Электронное научное издание
«Международный электронный журнал. Устойчивое развитие: наука и практика»
www.yrazvitie.ru вып. 2 (17), 2016, ст. 13
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УДК 504.062/911.6

ЭКОНОМИЧЕСКИЙ ПРИНЦИП «ЗАГРЯЗНИТЕЛЬ ПЛАТИТ» ОБЪЕКТИВИЗИРУЕТСЯ РЕШЕНИЕМ ОБРАТНОЙ ЗАДАЧИ КОМПЛЕКСНОЙ ЭКОЛОГИЧЕСКОЙ ОЦЕНКИ

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Аннотация

Авторами разработан метод обобщенной интегральной оценки для решения обратной задачи комплексной экологической оценки территорий. Метод основан на использовании опубликованных в Атласе Мангистауской области карт с готовыми комплексными экологическими оценками, учитывающими влияние всех источников воздействия на компоненты природной среды – рельеф, почвы, растительность и подземные воды, и реализуется методиками. Методика 1 направлена на получение конкретных фактических данных в форме, приспособленной для использования в целевых функциях, и обоснование достаточной объективности экспертных оценочных карт, используемых для получения фактического количественного материала. Для преобразования исходной картографической (рассредоточенной) информации в количественную (сосредоточенную) для частных целевых функций используются ГИС-технологии. Методика 2 основана на идее поиска частного решения обратной задачи частной комплексной экологической оценки как разности частных обобщенных целевых функций, отражающих усредненные (средневзвешенные) оценки антропогенного воздействия на компоненты природной среды в целом по Мангистауской области Республики Казахстан и для зон с наличием НГДК.

КЛЮЧЕВЫЕ СЛОВА: Мангистауская область, нефтегазодобывающий комплекс, обратная задача комплексной экологической оценки территории.

ECONOMIC PRINCIPLE “THE POLLUTER PAYS” IS OBJECTIFIED BY SOLUTION OF INVERSE PROBLEM OF INTEGRATED ENVIRONMENTAL ASSESSMENT

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Abstract

The method is based on the use of the published in the Atlas of Mangystau region map with pre-integrated environmental assessment, take into account the effect of all sources of impacts on the environmental components - relief, soil, vegetation and groundwater, and is being implemented by three methods. Method 1 It aimed at obtaining concrete evidence in a form adapted for use in the objective function, and justification enough objectivity expert evaluation map, for deriving an actual quantitative material. To convert the original map (dispersed) in the quantitative information (focused) to special objective functions used GIS technology. Method 2 is based on the idea of searching for a particular solution of the inverse problem of private integrated environmental assessment as the difference between the private generic objective functions reflecting the average (weighted) assessment of human impact on the environmental components in the whole of Mangistau region of the Republic of Kazakhstan and for areas with the

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presence of oil and gas complex. Method 3 is a generalized method of integral solutions of the inverse problem of integrated environmental assessment as the difference between the integrated functions of generalized trust, reflecting the average (weighted) assessment of human impact on all components of the natural environment as a whole on the Mangistau region of the Republic of Kazakhstan and for areas with the presence of oil and gas complex.

KEYWORDS: Mangystau region, oil and gas complex, the inverse problem of comprehensive environmental site assessment.

Introduction

The region is located in the southwest of the Republic of Kazakhstan in the desert zone and includes Mangyshlak, Ustyurt Plateau, Buzachi peninsula, litters and dead Kuluk Kaidak. The area is characterized by dry continental desert climate, strong winds and storms. In most of the winter Mangistau region dominated the eastern and south-eastern winds in the summer - the western and north-west. The average annual wind speed is 3-7 m / s, a maximum reaches 10-26 m / s winds of a hurricane character at a speed exceeding 15 m / s are observed on the coast in winter.

Most of the area is occupied by wormwood-saline desert with patches of shrub vegetation on brown soils: surface partially covered with salt marshes, takyr-like solonetz and sands with very sparse vegetation. Thus, the climatic conditions predetermine the development of Mangistau region and sor deflationary processes, the formation of scarce land cover c low capacity to mitigate the effects of anthropogenic influences [1].

The specifics of climatic conditions of the region, taking into account the complete lack of a permanent river flow causes the acuteness of water scarcity problems in the first place, drinking water shortages. According to experts, the shortage of drinking water in the Mangistau region of 40,000 m3 per day and will reach 70,000 m3 / day by 2020 [2].

The region recorded 559 industrial enterprises, including large and medium - 70. The raw material orientation of the economy of the region determined the priority of the mining industry, the state of development which are directly dependent on all other sectors of the economy. The area on the total volume of industrial output ranks third in the country. At the heart of the region's economy - oil and gas sector, where the volume of production occupies more than 90 percent of the total volume of industrial products manufactured in the region, which explains the relation to the oil and gas complex as the main source of anthropogenic disturbance components of the environment, since oil and gas industry has traditionally been considered one of the most environmentally hazardous industries management [1, 3].

Material and Methods

The ecological state of the territories is estimated based on the results of various kinds of environmental monitoring components. Performance monitoring tools reflect the influence of a

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variety of sources of anthropogenic impact on the state of air, soil, vegetation, topography, surface water and groundwater through a series of measured values. These parameters are the basis for constructing the complex (on all components) or private (for individual components) environmental assessments of the environment, taking into account that set fees for use of natural resources. However, the objective of the principle of "the polluter pays" is still needed and independent assessment of the contribution of individual sources in the complex or private environmental assessment, i.e. necessary to find ways to solve the inverse problem of the complex (or private) environmental assessment. In this case considered integrated environmental assessment in accordance with R. Pentl.

Results and discussion

In frame of project implementation on grant funding of MES RK №0589/GF-4 "Development of a method of objectification of expert estimations of inputs of pollution sources to overall environmental situation of the territory", the authors have developed a method of generalized integral evaluation for solution of inverse problem of integrated environmental assessment of the areas. The method is based on the use of maps with ready integrated environmental assessments published in the Atlas of Mangistau region, which take into account the effect of all sources of impact on natural environmental components - relief, soil, vegetation and groundwater, and is being implemented by using three methods.

Methodology 1 is aimed at obtaining specific factual data in a form adapted for using in objective functions. GIS technology is used for converting the initial cartographical (dispersed) data into quantitative (concentrated) data for particular target functions. Evaluation maps of human impact on environmental components from published "Atlas of Mangystau region" have been used as initial material. These are maps "Anthropogenic impact on relief", "Anthropogenic transformation of vegetation", "Soil surface degradation", "Anthropogenic disturbance of groundwater" and inventory map "Anthropogenic sources of exposure". Evaluation maps served as a source of actual quantitative material based on contour area sums of each of five levels of human impact on environmental component. These areas were determined by using Arc-GIS components with production of vector shape files, which automatically displayed contour areas on the map with indication of exposure levels. Then, the areas of each exposure level were summed and served as input data for construction of particular objective functions for each component of natural environment on the whole territory of Mangystau region. A similar procedure was carried out in zones with oil and gas complex.

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Methodology 2 is based on the idea of searching for particular solution of inverse problem of particular integrated environmental assessment as a difference of particular generated objective functions reflecting the average (weighted) assessment of anthropogenic impact on environmental components in whole Mangystau region of the Republic of Kazakhstan and for areas with OGEC with preliminary justification of sufficient objectivity of these functions. General view of objective function according to R. Pentle's proposal looks like equation of linear multiple regression (1):

$$OF_{IEA} = a_1 \cdot f_1 + a_2 \cdot f_2 + \ldots + a_n \cdot f_n, \quad (1)$$

where OF_{IEA} - calculated value of objective function for integrated environmental assessment; *fi*-value of specific environmental factor (*i*= 1,2,…, *n*) at observation point; *ai* - weight ratio, taking into account the direction (sign plus or minus with respect to target) and importance (weight) of this factor in formation of total exposure level.

In this formulation, the objective function is not understood in the classical mathematical sense (as a criterion when comparing alternatives using different optimization methods), as well as a function that implements the purpose of the evaluation. Formal similarities with mathematical sense observed here - the procedure is reduced to optimize the sorting of the coefficients ai significance (estimates are almost always expert) in compliance with the conditions of their study.

Objectification of objective function usually involves justification of selection of the most significant factors based on the account of specific geographical, environmental and economic conditions of evaluated area and completeness of evaluation scales range. To solve the latter problem the formula (2) in environmental engineering is proposed:

$$\Delta = \frac{1}{l^n}, \quad (2)$$

where *l* – level of quantization of evaluation scales used in estimation of environmental factors (number of divisions of evaluation scale) and *n* - number of factors involved in evaluation.

Formula (2) shows that even in rough grading scale with level of quantization 2 (ie for expert evaluation on principle "yes" or "no"), sufficient accuracy can be achieved with 5 accounted parameters 5=0,03125, или 3,1%). Thus, great impact on accuracy (ie actually on objectivity) of expert assessments has the number of analyzed parameters *n* (exponent in formula denominator), but not the level of quantization of grading scales *l* (number of divisions on our measuring "line"). Thus, when parameter amount ***fi*** in objective function is 5, which should describe anthropogenic impact at all levels, i.e. number of human impact levels, outlined at each evaluation maps, we will get very good result in terms of accuracy.

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Determination of weighted load of each parameter of objective function should comply with five levels of exposure on specific components of natural environment in traditional expert assessment ten-point scale. In case of linear scale there will be 2 points for each 5 levels, and increase in scoring which reflects the increase in complexity and cost of environmental protection measures will correspond to the increased level of transformation.

Taking for calculation of average weighted input of oil and gas extracting complex to anthropogenic transformation of vegetation, the average values between class limits, we will obtain the following form of particular objective function to overall transformation j- natural environment component (NEC*j*) on region (POF*NECjReg*):

$$\mathrm{POF}NECjReg=fNECjReg1+3\square fNECjReg2+5\square fNECjReg3+7\square fNECjReg4+9\square NECjReg5, \quad (3)$$

where *fNECjRegi* – function of *i* level of anthropogenic disturbance of *j* natural environment component for the whole region, which is calculated by dividing total area of polygons of *i* level of anthropogenic transformation for this j component in the whole region by whole region area. The evaluation function for OGEC areas (POF*NECjOGEC*) will differ from (3) only in replacement of values *fNECjRegi tofNECjRegjOGECi*:.

$$\mathrm{POF}NECjOGEC=fNECjHOGEC1+3fNECjOGEC2+5fNECjOGEC3+7fNECjOGEC4+9fNECjOGEC5, \quad (4)$$

Now this function of *i* level of anthropogenic disturbance of j- natural environment component for total area of OGEC zones, which is calculated by dividing total area of polygons of *i* level of anthropogenic transformation for this j- component in all OGEC areas, where this level exists, by total area of all OGEC areas. Weighted loads will remain the same as in equation (3). OGEC role in transformation of each j natural environment - component of Mangistau region as a whole is determined by subtracting the POF*NECjReg* value from *POFNECjOGEC* - equation (5).

$$PSIPNECj=POFNECjOGEC-POFNECjReg \quad (5)$$

The value obtained in ten-point scale scores represents a particular solution of inverse problem of integrated environmental assessment for j- natural environment component. *PSIPNECj* characterizes additional input of OGEC to anthropogenic disturbances of j- component of natural environment in Mangistau region at all levels of anthropogenic transformation. For visibility this value can be transferred into percentages.

Methodology 3 represents a method of integral solution of the inverse problem of integrated environmental assessment as difference of integrated generalized objective functions, reflecting average (weighted) assessment of human impact on all components of natural environment as a whole in Mangistau region of the Republic of Kazakhstan and for areas with OGEC.

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Integral objective functions are constructed by analogy with particular ones by replacing ***f****NECjRegi* to *POFNECjreg* in equation (3) and *f NECjOGECi* to *POFNECjOGEC* in equation (4). In their construction a new justification of load values is needed because now particular objective functions act as factors which are constructed for all components of natural environment of Mangistau region (topography, soil, vegetation and ground water) in the whole territory and for OGEC areas. As a result of changing essential content of factors we obtain the equations (6) and (7).

$$IOFReg=aPOFrelReg+asoiPOFsoiReg+avegPOFvegReg+aGWPOFGWReg \quad (6)$$

$$IOFOGEC=arelPOFterOGEC+asoiPOFsoiOGEC+avegPOFvegOGEC+aGWPOFGWOGEC \quad (7)$$

In justifying weight load in equations (6) and (7) the role of each component in anthropogenic transformation of natural environment of Mangistau region on the basis of literature on experimental and theoretical studies on geosystems, marking their practical equivalence due to close interactions of all environmental components in geoecosystem when each component influences the other. Some scientists note the regulatory role of vegetation and approximately equal roles of soils and terrain, although the mechanism of their appearance differs significantly.

Taking into account these assessments the equation for calculating integrated environmental assessment (cumulative) effects, last equations can be rewritten in the following form (in terms of standard load amounts to 1):

$$IOFReg=0{,}24POFterReg+0{,}24POFsoiReg+0{,}28POFvegReg+0{,}24POFGWReg \quad (8)$$

$$IOFOGEC=0{,}24POFterOGEC+0{,}24POFsoiOGEC+0{,}28POFvegOGEC+0{,}24POFGWOGEC \quad (9)$$

It is clear that load values selected from literature have only indicative character because each region has its own specifics, not only on purely natural factors, according to which the intersystem communications in literature have been observed, but also anthropogenic. To verify the obtained results the control calculations have been performed with different sets of weight loads.

The final result of generalized solution of the inverse problem of integrated environmental assessment (determination of OGEC input to formation of overall environmental situation) in Mangistau region is still determined by subtracting the *IOFReg* value from IOF*OGEC* value.

$$PSIP=\mathrm{IOF}OGEC–\mathrm{IOF}Reg \quad (10)$$

The obtained value in scores is converted to percentage and represents an additional (since *IOFReg* and *IOFOGEC* reflect total effect of all key factors on the whole territory of the region or OGEC areas according to the legends to evaluation maps) input of OGEC to anthropogenic total transformation of all natural ingredients in general.

Conclusion

The results of a particular solution of the inverse problem (*PSIPNECj*) have shown that additional input of OGEC to anthropogenic disturbance of environmental components of Mangystau region was as follows: on relief – 16.73%; soils – 16.51%; vegetation – 31.79%; groundwater – 24.55%. Thus, in all components of natural environment in areas with OGEC, the average level generated by all anthropogenic sources significantly exceeds in the whole region.

Integral estimation of anthropogenic disturbance of natural environment in the whole Mangistau region was 3.89 points (4.22 on specified loads) according to ten-point scale, and integral evaluation of anthropogenic disturbance of natural environment of Mangystau region in areas with OGEC – 6.28 (6.48) points. An additional contribution of oil and gas complex in the anthropogenic disturbance of the natural environment of Mangistau region is estimated at 22.78% (22.69 at equivalent loads).

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Статья написана в рамках выполнения проекта грантового финансирования МОН РК №0589/ГФ-4 «Разработка метода объективизации экспертных оценок вклада отдельных источников загрязнения в общую экологическую ситуацию территории».