 https://doi.org/10.1051/e3sconf/202016407004

Regional ecological security assessment in the environmental management

Natalya Vetrova[1], *Gennadii* Shtofer[1,*], *Anastasia* Gaysarova[1], and *Olga* Ryvkina[2]

[1]Crimean Vernadsky Federal University, 4, Acad. Vernadsky ave, 295007, Simferopol, Russia
[2]Sevastopol Institute (Branch) of Plekhanov Russian University of Economics, 29-4, Vakulenchuka Street, 299045, Sevastopol, Russia

Abstract. The environmental threats and risks assessment is carried out on the basis of various anthropogenic criteria analysis. It's reasonable to assess certain environmental indicators for each type of technogenic danger. The problems of the maximum permissible environmental load assessment and the development of the regional environmental security assessment methods have been actual. Therefore, the aim of the article is to develop the basics of the regional environment security level assessment methodology. It's expedient to assess certain partial environmental indicators for each type of technogenic hazard. Such partial indicators were analyzed by statistical methods. The integration method was used to develop partial and integral indicators for assessing the regional environmental security level. The result of the research is proposition to assess the regional environmental security level by two groups of environmental factors: 1) antropogenic substances ingress into the environment and 2) natural systems change, caused by natural resources consumption and spatial planning factors. Application of the regional environmental security assessment methodology will allow to formalize environmental management problems by using the following indicators: integral environmental security indicator of reducing the anthropogenic substances ingress into the environments (II_1) and integral environmental security indicator of reducing natural system change, caused by natural resources consumption and spatial planning factors (II_2).

1 Introduction

The important task of ecological theory [1-5] is determination of ecological hazards, threats and risks assessment methods on the basis of various anthropogenic criteria analysis:
- sanitary standards for the impact of hazards on environmental elements, based on approved and controlled maximum concentration limit (MCL), maximum permissible level (MPL), etc.;
- manufacturing standards, determining threshold pollutant level on the particular territory taking into account the affecting factors and natural resources;

* Corresponding author: cgena@mail.ru

- bioindication and bioassay criteria, determined by living organisms ability to concentrate particular types of pollutants and respond adequately to certain technogenic impact;
- environmental load standards, that haven't been developed concerning all components of technogenic impact at the moment and therefore need special research. Widely used sanitary standards in Russia as well as in other countries have certain limitation for generalized assessment of the territory ecosystems environmental security level. The problem of maximum permissible environmental load assessment has been extremely important at the moment [5-10], although this problem research analysis allows stating certain fragmentation in its solution.

In connection with described above, the article's goal is the regional ecological security level assessment methodology basics development.

2 Materials and methods

Author's analysis of different scientific and methodological approaches to the development of ecological issues and systems' environmental security [11, 12] confirm wide recognition of N.F. Ramers' study. The scientist studied environmental load limit manifestation peculiarities and developed a load assessment approach precisely according to the anthropogenic load system's reaction. But the author consider, that no less important scientific forecasting of the loads and ecosystems' conditions relationship is carried out by modeling. Famous environmental scientist Vernadsky V.I. considered the natural landscape sustainability as the environmental interaction derivative of the four spheres: atmosphere, hydrosphere, lithosphere and biosphere. The scientist evaluated the geospheres centers distribution asymmetry depending on their transformation features under the polluters influence to assess the anthropogenic landscapes degree of change. If the natural landscape integral characteristic mark as $e_п$, and atmosphere, hydrosphere, lithosphere and biosphere state characteristics mark as ε_A, ε_L, ε_B, then he expressed the landscape structural mechanism as the total differential function $\varepsilon_{птг}(t)$:

$$e_П = d\varepsilon_{ПТГ}(t) = \frac{\partial \varepsilon_{ПТГ}(t)}{\partial \varepsilon_A} de_A + \frac{\partial \varepsilon_{ПТГ}(t)}{\partial \varepsilon_G} de_G + \frac{\partial \varepsilon_{ПТГ}(t)}{\partial \varepsilon_L} de_L + \frac{\partial \varepsilon_{ПТГ}(t)}{\partial \varepsilon_B} de_B \tag{1}$$

Akimova T.A., Haskin V.V. and others have introduced security criteria and the following related notions to assess environmental security:

U – environmental carrying capacitiy: total amount of extracted and destructive local renewable resources including environmental pollution and other forms of the recipients technogenic inhibition;

T_e – the territory's environmental technological capacitiy – the territory's generalized characteristic, that reflects its self-reparative natural system potential and equals its maximum technogenic load, that all the territory's recipients and ecological systems can endure for a long time without structural and functional disruption.

Security criteria: $U \leq T_e$ means, that technogenic load can't exceed self-reparative territory's natural system potential. U and T_e magnitudes can be expressed by the substance mass that is standardized by hazard, and also have power and monetary expression. The environmental situation degree of tencity is calculated as the territory's nature capacity and environmental technological capacitiy ratio : $K_e = U / T_e$.

if $K_e \leq 0.3$ the situation is safe,

if $K_e \approx 1$ or $1 < K_э < 2$ - the situation is critical,

if $K_e \geq 10$ - the situation is extremely dangerous.

The approach to the territory environmental security level assessment has been developed. It's based on the territory environmental technological capacity and the power capacity maximum permissible level ratio.

In the whole, the approach is justified, but requires the complex information base.

One of the modern approaches to ecosystems sustainability assessment under anthropogenic impact is using Bystryakov's I.K. biosphere-forming framework on the basis of the territory landscape system. The main biosphere-forming framework elements are: biozones, pauses, connections and tissue filling.

The population density of 50-60 people per sq. km is recommended to fill 20-40% of the territory natural cenosis area. The population density of 100 people per sq. km is recommended to fill 20-40% of the territory natural cenosis area to achieve the conditional ecological balance.

3 Results

Summarizing the results of the territory systems ecological state assessment approaches and given the technological hazards development peculiarities [12], the authors of the article consider, that it's necessary to asses the regional systems environmental security level for the environmental management and control. It's appropriated to assess certain environmental indicators for each type of man-made hazards.

Developing the ecosystems state assessment theoretical basis, the authors have proposed to assess the regional systems environmental security level at two groups of environmental factors (hazards): 1) ingress of anthropogenic substances into the environment and 2) natural systems quality change, caused by natural resources consumption and spatial planning.

The first group includes the following indicators: "harmful substances concentration" in separate environments (atmosphere, hydrosphere, biosphere, lithosphere), caused by hazard types (chemical, physical, biological); "anthropogenic substances toxicity level", "substances mutual influence degree". The following indicators should be calculated in the second group: "territorial natural and man-made systems ratio", "deforestation area for production goals", "regional hydro balance level", "mineral production according to the types of minerals", "road area", "fishing and hunting scale (if the activity is organized in the region)", "biodiversity level", "deforestation area for construction purposes", "landslide, erosion and other forms of geological massifs disturbance areas", "protected natural areas", "land set-aside for landfills and solid waste storage".

When assessing the regional environmental security level with the indicators of the first group, it's necessary to calculate the integral security indicator for reducing the anthropogenic substances environmental ingress– II_1:

$$II_1 = \frac{1}{m}\sum_{i=1}^{m} PI_1^{ik} \cdot \beta \cdot \lambda, \tag{2}$$

where i - is the anthropogenic substance environmental ingress index (varies from 1 to m);

k – is the environmental component index (atmosphere, hydrosphere, biosphere, lithosphere); β – dangerous objects relative positioning ratio, that allows to take into account interaction patterns: for neutral positioning $\beta=1$, for adverse positioning $\beta > 1$; for favorable positioning $\beta <1$ (is defined by the research results of the separate regional hazards' nature and its local peculiarities); λ – the hazard duration ratio (requires additional research depending on the hazard's class).

PI_1^{ik} - is the regional environmental security partial indicators of separate dangerous substances (that vary from 1 to m) environmental ingress. It reflects the degree of compliance of fixed and permissible amount of the substances environmental ingress:

$$PI_1^{ik} = \frac{n_{basic}^{ik}}{n_{actual}^{ik}} \tag{3}$$

where n_{basic}^{ik} – basic level (that refers to the previous period of time or maximum permissible level) of the i-th anthropogenic substance that ingresses into the k-th environmental component. n_{actual}^{ik} – actual amount of the i-th anthropogenic substance that ingresses into the k-th environmental component.

Regional envornmental security special indicators of the substances environmental ingress PI_1^{ik} should be calculated for each type of hazard that's available in all the environments (atmosphere, hydrosphere, biosphere, lithosphere).

Regional environmental security criteria for the analyzed type of hazard of the i-th anthropogenic substance ingress into the k-th environmental component should be expressed by the inequality: $PI_1^{ik} \geq 1$, that's based on the nature of this indicator.

The authors of the article have analyzed the total pollution of the Crimean microdistricts while studying the regional environmental security level. Mutual desposition coefficients β_i^p were proposed on the basis of the influence of the following pairs of indicators: «amount of MSW - atmospheric pollutants» (β_1^p), «amount of MSW - pollutants in water» (β_2^p), «amount of toxic wastes - atmospheric pollutants» (β_3^p), «amount of toxic wastes - pollutants in water» (β_4^p) (Table 1).

Table 1. Regional environmental security threats mutual disposition ratios on the basis of 4 ecological state indicators.

Microdistrict	β_1^p	β_2^p	β_3^p	β_4^p
Central	0.779	0.813	0.887	0.880
The southern coast (Yalta, Alushta)	0.844	0.823	0.995	0.988
Southeastern (Sudak, Feodosiya)	0.992	0.814	0.988	0.998
Southwestern (Yevpatoriya, Saki)	0.855	0.787	0.959	0.884
Western	0.924	0.945	0.987	0.985
Northern	0.876	0.965	0.688	0.735

The integral environmental security indicator for reducing the anthropogenic substances environmental ingress (II_1)should be more than 1,0 for all types of hazard.

The integral environmental security indicator for natural systems quality change (II_2) according to the second group of factors is proposed:

$$II_2 = \alpha_j \sum_{j=1}^{l} PI_2^j, \tag{4}$$

where j is the index, numbering the environmental changes types (acording to the indicators that reflect changes) (varies from от 1 до l); α_j – environmental hazard changes mutual disposition ratio, which allows to take into account patterns of interference: for neutral disposition α_j=1; for adverse disposition $\alpha_j < 1$; for friendly disposition $\alpha_j > 1$ (was determined by experts – Table 2).

PI_2^j - regional environmental security special indicators with the j-th type of environmental change, caused by natural resouses consumption and spatial planning factors:

$$PI_2^j = \frac{n_{basic}^j}{n_{actual}^j} \quad (5)$$

where n_{actual}^j – is the actual level of the j-th environmental change; n_{basic}^j – is the basic level of the j-th environmental change. Regional environmental security special indicators for natural environment quality change PI_2^j should be calculated for each type of the threat.

Table 2. Environmental security threats mutual disposition ratios of the Crimean microdistricts.

	Microdistrict						
	Central	The southern coast	Southeastern	Southwestern	Western	Northern	Eastern
α	0.876	0.913	0.924	0.865	0.955	0.853	0.976

Evaluation technique of two integral environmental security indicators for reducing the anthropogenic substances environmental ingress and for natural systems quality change is represented in Fig. 1.

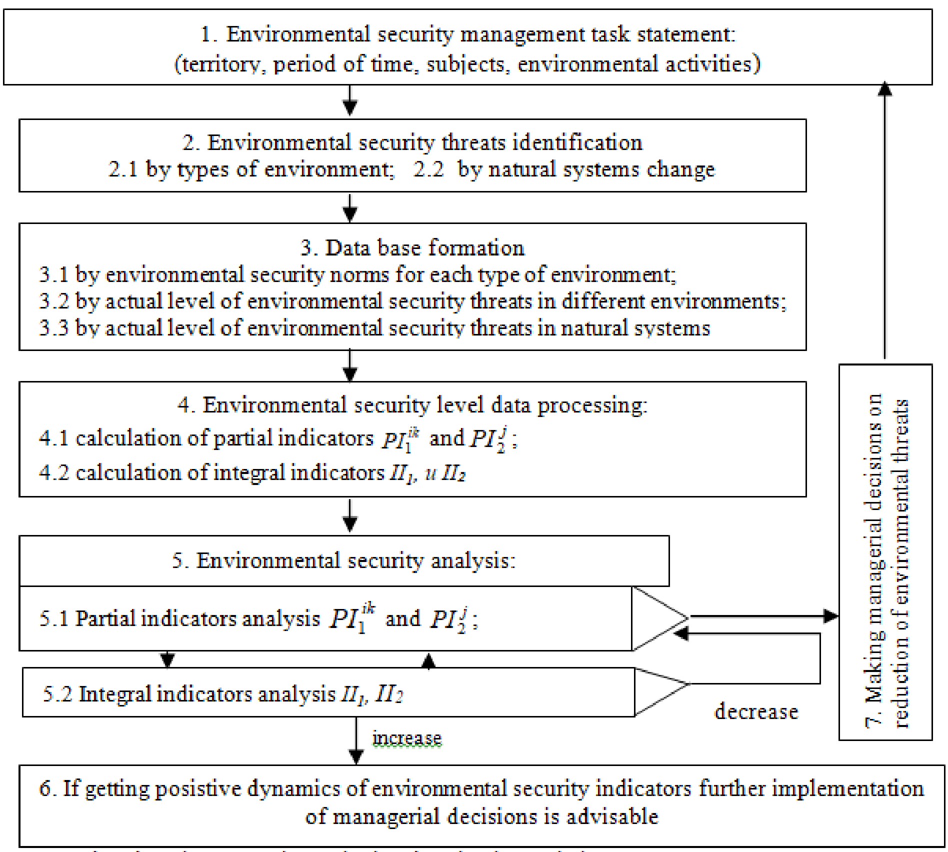

Fig. 1. Regional environmental security level evaluation technique.

Information is collected on the basis of actual quantity identified environmental threats and standard environmental maximum permissible values for each anthropogenic substance.

Except the environmental threats indicators, it's important to analyze cases of anthropogenic substances ingress into the environments with high level of hazard. The number of such emergencies should be monitored and their decline reflect regional environmental security growth.

Integral and partial environmental indicators dynamics is used to collect information about environmental changes.

When the proposed environmental security assessment methodology is introduced to the ecological management system, the environmental security assessment information base will require only updating that also provides the opportunity to reveal the long term processes dynamics.

4 Discussion

Proposed regional environmental security assessment methodology approach allows identifying environmental issues comprehensively unlike those, proposed in the studies [13, 14, 15]:

- natural anthropogenic environment ecological balance assessment approach is based on using a number of notions: complete ecological balance relatively to population density of the territory (for the area with population density of 60 people per sq. km, forests should not occupy less than 30% of the area in central Russia); conditional ecological balance is achieved when natural resources are not fully reproduced (for urban areas with population density of more than 100 people per sq. km and 20-30% of forest cover); relative ecological balance reflects the territory's extreme loading state but system elements interaction is created which provides environmental degradation slowdown;
- populated areas and natural environment ecological compatibility method is based on the territory's particular capacity evaluation of: energy consumption, carbon dioxide emissions, atmosphere oxygen reproduction, water availability and observance of spatial biotic compatibility conditions, observance of economic and protected areas relation, observance of permissible population density for power consumption, observance of the biosphere ability to reproduce resources. This approach is applicable for settlements.

The problems of the territory's ecological condition assessing and optimizing the level of urbanization have been studied by foreign scientists [3, 4, 6, 9].

Natural capital index analysis approach, that includes quantitative and qualitative elements, is one of the most studied.

The quantitative indicator of ecosystems characterizes the territory share that does not change during the study period.

The qualitative indicator reflects the degree of variability of a constant set of plants and animals in the territory during the study period. The natural capital index degree of variation is the ecosystem's sustainability characteristic.

Territory urban indicators are also calculated to ensure ecosystem resilience in spatial planning decision making.

5 Conclusion

Implementation of the proposed methodology for the region environmental security level assessing allows formalizing the environmental management problematic issues using quantitative indicators: integral environmental security indicator of reducing the anthropogenic substances ingress into the environments (II_1) and integral environmental security indicator of reducing natural system change, caused by natural resources consumption and spatial planning factors (II_2).

References

1. S. Emelyanov, N. Bacaeva, V. Gordon, JAES **15(470)**, **4**, 459-462 (2017)
2. E. Ganebnykh, T. Burtseva, A. Petuhova, A. Mottaeva, E3S Web Conf. **91**, 08035 (2019). https://doi.org/10.1051/e3sconf/20199108035
3. N. Bakaeva, L.Chaykovskaya, A. Kormina, Biospheere compatibility: human, region, technologie, **1 (25)**, 94-106, (2019). https:// doi: 10.21869/23-11-1518-2019-25-1-94-106
4. S. Belanger, M. Barron, P. Craig, S. Dyer, M. Galay-Burgos, M. Hamer, IEAM **13**, 664-674, (2017). https://doi.org/10.1002/ieam.1841.
5. V. Glinskiy, L. Serga, M. Khvan, Procedia CIRP **26**, 30-34, (2015). https://doi: 10.1016/j.procir.2014.08.017.
6. A. Wierzbicki, M. Makowski, J. Wessels, IIASA, 67–71, (2013).
7. M. Knowling, J. White, C. Moore, P. Rakowski, K. Hayley, HESS Discuss., (2019) https://doi.org/10.5194/hess-2019-436.
8. V. Ilyichev, N. Bacaeva, V. Kolchunov, AMM **725-726**, 1224-1230, (2015). https://doi.org/10.4028/www.scientific.net/AMM.725-726.1224
9. F. Adler, C. Tanner, *Urban Ecosystems: Ecological Principles for the Built Environment*, 345, (Cambridge University Press, NY, 2013)
10. R. Forman , *Urban Ecology: Science of Cities*, 462 (Cambridge University Press, NY, 2014)
11. N. Vetrova, E. Mennanov, T. Ivanenko, A. Gaisarova, G. Sadykova, ISEES **1,** (2019). https://doi.org/10.2991/isees-19.2019.26
12. N.Vetrova, T. Ivanenko, A. Gaysarova, E. Mennanov, Biospheere compatibility: human, region, technologies 2 **(26),** 59-73, (2019). https:// doi: 10.21869/23-11-1518-2019-26-2-59-73.
13. R. Fokov, *Ecological reconstruction and urbanized environment rehabilitation*, 304, (Publishing House ASV, Moscow, 2012).
14. E. Pupirev, *Comprehensive modernization of modern metropolis life support facilities*, 343, (K.D. Pamfilova Public Utilities Academy, Moscow, 2013).
15. D. Klimov, *Urban complexes design basics*, 151, (Publishing House ASV, Moscow, 2013).