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SOCIAL ECOLOGY AS A CONNECTING LINK BETWEEN FUNDAMENTAL SCIENCE AND SOCIO-ECONOMIC PRACTICE

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Abstract

The paper gives a definition of the socio-ecological system (SES). The global and regional models of SES are discussed in connection with practical macroeconomics. A number of model scenarios for development of SES in USSR up to the year 2070 are considered. The "Mir-2" model implemented in MathCad ("Mir-2 MC") was used in the paper to verify Eu. Odum's hypothesis on cyclical development of the civilization and a possibility to shift it to the stationary functioning mode. It is shown that the initial condition for the resource equation adopted in "Mir-2" model is understated by a factor of 3-9. The scenarios implemented in "Mir-2 MC" model showed that SES gives rise to macro-scale oscillations of all components with the increase of the traditional fossil fuel reserves. The number of cycles changes from 2 to 4. In case of the use of oil shale reserves, with profitable extraction, the number of oscillations increases to 15. When using thermonuclear energy, SES components shift to the simple harmonic motion mode close to the equilibrium state. The growth of the population size in every cycle, except for the last one, is limited not by fuel resources, but by food shortage and environmental pollution. Cyclic processes end in spontaneous transition to stationary development. An adjustable transition to SES' steady motion is possible only through population control after the completion of the first or subsequent cycles. A logistic model of growth with an acceptable population threshold of 1.5 billion is used as a regulator.

Keywords: Civilization**,** cyclic development, mathematical model, population, socio-ecological system, stationary mode.

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1. Introduction

There are several author-created definitions of social ecology. The most capacious of them is Reymers' definition: "Social ecology is a scientific discipline considering the relationship of the society with the geographical, social and cultural environments, i.e., with the man's environment" (Reymers, 1990, p. 596). The objects of its study are global and regional socio-ecological systems (SES) and their subsystems (Ponarina, 2012; Lior, 2013; Aladyshkin & Kulik, 2015; Aladyshkin, Kulik, Michurin, & Anosova, 2017; Gashkova, Berezovskaya, & Shipunova, 2017; Bylieva, Lobatyuk, & Rubtsova, 2018). The following definition of SES concept can be proposed: it is a dynamic, self-developing, self-regulating aggregate of interacting components of animate and inanimate nature in which the flows of energy, matter, information and value create a clearly set economic, social and cultural environment of the human society, a structure that takes into account the priority of the upper hierarchical level system over the lower system.

Mankind does not yet have due experience of development in the post-industrial epoch that had its onset in late 20th – early 21st centuries, while the negative, threatening processes are already taking place today. The negative processes evidence that today the humanity is experiencing an evolving demographic, socio-economic and environmental crisis that gradually develops into a catastrophe of civilization. Ignorant people do not see it, and social optimists do not believe in it. In 1989, the Report of the World Commission on Environment and Development "Our Common Future" adopted a soothing definition of sustainable development of civilization: "This is the development that meets the needs of the present, but does not threaten the ability of the future generations to meet their own needs" ("Our Common Future", 1988, p. 145). This definition does not contribute to due comprehension of the ways leading to mitigation or prevention of the crisis phenomena.

Meanwhile, this way is suggested by the economic models of SES development. The creator of the first such model, Forrester (1978), expounded his modelling concept at the meeting of US House of Representatives Commission as follows: "My main thesis is that the human brain is not able to comprehend how social systems function. ... Our social systems are incomparably more complex and difficult for understanding than our technical systems. Why then don't we model social systems before we try to introduce new laws and governmental programmes? I insist that we have sufficient knowledge to create useful models of social systems" (Arab-Ogly, 1978, p. 191).

In 1991-1974, Forrester and Meadows, with the support of the Club of Rome, proposed the first global models for development of civilization "Mir-2" and Mir-3, designed on the principle of system dynamics - a method for exploring complex systems with nonlinear feedback, developed at Massachusetts Institute of Technology (Forrester, 1978; Meadows & Meadows, 1974). The apocalyptic prophecies of these models aroused an extensive debate in the press and prompted the Club of Rome to continue the support of global modelling research. In the subsequent years, a number of SES models were designed, suggesting certain ways to prevent recessionary phenomena of the global and regional scale. A new direction in science called "Globalistics" appeared. The non-exhaustive analysis of global development models is offered in the articles (Gvishiani, 2013; Sergeev & Kulesh, 2017).

The first model of a regional SES with spatial structure was, apparently, a multiply repeated version of "Mir-2" used for research of interaction between the "rich" and "poor" regions of Switzerland (Theimann, 1973). The "Survival Strategy" model explores the interaction of SES in 10 regions of the world, each

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described by a system of submodels (demography, economics, power engineering, etc.) (Mesarovic & Pestel, 1974). "The Future of the World Economy" project uses a method known as "Input-output analysis". For each of 15 regions, economic sectors are modelled - 22 branches of industry and construction, 4 sectors of agriculture, trade, service industry, transport and communications. The pollution concentration spots are modelled (8 types of pollutants), and five purification methods are considered. The model comprises 2500 equations and is realized for the period 1980-2000, encompassing 8 scenarios of world economic development (Leontief, 1976). Particular mention should be made of a model "The Future of Civilization and the Strategy of Civilizational Partnership". The methodology for forecasting SES development is based on the use of additively applied logistic and cyclic models. Their parameters are determined by the least-squares method using the time series characteristics for the period 1950-2006. A forecast of innovative and technological development and of labour resource balance is made for 12 local civilizations and by countries included in each of them. The considered model belongs to the statistical class (Akayev, Yakovets, Sokolov, & Sarygulov, 2009) and is operable a posteriori. The obtained model forecasts for 2007-2050 will be justified to the extent the economic situations encountered in the training sequences for 1959-2006 can be reiterated.

In 1989, a regional SES model "USSR - Cities - Rural Settlements - Leningrad" was implemented in Leningrad State University. Structurally, it represents a symbiosis of "Mir-2" and "Mir-3" models. At the same time, many dependencies reflecting the intensity of demographic, economic and ecological processes were based on the data of USSR state statistics and environmental monitoring. The model realizes the principle of priority of the top hierarchical level system over the subsystem of lower levels. The calculations for the "basic" version developing SES for USSR showed that the country was gradually facing some crisis-specific phenomena connected mainly with the environmental pollution. The basic industrial, agricultural and service resources, after reaching the maximum in the 2030s, will shift to declining. From 2015 to 2030-ies, the net industrial output per capita will decrease twofold, and by 2060 it will drop to one third of the previous figure. The growth of service industry production will cease by 2030. The food supply of the population will decrease from 2.7 units of the annual subsistence level in 2020 to 1.9 in 2060. In the subsequent decades, a particularly sharp drop in the level of food supply will take place. The environmental pollution will reach its maximum by 2060. The population size on the territory of the former USSR will decrease from 290 to 220 million within the period 2030 - 2060. In the period from 2061 to 2070, the population will decrease by another 92 million people as a result of pollution and shortage of foodstuffs.

Let us note that the disintegration of USSR, the instantaneous (in terms of historical scale) transition from the planned to market economy and the simultaneous catastrophic slump of demographic and macroeconomic indicators, apparently, forestalled and prevented a crisis in Russia predicted for the second half of the 21st century. The "saving scenario" is a confirmation of the possibility to avoid the demographic and economic crisis in USSR in the second half of the 21st century. According to this scenario, the environmental pollution and military defence costs will not change at the rate that was specific for 1988, as is set for the "basic" scenario, but are fixed at the level of 1988. The calculations showed that in 2010-2020, some fundamental changes in the orientation of the production sphere will begin on the territory of the former USSR. The industrialized country will turn into an agrarian-industrial, and further - into an agrarian country, within a term of 20 years. However, despite such reorientation of economy and the increased

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production of agricultural products, the food supply of the population will gradually decline from 3.17 units of the annual subsistence minimum in 1990 to 1.47 units in 2070, which will take place due to the increased size of the country's population. In particular, the numbers will reach 375 million by 2040 and 640 million by 2070. The average life expectancy will increase to 91 years, mainly due to the advanced level of medical care. The growth of the population base, especially after the year 2030, will take place for account of senior age groups.

The SES development models do not exhaust the sphere of interests of social ecology. The objects of its research include the comestibles, energy and social problems; land resources and urbanization; restoration of productive potential of ecosystems and the biosphere, socio-economic metabolism, public health and many other problems. Let us consider only two of them in more detail: assessing the quality of life of the population and assessing the state and stability of SES.

The quality of life of the population is defined as a set of conditions providing for (or not providing) a complex of human health - personal and public, i.e. the concordance of the human environment and the man's needs that are integrally reflected through man's average life expectancy, the measure of health and the level of morbidity (Reymers, 1990). The quality of life is a complex function of many arguments, such as the standard of nutrition, medical care, material security, urbanization, environmental pollution, etc. - the parameters having different dimensions. Assessment of the living standards is the task of the statistical theory of pattern recognition. The recognition model consists of the learning and recognizing systems. Some composite (integral) indicators are used as a recognition criterion, that assess the multivariable objects through a single number (Dmitriev & Kaledin, 2016). The United Nations experts, in assessing the quality of life of the world population or the population of particular countries and regions therein, use the geometric mean of standardized private indicators as a composite indicator (Human Development for All and Everyone, 2017).

To analyze the state and sustainability of regional SES, multi-parameter integral estimates are also used. In Russia, they are usually called the method of consolidated indicators (MCI) and the method of randomized consolidated indicators (MRCI) (Dmitriev & Kaledin, 2016); in the United States they are known as the complex stability indicator (CSI) (Lior, 2015).

2. Problem Statement

The calculations performed using the global "Mir-2" and "Mir-3" models showed that the rapid development of civilization in 20th - early 21st century will be followed by a catastrophe connected with depletion of non-renewable natural resources, foodstuffs and environmental pollution. Starting from 20-30s of the 21st century, the Earth population growth will cease, and within the next 75 years it will decrease by 2 billion. The non-renewable resources will fall below 1/3 of the initial reserve. By the year 2050, the environmental pollution will exceed the level of 1970 7-8 times. The depletion of natural and labour resources will lead to a significant reduction in industrial and agricultural production by the middle of the 21st century. The scenarios of transition to global equilibrium (zero growth of the system components) proved to be practically unrealizable. The time required for the transition was missed.

However, from the standpoint of demographic ecology, the civilizational catastrophe predicted by "Mir-2" and "Mir-3" models do not look fatal. Odum (1975), a classic of ecology, proposes the following

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hypothesis for the development of civilization: "Man, apparently, faces two main options. The first is to allow unlimited population growth which will continue until the density exceeds certain limits (food, resources, space, pollution, etc.). After that, most people will have to die or drag out a miserable existence until the density decreases (or until the threshold is raised), if this proves to be possible. If no control is introduced at that moment, this might lead to another demographic outbreaks. The other option is to admit that the depletion in fact is caused by overpopulation. If the man assumes due responsibility, this would make it possible to predict thresholds in advance, to take measures towards population control (birth control, land use and water use restrictions, protection and renewal of resources, reduction of economic "growth incentives", etc.), so that the population density remains noticeably below the critical level" (Odum, 1975, p. 648).

There is an important argument in favour of Odum's hypothesis. It is known that the population size, if we consider many highly-organized animals, grows along the S-shaped curve. First it grows, then shifts to dying-out oscillations with respect to a certain state of equilibrium. This situation is conditioned by the maximum population size that can be maintained by the environment. The oscillations in the populations of animals occur because nutrients and other factors necessary for living have been accumulated before the S-shaped population growth began. This allows it to "jump" over the equilibrium position. But the reasons for emergence of oscillations in the animal world should be peculiar to the mankind. Being an integral part of the animal kingdom, man can not exist outside the biosphere and must obey the laws specific to it.

This gives rise to a research task that aims either to confirm or refute Odum's hypothesis, with the use of a mathematical model for development of the global SES.

The first task entails a second one - selection or construction of a SES model that would secure verification of the hypothesis.

A number of papers have been published, devoted to the search of algorithms transferring the global models to the stationary mode. We shall refer to two of them (Yegorov, Kalistranov, Mitrofanov, & Piontkovskiy, 1980; Makhov, 2005). The authors of these papers did not build any new models but engaged in modification of "Mir-2" and "Mir-3" models. The research was based on the concept of redistribution of the world economy capital in favour of industrial restoration of expended non-renewable resources and regeneration of polluted sites. It turned out that the model components can be shifted to the stationary mode in XXI century only on the condition that the capital of the newly created production industries would be comparable with the capital of all traditional economic industries. Without going into discussion on practicability of proposals for restoration of non-renewable natural resources, let us note the core idea: "Mir-2" model provides for modifications that allow the transition of SES to the stationary mode of development. Let us take advantage of this opportunity.

3. Research Questions

1. The first issue is to determine the extreme (critical) population size on the planet that would provide the stable condition of the biosphere. The answer to this question must be found before implementing the SES model, since the critical population size is one of the criteria of the model workability as well as the justification of Odum's hypothesis. Kondratyev proposed a biosphere-based concept of civilization development, based on the theory of natural biological regulation. It proves that the biosphere

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has a property for stability, that is, the ability to compensate for any perturbation caused by man's economic activity, until the human consumption of the primary biospheric products reaches 1%. The biota expends the remaining 99% on stabilization of the habitat. The consumption of 1% of the primary products is connected with energy costs of the order of 1 TW. The one-percent threshold of biospheric perturbation was exceeded at the beginning of the 21st century, according to the authors of the concept. During the following decades, the humankind consumed directly 6-8% of the products generated by the biosphere, and another 30-32% - indirectly: in industrial production, by urbanization, deforestation, desertification of territories, etc., using a capacity of 10 TW for this purpose, obtained by 90% from fossil fuel (Kondratyev, 1996).

The critical population size can be derived through calculations. According to Ramad (1989), the net primary productivity of terrestrial biomes of the biosphere is equal to $53 \cdot 10^9$ tons of dry matter per year, or in energy units – $2.385 \cdot 10^{17}$ kilocalories per year. The Lindeman-Odum law is applicable to the food web "primary producers - herbivorous consumers - people". In accordance with this law, only 10% of the energy entering the trophic chain remains at its outlet (Odum, 1975). Thus, the nature allocates only $2.385 \cdot 10^{15}$ kcal of energy per year to secure the needs of the mankind in food. Taking into account the age and labour differentiation of the population, we may assume the figure of 3.800 kcal/day to be the average norm of human nutrition. Then the critical population size is defined as the quotient, when dividing the energy used for food by the average nutrition norm. We derive that the critical number is 1.73 billion people.

2. The second research problem is the choice of substance to evaluate the store of non-renewable natural resources. Here two options are possible: the category of substance or the category of energy. "Mir-2" model, as well as most SES models, uses the category of substance. In this case, non-renewable resources are not divided into fuel energy resources and non-energy mineral resources. The accepted unit of natural resources (resource unit RU) in "Mir-2" model is their production per capita in 1970. It is believed that the store of resources, in case of 1970 production rate as a reference, would be sufficient for 250 years. Obviously, this is a very rough estimate. The population of the Earth in 1970 was 3.6 billion people. Thus, the initial store of resources amounted to $R_o=9 \cdot 10^{11}$ RU. The production of renewable food resources in "Mir-2" model depends on the share of agricultural capital in the total capital of the economy.

It is clear that the category of substance is wider, and therefore more preferable. But here exists a problem of too vague estimation of the store of non-energy resources. At the same time, the fuel and energy resources are sufficiently well studied in terms of quantity, are periodically reviewed and expressed in energy units (in SI system in joules). Therefore, when assessing the store of non-renewable resources, we shall consider the world reserves of fossil fuel only. This substitution should not raise objections on the part of potential critics, as the part is always less than the whole, and the apocalyptic forecast in respect of the future of civilization can only aggravate, it would seem.

3. The third research problem is estimation of the world's fossil fuel reserves, in order to set the initial condition for the resource equation in the modified "Mir-2" model. One of the most authoritative estimates of the potential extractable hydrocarbon reserves was given by the World Energy Conference 1980 (Skinner, 1989). In accordance with it, the world recoverable reserves of oil, gas and coal in 1900 are estimated at

$\mathbf{R}_{\mathbf{1900}}^{\mathbf{(oil)}}= 1{,}75 \cdot 10^{22}$ J, $\mathbf{R}_{\mathbf{1900}}^{\mathbf{(gas)}}=1{,}2 \cdot 10^{22}$ J, $\mathbf{R}_{\mathbf{1900}}^{\mathbf{(coal)}}=21 \cdot 10^{22}$ J, respectively.

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(J - joule)

Having the rates of their consumption with reference to the year 1970, their reserves would suffice for 384, 362 and 3500 years. If we assume that gas would be consumed at the previous rate and replace oil when the latter's reserves are exhausted, then movable hydrocarbons will run out on expiry of 227 years. If we deem that coal replaces oil and gas after their reserves are depleted, while the total rate of hydrocarbon consumption remains the same as in 1970, then all the traditional fuel will run out after a lapse of 1034 years (Sergeev & Kulesh, 2013).

According to the modern concepts, the development of shale deposits is considered cost-effective if the oil content in them is not below 90 litres per ton of shale. The world reserves of shale providing for profitable oil production are estimated at 650 trillion tons. 26 trillion tons of oil can be extracted from them. This exceeds the world's reserves of movable oil 13 times. With a shortage of natural resources, the profitability threshold for production of shale oil can be reduced to 40 litres/ton. According to the World Energy Conference (*Energy for our world: Energy, society, environment: Digest of the 11th World energy conf., 1980 Munich*, 1982), the petroliferous shale reserves with oil content above 40 litres/ton are estimated at $200 \cdot 10^{22}$ J. This is 8.5 times more than the energy contained in world reserves of oil, gas and coal. Let us assume that the reserves of fossil hydrocarbon fuel are $223.9 \cdot 10^{22}$ J. The production of shale oil, up to exhaustion of traditional fuel resources, will be assumed to be the same as in 2013 – $1.1 \cdot 10^{9}$ barrels a year. This is $6.6 \cdot 10^{18}$ J/year in energy units. If we suppose that shale oil would replace the traditional fuel resources after their reserves have been depleted and will be produced at the rate $1.97 \cdot 10^{20}$ Joules a year, then its exhaustion period will make 10,117 years. Assuming that the cost-effective production of oil from petroliferous shale covers 28% of its reserves, we derive the time for depletion of hydrocarbon fuel reserves – 2,220 years.

The methodology of energy calculations is hardly appropriate for detailed demonstration in this article. It is considered in the paper (Sergeev & Kulesh, 2017). Here we shall note that the transition from energy units to resource units, as accepted in "Mir-2" model, showed that the initial condition for the resource equation in this model is understated 3-9 times, depending on the scenario.

4. Purpose of the Study

The research has been carried out with the following objectives:

1. To demonstrate the potential of social ecology in solving the problems of socio-economic practice;

2. To check, using the mathematical model, the validity of Odum's hypothesis about the cyclic development of civilization and the possibility of its controlled transition to the stationary functioning mode;

3. To call for organization of university education in the field of social ecology in Russia.

5. Research Methods

To justify Eu. Odum's hypothesis, the algorithm of global development model "Mir-2" was used. The publication of "Mir-2" algorithm in the monograph (Forrester, 1978) and its software realization in the DYNAMO language has simplified the re-implementation of the model in the MathCad language. We shall

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refer to this implementation hereinafter as "Mir-2 MC". Its identification was made by comparing the results of the solution of the problem with the "basic" version of the model "Mir-2". The comparison of the results for the time interval 1990-2100 showed their identity. The modification of "Mir-2" model supposed the use of the resource equation in "Mir-2 MC" model for modelling the temporary variability of the fuel and energy resources, but not the resources in general. At the same time, the original fossil fuel reserves were cited from the data of the World Energy Conference (*Energy for our world: Energy, society, environment: Digest of the 11th World energy conf., 1980 Munich,* 1982) not derived on the basis of a scholastic estimate.

Four model scenarios with fixed values of the resource-energy potential of the Earth, corresponding to the traditional energy sources (oil, gas, coal), were realized. The first scenario will be connected with the current reserves of movable hydrocarbons that are supposed to run short in 250 years, i.e. in 2150. Their reserves will be taken as 100%, and the initial condition will be R_o=900•10^9 RU.

The second scenario corresponds to a perspective situation when the resource-energy potential will expand due to oil and gas produced offshore and on the continental slope of the World Ocean. In this case, the movable hydrocarbons reserves will increase to 150%, and they will last for 375 years, i.e. until the year 2275. Here the initial condition is R_o=1350•10^9 RU.

The third scenario corresponds to the situation when coal will replace the depleted reserves of movable hydrocarbons, but its extraction will be limited by profitability of applied technologies. In this case, the fuel resources will increase to 300%, and they will last for 700 years, that is, up to the year 2600, with the initial condition R_o=2700•10^9 RU.

In the fourth scenario, the requirements to the coal mining profitability threshold are reduced so that the coal reserves will run for 1,000 years, i.e. up to 2900; then the initial condition is R_o=3600•10^9 RU. The results of realization of these scenarios are discussed in detail in the article (Sergeev & Kulesh, 2017).

The model scenarios of civilization development in case of expansion of the resource-energy potential owing to the use of perspective fuel resources - petroliferous shale and thermonuclear energy - are considered separately.

In the fifth scenario, it is assumed that the cost-effective production of oil from petroliferous shale, with its content exceeding 40 litres per ton of shale, is 28% of the world reserves. The time of depletion of the resources is 2,220 years, and they will last until 4120.

The sixth scenario involving thermonuclear power supposes that until 2075, which time is deemed to be the first locally-stable state in terms of population size, the civilization will develop in accordance with the scenario R_o=2700•10^9 RU. In 1975, against the backdrop of the current reserves of traditional fuel resources, commercial controlled-thermonuclear-fusion reactors start operating, increasing the civilizational power supply to the level R_{max}=2100•10^9 RU under the logistic laws. According to the scenario, this state may keep on for an indefinite time. The results of the fifth and sixth scenarios are discussed in the article (Sergeev & Kulesh, 2017).

The seventh scenario illustrates the process of accelerated transition of the world SES from cyclic to stationary movement. The transition is carried out according to a logistic law, by example of the scenario with traditional fuel resources R_o=2700•10^9 RU, with the population of P_{min}=0.54 billion people, the cohort reproduction factor of $\boldsymbol{\varepsilon_0}$ =0.02 and the population size saturation limit of P_{max}=1.5 billion people (Sergeev & Kulesh, 2017).

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The analysis of modelling results showed that the oscillations of SES components correlate qualitatively with the ethnogenesis phases. This circumstance makes it possible to consider the ethnic and socio-ecological components of the civilizational development in the aggregate.

6. Findings

The scenarios implemented as based on the model of global development "Mir-2 MC" make it possible to arrive at the following conclusions that have no prognostic character, but point only to the civilization development tendencies.

1. The mathematical model helped to confirm Eu. Odum's verbal hypothesis of cyclical development of the civilization and a possibility of its controlled transition to the stationary functioning mode.

2. In the 21st century, the civilization faces not a catastrophe, as predicted by the global development models "Mir-2" and "Mir-3", but extremely grave demographic, economic and environmental crises, followed by recovery. The history of mankind knows less abysmal regional crises having a different genesis.

3. The development of civilization in the third millennium must have potentially a cyclic character. The number of cycles will increase in proportion to the power resources of the civilization. Each cycle ends in a crisis of civilization. Having the resource-energy potential limited by traditional fossil fuel reserves (oil + gas + coal), 3-4 development cycles are expected; in case of expansion of the potential owing to shale oil - up to 15 cycles, following which the civilization shifts to the stationary movement of its components.

4. With the wide use of controlled thermonuclear fusion energy, the number of cycles increases indefinitely, and the World system shifts to the harmonic oscillator mode, with the periodic motion of the components relative to the equilibrium states.

5. The humanity is the ecological dominant of the biosphere within the boundaries of one particular development cycle of the World system. The capital, food and pollution of natural environment, that are products of the socio-economic metabolism of the mankind and that are dependent on the current energy resources, limit the population size within one particular development cycle, but do not determine the number of cycles.

6. In the five model scenarios differing in store of the fuel resources, the size of the steady-state-motion-conditioned population, reached by the system after the concluding cycle, varies between 1.3-1.6 billion. The population size corresponding to the one-percent threshold of the primary products consumption, that ensures the stability of the biosphere, is 1.7 billion.

7. The cyclic movement of the planet's population is formally determined by the helixed shape showing the dependence of the increment rate on the population size, known as Ollie type curve in demographic ecology. This curve explains the existence of several stable and unstable local-stationary states of cyclic movement of the population. The stable states provide a possibility of accelerated transition to the civilizational steady motion.

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8. The transition from cyclic to stationary movement takes place on the basis of a stable local-stationary state, according to the logistic model of population growth with a saturation threshold of 1.5 billion people.

9. The "seamless" transition is possible, apparently, only after the formation of a global hyper-ethnic system with common mentality of the population, that is, specific mental make-up and world outlook of people living in a controlled planned socio-economic system of "ecological socialism" type.

7. Conclusion

At present, the higher educational institutions of Russia do not provide for training of specialists (bachelors and masters) in the field "social ecology". Only an introductory lecture course on this discipline is delivered within one term to the students of ecological profile. The teaching aids are mostly of humanitarian nature. The exception is the manual (Osipov & Lisichkin, 2015). Meanwhile, training of such specialists would be expedient for the solution of a number of economic problems. It could be organized as a pilot project in the leading universities of the country.

On a first approximation, the model of training a student in the sphere of social ecology should provide for:

- general mathematical schooling within the scope not beyond the one practiced at prestigious technical universities. The rough list of disciplines might include: mathematical analysis, theory of ordinary differential equations, mathematical physics, higher algebra, computational mathematics, theory of probability and mathematical statistics, theory of random processes;

- proper schooling in the field of AT-technologies, that secures the problem programmer's sound skills: good command of one of the mathematical programming languages, application software packages (MathCad), the ability to work with databases and knowledge bases, knowledge of GIS technologies providing due transition to socio-ecological engineering (systematization of knowledge, development practices, expert examination and realization of projects connected with transformation of social reality);

- extensive special training in the field of population demography and statistics, sociology, macroeconomics and mathematical economics, linear programming, general ecology and human ecology, geoecology, nature management, system modelling, global and regional models of human development.

The educational disciplines curricula should be formed on an expert basis, and the syllabus should provide for logical sequence and continuity of lecture courses, seminars and practical classes. Due teaching aids, manuals and training programmes based on AT-technologies should be developed for the core disciplines.

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eISSN: 2357-1330

References

Akayev A., Yakovets Yu., Sokolov N., & Sarygulov A. (2009). *Forecasting Calculations of a Civilization Based on a Logistic Model*. Moscow: MISK

Aladyshkin, I., & Kulik, S. (2015). Contradictions and prospects of the synthesis of technical Sciences and the Humanities in technical education. In A. G. Becker (Ed.), International scientific conference "Modern technologies and development of Polytechnic education" (pp. 684-688). Vladivostok, Russia: Far Eastern Federal University. http://dx.doi.org/10.15405/epsbs.2018.02.3

Aladyshkin, I., Kulik, S., Michurin, A., & Anosova, N. (2017). Information Prospects For Socio-Cultural Development: Contradictory Grounds. The European Proceedings of Social & Behavioural Sciences, 35, 19-25. doi:10.15405/epsbs.2018.02.3

Arab-Ogly, E. (1978). *Demographic and Ecological Forecasts*. Moscow: Statistika

Bylieva, D., Lobatyuk, V., & Rubtsova, A. (2018). Homo Virtualis: existence in Internet space. SHS Web of Conferences 44, 00021 (2018) CC-TESC2018. doi: 10.1051/shsconf/20184400021Gvishiani, D. (2013). Brief Overview of Reports to the Club of Rome. *Energy Service, 9*. Retrieved from http:// journal.esco.co.ua

Dmitriev, V., & Kaledin, N. (2016). Russian Northwest: An Integral Assessment of the Conditions of Regional Social, Environmental and Economic Systems and Quality of Life. *Baltic Region. Vol 2 (2)*, 125-140. doi: 10.5922/2074-9848-2016-2-7

Energy for our world: Energy, society, environment: Digest of the 11th World energy conf., 1980 Munich. (1982). London: Organizing comm. of the 11th WEC for the World energy conf.

Forrester, J. (1978). *World Dynamics*. Cambridge: Massachusetts Wright-Allen Press

Gashkova, E., Berezovskaya, I., & Shipunova, O. (2017). Models of self-identification in digital communication environments. *The European Proceedings of Social & Behavioural Sciences, 35,* 374-382. doi:10.15405/epsbs.2018.02.44

Human Development for All and Everyone: Report on Human Development. (2017). Moscow: Ves Mir *[The Whole World]*

Kondratyev, K. (1996). Global Ecodynamics and Its Tendencies. In K. Kondratyev. (Ed.) *Ecodynamics and Ecological Monitoring of the Saint-Petersburg Region in the Context of Global Change.* (pp.5-60). Saint-Petersburg: Nauka

Leontief, W. (1976). *The Future of the World Economy*. New York: Oxford University Press

Lior, N. (2013). Sustainability Ethics and Metrics: Strategies for Damage Control and Prevention, *Journal of Environmental Accounting and Management 1(1)*, 15-24.

Lior, N. (2015). Quantitative Indicators for Energy Development Sustainability. *Energy Bulletin, 18*, 8-28. Derived from http:// www.isedc-u.com/8-izdatelskie-proekty.

Makhov, S. (2005). *Mathematical Modelling of World Dynamics and Sustainable Development*. Moscow: Institute of Applied Mathematics of the Russian Academy of Sciences.

Meadows, D.L. & Meadows, D.H. (1974). *Dynamics of Growth in Finite World*. Cambridge: Massachusetts. Wright-Allen Press

Mesarovic, M., & Pestel, E. (1974). *Mankind at the Turning Point. Second Report to the Club of Rome*. New York: Dutton.

Odum, P. (Eds). (1975). *Fundamentals of Ecology*. Naumov. Moscow: World

Osipov, G., & Lisichkin, V. (2015). *Global Models of Human Development*. Moscow: NormaInfra

Our Common Future: Report of the International Commission on Environment and Development (ICESD) (1989). Moscow: Progress

Ponarina, N.N. (2012). Globalization and the information society. *Society, Politics, Economics, Law, 1,* 19-24.

Ramad, F. (1989). *Fundamentals of Applied Ecology*. Leningrad: Gidrometeoizdat

Reymers, N. (1990). *Nature Management*. Moscow: Misl [*Thought*]

Sergeev, Yu. & Kulesh, V. (2017). Cyclic and Stationary Modes of the Development of Civilization in Global Models. *Biosphere, Vol. 9, 1*, pp. 13-47. doi: 10.24855/biosfera.v9i1.322

Sergeev, Yu., & Kulesh, V. (2013). The Concept of Cyclic Development of Civilization. *Bulletin of Saint-Petersburg University, Series 7, 4*, 57-70. Derived from http://vestnik.spbu.ru/

Skinner, B. (1989). *Will the Earth Resources Be Sufficient for the Mankind?* Moscow: Mir [*World*]

Theiman, H. (1973). *Report on Battele's Activities to the Club of Rome*. Tokyo: Battele, Geneva

Yegorov, V., Kalistranov, Yu., Mitrofanov, V., & Piontkovskiy. (1980). *Mathematical Models of Global Development*. Leningrad: Gidrometeoizdat