Corporative Ecological System and Processes Mathematical Modelling

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Abstract – **In the article the basics of the corporate approach in the system of ecological monitoring for solving of ecological problems tasks macro- and a microlevel are considered. Practical results of realization of corporate system in definition of an ecological estimation of processes in the soils are submitted.**

Index Terms – **Corporative system, ecological monitoring, entropy, information, thermodynamic function.**

I. Introduction: Relevance of the Work and Relation with Scientific Practical Tasks

Mathematical modelling in ecology has its own peculiarity and hardship, which are connected with selection of simulated objects, with a great amount of problems, which are solved in this branch. Models based on differential equations are dealt with frequently. The principle of such models building is connected with determination of half-empirical patterns, analogies and specious conclusions, hypotheses.

There are two main types of models depending on the aim of modelling: descriptive and behaviour models.

Statistical methods, that ignore time as independent variable, are viewed in ecological monitoring. They include simple and multiple linear and nonlinear correlation and regression, dispersive, discriminant and factor analyses, parameter assessment method. Only these methods have been used for analysis of local corporative ecological system functioning, where the soil is the main object of research.

Dynamical methods take into account time changes and use Fourier analysis, spectral and correlation analysis, weight and transfer functions for model development. In general such models are regression and other quantitative dependencies, that do not show the mechanism process.

The determinations of input and output signal structure system, special conditions system response, internal system structure are very important during model formation. Such approach lets to describe cause-effect relations in ecological or any other system with the help of differential equations due to the generated model conception and formed equations, which show system behaviour.

According to R. Shennon (1978), any material system is an assemble objects, which are connected by the form (structure) of control interaction or interdependences for its functioning.

A lot of theoretical material is presented in science literature, which refers to the problem of creating complex systems for administrative decision making for the purpose of harmonization of interaction in the system "nature-society". It was suggested to represent the whole world's multiplicity like three hierarchies: natural or biophysical, social and technical. The integration of subsystems from different hierarchies causes mixed class systems forming: ecological anthropogenic or ecological economic. The failing of these systems is that man is not taken into account as obligatory component, man is given a role of a person who makes decisions (PMD).

The rational usage of nature is first of all and mainly aimed at providing effective and unlimited usage of natural components for natural complex not to lose its functional ability:

1) optimal functioning of life support systems due to fundamental ecological processes;
2) the support of (technical and natural) capacity and buffer capacity of natural ecosystems;
3) self-regeneration and conservation of gene pool (the man is thought to be the biological component of the planet) [1].

The basis of ecological economic approach, the conception of environment quality management is in fact anthropocentric. The interests of other creatures are of no importance even empirically beyond the bounds of man society. The state of society is optimal, when the possibility of changing this state is absent, under the condition that there is no way for any member of society to improve his state without changing for the worse somebody other's, according to Paretto-optimality criteria [2]. In general, a necessary component in formation of normative part of such approach is economics, which plays is a part a method of decision-making critical analysis.

Let us look at this problem from the point of view of ecology as a science about interaction and state of creatures, including man as social system component. Then it is expedient to introduce global corporative ecological system

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(CES) as the aggregate of ecological, economic and social systems. Administrative decision-making concerning ecological problems solution should be carried from the area of ecological economic system functioning and micro and macro economic system optimization criteria effect into new, corporative ecological system (CES), and new optimization criterion – ecological comparator should be introduced. It will become a new criterion in decision-making and decision optimization process structure, and play the part of corporative formation as its basis will be the complex of thermodynamic indices, which will control optimality of alive and not alive components of natural ecosystems functioning, techno economic and social system balance including man as bio element. It will allow optimizing or maintaining constant the optimal functioning of physical, chemical and biological processes of the system and its components, similar to CES normative state. The basis of CES conception realisation is a permanent global and regional, including ecological, monitoring system functioning.

The best system of ecological management is such system which prefers properties of self-maintaining of natural characteristics (the principle of careful interference) [3]. Such approach notices upon harmonization of ecological systems and processes inside of them.

It is to be noticed that ecological and economic system functioning will be extensively influenced by social system, in which man's state as of the member of society and biological organism is very important. So the elaboration of new conception of ecological problem solving on global level in modern conditions is of current importance and necessary.

II. Aims and Problems of Investigation

The aim of the investigation of ecological, social, economic system development harmonisation is inculcation of corporative ecological system conception [4, 5] and determination of ecological state of the territory on the basis of ecological monitoring and inculcation of thermodynamic methods in analysis of input data with its help. The following problems were determined and solved during theoretical analysis and selection of mathematical processing method of information:

1) justification of corporative system structure for ecological monitoring, that will be ecological as ecological problems have the priority in solution of any problem;

2) usage of corporative system at micro level and usage of thermo dynamical indices, entropic basis namely, for decision making in ecological monitoring system.

III. Research Materials and Scientific Results

Elementary structural unit, which is subject of research, is used to be examined first of all for system analysis. The necessary condition of structural unit construction is that it has to keep all system's properties. If natural ecosystems are taken, biogeocenose is such a unit.

The subject of inquiry and elementary structural unit accordingly, change, taking into account man-caused activity, that is to say techno sphere existence. Noobiogeocenose is suggested to be such a unit in literature [6]. It is a complicated system according to its structure. The basis of "society-nature" interaction is social production, all abstract methods of which are included into noobiogeocenose. The process of labour is the main process, which defines noobiogeocenose functioning, as of the "society-nature" system elementary component.

Therefore the most attention is paid to the technological processes and changes caused by them in natural environment during investigation of "society-nature" system components interaction.

Proposed corporative ecological system (CES) has a simpler structure, as microelements are not taken into consideration as components for solution of problems of optimization and regulation of the state of the system on the whole. Ecological corporative system allows to abstract one's mind from delicate system structure and to consider as a aberration any irregularities in any component, which are determined and are taken into account in ecological state analysis via thermo dynamical parameters. Such approach allows solving ecological problems on global level, as well as on the micro one for local problems solution (Fig. 1).

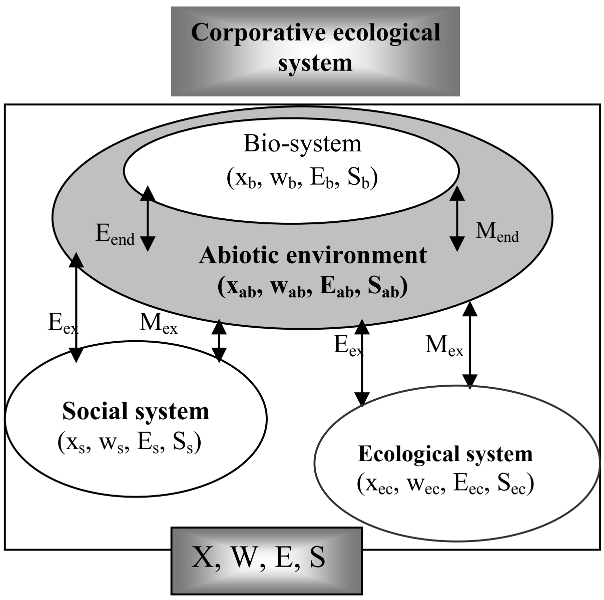

Fig. 1. Structure of corporative ecological system

Hence existent approach to system organizations process of "man-nature", "economics-nature" relations, that has at a basis of research hierarchically subordinate model (natural-industrial system), is changed upon corporative approach concerning natural ecological, social and economic systems relations determination.

Introduction not of hierarchical but of integral corporative system into ecological monitoring system is expedient for single-valued environment ecological state determination as of natural, social and economic systems complex and for social-economic activity.

Exactly such system will have three equivalent and interrelated components, whose states can be explicitly determined after one complex criterion, which is responsible for the composition of any part of the CES (X), its structure (W), energy and entropy state (E, S). Peculiarity and scientific-theoretical novelty of innovation is that it equally determines the state of corporative system as a whole and its components separately, taking into account the basis of thermodynamics for isolated system such as CES, in which endogenous flow of energy and matter (E_{end}, M_{end}) and exogenous (E_{ex}, M_{ex}) among its components exists.

CES allows solving problems of stable equilibrium development as problems of directed, irreversible and natural change of ecological (natural), social and economic subsystems according to their structure, properties and providing integral development. Ecological problems are prevailing for CES as just natural component provides development basis for two others subsystems of corporative system. CES can be presented as priority matrix for the person, who makes decisions and ensures favourable social and economic society development, according to solving problems of first priority evaluation:

Equilibrium social-economic development	Ecological subsystem C_1	Economic subsystem C_2	Social subsystem C_3
C_1	1	2	3
C_2	½	1	3/2
C_3	1/3	2/3	1

Let us find maximum or main characteristic constant, consistency index (CI) as consistency and priority vector ratio for imaging advantages and consistency proportionality for mentioned equilibrium development CES matrix:

$$\begin{pmatrix} 6 \\ 3 \\ 2 \end{pmatrix} : 3 = \underset{\sum = 3{,}6}{\underline{\begin{pmatrix} 2 \\ 1 \\ 0{,}6 \end{pmatrix}}} : 3{,}6 = \begin{pmatrix} 0{,}555 \\ 0{,}278 \\ 0{,}167 \end{pmatrix}.$$

As $\lambda_{\max} = 2$ then $CI = 0.5$, $CR = 0.58$, meanwhile the closer $\lambda_{\max}$ value to n is the more consistent result, random index value is $RI = CI / CR = 0.86$. Ecological problems are the most priority for present corporative system according to finding, and ecological or natural component is important CES subsystem (its weight is 0.555).

The idea of thermodynamic basis usage managerial decision optimisation area in the ecological monitoring system is objectively conditioned by course of investigation – CES introduction as of:

1) necessary interaction realisation model between complicated dynamical systems: natural, ecological, social and economic;

2) optimisation of managerial decision concerning CES with the aim of natural and social-economic systems relations harmonisation and their equilibrium development;

3) as identification and estimation basis of standardized equilibrium development of CES and its components due to introduction of corporative approach for micro level ecological problems solution.

Since CES is connected with system analysis so assigned tasks solution does with mathematical description of complicated objects. And such findings are grounds for prognostic information synthesis about CES functioning.

Consideration of complicated systems regulation problems and databank structure creation is attended in some works [8, 9]. Necessity of interdisciplinary approach for such system components, like global natural-social-economic, research is shown in these works, yet everything is reduced to the ecological-economic system and its division into components using anthropocentrism during solving corporative decision making problem while examining real questions. Division and multilevel examination may be equivalent to the natural hierarchical organisation of real world objects, having conditional methodological character in common view, which expresses Leibniz identification principle. The system is divided into components during representation according to this principle, and all components that are included into this system cannot be discerned at the abstraction level, and only in such case the component may be considered to be the system with its own structure: ecological, social and economic systems are exactly such components of CES. Regardless of peculiarities of their composition and structure they should be in optimal-normalized state and decisions of their interaction $F(U)$ will be controlled by minimum of $F(X, W, E, S)$ for solution of main ecological problem – preservation of all living things and man protection. The systems themselves will be characterized by parameters X, W, E and S according to their composition, structure and adaptive facilities of alive and abiotic components at any time. The last ones, E and S, are thermodynamic functions, which is reasonable in the given approach of research aim solution, as any physical-chemical system state can be forecast just with the help of thermodynamic factors, and CES state as such system can be forecast too. First components, X and W, are responsible for the system view: X – composition, W – structure.

Hence CES is a complicated, unique object, which cannot be experimented at. Listed parameters are distributed according to some real system state and their changes a given period of time is determined as a result of transition between states. State $F(X,W,E,S)$ changing in time is called a process. Since these changes can be controlled, such processes are described as a rule by showing the law of transition from previous state $F(X_i,W_i,E_i,S_i)$ to the next one $F(X_{i+1},W_{i+1},E_{i+1},S_{i+1})$ at every step against controlling influence, which is characterised by function $F(U)$ or some vector $U=(u_1,u_2,\dots u_n)$ (the set of independent parameters), or element of U_0 set, which is called control set, in the general case.

Other factors, that are not manageable and strictly accountable, can influence the system transition from one state to another. They are characterized as a state and control of some vector or other nature set, which is called disturbance $\nu(i)$.

Mathematical model of management process for our CES is a solution that connects the following system state with the previous one, management process and disturbance:

$$F(X_{i+1},W_{i+1},E_{i+1},S_{i+1})=f(\{t(i)\},\{u(i)\},\{\nu(i)\}). \quad (1)$$

The factors that are not used for X, W, E and S for CES at a moment are not essential and they can not be included into mathematical models. Then equation (1) describes the process with the full information. In this case the process is determined wholly if start management state $F(X_0,W_0,E_0,S_0)$ is given at each step. Otherwise the incomplete information process occurs. CES state change in time in initial state, control and disturbance definiteness is called control process implementation with defined disturbance. Flows of mater, energy and information of exogenous character that change state $F(X,W,E,S)$ are considered to be disturbance during CES functioning. Further term "process" should be understood as mathematical model of a real process.

All CES processes are such where the next state depends only on previous one, on control and on the considered:

$$\begin{aligned}&F(X_{i+1},W_{i+1},E_{i+1},S_{i+1})=\\&=f(\{t(i)\},\{W(i)\},\{U(i)\},\{\nu(i)\})\end{aligned}. \quad (2)$$

These processes are called processes without consequences or markovian processes. State change velocity approximately equals state change divided by time elapsed if the last one is big enough.

When $t(i+1)-t(i)\to 0$ we have:

$$\dot{X}(i)\approx=\frac{\{X(i+1)-(X(i))\}\{W(i+1)-(W(i))\}}{t(i+1)-t(i)}. \quad (3)$$

Equation (2) has an analogous equation:

$$\dot{F}_{X,W,E,S}=f(t,X(t),W(t),U(t),V(t)), \quad (4)$$

which is called differential equation with control and disturbance.

Equation with the divergent argument can be continuous equation (1) analogue:

$$\begin{aligned}&\dot{F}_{X,W,E,S}=f(\{t-t_q)\},\{X(t-t_q)\},\{W(t-t_q)\},\\&\{U(t-t_q)\},\{V(t-t_q)\})\end{aligned} \quad (5)$$

where $q=1,2,\dots,t_0$.

Additional limitations can be used for state $F(X,W,E,S)$ and control $F(U)$, which are determined by real conditions, in which the process is in progress. It is reached by giving sets X, W, E, S, to which x, w, e and s belong, and U set, from which u control can be chosen.

CES state is represented not by the final set of indices but by their continuous distribution. Soil surface distribution of temperature, humidity and matter concentration and chemical elements just like CES and its components distribution of energy, entropy, matter is represented as diffusion and transfer (migration). Partial differential equations answer this:

$$\begin{aligned}&\frac{\partial \dot{F}_{X,W,E,S}}{\partial t}=\\&=f(t,X(t,z),W(t,z),E(t,z),S(t,z),U(t,z))\end{aligned}, \quad (6)$$

where z – spatial variable (distribution parameter);

$f(\bullet)$ – some differential operator.

Such approach to CES description is natural because its components, components' components and elements are real objects that are related to complicated ones, distributed in space. Most of the models existing at the present moment are mostly like collection models of ordinary equations since natural observations have a discrete character.

If to proceed from suggested corporative system basis then ecological estimation of local equilibrium in natural systems should be directly connected with economic system matter flows interconnection analyses (or of the emissions and dumping into environment in micro level case) and population health. It is well known that soil as natural system object is central and the most complicated component. All energy and matter flows concentrate just in the soil where they are reallocated among other system components, where their further motion into economic and social system is formed. The soil plays the role of such a depot of all matter flows and pollutants particularly, which influences social system equilibrium.

Let us have a good look at practical realization of thermo dynamical approaches of common system state determination by separate local processes and phenomena data, which take place in the system, and managerial decision formation during corporative approach application for common state estimation of explored territory. Statistical data of soil ecological monitoring were used for this, whose samples were periodically taken in autumn and spring at a period of time between 1994 and 2004 in places that were under anthropogenic influence of Zmiev National Power Plant (NPP) (Kharkov region) and in anthropogenic loaded areas of Kharkov city. (Numerical content values of heavy metals in spring and autumn soils were taken at random, samples were taken from 5 and 6 constant monitoring points and 16 control ones during 1994-2004, and that is 400 samples and 10 800 element analysis).

By means of X-ray phase analysis (XPA) data the following slightly soluble and insoluble chemical compounds were determined on qualitative level in soils: $Zn_2V_2O_7$, $Zn_3(VO_4)_2$, $Zn(VO_3)_2$, $Pb(VO_3)_2$, $4PbOxV_2O_5$, $Pb_3(VO_4)_2$, $PbCrO_4$, $PbCr_2O_7$, $SrCrO_4$, $SrCr_2O_7$, $Sr(VO_3)_2$, $Ni_2V_2O_7$. Thus heavy metals are in the ionic form (Zn^{2+}, Co^{2+}, Ni^{2+}, Pb^{2+}, Sr^{2+}, Cd^{2+}, Cu^{2+}, CrO_4^{2-}, $Cr_2O_7^{2-}$, VO_3^-, $V_2O_7^{4-}$, VO_4^{3-}) due to the transformation in the soil solution after getting into the air as oxides, sulphides and elemental forms. Anionogenic produce oxide containing acid residuals that are able to react with metal cations and to produce insoluble salts, according to XPA results. Exactly these matters of chemical-transformation flow accumulate in soils and decrease migratory abilities of anthropogenic elements.

Soil macro composition influences pollutant migration greatly, and that promotes cationogenic substance delay as soil fraction is negatively charged. The structure and macro matters ratio create certain pH of environment, which controls migration abilities of pollutants. The most attention is paid to the Al_2O_3 / SiO_2 ratio and presence of K, Ca and Mg oxides, which create main conditions, that increase migration abilities of such toxic anionogenic elements as $Cr(VI)$, $V(V)$, $As(V)$, Mo and W. Considerable inclusion of SiO_2 and presence of sulphate and chloride ions in the soil solution is soil acidation condition, which leads to the heavy metals cationogenic migration abilities increase, their inflow into plants and further spread along food chain.

Practical results of heavy metals concentration measurements in soil samples were analyzed with the help of program package “STATISTICA 6.0”. Mathematical model of pH indicator dependency from main soil components ratio is the following for city soils:

$$pH = 7.3 + 0.92K_{Al/Si} \text{ or } pH = 0.216K_{Fe/Si} + 0.711K_{Al/Si} + 7.3, \quad (7)$$

$$pH = 0.85C_{SiO_2} - 0.22C_{Al_2O_3} + 0.19C_{Ti_2O_5} + 0.13C_{K_2O,CaO,MgO} \quad (8)$$

where $K_{Fe/Si}$, $K_{Al/Si}$ are coefficients of Fe/Si, Al/Si microelements ratios.

Such dependence for Zmiev region soils is absent and the following parameters of pH and soil composition relation are determined according to the statistic data processing (table I).

Mathematical model of certain environment pH formation for examined soils is as follows:

1) for soils of Zmiev region:

$$pH = 0.99C_{Mo} + 0.47C_{Cr} - 49.95; \quad (9)$$

2) for city soils:

$$pH = 1.1C_{Pb} + 0.07C_{Sr} - 0.16C_{Cr} + 0.22C_{Ni} - 25.8 \quad (10)$$

where C_{Mo}, C_{Cr}, C_{Pb}, C_{Sr}, C_{Ni} are molybdenum, chromium, lead, strontium and nickel concentrations in the soils, respectively.

TABLE I

Multiple Regression Results, Standard error of estimate: 0,529053012

Dependent: **pH** Multiple R =0,99992555 F = 26860,92
R^2= 0,9998 df = 1,4 adjusted R^2= 0,9998 p = 0,000000
Intercept: 6,9160 Std. Error: 0,2368 t (4) = 29,200
p-level= 0,000008

	Beta	Std.Err.	B	Std.Err.	t(4)
Intercept			6,916	0,237	29,2003
pH	0,999	0,0061	0,932	0,0057	163,8930

Analysis findings corroborate the theory of cationogenic and anionogenic interaction in the transformation flow and formation of pH environment and certain conditions for their accumulation and migration: presence of heavy metals chromates in the soils, which according to thermo dynamic rules decrease system malfunction, decrease exogenous matter flow into social CES component and cause avoiding of system disequilibrium. Economic system regulation caused matter inflow into natural systems due to the self-control processes and endogenous processes in the soil and ecological system as a whole, and that can lead to system load decrease on the whole according to (6) we come to:

$$\frac{\partial \dot{F}_{X,W,E,S}}{\partial t} \to 0 .$$

When CES comes to equilibrium state by existing conditions as a result, its entropy will level maximum. CES equilibrium criterion will be:

$$(dS)_{U,V} = 0, (d^2S)_{U,V} < 0 .$$

IV. CONCLUSION

A Theoretical And Practical Work Significance

Introduction of corporative approach into the ecological monitoring system les form and ground CES structure for ecological problems solution on micro- and macro- level. The possibility of result comparison in different CES subsystems, such as natural ecosystem, social and economic systems, is essential in CES introduction. Thermo dynamic approach usage and complex state criterion taking into account both of the corporative system and its components on the basis of composition, structure, energy properties and system order (entropy) analysis makes it possible to unequivocally determine optimal CES directed influence upon itself and its components, which secures equilibrium state, and exactly the last one is the aim of managerial decision making in the ecological monitoring system.

B Development Perspectives

1) CES data base structure development, taking into consideration suggested approaches of its state and equilibrium stability determination with the help of thermo dynamic functions.

2) Development of new theoretical practical approaches of managerial solution optimization problem solving with the goal of natural and social-economic systems interaction equilibrium attainment.

3) Forecasting and development mathematical models of chemical transformation flows taking into account qualitative and quantitative composition of anthropogenic matters, soil macro composition, and environment pH. Determination of rated territory pollution level and ecological danger level of anthropogenic sphere for ecosystems and man on the basis of statistical models.

C Summary

Modern ecological problems solution approaches for making well grounded optimal managerial decisions analysis made possible to determine a new way of problem solution in the system of ecological monitoring.

1) Reasonability of corporative approach introduction for studying and analysis of interaction between three main components of environment, natural, social and ecological systems, has been examined and proved. The last two systems are connected by natural links of matter, energy and information with the natural ecological system and are represented as thermo dynamic energy and matter flows of exogenous character inside of CES and influence corporative system and its components state, which is characterized by system complex criterion $F(X, W, E, S)$.

2) Thermo dynamic factors, internal energy E and entropy S, are the main criteria of equilibrium optimally close to the standard CES state determination. CES state is represented not as an ultimate factors set, but as their continuous distribution and state change according to the equation (6).

3) It seems possible to forecast and develop mathematical models of chemical transformation flows formation taking into account qualitative and quantitative composition of anthropogenic matters, soil macro structure and environment pH. Territory pollution level and anthropogenic influence, ecological safety level for man and ecosystem have been determined and estimated on the basis of the above given models.

Hence the determined research direction is a perspective one for modern ecological problems solution, aimed at natural and social-economic systems relations harmonization, and decision taking problem in the absence of risk solution for stochastic dynamic decision making model in the ecological monitoring system.

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