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Ecological and Economic Model of Performance Evaluation of the Companies Involved in the Responsible Care® Program

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The Russian Federation takes an active part in the international initiative of the chemical industry Responsible Care® program over last a ten-year period. Chemical companies who have declared their commitment to the program agreed to follow the basic principles and to report annually their data. The key indicators of ongoing activities in the field of environmental protection, industrial safety and the preservation of the health of the staff have been provided. System analysis provides conclusions analysing the achievements and challenges of the chemical industry. However, the data coverage of the Russian Federation still has some gaps. A heuristic and approximation algorithm, which considers large volume of information, has been developed for the analysis of existing business processes and trends. The economic damage caused by the air, water and soil pollution is assessed facilitate the expansion of the environment impact assessment analysis of the chemical companies - participants of the Responsible Care® program. The calculation of economic damage of the impact on the environment subsystems helps to make conclusions of the efficiency of the resources that have been allocated by chemical companies for environmental protection. This calculation tool can be also used for assessing the effectiveness of the direction implementation of the program, for the integration of the production activities of the company with its environmental activities.

1. Introduction

International program Responsible Care® was established in 1980ies in Canada (Simmons and Wynne, 1993). The program has been widely recognised and used by chemical companies in more than 60 countries worldwide (ICCA, 2015) including the Russian Federation. The Responsible Care® program is a voluntary initiative for promoting business to continual improvement of safe handling of chemical products throughout the supply chain and providing sustainable development of its member companies. The program is aimed at prevention of excessive regulatory measures initiated by the state (King and Lenox, 2000) and fosters the transparency of activities of all interested parties. Some experts pointed out (Purvis and Bauler, 2004) that despite all advantages of the program, the steps and measures taken within it are still not sufficient for protection against releases of pollutants into natural subsystem in case of emergencies and terrorist attacks

To quantify the results of the reporting activities provided by program members, chemical companies are obliged to annual reporting of key performance indicators (KPIs) on environmental protection, health and safety of their staff and industrial safety (Bélanger et al., 2013). Substantial amounts of data of KPIs and different types of activities have been collected during the course of the program from 2000 to 2013 at international level. It should be noted that the use of indicators for the estimation of environmental impact assessment (Meshalkin, 2009) and sustainable development indicators (Klemeš, 2015) is usual practice in the analysis of the complex systems. However, it has been still difficult to definite conclusions on trends for each indicator because the provision of data on voluntary basis often leads to some gaps. It is important to keep in mind when analysing the presented

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data that companies providing reports may have undergone modernisation and retrofits, commissioning new plants and expanding production capacities. These actions affect reliability and amount of actual data reported. To assess the effectiveness of implementation of the Responsible Care® program in the field of environmental protection in the Russian Federation a heuristic-approximating algorithm has been developed. Testing of this algorithm enabled to identify a number of indicators, which demonstrate the trend of reduction of load on environmental subsystems. Those indicators also demonstrate priority matters requiring attention both from chemical companies-members of the program and of state authorities responsible for environmental protection.

2. Ecological and economic model

They are seven priority directions of development for the program which could be considered while working out the environmental policy of chemical companies and for further planning of their activities in the Russian Federation. A principal issue is the integration of main business activity with environmental protection activities, health and safety of staff and industrial safety. The authors propose to consider positive environmental effect against KPIs which is directly linked to production and subsequent marketing of chemical products and expenses on environmental protection. The positive environmental effect is a result of improvement of technological process and/or implementation of best available technologies that concurrently aim at minimization of negative impact on environmental subsystems. The positive environmental effect is directly connected to environmental protection cost, including improvement and rational use of natural resources (Sarkisov and Meshalkin, 2001) and reduction of emissions into the air, discharges into water, disposal of waste and limitation of other types of negative impact on environmental subsystems. On basis of available data reported by chemical companies the authors propose to assess the effectiveness of environmental expenses using tools of integrated evaluation of economic damage. The algorithm for the evaluation of economic damage presented in Figure 1 was developed using the methodology of functional modelling IDEF0 (Šerifi et al., 2009).

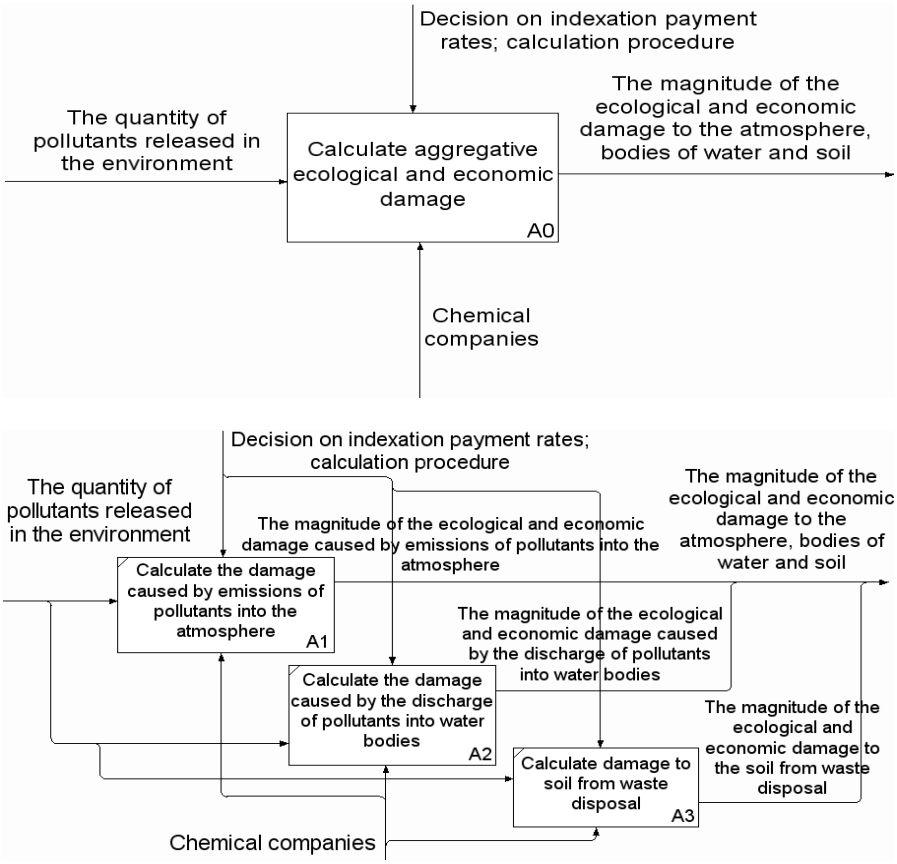

Figure 1: The algorithm of an integrated evaluation of economic damage: above – parent unit; below – details of the parent unit.

Additional to standard KPIs the chemical companies of the Responsible Care® program annually report environmental cost. When information on expenses on water and land protection is not reported, the authors

considered the allocation of funds to environmental activities, which is presented in the State Reports mapping the environmental situation in the Russian Federation. The analysis of reported data has revealed that the total amount of funds is on average distributed as: 57.5 % - allocated to collection and treatment of wastewater; 29.9 % - allocated to protection of atmospheric air; 10.5 % - allocated to waste management; 0.9 % - allocated to protection and rehabilitation of lands and water resources and 1.2 % - other environmental activities.
Based on those assumptions, the cost of environmental activities of members of the Responsible Care® program was divided into three main categories by the impact on the environment subsystem, allowing to compare them with the calculated economic damage. The total amounts in of G USD from 2005 to 2013 are presented in Figure 2.

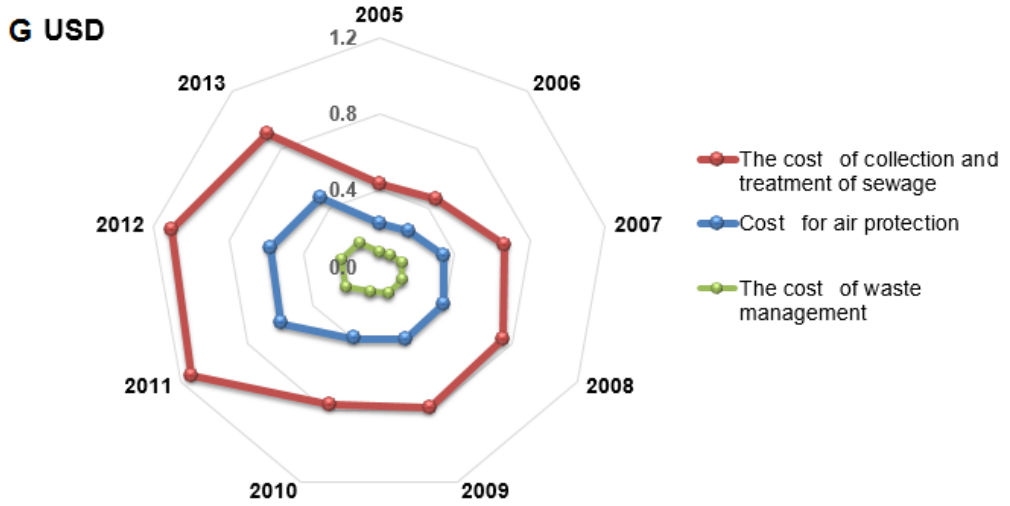

Figure 2: The total amount of environmental protection cost by Russian Federation chemical companies of the Responsible Care® program.

Payment for negative impact on the environment is a form of penalty for economic damage caused by such impact and has compensatory nature (Government of the Russian Federation, 1992). Positive efforts of chemical companies to minimise the negative impact on environmental subsystems, for example, by ensuring the safety of technological operations or implementation of innovative technologies allows obtaining both environmental and economic effect. This is a methodology similar to burdening and unburdening (Čuček et al., 2015).
The data reported by the members of the Responsible Care® program is presented in Figure 3. This data was used by authors to calculate economic damages from emissions, discharges and waste disposal.
The calculation of the economic damage from air pollution was carried out by using the economic damage method of calculation for "one pollutant" (Tarasova et al., 2006). Different equations are used to determine the economic damage from air pollution, see e.g. Eq(1):

$$Y_{atm} = I * Y^a * \sum Kx_i * m_i \quad (1)$$

where Y_{atm} – is economic damage to the atmosphere, RUB/y; I – indexation coefficient to payment rates for reporting year; Y^a – specific damage caused by emission of 1 reference t of pollutant, RUB/ref t (Y^a=144 RUB/ref t (2.46 USD/ref t)); K_{xi} – coefficient relative aggressiveness emitted into the atmosphere i^{th} pollutant (relative risk characterizes impurities present i^{th} species in the air inhaled by man in relation to the level of danger of conditional pollutant – CO_2), ref t/t (16.43 ref t/t – for emissions SO_2, 41.08 ref t/t – for emissions NO_2, 1 ref t/t – for emissions CO, 0.04 ref t/t – for emissions CO_{2total}); m – mass of annual emissions of the pollutant, t.

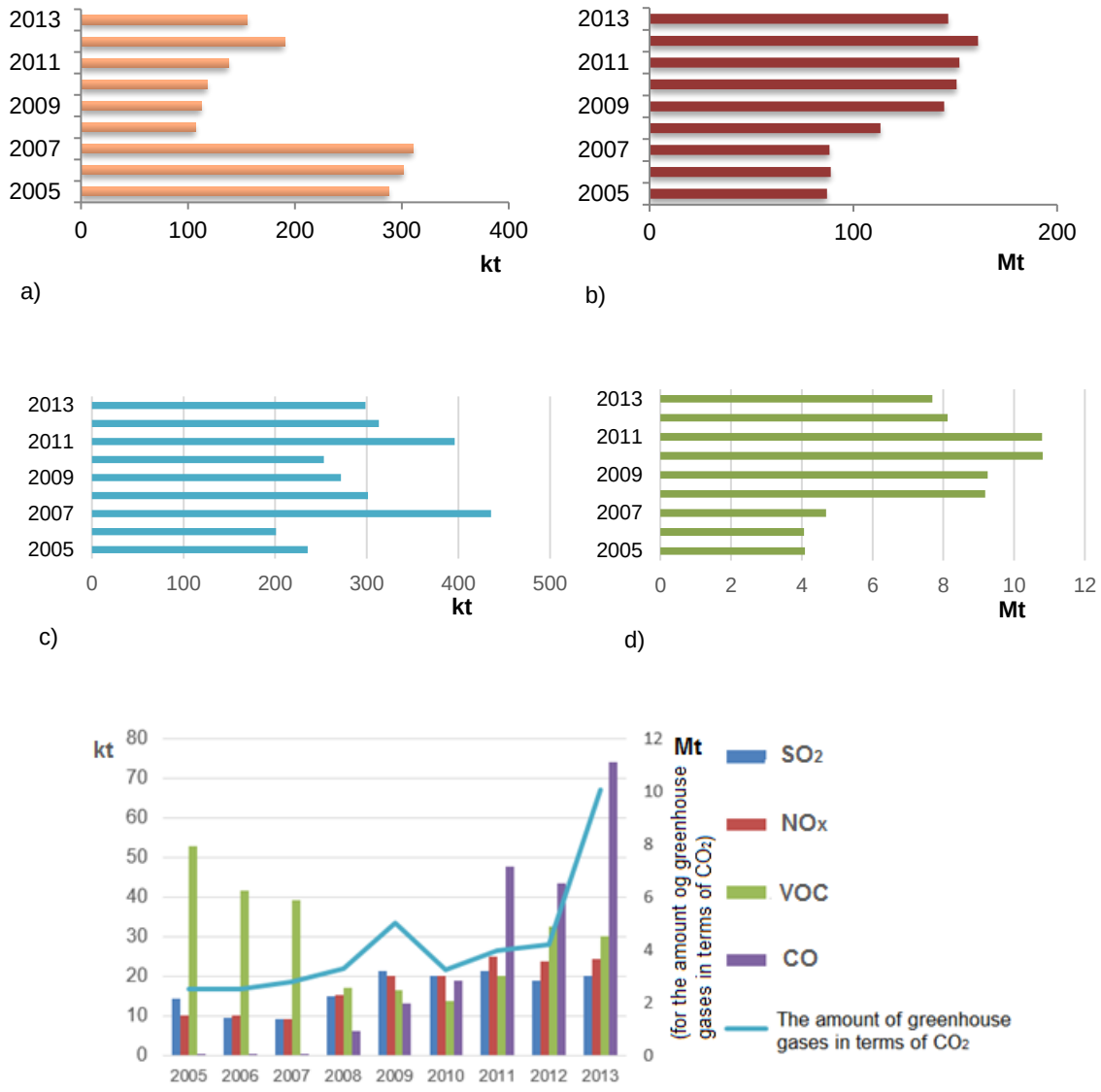

Figure 3: The data reported by Russian Federation chemical companies of the Responsible Care® program a) Dynamics of hazardous waste disposal by years; b) Dynamics of non-hazardous waste (hazard class V) disposal by years; c) Amount of discharges from sewage phosphorous-containing compounds; d) Amount of discharges from sewage nitrogen compounds.

Integrated evaluation of the environmental and economic damage caused by the discharge of chemicals in water is described by Eq(2):

$$Y_{water} = I^{*}Y^{w*}\sum Lx_i * m_i \quad (2)$$

where Y_{water} – damage to water bodies, RUB/y; Y^w – specific economic damage caused by discharge of 1 t of reference pollutant into water body, RUB/ref t (Y^w = 24,000 RUB/ref t (410.26 USD/ref t (exchange rate as of March 03, 2017 1 USD ~ 58.50 RUB)); Lxi – coefficient relative aggressiveness entering the water body of i-pollutant (number of conditional pollutant equivalent of one t discharged into water bodies i^{th} substance), ref t/t (6.67 ref t/t – for phosphorous compounds, 0.11 ref t/t – for nitrogen compounds); m – mass of annual discharge of pollutant, t.

In an analogous way was estimated the sufficiency of funds allocated to the protection of lands. The companies reported the amount of toxic (categories I - IV) and nontoxic wastes (category V). Considering that for calculation of economic damage caused by waste disposal it is necessary to use payment rate for disposal of waste of each

category separately, the following assumption was made: the amount of disposed waste of the 1st category for each company is 1 %, 2nd category – 3 %, 3rd category – 6 %, 4th category – 90 % of total amount. Payment rate for disposal of waste:
- 1,739.2 RUB (29.73 USD) for 1 t of waste class 1;
- 745.4 RUB (12.74 USD) for 1 t of waste class 2;
- 497 RUB (8.49 USD) for 1 t of waste class 3;
- 248.4 RUB (4.26 USD) for 1 t of waste class 4;
- 8 RUB (0.14 USD) for 1 t of waste class 5.

The economic damage caused by waste disposal within the established limits is determined as payment rate for respective hazard category times amount of disposed of wastes and by further summing the resulting values. Depending on landfills, multipliers can be used to consider the environmental situation and the importance of the value of land for the Russian Federation.

3. Results and discussion

The results of the calculation of economic damage from the impact on the environmental subsystem by Russian Federation members of the Responsible Care® program are presented in Table 1.

Table 1: Results of the calculation of economic damage from the impact on the environmental subsystem chemical companies of the Responsible Care® program.

Reporting year	Indexation coefficient	Economic damage from exposure to air MRUB (MUSD)	Economic damage from the impact water bodies MRUB (M USD)	Economic damage from the impact on soil MRUB (M USD)	Production Mt
2005	1.20	125.22 (2.14)	58.30 (0.99)	281.01 (4.80)	5.76
2006	1.30	116.31 (1.99)	55.88 (0.96)	311.99 (5.33)	9.01
2007	1.40	124.46 (2.13)	115.06 (1.97)	334.73 (5.72)	15.89
2008	1.48	211.72 (3.62)	107.63 (1.84)	416.45 (7.12)	41.06
2009	1.62	232.97 (3.98)	110.41 (1.89)	578.07 (9.88)	42.74
2010	1.79	223.65 (3.82)	124.11 (2.12)	665.67 (11.38)	50.56
2011	1.93	501.57 (8.58)	177.78 (3.04)	727.88 (12.44)	76.15
2012	2.05	377.98 (6.46)	147.12 (2.52)	827.29 (14.14)	80.69
2013	2.20	488.31 (8.35)	150.17 (2.57)	798.98 (13.66)	86.82

The economic damage was divided per t of the product. This has been done to analyse the effectiveness of the implementation of environmental protection activities, by the Responsible Care® program. This allowed calculating some possible scenarios. For example, a member joining the program later than others: a member lacking reports for different reporting years: member companies being upgraded: those being newly commissioned for production or those having their production capacity increased. The slope of the trend line of the economic damage changes showed that common economic damage for all of the reported chemical companies per t of the product had been annually reduced in the period from 2005 to 2013. From this trend is evident that the funds allocated by member companies for environmental protection, contribute to a positive environmental effect.

During the reporting period, 69.82 G RUB (~ 1.19 G USD) - have been allocated for environmental protection purposes. The economic damage to the environment subsystem has reduced to 80 % of the initial level as result the allocated money.

A number of assumptions had been adopted in the calculation of the economic damage: an integrated evaluation of economic damage was based on the assumption that all emissions did not exceed the established maximum permissible amounts. However, that has not always been the case (e.g. the lack of technical facilities for cleaning up emissions leads to excessive air pollution). When calculating the correction, the nature of the impurity scattering in the atmosphere and an indicator of the relative hazard of the pollutant to different recipients were omitted, due to a lack of accurate data on the sources of emissions and other parameters as the source altitude, ambient temperature and others.

The calculated economic damage of wastewater discharges into water bodies is lower than the actual. This can be explained by the fact that chemical companies provide data only on nitrogen- and phosphorus-containing compounds, while in practice discharged pollutants include sulphates chlorides, suspended substances, petroleum products, etc.

However, that calculations assumed that the waste sent for disposal within the established limits on specialised landfills was in accordance with applicable law. Multiplying factors could not be taken into account in the calculation due to the lack of accurate data on landfills.

4. Conclusions

The analysis of data provided by the chemical companies - members of the Responsible Care® program was carried out by tools of integrated evaluation of the economic damage caused by negative impact on environmental subsystems. This analysis and the results of testing of the heuristic-approximating algorithm, lead us to the following conclusions:

(i) The analysis revealed a positive trend of reducing the value of ecological and economic damage to 80 % of the initial level. This indicates that the Russian Federation chemical companies of the Responsible Care® program have an interest both in expanding production capacity and also in minimising the negative environment impacts.

(ii) The analysis presented can be used as an informational support of eco-oriented management decisions being adopted by the chemical companies. The approach for handling reported data can be considered as an assessment tool of the effectiveness of implementation of the Responsible Care® program direction such as the integration of core business activity with activities in the field of environmental protection.

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