Interdisciplinary Model of Subsoil Use System

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Abstract. The difficult environmental, economic, social and political situations require a deep analysis of interdisciplinary connections in industrial areas. The “system of subsoil use” is a set of mined subsoil areas characterized by geological, geomechanical and aerogasdynamic processes, and industrial production, connected to the civil society and the natural environment by the flows of energy, substance, and information. The flows of biogenic elements in the areas of subsoil use change in the direction of increasing the physical flows of the bio-elements carrying (into the World Ocean) the biological product flows. Energy flows in the areas of subsoil use, that are present in the form of net primary production of the biosphere, radically change in the direction of increasing the anthropogenic (man-made) channel to 8-12%. Environmental information flows in subsoil use areas contain data about whether the environmental conditions are suitable for the biotic regulation. The originality of the “system of subsoil use” concept lies in taking into account the energy, substance, and information flows distribution between the system components and the possibility of an objective analysis of the system effectiveness and its compliance with the concept of sustainable development of industrial areas.

1. Introduction
Difficult environmental (pollution and transformation of the environment), economic (depletion of available mineral resources), social (high poverty rate, increase in civil society protest activity) and political (development of remote areas containing large mineral deposits, that are using foreign investment) situations require a deep scientific analysis of the connections between natural, economic, social and technological factors present in industrial regions.

In the case of an interdisciplinary study of the industrial areas environmentally sustainable development, it is important to have a clear understanding of the “system of subsoil use” concept. Currently, the views on the method of mineral resources use known as the “system of subsoil use” are the following: V.L. Yakovlev, S.V. Kornilkov [1] characterize the subsoil use system as a technological platform that involves many technological operations on the given territory and “uses external resources”; D.V. Kaplunov [2] presents it as a combination of mining structures and technological systems in conjunction with the subsoil areas where they are located, as well as technological, economic and social processes connected to external environment. L.A. Puchkov [3] made the following conclusions and proposals, explaining the concept of ”system of subsoil use” in a rather precise way: "The nature of world energy consumption (subsoil use included) indicates poorly
defined goals ... Economy and civilization further development should be coordinated in accordance with the laws of nature." E.A. Hopunov [4] states that "Modern technology development is connected to convergence based on the interdisciplinary approach principles ..."

The drift to the system of reviewing the connections between technological operations performed in the surrounding environmental, social and economic fields in industrial areas leads to the consideration and recording of energy (in natural and man-made channels), substance (resources, products) and information (biological, social, economic and technological) flows based on the interdisciplinary approach.

2. Methods
The “system of subsoil use” is a combination of mined subsoil areas (characterized by geological, geomechanical and aerogasdynamic processes), industrial production (geological exploration, mineral raw materials mining and beneficiation, its deep processing, use and waste disposal) with civil society and the surrounding natural environment (atmosphere, water, land cover). Such a system takes into account the history (the formation of vegetation cover and fauna, the formation of mineral resources, the evolution of vegetation cover), the current state of subsoil and the future consequences of its use.

Energy, substance, and information flows in the “systems of subsoil use” operate in the environmental, social, economic and technological spheres. The distribution and general characteristics of the energy, substance, and information flows in the “systems of subsoil use” are presented in Table 1.

3. Results
3.1. Energy flows
Energy (SES, 1984, p. 1545) is a general quantitative measure of various forms of matter motion. In systems of subsoil use in the environment (biology), energy flows are manifested in the form of biochemical energy, which is radically changing in the direction of increasing the anthropogenic (man-made) channel to 8-12% (under natural conditions, it is less than 1%).

Social energy [5] represents human labor in the form of retention, accumulation, protection from dissipation (“plundering”) of solar energy transformable forms, which are necessary to meet the needs of people. The energy of thoughts, human consciousness can be seen in the systems of subsoil use in the process of improving production, domestic and creative living conditions. The existence of various creative groups, societies of rationalizers and inventors in the collectives of mining complexes in the past was a manifestation of this type of energy. In recent years, the level of social conflicts has increased in systems of subsoil use.

In the economic sphere of subsoil use systems, energy flows are manifested in the energy of the authorities (state), production (business) and civil society (labor collectives) interaction.

In the production and technological spheres of systems of subsoil use, energy flows include chemical, thermal, electromagnetic, mechanical (including transport), and gravitational energies. In this case, energy is the basis of the mining complex state and development. Mining is considered to be one of the most energy-intensive types of production in the world. In the structure of energy consumption in different countries its share varies from 4 to 55% [6]. The inclusion of the base ores, small-scale and structurally complex deposits into mining, as well as unfavorable geological and climatic conditions, lead to an increase in energy consumption in subsoil use. Unconventional energy sources have been introduced recently: rock pressure and elastic oscillations of a massif (utilized for rock destruction, in order to receive electrical energy by using special sensors (Jarreie, 2015), kinetic energy is directed from above the filling mixtures to the goaf, the gravitational energy of heavy-load mining transport equipment, the energy of exhaust air flows of the mine ventilation system, etc. According to D.R. Kaplunov and M.V. Rylnikova [6], all the potential energy of solid, liquid and gaseous masses moving in a mining enterprise can be effectively converted into renewable electrical energy.
Table 1. Characteristics of the energy, substance, and information flows in the "systems of subsoil use" (while using the interdisciplinary approach).

| Components of the "system of subsoil use" | Flows in the "system of subsoil use" components |
|-------------------------------------------|-----------------------------------------------|
| **Environment (nature)**                  |                                               |
| Biochemical bonds in vegetation cover.    | The composition of the atmosphere.            |
| Conserved energy in the potential reserves of hydrocarbon underground storage. | Biological resources (vegetation cover).     |
|                                            | Flows of biogenic elements.                   |
| Social energy.                            | The genetic information of species.           |
| The energy of thoughts, consciousness.    | Transformation of the environment.           |
| The energy of compliance with moral laws. | Conditions of biotic regulation suitable for the environment. |
| The energy of social conflicts.           | The employment rate in the economy.          |
|                                            | Public health.                                |
|                                            | Social stratification based on income in subsoil user companies |
| Civil society                             |                                               |
| The energy of the interaction between the authorities (state), production (business) and civil society (labor collectives) | Financial resources and their equivalents. |
|                                            | Investments in subsoil use.                  |
|                                            | Various taxes.                               |
|                                            | Use of the revenue in the system of subsoil use. |
| Economy                                   |                                               |
| The increase in energy consumption on locations of base ores deposits, small-scale and structurally complex deposits. | Mined mineral resources: coal, oil, gas, ores of ferrous and non-ferrous metals, etc. |
| The energy of moving masses at mining enterprises. | Products of their processing. |
| Production, technology                    | Renewable Energy (sun, wind, geothermal sources) | Man-made pollution flows. |
|                                            | The objectives of the subsoil use development. |
|                                            | Ways of solving the problem in the subsoil use industry. |
|                                            | Effective methods and ways of subsoil use as well as facilities and specialists. |
3.2. Substance flows
In the environmental field, the substance flows in a system of subsoil use include biogenic elements, the composition of the atmosphere, water resources and biological resources (vegetation cover).
In the social sphere, substance flows in the systems of subsoil use (natural, industrial and household waste) provide favorable conditions and a decent quality of life for citizens who live in industrial regions.
In the economic sphere, substance flows are financial flows and their equivalents.
Financial flows include: investments, costs (prices), fees for subsoil use, various taxes, use of revenues.
In the production and technological sphere, substance flows are flows of mined mineral resources, transformed qualitatively and quantitatively in geomechanical, geochemical and biotechnical processes of subsoil use, and flows of industrial waste, including process water and pollution, containing gaseous, aerosol and dust (including radionuclides) substances.
The substance flows in the technological sphere of the system of subsoil use are characterized by a combination of qualitative and quantitative indicators of mineral resources mined. Tables 2 and 3 show the individual characteristics of iron ore mined in the Kachkanarsky GOK in the Sverdlovsk Oblast [7, 8].

Table 2. Titanium magnetite ores stocks of the Kachkanarsky GOK (Lyapunov A. V., et al., 2013).

| Deposits            | Iron ore balance reserves as of 01/01/2013, million tons |
|---------------------|----------------------------------------------------------|
|                     | A + B + C1 | C2           |
| Gusevogorskoe      | 2543.3     | 2410.3       |
| Kachkanar Proper   | 3602.6     | 3269.9       |

Table 3. Types of the Kachkanarsky GOK (Gusevogorskoe deposit) ores by beneficiation and their variety (Kornilkov S.V., et al., 2016).

| Quarry   | The ores proportion by beneficiation (impregnation, magnetic iron content),% | The ores proportion by type, % |
|----------|-------------------------------------------------------------------------------|--------------------------------|
|          | easy | intermediate | medium | difficult | low-grade titanium | intermediate titanium |
| Northern | 1.1  | 26.5         | 30.1   | 42.3      | 61.0               | 39.0               |
| Main     | 1.6  | 10.5         | 23.0   | 64.9      | 28.0               | 72.0               |

3.3. Information flows
Environmental information flows in systems of subsoil use contain information on the environment transformation on the genetic (influence of industrial pollution on the living organisms genetic codes), species (change that manifests in appearance of atypical flora in the industrial areas and loss of biodiversity which takes the form of the disappearance of fauna) and ecosystem levels (replacement of primary vegetation types by secondary ones).
Environmental information flows in subsoil use areas contain information on whether the environmental conditions are suitable for biotic regulation; in critical cases (areas of disturbed land) the environment loses its stability.
Social information flows in the system of subsoil use include the parameters of employment rate in the region's subsoil use economy, its health status (Table 4) and the degree of social stratification based on income.
Table 4. Overall and primary mental disorders incidence rate per 100,000 people in areas of subsoil use in the Sverdlovsk oblast (based on the data provided by the "Sverdlovsk Regional Clinical Psychiatric Hospital").

| Industrial areas                              | Overall incidence | Primary incidence |
|-----------------------------------------------|-------------------|-------------------|
|                                               | 2008   | 2009   | 2010   | 2008   | 2009   | 2010   |
| Asbest (mining and processing of asbestos)    | 1,884  | 3,254  | -      | 335    | 347    | -      |
| Kachkanar (mining of iron ore)                | 1,477  | 1,782  | 1,898  | 72     | 477    | 393    |
| Kushva (mining and processing of iron ore)    | 2,801  | 1,777  | 1,873  | 331    | 411    | 524    |
| Rezh (mining and processing of non-ferrous metals) | 3,986  | 3,271  | 2,601  | 469    | 416    | 461    |

Economic information flows in the system of subsoil use include: parameters of regional (national) wealth, natural capital, environmental and production potential; parameters of gross domestic product (GDP) with their reconsideration occurring in Russian and world economic science (43rd report of the Club of Rome [11], monographs by foreign economists D. Quiggin [12], D. Akerlof, R. Schiller [13], T. Piketty [14], R. Solow [15]). The ratio of various discount rates to the norms (discount factors) of the social time preference; methods of institutional solutions of "emergency" imbalances in subsoil use, elements of indicative planning.

Production and technological information flows contain data about:
- geological, geomechanical and aerogasdynamic processes, geological exploration, extraction and beneficiation of mineral raw materials, processing of the extracted resources and production wastes disposal;
- the objectives of the "system of subsoil use " development in accordance with the territories characteristics and conditions in the coal mining, oil and gas production, iron ores and non-ferrous metal ores mining sectors in the old industrial (South and Middle Urals) and the new regions (Polar Urals);
- various possible solutions to specific problems in the field of subsoil use;
- ways of effective application of promising methods and ways of subsoil use, the capacities of technical and technological potential of the subsoil use sector, as well as of the specialists working in the field.

4. Conclusion
The proposed structure of the “system of subsoil use” in the form of a combination of mined subsoil areas, industrial production, civil society, and the environment, all of which are connected by the energy, substance, and information flows, allows for the use of an interdisciplinary scientific approach based on ecology, sociology, economics as well as production and technological factors for the purpose of a multi-criteria optimization of the system. This methodology of efficient management in the subsoil use field will allow to minimize corporate (striving for maximum profit in the economic sphere while suffering damages in the environmental and social spheres), regional (ignoring the relationship with other regions) and temporal (ignoring the need for minerals that will occur in future generations) subjectivity.

The originality of the “system of subsoil use” concept consists in taking into account the distribution of energy, substance, and information flows between the system components and the possibility of an objective analysis of the system functioning effectiveness and its compliance with the concept of sustainable development of industrial territories.
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