ENSEMBLE METHOD FOR ASSESSMENT OF MARINE ENVIRONMENT QUALITY

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Currently meteorology makes a wide use of the ensemble method for forecasting weather and climate changes. The method is based on the use of different models (or one model, but different source data) for the preparation of forecasts. The results obtained by different models are averaged at the final calculation stage. A similar approach can be used for the assessment (estimation) of environmental quality in general and for marine environment in particular.

The "ensemble" described in this research includes methods for quality assessment (estimation) of marine water and bottom sediments used in the Caspian Marine Scientific Research Center (KaspMNIZ) for the estimation of marine environment quality in the areas of HC search, prospecting and extraction in the Caspian Sea. Some of these methods were developed in the Center.

The following parameters are used as a criterion ($\mathbf{C_k}$) to estimate the quality of marine water and bottom sediments:

a) maximum permissible concentration (MPC, $\mathbf{C_l}$) of pollutants (P);

b) background concentration of pollutants ($\mathbf{C_f}$) and the difference between it and MPC ($\mathbf{\Delta_{lf}} = C_l - C_f$);

c) typical concentration of pollutants ($\mathbf{C_t}$) and the difference between it and MPC ($\mathbf{\Delta_{lt}} = C_l - C_t$);

d) characteristic concentration of pollutants ($\mathbf{C_{ch}}$) and the difference between it and MPC ($\mathbf{\Delta_{lch}} = C_l - C_{ch}$).

It should be noted that there're no quality guidelines for marine bottom sediments in the Russian Federation, so MPCs set by other countries are used for their quality assessment (estimation) if necessary.

The Russian term "background concentration" can have two different meanings. To set standards for discharges of harmful substances into the water bodies we use standard background concentration selected from the domain of maximum values in accordance with formally accepted methods. To characterize external pollution (of a water body or water area site) we use geochemical background concentration, which calculation methods are not clearly determined. To perform ensemble assessment (estimation) geochemical background concentration is applied, which is assumed as a median - a statistical sampling parameter, which is more stable.

The typical concentration (C_t) is assumed as average concentration of pollutants in any type of water or bottom sediments. Water types in the Caspian Sea are determined by salinity, and sediment types are determined by the content of silt (or organic carbon or iron). Characteristic concentration (C_{ch}) is assumed as average concentration in a local water body or a mass of bottom sediments. Local masses are visualized as "clouds" on the diagrams "temperature - salinity" (for marine water) or "sand - silt" (for bottom sediments).

At the first stage of the marine environment estimation the actual concentration of the $\boldsymbol{i}^{th}$ pollutant in the $\boldsymbol{j}^{th}$ point of the spatial - temporal continuum is compared to the criterion of marine quality estimation (we offer to denote the result of this comparison as $\mathbf{D_{ij}}$). Generally, three comparison methods are used: a) difference [a – b]; b) relative difference [(a – b)/b]; c) ratio [a /

b]. Without describing advantages and disadvantages of each of these methods we can say that we have used the third one (table 1).

Table 1

Methods used for comparing pollutants actual concentration with the criteria of marine environment quality estimation

##	Criterion	Comparison method
1	C_l	C_{ij} / C_l
2	C_f	C_{ij} / C_f
3	C_t	C_{ij} / C_t
4	C_{ch}	C_{ij} / C_{ch}
5	Δ_{lf}	$(C_{ij} – C_f) / (C_l – C_f)$
6	Δ_{lt}	$(C_{ij} – C_t) / (C_l – C_t)$
7	Δ_{lch}	$(C_{ij} – C_{ch}) / (C_l – C_{ch})$

At the second stage the obtained values Dij are averaged for the time series (T) and/or spatial field (S) by calculating the mean arithmetic (Xi) or mean geometric (Gi) value for each pollutant substance separately. This mode of averaging has been chosen because D_{ij} can take positive, zero and negative values and to compact the distribution of D_{ij}.

It should be noted that $G_i$is in fact an estimate of the marine environment quality, but it is mono-criterion and mono-parametric. To shift from mono-criterion to multi-criteria estimate, we should use a unified scale of five scores (table 2). The following stage is the calculation of the multi-criteria estimate $\mathbf{E_k}$value, where the scores obtained by different methods are summarized and divided by the number of the methods applied.

Table 2

A unified scale for interpreting mono-criterion estimates into multi-criteria estimates

Verbal assessment	Score estimate	Variation intervals $\mathbf{G_i}$			
		$\mathbf{G_i}$ to $\mathbf{C_l}$	$\mathbf{G_i}$ to $\mathbf{C_f}$	$\mathbf{G_i}$ to $\mathbf{\Delta_l}$*	
				If $\mathbf{C_l > \Delta_l}$	If $\mathbf{C_l < \Delta_l}$
Clean	**0**	$G_i \leq 1.0$	$G_i \leq 2.0$	G_i** ≤ 1.0	$G_i \geq 1.0$
Moderately polluted	**1**	$1.0 < G_i \leq 2.0$	$2.0 < G_i \leq 3.0$	$1.0 < G_i \leq 2.0$	$-1.0 \leq G_i < 1.0$
Polluted	**2**	$2.0 < G_i \leq 3.0$	$3.0 < G_i \leq 4.0$	$2.0 < G_i \leq 3.0$	$-1.0 \leq G_i < -3.0$
Dirty	**3**	$3.0 < G_i \leq 5.0$	$4.0 < G_i \leq 5.0$	$3.0 < G_i \leq 5.0$	$-3.0 \leq G_i < -5.0$
Very dirty	**4**	$G_i > 5.0$	$G_i > 5.0$	$G_i > 5.0$	$G_i < -5.0$

Note: Δ_l* means Δ_{lf} or Δ_{lt} or Δ_{lch}; ** G_i here can take negative values

At the final stage mono-parametric multi-criteria estimates E_{ki} are transformed into multi-parametric (combinatoric) estimate E_{kn} which is in fact an ensemble assessment of marine environment quality (E), as it comprises both combinatoric and multi-criteria estimates. To completely estimate marine environment quality, we recommend to introduce three types of E values: 1) $E_1 = E_{ki}/n$; 2) $E_2 = E_{ki}/N$; 3) $E = \max E_{ki}$, where n – is the total number of factors; N – is the number of factors, which $E_{ki} > 1$; max E_{ki} – is the maximum value of E_{ki}.

The results of the ensemble assessment (estimation) of the marine environment can be best presented as a matrix, which columns are criteria and rows are pollution factors. The number of criteria should be at least 3 and the number of factors - at least 5. The results (estimates) of the ensemble assessment are fractional. To compare verbal quality assessment and fractional and integer estimates (table 2) we use the scale presented in table 3.

Table 3

Scale for interpreting marine environment quality assessments and estimates.

Quality class	Verbal quality assessment	Fractional quality estimate
First	Clean environment	Less than 0.50
Second	Moderately polluted environment	ranging from 0.51 to 1.50
Third	Polluted environment	ranging from 1.51 to 2.50
Fourth	Dirty environment	ranging from 2.51 to 3.50
Fifth	Very dirty environment	More than 3.50

And another important point. The estimate (E), accepted in accordance with the above described procedure characterizes separately the quality of marine water and bottom sediments. As these estimates are expressed numerically, they can be easily joined in one (average) estimate of marine environment quality.