population health, a degradation of flora and fauna in surface waters, favoring the development of micro-parasites (viruses, bacteria, pathogen germs, etc.), and the introduction into the natural environment of chemical compounds which on the long run, have a toxic effect. Some of these compounds can even accumulate in living organisms.

One of the most serious effects caused by industrial emissions acidifying is the destruction of organic matter found in the soil, which could eventually block humification processes.

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