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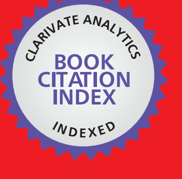

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Environmental, Medical, Technogenic and Computer Technology: Modeling, Risk Assessment and Cost/Benefit Analysis of the Accidents

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1. Introduction

The modern environmental technology or "green technology" is developed to have a possibility for the united computer assessment of the condition indexes, risks of the irreversible changes of the technogenic, ecological, bio- and medical systems and to evaluate its reserve possibilities. That technology allows us to estimate the condition and risks of the personal and population illness at the handling with consequences of the accident, for instance, with the radioactive wastes of the Chernobyl Alienation Zone, to estimate a cost\benefit ratio and to assess risks of the dangerous situations, to restore damaged data etc.

1.1 Mathematical Model of the Region

The method of restoring damaged data is based on decision of a task of the identification for the model of the region. The model of the region has potentially dangerous objects with the technologies of production of the useful products, utilization and elimination of the contamination to research the ecological and economical situation in the region suffered by the technogenic accident (Lyashenko I., Yanenko N., 1999), (Yanenko V. et al., 2006). The mathematical model is an open system with intake means and resources and outside – products and contaminations. The model consists of the following system levels: V_1 - money equivalent of the funds in the region, V_2 - money equivalent of the funds produced in the region (integrated products), Z – level of the environmental contamination, M - power of binding of the pollution, V^+ - flow of money resources to the region, Q – integral index for quality of life of the personal-liquidators of the technogenic accident.
The model is based on the following assumptions: decreasing level M is directed to transiting a part of Z to the free condition and to increasing the common level of contamination. V^+ includes money resources directed to restoring the resources (U_M), to liquidating the pollution (U_Z), to reproducing the base capital (U_V), to preventing migration of the pollution for bounds of the region (U_T), to decreasing risk of the illness of the liquidators (U_Q), to progressing the production technology of the useful products and

technology of the wastes utilization and elimination of the contamination (U_C). I_Z is a flow out of the region such as fire, floods, wind, ground water etc.
The model is:

$$Z_M = Z_M(M_0/M),\ \frac{dV_1}{dt} = -\frac{V_1}{T_V} + \frac{U_V V^+}{C_V(U_C)},$$
$$V_2 = \begin{cases} f_1(V_1), t < t_1 \\ f_2(V_1), t > t_1 \end{cases},\ \frac{dZ}{dt} = Z_V V_2 + Z_N Z_M - \frac{Z}{T_Z} - \frac{U_Z V^+}{C_Z(U_C)} - I_Z, \quad (1)$$
$$I_Z = I_N Z - \frac{U_T V^+}{C_T(U_C)},\ \frac{dM}{dt} = -M_N + \frac{U_M V^+}{C_M(U_C)},\ Q = Q_Z(\frac{Z_0}{Z})Q_M(\frac{U_0}{U_Q}),$$

where V^+ - a function determined on the base of empirical data analysis; $C_M = C_M(U_C)$ - cost of the unit of the power renewal of binding of the pollution; $C_Z = C_Z(U_C)$ - cost of the unit of the pollution elimination; $C_V = C_V(U_C)$ - cost of the unit of recovery funds; $C_T = C_T(U_C)$ - cost of the migration prevention of the pollution unit for bounds of the region; T_V - a period of the depreciation of the funds; T_Z - a period of the disintegration of the unit of the technogenic pollution is an integral parameter that includes a time of the natural disintegration and constants of the speed of the pollution transformation in the eco-systems; Z_V - speed of the pollution generation at the unit of the produced funds; Z_N - a normal speed of the pollution in depending of the resources condition generation; Z_M - a table function determined in a result of solution of the identification task; I_N - a normal speed of the flow generation of the pollution out of the region; M_N - a speed of the depreciation of the resources; t_1 - a time moment corresponding to the accident conditioned the technogenic catastrophe; $Q_Z(\frac{Z_0}{Z})$ - a table function that determinates a level of the illness risk of the personal that liquidate the consequences of the technogenic catastrophe; $Q_M(\frac{U_0}{U_q})$ - a table function that determinates a decreasing of the illness risk at the increasing of the part of means U_q .

Cost/benefit analysis is researched by the modeling of the ecological and economics situation in the region. The following functions are introduced:

1) The function of the cost caused by migration of the technogenic pollution out of the region, binding pollution inside of the region and increased risk of the illness of the liquidators and suffered by the accident:

$$L = l_Z Z + l_I I_Z + l_Q Q_Z \quad ,$$

where Z is a free pollution; I_Z - a flow of the pollution out of the region; Q_Z - a function that determinates a level of the liquidators illness of the technogenic consequences; l_Z , l_Z , l_Q are coefficients that normalize.

2) The function of benefit

$$P = L - L_{opt} + V^{+}(1 - U_M - U_Z - U_V - U_T - U_Q - U_C),$$

where L - a determent is a result of solution of the dynamic modeling task; L_{opt} - a determent is a result of solution of the task of the optimal control;

$$V^{+}(1 - U_M - U_Z - U_V - U_T - U_Q - U_C) \text{ - unused means.}$$

At the numerical decision of the system of the fundamental differential equations we use the method of Runge-Kutt of the 4th array.
Target setting. The mathematic model (1) is given. The given sample consists of the values that correspond to the variables of the model within the time $[t_1, t_k]$:

$$\left\{X_i^j = X_i(t_j)\right\}, i = \overline{1..N}(N = 7), j = \overline{1..M}(t_j \in [t_1, t_k]),$$

where X_1^j corresponds to the value V_1 (money equivalent of the funds in the region) at the time t_j; X_2^j corresponds to the value Z (pollution of the technogenic nature); X_3^j corresponds to the value M (power of binding of the pollution); X_4^j corresponds to the value V^{+} (flow of money resources); X_5^j corresponds to the value V_2 (money equivalent of the funds produced in the region); X_6^j corresponds to the value I_Z (pollution flow out of the region); X_7^j corresponds to the value Q (index for illness of the liquidators of the technogenic accident).
The particularity of the given sample is that some parameters of the model are not determined at the time moments. Let us point as A is a lot of ordered pair of the indexes $\langle i, j \rangle$ for that the values X_i^j are determined.
The parameters of the model are given

$$D_i = D_i(t), i = \overline{1..K}(K = 8),$$

where D_1 is a value of the coefficient U_M (money resources directed to restoring of the resources); D_2 is a value of the coefficient U_Z (a part of the costs that is directed to changing a free pollution to the connected condition); D_3 is a value of the coefficient U_V (a part of the costs that is directed to reproducing the base capital); D_4 is a value of the coefficient U_T (a part of the costs that is directed to preventing migration of the pollution out of the region); D_5 is a value of the coefficient U_Q (a past of the costs that is directed to decreasing risk of the illness of the liquidators and suffered); D_6 is a value of the coefficient U_C (a part of the cost that is directed to progressing the production technology of the useful products and technology of the wastes utilization and elimination of the contamination); D_7 is a value of the function V^{+} (flow of the costs); D_5 is a value of the function V^{+} that determines a flow of the costs; D_8 is a value of the function V_2 that determines the money equivalent of the funds produced in the region.

Each parameter $D_i = D_i(t), i = \overline{1..K}$ is shown as the polynomial of the 3rd range: $D_i(t) = d_{0i} + d_{1i}\tau + d_{2i}(1-\tau)\tau + d_{3i}(\tau-1)\tau^2$, where $\tau = \dfrac{t - t_1}{t_K - t_1}$.

The area of the parameters of the model is given: $\vec{X}(t) \in X^{'}$ and limits to the control influence $\vec{D} \in D^{'}$, where $\vec{D} = (D_1,...,D_K)$. The value $\vec{X}_1 = \vec{X}(t_1)$ at the time moment t_1 is given. It's a task to define a value $d^*_{1i}, d^*_{2i}, d^*_{3i} (i = \overline{1..K})$ that reaches to the minimum of the derivation in contents of the mean square values of sample $\left\{X_i^j = X_i(t_j)\right\}, i = \overline{1..N}, j = \overline{1..M} (t_j \in [t_1, t_k])$ from the results given by model (1) $\left\{\overline{X}_i^j = \overline{X}_i(t_j)\right\}, i = \overline{1..N}, j = \overline{1..M} (t_j \in [t_1, t_k])$, e.g.

$$\sqrt{\sum_{i=1}^{N} \sum_{\substack{j=1 \\ \langle i,j\rangle \in A}}^{M} \left(\frac{X_j^i - \overline{X}_j^i(\overline{D^*})}{X_j^i} \right)^2} = \min_{\substack{\vec{X}(t) \in X \\ \vec{D} \in D^{'}}} \sqrt{\sum_{i=1}^{N} \sum_{\substack{j=1 \\ \langle i,j\rangle \in A}}^{M} \left(\frac{X_j^i - \overline{X}_j^i(\overline{D})}{X_j^i} \right)^2} .$$

1.2 Results

The modified method of the accidental search is a method of statistic gradient that used for the numerical result of the identification task of the model parameters. There were used data from works (Baloga V., Kholoscha V., et al., 2006) at the preparation of the information to modeling of the technogenic and eco-safety. The data were defined more precisely after the decision of the identification task. The result of the model parameters analysis is given in the Table 1 where U_V - a part of the costs that is directed to reproducing the base capital; U_Z - a part of the costs that is directed to liquidating pollution; U_T - a part of the costs that is directed to preventing migration of the pollution out of the region; U_R - a part of the costs that is directed to restoring the resources; U_C - a part of the cost that is directed to progressing the production technology of the useful products and technology of the wastes utilization and elimination of the contamination; U_Q - a past of the costs that is directed to decreasing risk of the illness of the liquidators and suffered by the technogenic accident; V^+ - flow of the costs, mln. fixed unit; I_N - a speed of the flow generation of the pollution out of the region; C_M - cost of the unit of the power renewal of binding of the pollution; fixed unit; T_V - an average period of the working term of the power of binding resources, year; V_1 - a summary cost of the main industrial funds, mln.fixed unit.

Year	Parameter of the model										
	U_V	U_Z	U_T	U_R	U_C	U_Q	V^+	I_N	C_M	T_V	V_1
1991	0.13±0.02	0.1±0.02	0.4±0.15	0.25±0.08	0.05±0.02	0.05±0.02	-	0.01±0.002	50±15	30±10	700±60
1992	0.1±0.02	0.03±0.01	0.48±0.16	0.25±0.08	0.05±0.02	0.05±0.02	600±50	0.02±0.004	50±15	30±10	680±60
1993	0.08±0.02	0.02±0.01	0.51±0.17	0.25±0.08	0.05±0.02	0.05±0.02	600±50	0.02±0.004	50±15	30±10	640±60
1994	0.07±0.02	0.02±0.01	0.51±0.17	0.26±0.08	0.06±0.02	0.06±0.02	650±60	0.02±0.004	50±15	35±15	620±60
1995	0.08±0.02	0.05±0.02	0.48±0.16	0.27±0.08	0.06±0.02	0.06±0.02	750±60	0.01±0.002	60±20	40±15	600±50
1996	0.08±0.02	0.05±0.02	0.41±0.15	0.26±0.08	0.06±0.02	0.06±0.02	800±60	0.01±0.002	60±20	40±15	560±50
1997	0.09±0.02	0.07±0.02	0.4±0.15	0.25±0.08	0.06±0.02	0.07±0.02	890±60	0.01±0.002	60±20	50±15	530±50
1998	0.1±0.02	0.08±0.02	0.35±0.12	0.25±0.08	0.07±0.02	0.07±0.02	930±70	0.01±0.002	60±20	50±15	500±50
1999	0.1±0.02	0.09±0.02	0.32±0.10	0.25±0.08	0.07±0.02	0.08±0.02	900±70	0.009±0.002	60±20	50±15	480±50
2000	0.1±0.02	0.1±0.02	0.30±0.10	0.24±0.07	0.07±0.02	0.08±0.02	850±60	0.009±0.002	60±20	45±15	450±40
2001	0.1±0.02	0.1±0.02	0.28±0.10	0.22±0.07	0.07±0.02	0.09±0.03	800±60	0.009±0.002	60±20	45±15	450±40
2002	0.1±0.02	0.08±0.02	0.26±0.10	0.21±0.07	0.07±0.02	0.10±0.03	820±60	0.009±0.002	70±20	45±15	400±40
2003	0.1±0.02	0.07±0.02	0.24±0.08	0.19±0.06	0.08±0.02	0.12±0.03	850±60	0.009±0.002	70±20	40±15	380±40
2004	0.1±0.02	0.06±0.02	0.22±0.08	0.17±0.06	0.08±0.02	0.14±0.03	880±60	0.009±0.002	70±20	40±15	360±40
2005	0.1±0.02	0.05±0.02	0.20±0.08	0.15±0.05	0.05±0.02	0.17±0.03	890±60	0.01±0.002	70±20	40±15	320±40

Table 1. The result of the mathematical model parameters analysis for modeling of the technogenic, ecological and medical safety

The results of the modeling, redistribution of the means allow us to increase the quality of life and cost\benefit ratio on the interval from 2002 to 2010. At the same time and on the same interval we have an increasing the pollution connected with decreasing a part of the means directed to liquidating consequences of the technogenic catastrophe and increasing a part of the means directed to increasing risk of illness of the liquidators of the consequences of the technogenic catastrophe.

2. Risk Assessment of the Extreme Situations Occurrence on the Object "Ukrytie" (Shelter) in the Chernobyl Alienation Zone

2.1. The main idea of the method. Overall risk assessment of the extreme situations occurrence was researched on the base of theory of statistic functions. But some aspects of the quantitative calculations of risks need to be improved in further because of the difficult conditions of absence of the initial data and statistically represented samples. The main idea of the method is to present all parameters of the potentially dangerous object in a form of the dynamic system; to reduce the system to one equation that presents a surface of the three-dimensional area to an universal deformations of the theory casp catastrophes (I.V.Sergienko et al., 2000), (Yanenko V.M., 2003). There are sub surfaces that have stable and unstable positions of the balance. In the parametric area the distance between trajectory of the current condition of the potentially dangerous object and limit of stable and unstable position of the balance is a measure of risk of extreme situations occurrence.

2.2. Computing and modeling technology of solving the problem of quantitative risk assessment of extreme situations occurrence and assessment of nuclear safety of the object "Ukrytie". To solve the problem quantitative risk assessment of extreme situations occurrence and assessment of nuclear safety we have developed mathematics and software for blocks "Modeling" and "Forecasting" to join a technological and computing link. The link is a sort of information conveyor where are linked the problem-oriented program modules for risk assessment of extreme situations, on example of handling with radioactive waste on the potentially dangerous object "Vector" in the Chernobyl Alienation Zone. At the same time we need to improve mathematic tools to join data of monitoring using a vector map of the Alienation Zone (geo-information technology) with information about of pollution level of radionuclides 137Cs and 90Sr. The vector map of the Alienation Zone is used on the stage of data preparation for risk assessment of the technogenic and ecological accidents in the Chernobyl Alienation zone.

To solve the problem quantitative risk assessment of extreme situations occurrence let us remind of some states. According to general note, the base of safety of the objects of nuclear power composes: a) safe construction and quality of the objects of nuclear power; b) appropriate and safe maintenance of the objects of nuclear power minimizing risk of extreme situations occurrence; c) possibility of realizing the technical measures minimizing negative consequences of extreme situations on the objects of nuclear power if they still occur. The majority of experts working on the problem of the liquidation of the Chernobyl catastrophe consequences consider that the object "Shelter" doesn't answer safety characteristic and represents the greatest threat for nuclear safety among all objects of the Alienation zone (Yanenko V. et al., 2003).

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The following factors make the main contribution to such an unsuccessful situation, first of all, progressive wear of building constructions of the object “Shelter”, secondly, destruction processes proceeding in the fuel-containing masses and, at last, the threat of fire connected with plenty of easily inflammable materials in the object “Shelter”.
Mass gush of a radioactive dust outside the object “Shelter” will take place with disastrous radiation consequences in case of extreme situation occurrence, caused by any of the above-listed reasons, namely: a) disturbance of the object “Shelter” shell (including the destruction of carrying constructions and roof), b) transition of radionuclides from the binding state to sliding dust particles, c) gush of aerosols.
The values of parameters are constantly varying, characterized as a state of the fuel-containing masses, contained in the object “Shelter”, and its shell state, when because of inaccessibility to the most places for measuring and stochastic character of the transformation of nuclear power are occurred the deficit of the objective information. In these conditions the task of decreasing the degree of uncertainty with regard to the developing the joined technological and calculation link for risk assessment and ranking of extreme situations becomes of prime importance.
The international committee for radiological defense introduced the conception “RISK” and “COST” as the third principle of the radiological safety to quantitative definition of danger factors. The ecological risk is a possibility of unfavorable consequences for ecological resources any anthropogenic changes of nature objects and factors. The international committee for radiological defense formulated the principal “ALARA” that means construction and waste of sources and connected with it the practice activities must guarantee as the lowest irradiation as the most it’s possible practically with regard to social and economical factors.

Traditionally the quantitative risk assessment is a multiplication of size of the event (P) and measure of possibilities its realization (q):

$$R = \sum_{i=1}^{k} P_i q_i \quad .$$

The size of consequences can be presented by the number of the killed at the accident or by cost form, and a possibility can be presented by the number of the accidents at the unit of time.
In numerous works connected with various aspects of the Chernobyl catastrophe risk assessment is based on the application of probability theory methods. Thus the authors should meet with difficulties of authentic probability assessment not only because of the incompleteness of the sample, but also more often because of the complete absence of the information, owing to the impossibility of taking measurements in some premises of the object “Shelter” which are inaccessible because of a high radiation level. Besides, there are some methodological difficulties stipulated first of all by uniqueness of the event – accident on the nuclear power plant, by virtue of which it’s impossible to calculate probability of the event on the basis of statistical data processing.
As an example can be a results connected with calculation of probability of the roof destruction of the object “Shelter” made by Research institute for building constructions. Their main hypothesis is that if the object “Shelter” has stood under loadings without

destruction for 10 years so Shelter will stand under the same loadings and further, and its probability is 0.1.
To except such difficulties another approach to risk assessment was developed. The approach is based on methods of theory of caspoidal catastrophes (Poston T., Stuart I., 1980), (Guastello S.J., 1981). The risk is estimated on a degree of approximation of system parameters to their bifurcation values, which characterize system transition from one state (norm) to another one (catastrophe). The realization of this approach allows us not only the assessment of the risk of extreme situations occurrence, but also the receiving the quantitative characteristic of reserve possibilities of the system and its components.
The obtained calculations allow us to describe the current state of the system by ranking the set of the risks of extreme situations occurrence into their separate links, and by that to find the "weakest" link, the strengthening of which is necessary to direct main efforts.
By using this method, the probability account of the Shelter's roof collapse will be based on parameters of separate elements of building construction the most sensitive to earthquakes, tornadoes and other natural cataclysms, which are close to critical values (exhaust tower of the block "C", supports of beams B1 and B2, the southern shields – between axes B-C, the western zone of the object t "Shelter").

3. Risk Assessment and Ranking Risk Systems

Modeling and assessment of levels of risk occurrence of ecological and technogenic catastrophes for concrete potentially dangerous object – object "Shelter". The task of risk assessment of extreme situations occurrence is presented in terms of the theory of caspoidal catastrophes using the universal deformation type "swallow's tail". It's necessary to research a state of the safety of the system of the object "Shelter" to the effect of different factors: within the model – the universal deformation type "swallow's tail", which has three steady states. We have to research a balance of one from them at the defined parameters. There is defined the safety state of the system of the object "Shelter" after estimation of the balance of one from the states.
3.1. To assess the risk of extreme situations occurrence in the Alienation zone let us consider the first state (state 1) corresponds to a regular situation in the Alienation zone. The second state (state 2) is an occurrence of some local extreme situations, which do not result to a growth of radiation pollution levels outside of the Alienation zone. The third state (state 3) corresponds to extreme situations occurrence, which results to growth of radiation pollution level outside of the Alienation zone.
The biggest threat for the Chernobyl Alienation zone safety is the object "Shelter". Thus, let us base on that the threat of the Alienation zone safety disturbance is connected, on the one hand, with a state of elements of building constructions in the Shelter (subsystem A), and, on the other hand, with destruction processes, proceeding in fuel-containing masses (subsystem B). But the safety level also depends on flows of radionuclides from different sources (subsystem C) and human factor (subsystem D).
According to the universal deformation type "swallow's tail" the risk of extreme situations occurrence is described by the following equation:

$$\frac{dX}{dt} = X^5 + AX^3 + BX^2 + CX + D \quad , \tag{2}$$

Where coefficient A includes the integral expert parameters assessments of type – state of support beams B1 and B2, state of the western zone, state of the southern shields between axes B-C, state of block B;

- coefficient B is estimated on the base of the following parameters – activity of radioactive waste in fuel-containing masses, activity of radioactive waste in the air, activity of the water samples in wells;
- coefficient C is estimated on the base of the following parameters – efficiency of the protective systems of the Shelter, condition of the dams and systems of flood control, condition of the system of the radioactive monitoring, condition of fire-prevention devices, a level of the technologies, a level of the capital investments;
- coefficient D is estimated on the base of the following parameters –a level of staff qualification, state of work condition and labor payment. We use a point estimation based on expert conclusion at the estimating values of the parameters.

Let the system, presenting a condition of the Shelter, be at norm (state 1). There are trajectories of change of its parameters, which pass the system at first in state 2 (local extreme situations, not causing pollution growth outside of the Alienation zone), an then in state 3 (extreme situations that result in pollution growth outside of the Alienation zone). Also there are trajectories immediately passing the system from state 1 to state 3. If the initial state of the system corresponds to state 2 or 3, the trajectories that return the system to state 1 (normalization of ecological radiation situation) can be determined. Thus, the task of risk assessment of the extreme situations occurrence can also be formulated to define a concrete stationary state in the model (2). For that can be used:

1) The values of the parameters corresponding to the current state of the system are determined.
2) The array of their bifurcation values corresponding to changes of number of stationary states is determined.
3) The 4th dimensional vector of distance $R_i, i=\overline{1,...,4}$ from an initial state of the system up to surfaces, which divide parameter areas corresponding to different number of stationary states is determined.
4) The risk value $Risk_i, i=\overline{1,...,4}$ is determined as the ratio of this vector to a vector describing appropriate distance in norm $R_i^{(N)}, i=\overline{1,...,4}$, as follow:

$$Risk_i = R_i \big/ R_i^{(N)}, i=\overline{1,...,4}\,. \tag{3}$$

5) The reserve values $res_i, i=\overline{1..4}$ is determined as distances from the initial state of the system up to surfaces, which divide the parameter areas corresponding to different number of stationary states.

The index of the state is calculated for every subsystem.

The state index of the subsystem "A" is calculated by:

$$I_A = \frac{1}{4}\sqrt{\sum_{i=1}^{4} a_i (X_i - X_i^{\blacklozenge})^2} \ ,$$

where I_A is an index of the subsystem "A", X_1 - estimation of the condition of beams support B1 and B2, X_2 - estimation of condition of the western zone, X_3 - estimation of condition of the southern screens between axes B-C, X_4 - estimation of the condition of the block B, $X_i^{\blacklozenge}$ - values of the appropriate parameters in a norm, $a_i\,(i = \overline{1..4})$ - norm coefficients.

The state index of the subsystem "B" is calculated by:

$$I_B = \frac{1}{3}\sqrt{\sum_{i=1}^{3} b_i (X_i - X_i^{\blacklozenge})^2} \ ,$$

where I_B is an index of the subsystem "B", X_1 - estimation of activity of the radioactive waste in the fuel-containing masses, X_2 - estimation of activity of the radioactive waste in the air, X_3 - estimation of activity of the water samples in wells, $X_i^{\blacklozenge}$ - value of the appropriate parameters in a norm, $b_i\,(i = \overline{1..3})$ - norm coefficients.

The state index of the subsystem "C" is calculated by:

$$I_C = \frac{1}{4}\sqrt{\sum_{i=1}^{4} c_i (X_i - X_i^{\blacklozenge})^2} \ ,$$

where I_C - is an index of the subsystem "C", X_1 - estimation of the condition of efficiency of the protective systems of the Shelter, X_2 - estimation of the condition of dams and systems of flood control, X_3 - estimation of the condition of the radiological monitoring systems, X_4 - estimation of the condition of fire protection devices, $X_i^{\blacklozenge}$ - value of the appropriate parameters in a norm, $c_i\,(i = \overline{1..4})$ - norm coefficients.

The state index of the subsystem "D" is calculated by:

$$I_D = \frac{1}{4}\sqrt{\sum_{i=1}^{4} d_i (X_i - X_i^{\blacklozenge})^2} \ ,$$

where I_D - is an index of the subsystem "D", X_1 - estimation of the technology level, X_2 - estimation of the investments, X_3 - estimation of the staff qualification, X_4 - estimation of the payments and condition of work, $X_i^{\blacklozenge}$ - value of the appropriate parameters in a norm, $d_i\,(i = \overline{1..4})$ - weight coefficients.

3.2. Modeling and risk assessment of extreme situations occurrence on the Shelter. Let us consider the results of the modeling and risk assessment of extreme situations occurrence with help of the method and software – the subsystem "Risk assessment of extreme situations occurrence on the Shelter. These results have been obtained at the solution of control examples for mathematics modeling and risk assessment of extreme situations occurrence in the Alienation zone. The results have a general type and can be used for the same type of potentially dangerous object. Let us use the input data from the Table 2 for solution of two examples.

The results of the modeling are presented in the Table 3, where state is a current stat of the system, risk is a summary risk of conversion in the state 3, $I_i, i = \overline{1,...,4}$, I are indexes of the states of the subsystems, $R_i, i = \overline{1,...,4}$ are risks of conversion for subsystems to the state 3, $rez_i, i = \overline{1,...,4}$ – reserve values for the subsystems.

Subsystem	Parameter	Task No.1	Task No. 2
A	Condition of beams support B1 and B2, points	8	7
	Condition of the western zone of the Shelter, points	8	6
	Condition of the southern screens between axes B-C, points	8	6
	Condition of the block B, points	8	6
B	Activity of the radioactive waste in the fuel-containing masses, points	4	3
	Activity of the radioactive waste in the air, points	4	3
	Activity of the radioactive waste in the water samples in wells, points	4	3
C	Efficiency of the protective systems of the Shelter, points	7	7
	Condition of the dams and systems of flood control, points	5	5
	Condition of the radioecological monitoring systems, points	6	6
	Condition of the fire protection devices, points	6	6
	Technology level, points	7	6
	Level of the investments, points	8	6
D	Level of staff qualification, points	8	8
	Condition of payments and condition of work, points	7	6

Table 2. Input parameters for examples No.1-2

The values of reserves $res_i, i = \overline{A,...,D}$ are determined as a distances from the current state up to the surface that divide the area of the parameters corresponding to change of the number of stationary states $res_i = \left|R^*_i - R_i\right|, i = \overline{A,...,D}$.

Current state	Risk	Systems of the parameters											
		Subsystem A			Subsystem B			Subsystem C			Subsystem D		
		IA	RA	rezA	IB	RB	rezB	IC	RC	rezC	ID	RD	rezD
1	0.004	0.1	0.0	-	0.2	0.0	-	0.2	0.0	-	0.2	0.004	0.005
2	0.008	0.2	0.0	-	0.1	0.0	-	0.2	0.0	-	0.2	0.008	0.003

Table 3. The results of the control examples o risk assessment for conversion to the state 3

As we see from the examples No.1 and 2, the main factor at the given set of input data, having influence to the extreme situations occurrence, a is state of the subsystem D (technology level, level of the investments, level of staff qualification, condition of payments and condition of work). The decreasing the protection level of the Shelter that at the same time corresponds to decreasing the technology investment levels, level of staff qualification, condition of payments and condition of work leads to double increasing risk of extreme situations occurrence from 0.004 to 0.008.

4. Research of Risk Ranking of the Various Technogenic Accidents on the Potentially Dangerous Objects and its Medical and Ecological Consequences

The models of faultness of the technological systems on the potentially dangerous objects depend on its destination and conditions of use. There are known more than ten models of faultness at the handling with the radioactive waste. The base of them is the first exponential model of distribution of duration of Mean Time Between Failures that leads to the extreme situations occurrence. That model is correct to Poisson flow of failures.

With help of developed software it was performed a risk ranking of the various technogenic operations at the disposal and conservation of the radioactive waste.

The results of risk ranking research of the various technogenic operations are presented in Table 4.

Elements of scheme of processing radioactive waste - hard radioactive waste	Rank	Elements of scheme of processing radioactive waste – liquid radioactive waste	Rank
Mechanisms of giving of hard radioactive waste	1.0	Mechanisms of receiving of liquid radioactive waste	1.0
Bunkers for substances	0.98	Mechanisms of mechanical depuration	0.98
Batchers	0.7	Filter-press	0.9
Devices for mixing	0.85	Devices of cementation	0.9
Devices of steam heating	0.84	Evaporator	0.8
Temperature press	0.79	Condenser of steam	0.7
Mechanisms of packing	0.6	Pressing mechanisms	0.82
Loaders	0.5	Mechanisms of packing in plastic	0.95
Mechanisms of packing in plastic	0.5		

Table 4. The results of risk ranking research

4.1. Research and risk assessment of personnel illness on the potentially dangerous object. We will perform the research and assessment on example of risk assessment of illness occurrence of personnel of the Chernobyl Alienation zone at the possible safety violation at the handling with the radioactive waste.
At the same time, we have to calculate of the additional irradiation that the personnel get at the handling, shuttling and transportation of the radioactive waste at the extreme situations.
The situations connected with handling and shuttling of the radioactive waste can be divided to three groups: D1 - accident-free handling and shuttling, D2 - accident leaded to partial damage of the part of containers without ground pollution; D3 - accident leaded to atmosphere and ground pollution.
General additional dose of radiation that the personnel gets at the transportation, shuttling and storage of the radioactive waste - D, is calculated by:

$$D = D1 + D2 + D3, \quad (4)$$

where D1, D2, D3 are calculated from (5), (6) and (8).

Consideration of the additional factors that define the level of the catastrophe weight from that depends the quantity of the radioactive waste from the containers at the transport catastrophe, allows us calculate the parameters k3 and k2 . Those are practically possibilities of appropriate catastrophes. To the number of such factors can be taken the followings: speed of collision, fire, angle of blow, meteorological condition, relief etc.
The calculation of risk of illness occurrence after received the additional radiation dose is obtained by (Yanenko V.M., 2003) and by additional coefficients:

$$R\ il = Kr*D, \quad (5)$$

where Kr is an additional coefficient of risk (see Table 5); D is received dose (Gr) (see formula (4)).

Tissues	Additional coefficient of risk (1e-2 1/Zv)	Weight factor
Gonads	0.40	0.25
Mammary gland	0.25	0.15
Red bone marrow	0.20	0.12
Lungs	0.20	0.12
Thyroid gland	0.05	0.03
Bone surface	0.05	0.03
Other	0.50	0.30

Table 5. Additional coefficients of risk calculation Kr of tumor with death or with inherited effects of person of any sex and age

Additional coefficients of risk Kr for some illnesses: - leukemia - 1 e^{-8} 1/Zv; death from cancer - 4 e^{-5} 1/mZv; - cancer - 0.8 e^{-5} 1/mZv; death from cardiovascular diseases - 4 e^{-5} 1/Zv; worsening of inheritance - 8 e^{-6} 1/mZv.

4.2. Modeling of distribution of the radioactive waste release in result of the accident without fire and explosion. Let us consider the task solution of mathematical modeling of distribution of the radioactive waste at the following set of input data (example No.1): type of explosion – gas substance, radionuclide Cs137, duration of the accident – 40 hours, speed of the wind – 0.5 m/s; activity of the explosion – 100 Bk/z; modeling is performed on the section of the area 3000×400 m. The screen form with results of the modeling is presented on the Figure 1. In the point of observation density of pollution is 1.2*104 Bk/sq.m, individual dose is 1.0*10-3 Zv. The risks of diseases occurrence: Leukemia - 1.0*10-8, Cancer - 8.1*10-6, Death from cancer - 4.0*10-5, Worsening of inheritance - 8.1*10-6. The risks of tumor occurrence with death results and inherited effects: Honads - 4.0*10-6, Mammary gland - 2.5*10-6, Red bone marrow - 2.0*10-6, Lungs - 2.0*10-6, Thyroid gland - 5.1*10-7, Bone surface - 5.1*10-7, other - 5.1*10-6.

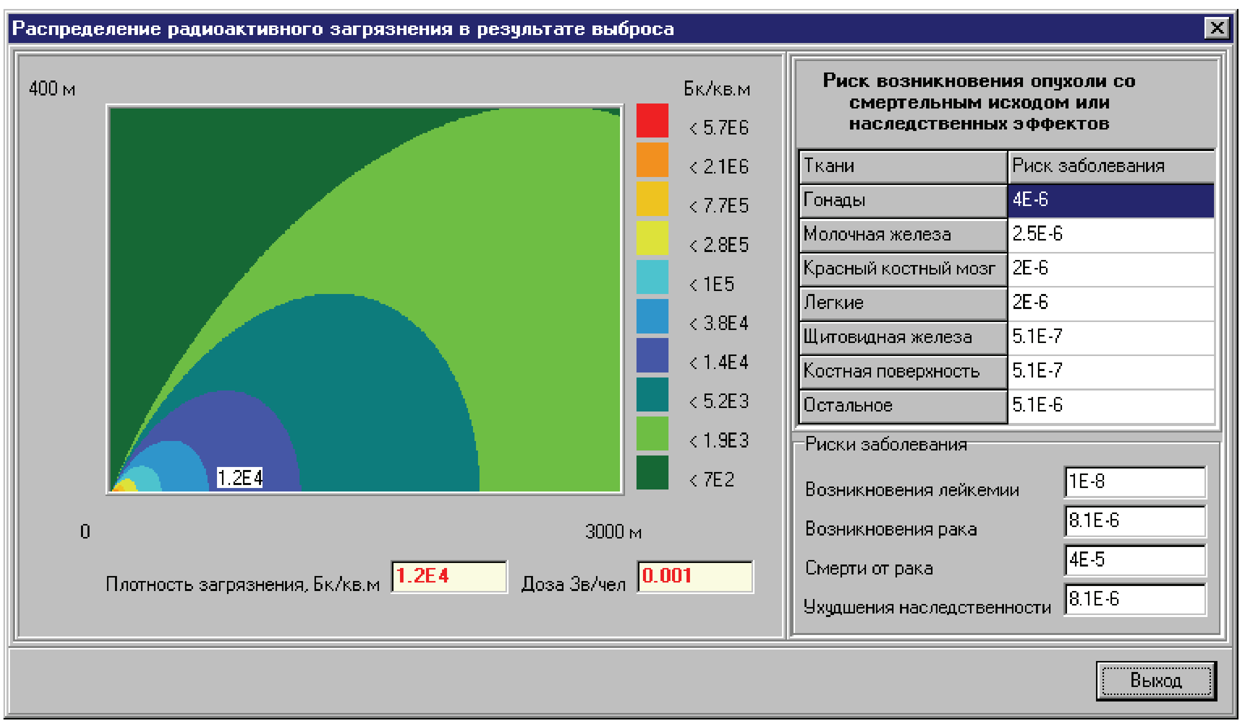

Fig. 1. Screen form with results of the modeling for task No.1

5. Medical and Cybernetics Systems

5.1. Software and information technologies allowed one to research the condition, reserves and risks of illness of the liquidators of the catastrophe under the influence of the negative factors of the Chernobyl catastrophe.

The traditional register of changes only conservative values of the parameters of cardiovascular system and system of regulation of protective functions of organism to the object doesn't give all-round estimation of possible self-healing of the subject, their reserve possibilities and risk assessment of the pathological changes of different systems of regulation of the organism.

To make the process of decision making more effectively it should be noticed the dynamic characteristics of the subject including the estimation of the irreversible changes and the estimation of reserve possibilities of the investigated object.

According to the traditional approach it's required to reduce the dynamic models of cardiovascular system and system of regulation of protective functions of organism to the feature of smooth reflection "swallow's tail" of the universal deformation in the theory of casp catastrophes. Then there are investigated the types of steady functioning of the systems and initial conditions of the system up to surface divided area of the parameters that correspond to changes of the number of stationary conditions.
Lets' base on that condition of the initial models after the reduction to the model "swallow's tail" is given by (3), where the parameters of the 4th subsystems correspond to: A – energetic subsystem, B - immune, C – myeloid and D – cardiovascular.
The task of reserve possibilities assessment and risk of the pathological changes in cardiovascular and regulation immune systems lead to estimation of characteristics of the stationary conditions (3) and others.
The results of the risk modeling are presented in the Table 6, where S is the current condition of the system, P is the summary risk of conversion to the condition of pathology, I is an index of subsystem condition, R is a risk of conversion for appropriate subsystem in the condition of pathology, Res is a value of reserve for the appropriate subsystem.

No	S	RISK	Subsystems											
			Subsystem A			Subsystem B			Subsystem C			Subsystem D		
			IA	RA	RezA	IB	RB	RezB	IC	RC	RezC	ID	RD	RezD
1	Norm	0.22	0.0	0.0	0.12	0.0	0.0	-	0.03	0.22	0.1	0.09	0.0	-
2	Norm	0.50	0.44	0.0	-	0.0	0.0	-	0.03	0.0	-	0.14	0.50	0.138

Table 6. Results of the indexes of conditions, reserves of the subsystems and risk the cardiovascular diseases

As it's shown in the control examples the main factor that defines the risk of the cardiovascular disease is the condition of the subsystem C (condition of the blood system). In that case the risk of pathology equals to 0.22. In case of another set of data the main factor is the subsystem D (cardiovascular system) with insignificant worsening of the parameters of the energetic system. The risk of the cardiovascular disease increases more then two times and equals to 0.50.
5.2. The research of the neuro-immune and endocrine regulation and system of regulation of protective functions of organism let us develop the software to restore damaged data for risk assessment of illness and for forecasting some processes (Yanenko V.M. et al., 2006).
Mathematical modeling of the neuro-immune and endocrine regulation. To provide the mathematical modeling of the condition of the system of neuro-immune and endocrine regulation the data of five patients have been chosen. The condition of immune system of the patients is characterized by indexes in the Table 7. The indexes of peripheral blood are presented in the Table 8. The results of hormone research are presented in the Table 9.

Parameter	Number of the patient				
	1	2	3	4	5
Lymphocytes, %	30	60	42	40	48
T-lymphocytes, %	50	80	60	80	70
T-active lymphcytes, %	30	50	30	50	50
T-helpers, %	35.3	50	28	50	55
T-suppressors	20	35	12	30	30
Coefficient helper/suppressor	1.8	1.7	2.3	1.7	1.9
B-lymphocytes, %	20	85	35	45	45
Ig, g/l	2	4	2.5	4	4
Ig, g/l	2	2.5	1	2.5	2.5
Ig, g/l	10	17.5	15	15	10
Ig, g/l	0.05	1.75	0.05	1.0	0.8

Table 7. The indexes characterizing the condition of immune system of the patients

Parameter	Number of the patient				
	1	2	3	4	5
WBC – leucocytes, 109/l	6	9.4	8.2	7	7
RBC – erythrocytes, 1012/l	4	6	5	6	5
HGB – hemoglobin, g/l	120	175	140	110	115
PLT – platelet, 109/l	247	550	350	500	450
LYM – lymphocytes, %	35	70	42	60	50
MO – monocytes, %	5	5	5	4	4
Eosinophils, %	2	4	4	3	4
Stab, %	3.6	5	5	5	4
Segmentonuclears, %	51	60	60	55	55
SOE, mm/hour	10	12	12	12	14

Table 8. The indexes of peripheral blood of the patients

Parameter	Number of the patient				
	1	2	3	4	5
TTG, med/l	2	20	1	1.25	1.5
T-4, nmol/l	90	35	242	85	245
T-3, nmol/l	1.8	0.8	5.7	6	2
FT – 4, pmol/l	15	12	21	15	21
FT - 3, pmol/l	4	6	7	7	5
r – 3, pmol/l	0.65	0.5	0.5	0.4	0.6
KT, pg/mol	240	300	350	300	300
TSG, mkg/mol	18	20	22	20	22
AKTG, pg/mol	50	65	40	40	35
Cortisol, nmol/l	290	300	340	320	330

Table 9. The indexes of the endocrine system condition of the patients

The numerical experiments were performed. The screen form with predicted dynamics and with appropriate dynamics obtained in the result of the task of optimal control is presented for the patient No.2 on the Figure 2 . The screen form with graphics of control influences (activators of oxidative phosphorylation (U1), activators of calcium transportation (U2), level of iodine (U3)) obtained in result of the optimal control is presented for the patient No.2 on the Figure 3. The screen form with risk assessment of pathological changes is presented for the patient No.2on the Figure 4.
The results of risk assessment are presented for the patient No.2 in the Table 10.

Pathology	Risk predicted	Risk obtained in result of task of optimal control
Hypothyroidism	1.0	0.41
Hyperthyroidism	0.02	0.09
T3- thyrotoxicosis	0.03	0.11
T4- thyrotoxicosis	0.04	0.14

Table 10. The results of risk assessment of pathological changes for the patient No.2

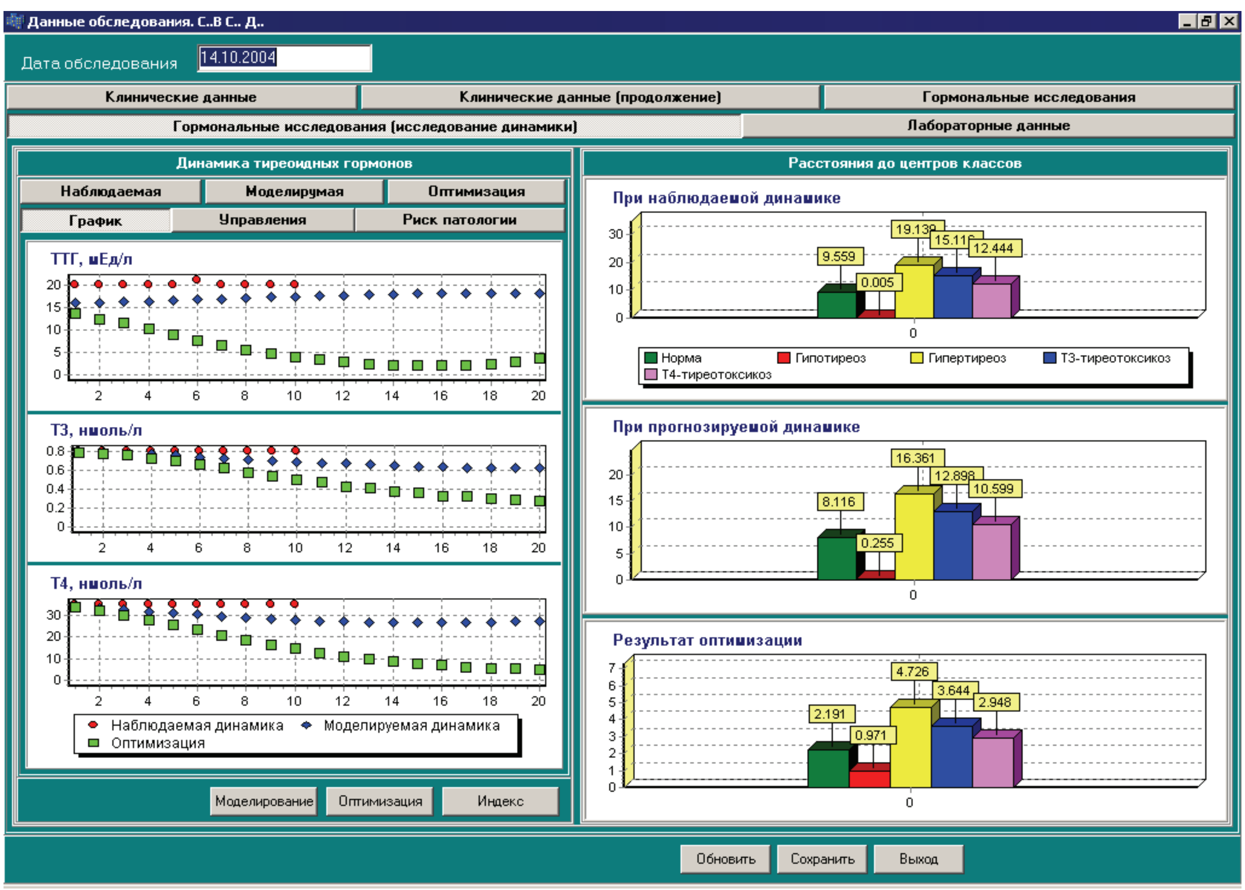

Fig. 2. The form "Research Data", subsection "Hormonal research (research of dynamics)", page "Graphic". .for the patient No.2

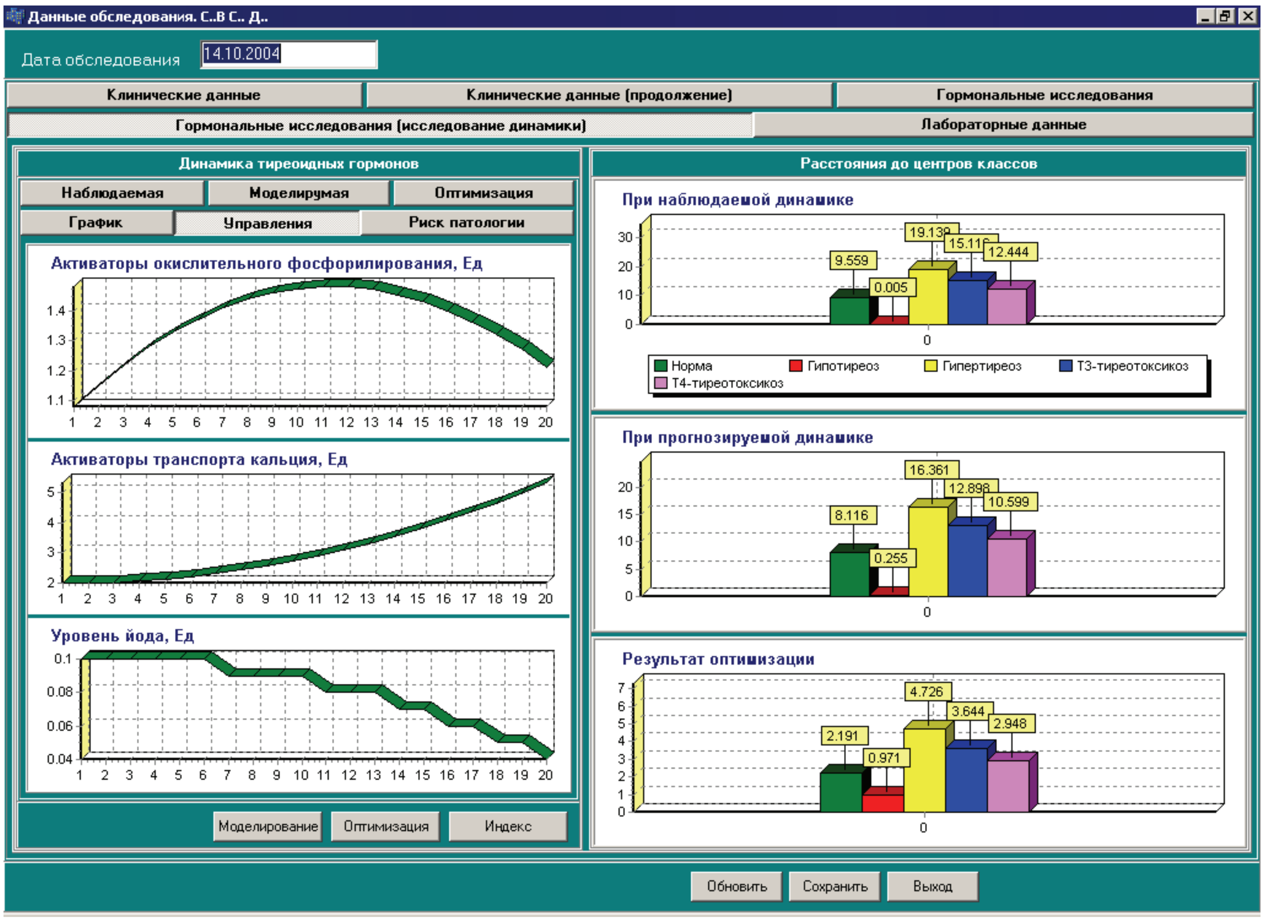

Fig. 3. Screen form with graphics of the control influences obtained in result of task of optimal control ofr the patient No.2

Thus, the condition of the patient No.2 is characterized as hypothyroidism. The risk of hypothyroidism equals to 1.0. In result of task of optimal control the risk of hypothyroidism decreased to 0.41.

5.3. Information software. There is developed a software product C/BR-RAW-ChAZ-2.0 (volume 40.4. Mb) - "System for database administration" described the 10th km of the Chernobyl Alienation zone, subsystems "Risk assessment and rating», «Modeling and forecasting dynamics of cost/benefit ratio from consequences of possible accidents and impact of radiation at the hand ling with radioactive waste of the Alienation zone», scientific and technical documentation (volume 17.3 Mb).

5.4. Information and program-technical providing with "Medical decision making for endocrinologist" (volume 7.0 Mb), "Medical decision making for cardiologist" (volume 7.0 Mb) support: administrating database of the patients, forecasting the influence of post-Chernobyl thyroid and cardiovascular pathologies to evolution of appropriate human organism systems, assessments of pathological changes in thyroid gland and in cardiovascular systems caused by the Chernobyl catastrophe's factors. These software products also provide the work with database using technology File-Server.

6. Gratitude. This work was started in 1979. We express our gratitude for all colleagues for creative and assiduous work.

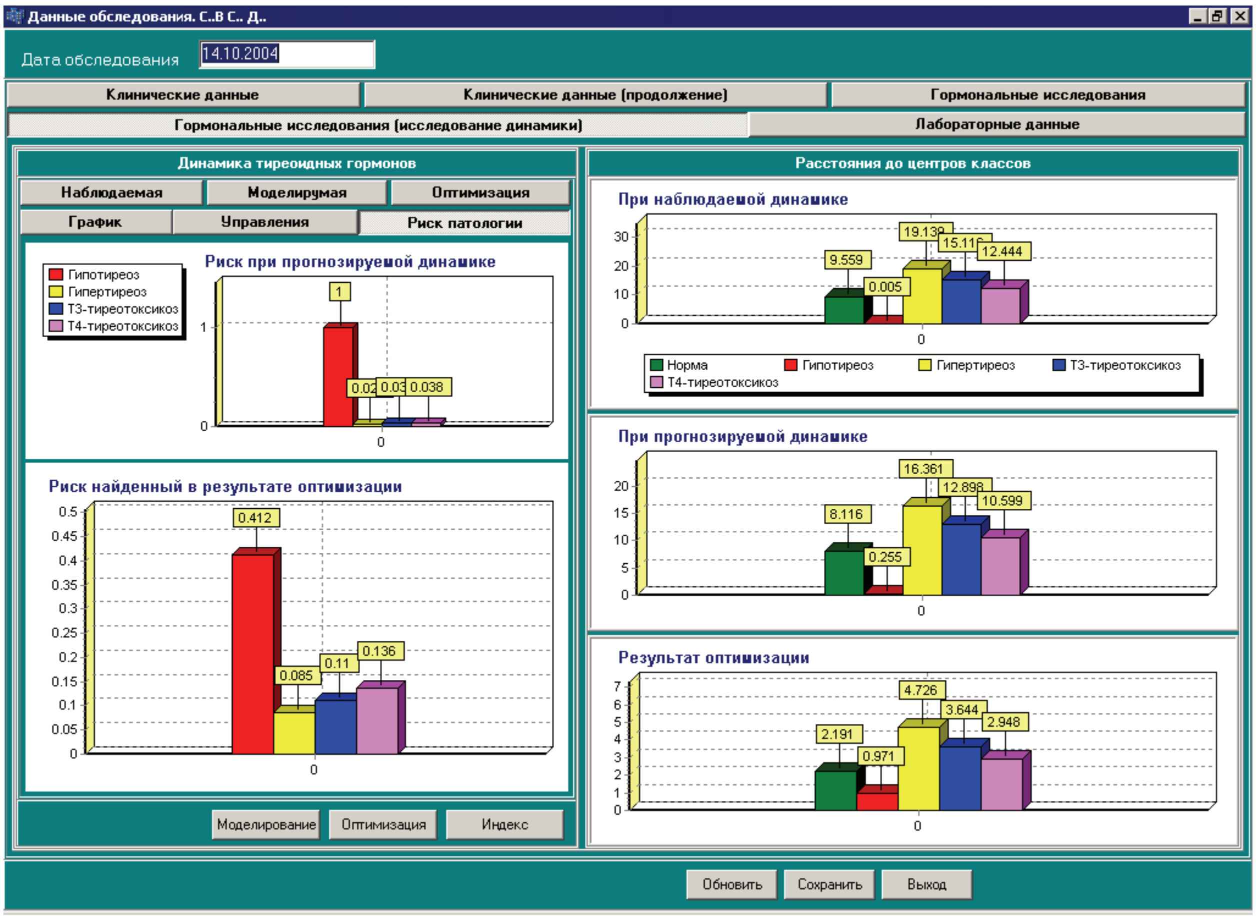

Fig. 4. Screen form with risk assessment of the pathological changes for the patient No.2

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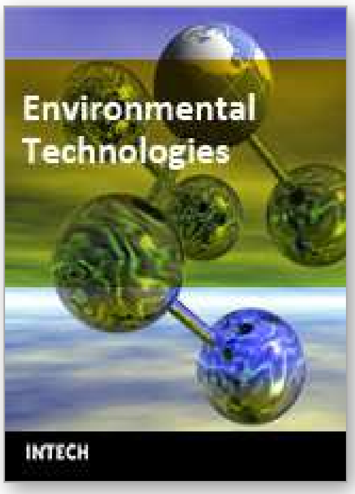

Environmental Technologies

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This book on Environmental Technology takes a look at issues such as air, soil and noise pollution problems, environmental quality assessment, monitoring, modelling and risk as- sessment, environmental health impact assessment, environmental management and envi- ronmental technology development. It represents institutional arrangements, financial mechanisms and some sustainable technologies. The user can always count on finding both introductory material and more specific material based on national interests and problems. The user will also find ample references at the end of each chapter, if additional information is required. For additional questions or comments the user is encouraged to contact the author.

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