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A Normative Model of Balanced Nature Management

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Abstract—The risk of erroneous regulation in multilevel normative environmental chains, at the federal, regional, and lower levels, down to the corporate one, has been studied. This risk has been demonstrated to increase unacceptably rapidly in the framework of the existing system of "unconditional acceptance" of normative standards. To mend the situation, it is necessary to use the "conditional acceptance" model by regarding post hoc decisions made at higher levels as a priori ones at the next (lower) levels. A strategy of environmentally and economically balanced corporate regulation of nature management through minimization of the losses resulting from both excessive caution and breaching the existing regulations has been proposed. This system, combined with the European approach to nature conservation, requires that the "riskless" regulation should be abandoned and is expected to improve the parameters of nature management quality by three to four orders of magnitude.

Key words: measuring control, traceability, variability of controlled parameters, risk of breaching the existing regulations, environmental normative standards.

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The so-called sustainable development "without compromising the ability of future generations to meet their own needs"[1] nevertheless entails exhaustion of Earth's natural resources. This raises the issue of balanced nature management, with account taken that environmental damage is inevitable and should be restricted to the level commensurate with economic profitability. The transition to environmentally and economically balanced nature management requires unified principles in developing the normative standards of the allowable environmental impact. Such standards are difficult to develop because the tolerance of natural system to external factors varies depending on the characteristics of environmental objects (Chereshnev et al., 2008; Martin, 2002). Together with the limited number of dose–effect estimates, this has resulted in a situation where the normative standards are set under the conditions of statistical uncertainty and may be either too strict or too loose, i.e., economically unacceptable or environmentally hazardous. Hence, the risk of environment–economy imbalance appears at all levels of normative regulation: international, national, regional, district/industrial, etc., down to intracorporate.

[1] Rio Declaration on Environment and Development (*Rio-92*).

Estimation of and Allowance for Erroneous Multilevel Normative Regulation

The conditions set at the *i*th level of the normative environmental chain may be either optimal (acceptable) or suboptimal (unacceptable) with probabilities of R_{iA} and $1 - R_{iA}$, respectively. They may be accepted or rejected with probabilities of R_{iB} and $1 - R_{iB}$. Because of the statistical uncertainty of these parameters (Deming, 2007; Danilov-Danil'yan and Rozental', 2009), the values R_{iA} and R_{iB} differ from each other; therefore, the following outcomes are possible with their respective probabilities:

– an acceptable normative standard is accepted at a probability of P_{iAA};

– an acceptable normative standard is rejected at a probability of P_{iAU};

– an unacceptable normative standard is accepted at a probability of P_{iUA};

– an unacceptable normative standard is rejected at a probability of P_{iUU}.

Here, $P_{iAA} + P_{iAU} + P_{iUA} + P_{iUU} = 1$; $R_{iA} = P_{iAA} + P_{iAU}$; $R_{iB} = P_{iAA} + P_{iUA}$. In addition, the relative probability of rejecting an acceptable normative standard, i.e., type 1 error, is $\alpha_i = P_{iAU}/R_{iA}$, and the relative probability of accepting an unacceptable normative standard, i.e., type 2 error, is $\beta_i = P_{iUA}/(1 - R_{iA})$.

Table 1. Ordinal numbers of normative regulation outcomes (numerator) and their probabilities (denominator)

Decision	At the level i		At the level $i + 1$	
	the normative standard is acceptable	the normative standard is unacceptable	the normative standard is acceptable	the normative standard is unacceptable
The normative standard is accepted	$\frac{1}{P_{iAA}}$	$\frac{2}{P_{iUA}}$	$\frac{3}{P_{(i+1)AA}}$	$\frac{4}{P_{(i+1)UA}}$
The normative standard is rejected	$\frac{5}{P_{iAU}}$	$\frac{6}{P_{iUU}}$	$\frac{7}{P_{(i+1)AU}}$	$\frac{8}{P_{(i+1)UU}}$

For the purpose of this study, the corresponding summary errors are of interest: $\alpha = P_{AU}/R_A$ and $\beta_i = P_{UA}/(1 - R_A)$.

Let us first estimate these values for two arbitrarily selected levels of normative regulation, the ith and $(i + 1)$th levels (Aleksandrovskaya and Rozental', 2008). In the existing system of control, the environmental normative standard established at a higher (ith) level has to be unconditionally accepted at the $(i + 1)$th level. Table 1 shows the possible outcomes and their probabilities.

Normative standards are accepted in the cases of the following combinations of outcomes at the two levels: [1, 3], [2, 3], [1, 4], and [2, 4]. Here, only the first combination corresponds to an accepted normative regulation, whereas the others correspond to undetected erroneous ones. In addition, a normative regulation in the given system is rejected in the cases of the combinations [5, 7], [5, 8], [6, 7], [6, 8], [1, 7], [1, 8], [2, 7], [2, 8], [3, 5], [3, 6], [4, 5], and [4, 6]. Here, the combinations [5, 8], [6, 7], [6, 8], [1, 8], [2, 7], [2, 8], [3, 6], [4, 5], and [4, 6] correspond to correct decisions, and the others, to incorrect ones. Therefore, the probabilities of erroneous decisions of "the normative regulation is set incorrectly" and "the normative regulation is set correctly" types are determined by those of the combinations [5, 7], [1, 7], [3, 5] and [2, 3], [1, 4], [2, 4], respectively, or by the following equations:

$$P_{AU} = P_5P_7 + P_1P_7 + P_3P_5, \quad (1)$$

$$P_{UA} = P_2P_3 + P_1P_4 + P_2P_4. \quad (2)$$

After substituting the values of the probabilities from Table 1 and rearranging both sides of Eq. (1), we obtain

$$R_A - P_{AA} = R_{iA}\alpha_i R_{(i+1)A}\alpha_{(i+1)}$$
$$+ R_{iA}(1 - \alpha_i)R_{(i+1)A}\alpha_{(i+1)} + R_{(i+1)A}(1 - \alpha_{(i+1)})R_{iA}\alpha_i.$$

Further rearrangements yield

$$1 - \alpha_{i,\,i} + 1 = (1 - \alpha_i)(1 - \alpha_{i+1}).$$

Using the method of mathematical induction, we obtain, from this equation, an expression that is suitable for estimating the summary type 1 error in a chain of normative regulation consisting of k levels:

$$1 - \alpha = \Pi_{i=1}^{k}(1 - \alpha_i). \quad (3)$$

For the summary type 2 error, it is impossible to obtain a relationship that would be as suitable as Eq. (3). However, in terms of the problem of correct nature management, to estimate the proportion of erroneous normative standards among the accepted ones (i.e., the parameter $\beta' = P_{UA}/R_B$) is the first priority. Taking into account Eqs. (1) and (2), we obtain an expression for this value that is suitable for practical use:

$$1 - \beta' = \Pi_{i=1}^{k}(1 - \beta'_i). \quad (4)$$

It follows from Eqs. (3) and (4) that the member of the system that is at the last (kth) level of the normative environmental chain, i.e., the user of natural resources, is under the most unfavorable conditions.

Indeed, let normative standard be set, e.g., at three consecutive levels, with the acceptable risk of normative regulation error at the third level being α_3, β'_3. Obviously, the risk at the preceding (second) level should be lower than α_3, β'_3. Otherwise, the summary risk of error will be unacceptable, because $\alpha_2 = 1 - (1 - \alpha_3)^2 > \alpha_3$, $\beta'_2 = 1 - (1 - \beta'_3)^2 > \beta'_3$.

This consideration is all the more true for the first level, because

$$\alpha_1 = 1 - (1 - \alpha_3)^3 > \alpha_2 > \alpha_3,$$

$$\beta'_1 = 1 - (1 - \beta'_3)^3 > \beta'_2 > \beta'_3.$$

This conclusion is especially obvious for small values of the risk, when $\ln(1 - \alpha) = \sum_{i=1}^{k} \ln(1 - \alpha_i)$ or even $\alpha \approx \sum_{i=1}^{k} \alpha_i$. Let, e.g., again $k = 3$ and the risk of type 1 error at each level is $\alpha_i = 0.01$. Then, the summary risk at the third level is $\alpha_3 = 0.03$. Also the user of natural resources makes a contribution to this value (0.01), this is smaller than the contribution of the two

Table 2. Loss of quality of normative regulation when the traceability is and is not taken into account

Level	Types 1 and 2 errors in the systems of unconditional (numerator) and conditional (denominator) acceptance of normative standards		
	example 1	example 2	examples 1–2
$i = 1$	0.07/0.07	0.13/0.13	0.19/0.19
$i = 2$	0.14/0.005	0.24/0.017	0.34/0.036
$i = 3$	0.20/<0.001	0.34/0.002	0.47/0.007

higher levels of normative regulation (0.02). This situation can be partly avoided by reducing the errors at the initial levels of normative regulation[2]. If, e.g., $k = 2$, where $i = 1$ corresponds to the agency establishing the normative standard of nature management and $i = 2$ corresponds to the user of natural resources, and, again, $\alpha = 0.03$ and $\alpha_2 = 0.01$, then $\alpha_1 = 0.02$, which differs from α less than in the previous example.

In the world's industrial practice, the so-called traceability is generally used to change this situation in multilevel chains (Smirnov, 2003)[3]. Examples of traceability are the metrological traceability of the results of analysis up to the highest level of the reference material (primary reference samples) and the traceability in chains of food supply[4]. Minimization of the risk of the loss of nature management controllability requires the introduction of traceability and replacement of the system of "unconditional acceptance" of normative standards set at a higher level with a system of "conditional acceptance."

By "conditional acceptance" of normative standards we mean that the posterior probability of error-free normative regulation (the proportion of correctly established normative standards among all accepted standards) set at the ith level is regarded as an a prior probability at the $(i + 1)$th level.

The posterior probability at the ith level is

$$P_{i\mathrm{AB}} = \frac{P_{i\mathrm{AA}}}{R_{i\mathrm{B}}} = \frac{(1-\alpha_i)R_{i\mathrm{A}}}{(1-\alpha_i)R_{i\mathrm{A}} + \beta_i(1-R_{i\mathrm{A}})}.$$

Therefore, the same value at the $(i + 1)$th level is

$$P_{(i+1)\mathrm{AB}} = \frac{(1-\alpha_{i+1})P_{i\mathrm{AB}}}{(1-\alpha_{i+1})P_{i\mathrm{AB}} + \beta_{i+1}(1-P_{i\mathrm{AB}})}$$
$$= \frac{(1-\alpha_i)(1-\alpha_{i+1})R_\mathrm{A}}{(1-\alpha_i)(1-\alpha_{i+1})R_\mathrm{A} + \beta_i\beta_{i+1}(1-R_\mathrm{A})}.$$

Then, the type 1 error for a chain consisting of two levels is $\alpha_{i,\,i+1} = \alpha_i + \alpha_{i+1} - \alpha_i\alpha_{i+1}$ and the summary type 2 error is $\beta_{i,\,i+1} = \beta_i\beta_{i+1}$. Therefore, in the case of k levels of normative regulation, Eq. (3) is still true for α, and β is calculated as

$$\beta = \Pi_{i=1}^{k}\beta_i. \tag{5}$$

It is easy to see that "conditional acceptance" of normative standards in the chain of normative regulation does not change the type 1 error but considerably reduces the type 2 error.

Let us estimate the risks of erroneous normative regulation in the example of water use. Assume that, according to the current strategy of normative regulation, the maximum allowable concentration (MAC) of a water pollutant is set at the federal level, and the normative maximum permitted discharge (MPD) is determined from the condition of compliance with the MACs. The user of water plans the normative corporate maximum discharge (CMD) on the basis of the condition of not exceeding the MPD. The normative water-environmental chain consists of three levels, MAC ⟶ MPD ⟶ CMD, with normative standards being set at each level with a certain risk of error. Let us use model examples to estimate the risks.

Example 1. One of the sources of the risk of error in establishing the MAC is the necessity to determine this normative standard by analyzing the dose–effect relationships in laboratory samples of water ecosystems. If the test sample is more resistant to the given factor than the natural ecosystem is, then an insufficiently "strict" normative standard will be established, which will make water use environmentally hazardous. If, conversely, the resistance of the test sample is lower, a too "strict" normative standard will be established, which will unjustifiably restrict water use. Let us estimate the risk of error in establishing the MAC defined as the maximum dose of the pollutant at which no signs of suppression of the test sample are observed[5].

Solution. Let the probability of suppression of the test sample be binomially distributed. Then, the confidence limits for the observation of the signs of suppression when the number of tests is n is calculated as

$$\Delta, \Delta' = w + u_\gamma^2/2n \pm t\sqrt{w(1-w)/n + (u_\gamma/2n)^2}.$$

[2] This is provided for in the chain of transfer of unit sizes (GOST (State Standard) R ISO/MEK 17025-2006) from primary reference samples at the international level to corporate reference samples.

[3] *Eurachem/CITAC Guide: Traceability in Chemical Measurement*, 2003.

[4] Traceability in EU countries is provided for by Regulations 178/2002 and other documents; in Russia, *GOST (State Standard) R ISO 9001-2002: Systems of Quality Management*) and guidelines R 50-601-36-93 (Recommendations: System of Quality: Identification and Traceability of Products.

[5] According to MU po ustanovleniyu ekolog-vodokhozyaistvennykh normativov zagryaznyayushchikh veshchestv dlya vody vodnykh ob"ektov,imeyushchikh rybokhozyaistvennoe znachenie (Guidelines on Setting Environmental Water Management Normative Concentrations of Water Pollutants for Water Objects Important for Fishery), Moscow: VNIRO, 1998.

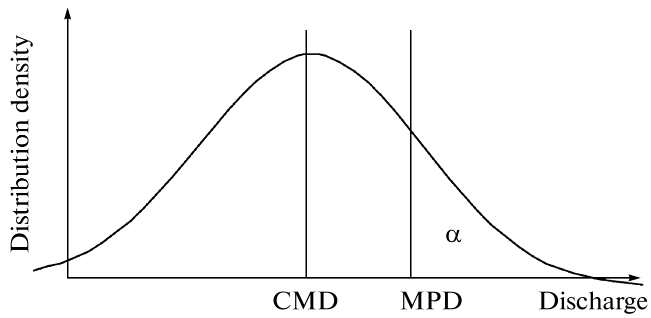

Fig. 1. Ratio between the CMD and MPD.

Here, w is the relative frequency of the target signs, and u_γ is the distribution quantile.

According to the conditions of the problem, $w = 0$; therefore, $\Delta' = 0$, and $\Delta = u_\gamma^2/n$. At $\gamma = 0.95$ and $n = 100$, the risk of the loss of quality because of suboptimal normative regulation is $\Delta \approx 0.07$.

An incomplete sample is not the only cause of errors in establishing the MAC. These may also result from differences in resistance to external factors among ecosystems developing in different aquatic environments.

Example 2. A bog area is located in several geochemical provinces differing in the sensitivity of the aquatic biota to the toxicant. Let us estimate the risk of erroneous establishment of the MAC if the aquatic biota spontaneously moves so that the samples for analysis may randomly contain water organisms developing in different provinces.

Solution. Let organisms typical of the bog ecosystem randomly move, traveling over a distance of $\sim x^2$ for a fixed interval of time and moving over a distance of $x = x_0$ on average. In this case, the density of the probability distribution function for the finding of "alien" organisms developing at a distance of x from the sampling site is

$$f(x) = \frac{1}{\pi(1 + x^2/x_0^2)},$$

where $\int\limits_{-\infty}^{\infty} \frac{1}{\pi(1 + x^2/x_0^2)} dx = \frac{\arctan x/x_0}{\pi}\bigg|_{-\infty}^{+\infty} = 1.$

If the mean linear size of the provinces is $\pm 10x_0$, then the proportion of "alien" organisms in the sample, which is equal to the probability of erroneous normative regulation is

$$\Delta' = 1 - \int\limits_{-10}^{10} \frac{1}{\pi(1 + x^2/x_0^2)} dx \approx 0.13.$$

In these examples, the calculated risk varies from $\Delta = 0.07$ (Example 1) to $\Delta + \Delta' = 1 - (1 - 0.07)(1 - 0.13) \approx 0.19$ (Example 2).

Example 3. Let us compare the risk of erroneous normative regulation at the first level of the normative environmental chain in Examples 1 and 2 with the summary risk at all levels in the case when the type 1 and type 2 errors are equal to each other ($\alpha_i = \beta_i$).

Solution. From Eqs. (3) and (4), we obtain the results shown in Table 2. As evident from these data, the type 1 and type 2 errors increase with increasing ordinal number of the level to about 50% in the "unconditional acceptance" system, whereas the risk of undetected errors rapidly decreases in the "conditional acceptance" system.

Our results allow us to estimate the efficiency (E) of normative regulation. Let us do it using the method of estimation of the efficiency of tolerancing. The estimation is based on the ratio between the losses in the absence and presence of tolerancing (Aivazyan and Mkhitaryan, 2001; Aleksandrovskaya et al., 2003). In the case of normative regulation, this is the ratio between the probability of a priori erroneous normative regulation $P_{UU} + P_{UA} = 1 - R_A$ and the sum of the probabilities of rejecting a correct normative standard ($P_{UA} = \beta(1 - R_A)$) and accepting an incorrect one ($P_{UA} = \alpha R_a$):

$$E = \frac{(1 - R_A)}{\alpha R_A + \beta(1 - R_A)}.$$

A necessary condition of efficient normative regulation is $E > 1$, i.e., $\beta + \frac{R_A}{1 - R_A} < 1$ or

$$\frac{R_A}{1 - R_A} < \frac{1 - \beta}{\alpha}, \qquad (6)$$

in the case of "unconditional acceptance" of the normative standards established at the higher level and $\alpha = \beta$. Then, $\frac{R_A}{1 - R_A} < \frac{1 - \alpha}{\alpha}$ or $\alpha < 1 - R_A$.

In the case of "conditional acceptance, $\alpha > \beta$ (Table 2), the inequality being the stronger, the more levels of normative regulation are used. In the extreme case, when β is negligible compared to α, we obtain

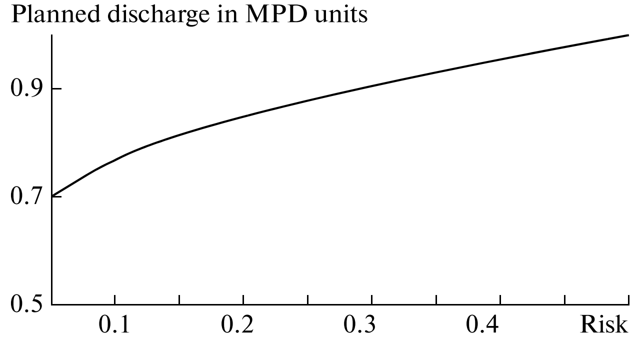

Fig. 2. Dependence of the CMD planned by an enterprise (expressed as a proportion of the MPD) on the specified risk within the range 5–50% at $\sigma = 0.18\mu$.

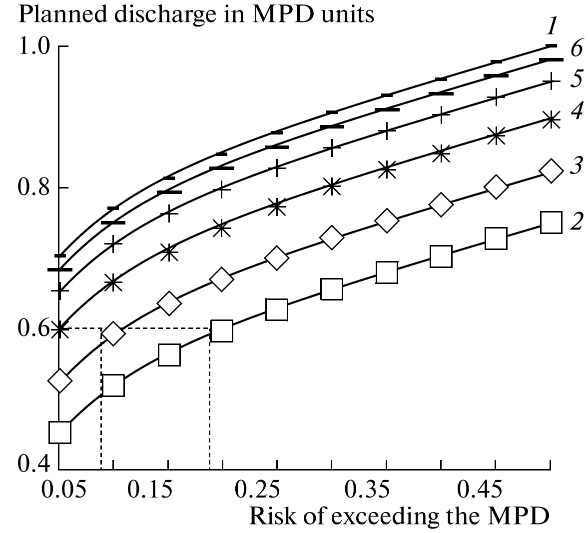

Fig. 3. The optimal amount of discharge at $\sigma = 0.18$ and $\gamma = 0.95$. (*1–6*) The dependence of α on the measurement frequency at a fixed μ': (*1*) permanently; (*2*) semiannually; (*3*) quarterly; (*4*) monthly; (*5*) weekly; (*6*) daily.

from Eq. (6) that $\alpha < \frac{1 - R_A}{R_A}$; i.e., the range of reliable normative regulation is extended by a factor of $1/R_A$.

Let us now consider a model of corporate nature management.

CORPORATE PLANNING AND CONTROL

If an enterprise has received an unlimited right to use nature resources, it is in its interests to use this right to as much advantage as possible and provide the measuring control that would prove that the existing requirements are complied with. Let us consider the algorithms of achieving these targets.

1. Corporate planning of nature management should take into account the risk of violation of the set conditions because of variability of the monitored parameters depending on a set of poorly predictable technological, metrological, and other factors, which is inevitable in any industry (Rozental' and Kopnova, 2006; Daiman et al., 2003). To avoid fines for excess use of natural resources, the enterprise should be cautious and plan an underestimated standard of resource use.

For example, let the enterprise has been given the MPD, and the task is to establish the CMD at which the probability of exceeding the MPD is no higher than a certain value (α). Then, if the CMD probability density is described by a normal distribution law with the standard deviation σ, then CMD + MPD – $u_\alpha\sigma$.

In contrast, the current "risk-free" nature management practice usually sets CMD + MPD. As seen from Fig. 1, $\alpha = 0.5$ when CMD and MPD coincide. To decrease α, self-limitation is necessary: the stronger the inequality CMD < MPD, the smaller the α value. To decrease α to the "natural level" of 0.10–0.05, the CMD should be maintained at a level of (0.8–0.9)MPD (Fig. 2), which is actually the case in developed economies (Daiman et al., 2003; Pablos, 2003; Rozental' and Kopnova, 2006), where the user of natural resources has a limited "right to risk." For example, the United Kingdom standards[6] allow for the correspondence of the quality parameters of natural waters to the established conditions with a confidence probability of 90%. European Union Regulations 91/271/EEC of May 21, 1991, allows for the occurrence of the following numbers of inconsistent water samples: 1 at $n = 4$–7; 5 at $n = 41$–53; 15 at $n = 188$–203, etc.

In contrast, the Russian system of "risk-free" nature management creates a considerable environmental/economic imbalance. This is evident from comparison of the risks of violation of the normative

[6] Martin, D., *Water Quality Consenting: Work Instruction for the Calculation of Permit Limits for Discharges to Inland and Tidal Waters to Protect Water Quality*, New York: Richard Brooks, 2002.

Table 3. The risk of violation of the regulations on sewage and CMD as dependent on the payment for excess discharge (in units of *K*)

K	2.3333	5.3012	19.0000	42.8596	369.3704	739.7400
α	0.3000	0.1687	0.0500	0.0228	0.0027	0.0013
Optimal discharge	MPD–0.53σ	MPD–σ	MPD–1.65σ	MPD–2σ	MPD–2.78σ	MPD–3σ

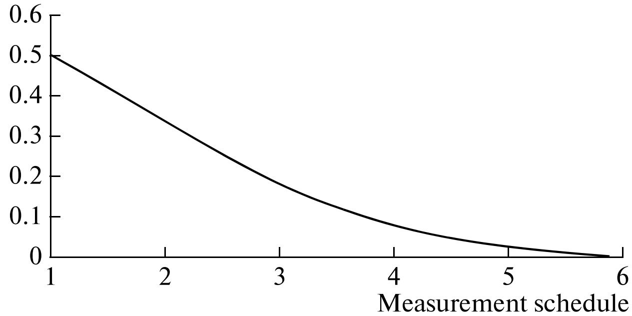

Fig. 4. Probability of erroneous proof of the observance of established regulations based on the results of 2 (point 1 on the abscissa axis), 4 (point 2), 12 (point 3), 52 (point 4), and 365 (point 5) measurements and in the case of permanent measurement (point 6).

standards regulating the safety of marketed products and the environment: the enterprises concerned with satisfying the consumers implement the "six sigmas" methodology (Pablos, 2003), at which the risk of rejects is decreased to $\sim 10^{-5}$ to 10^{-6}.

2. Reliable proof of the results is ensured by measuring control according to the *GOST (State Standard) R ISO 5725/2002: Correctness (Accuracy and Precision) of Methods and Results of Measurement* (parts 1–6). Permanent control yields the most accurate results. However, its high cost makes it necessary to employ sampling with analysis of the samples. This makes it possible to draw conclusions with a certain limit sampling error δ depending on the specified confidence probability γ:

$$P\{|\bar{X} - \mu| < \delta\} = \gamma, \tag{7}$$

where P is the probability of the event $\{|\bar{X} - \mu| < \delta\}$ consisting in that the mean value of the controlled parameter ($\bar{X}$) differs from the planned one (μ) by δ.

Here, the expectation of the mean value of the analyzed parameter coincides with the expectation of its individual value $M[X] = M[\bar{X}] = \mu'$, and the variance of the mean is $D[\bar{X}] = \sigma^2/n$.

A simple calculation[7] shows that $\delta = \frac{\sigma}{\sqrt{n}} u_\gamma$, and the pollutant discharge in the above example should be planned at the level $\text{CMD}' = \text{MPD} - \sigma\left(u_\alpha + \frac{u_\gamma}{\sqrt{n}}\right) \le$ CMD, as shown in Fig. 3. It is evident that both technological and metrological methods can be used to

Table 4. The risk of violation of the regulations on sewage as dependent on the number of tests at $K = 5$ and $\gamma = 0.95$

n	4	12	52	365	∞
Risk (α) under the conditions of periodic measurements	0.50	0.35	0.25	0.20	0.17

decrease α (i.e., to increase the reliability of the proof that the specified conditions are met). For example,

– when the pollutant discharge is decreased, the α value decreases by shifting leftwards and downwards along one of the curves in the figure;

– when the frequency of measurements is increased, this value decreases by shifting leftwards parallel to the abscissa axis between these curves.

It is also evident from Fig. 4 that if, given a planned discharge of 0.6 MPD, the frequency of measurement is increased from two to four times a year, then α will decrease from 0.2 to 0.1. At larger n, this effect will be weaker, but the expenses for increasing the reliability of control will inevitably remain much smaller than the technological cost of decreasing the discharges.

3. The optimal strategy of corporate nature management is minimization of the possible loss due to

– "self-limitation" (water use reduced compared to the maximum permitted level) in order to decrease the risk of violation of specified requirements;

– sanctions of national agencies for environment management regulation.

An example of the expected sanctions is payment for excess use of natural resources at a higher rate. Given that $\alpha \approx 0.5$ in the case of the current "risk-free" approach, the rate should be K times higher than the normative one (where K is a multiplying factor) in about half of all cases.

If enterprises seek to equalize the payment rates for the normative and excess use of natural resources rather than the proportions of these categories of their use as the first step towards saving funds, then, given the above data on water use, we obtain $\alpha = 0.17$. This means that the discharges should be limited by the level CMD = MPD – 0.9σ. Therefore, at $\sigma \sim$ (0.2–0.3)MPD, the discharge should be decreased by 20–30%.

National regulatory agencies can influence the policy of an enterprise by regulating the multiplying factor K: the higher the K value, the more profitable the decrease in α. To equalize the payments for the normative and excess use of natural resources, it is expedient to set the CMD depending on the specified K at the level shown in Table 3. For example, to decrease the risk α to $\sim 10^{-3}$, which is close to the safety of marketable products (Pablos, 2003), it is necessary to

[7] From Eq. (7), we obtain $P\{\mu - \delta < \bar{X} < \mu + \delta\} = \gamma = \Phi\left(\frac{(\mu+\delta)-\mu}{\sigma/\sqrt{n}}\right) - \Phi\left(\frac{(\mu-\delta)-\mu}{\sigma/\sqrt{n}}\right) = 2\Phi\left(\frac{\delta\sqrt{n}}{\sigma}\right)$, where Gauss' function $\Phi\left(\frac{\gamma}{2}\right) = u_\gamma^{-1} = \frac{\sigma}{\delta\sqrt{n}}$. Therefore, $\delta = \frac{\sigma}{\sqrt{n}} u_\gamma$.

Table 5. Institutional substantiation of balanced nature management

Activity	Substantiation	Standards
	184-FZ and other laws	
In regulating the use of natural resources: Establishment of an acceptable reproducibility of the dose–effect relationship. Customization of environmental normative standards	The minimum necessary requirements a set according to the risk of damage (184-FZ, article 7). Financial cost analysis of sewage processing projects is necessary (US Law 99-662)	Water Quality Consenting. Work Instruction for the Calculation of Permit Limits for Discharges to Inland and Tidal Waters to Protect Water Quality. EA, 2002 (United Kingdom regulations for setting normative standards of water quality with a 90% confidence interval)
In observing the established requirements: Planning an economically acceptable level of the use of natural resources with allowance for the variability of production parameters	No Russian legislations are available. Available legislations: European Union Water Framework Directive 2000/60/EC of 23 Oct. 2000. European Council Directive 91/271/EEC of 21 May 1991 on sewage. Council Directive 76/464/EEC of 4 May 1976 on the pollution with some hazardous substances discharged to the water environment of the Community	*BS 6143:92*: Guidelines on quality economics; *BS 6143:90*: Guidelines on quality economics; *GOST (State Standard) R 50779.11-2000*: Statistical methods: statistical quality control
In supervising: Establishment of the acceptance quality level (AQL) and limit quality (LQ) of the use of natural resources, which are the points of compromise between the user of natural resources and the state supervising agencies	Regulation based on unified rules and methods of studies (tests) and measurements (184-FZ) for protection against unfavorable consequences of unreliable results of measurements (102-FZ *On Ensuring Unification of Measurements*)	PR 50-732-93 *GSI: Model Regulations on the Metrological Service*; *GOST (State Standard) R 51592-2000*: Water: General requirements for sampling; ISO Standards, series 5667: Sampling

increase the payment for violation of the regulatory requirements by a factor of almost 1000[8].

It is also noteworthy that the limit sampling error should be taken into account to meet the regulatory requirements. For example, at $\alpha = 0.17$, measurements should be made at least once a day, because α rapidly increases as measurement become rarer (Table 4).

CONCLUSIONS

A balanced nature management based on the concept of acceptable environmental damage commensurate with the economic profitability entails reforming the system of environmental/economic regulation. In the new regulatory system, the risks that appear at the stages of development, acceptance, enforcement, and observance of the established regulations should be known and held within the established limits at a specified probability. Substantiations for these efforts are listed in Table 5.

The development, institutionalization, and implementation of the system of nature management based on generally accepted criteria and the statistics obtained by authorized methods will make it possible to regularize the relationships between the authorities and the users of natural resources and increase the resultant efficiency of their activities. The new system will allow the quality of the use of natural resources to be improved by three to four orders of magnitude[9]. Therefore, reforming the environmental/economic regulation is a problem arising from the requirements of sustainable development. To solve it is necessary for conserving the Russian stock of natural resources and integrating into the global market of raw materials under the conditions of their globally growing deficit.

[8] Consultations with economists show that this increase in *K* is currently impossible. This further emphasizes the large gap between the levels of the organizations of nature conservation and industrial production. This is a worrisome circumstance, because even products of the highest quality will not save the society from the hazards of environment degradation.

[9] Such is the difference between the low risks of erroneous decisions in industries employing standards of statistical control and the high risks in nature management.

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