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ECOTECHNOLOGY AND POLLUTION PREVENTION OF ENVIRONMENT

EKOTECHNOLOGIA I OCHRONA ŚRODOWISKA PRZED ZANIECZYSZCZENIEM

Key words: Ecotechnology, industrial ecology, pollution prevention, environmental regulations, residuals management.

Summary: The report presents methodology of theoretical approach in analysis of environmentally safe technologies and their parameters. The development of complex analysis ecotechnology system parameters is based on studies of conventionally separated parts of industrial plant in their sequences in the technological processes and their energy and materials inputs and outputs, searching optimised intersystem communications between them. As a result it is possible to obtain the most appropriate complex and complete ecologically safe resources saving and pollution preventing solution for industrial object in general.

Słowa kluczowe: Ekotechnologia, ekologia przemysłowa, zapobieganie zanieczyszczeniom, regulacje środowiskowe, zagospodarowanie odpadów.

Streszczenie: Artykuł przedstawia metodologię teoretycznego podejścia do analizy bezpiecznych dla środowiska technologii i ich parametrów. Rozwój złożonych parametrów w analizie systemu ekotechnologii oparty jest na badaniu konwencjonalnie rozdzielonych części zakładu przemysłowego w ich kolejnych procesach technologicznych, energii, materiałach wyjściowych oraz produkcji i poszukiwaniu optymalnego systemu komunikacji między nimi. Wyniki tych badań umożliwiają uzyskanie kompletnej i ekologicznie bezpiecznej oszczędności zasobów oraz rozwiązanie zapobiegania zanieczyszczeniom przez przemysł w ujęciu ogólnym.

INTRODUCTION

Despite the fact that environmental indicators are investigated for long time the solving of indicators problem is far of completion yet. The investigation of environmental indicators in conformity with quality of environmentally sound technologies and their impact on man's life quality is important problem.

The environment quality usually is estimated by variable indicators. The type of indicators and their nature depends on the aims they are used for and objects they must to characterize.

For example, three groups of indicators elaborated by the OECD, which are widely recognized – "Pressure", "State" and "Response" were accepted by Baltic States for their environment reports since 1998 [BEF, 1998]

But these indicators cannot be used for more local and specific territories – such as separate ecosystems or urbanosystems.

The quality of natural ecosystem is connected with energetic and dynamic ecosystem properties such as growth of biomass, biodiversity, laws of succession etc.

The quality of natural resources depends on intensity of their exploiting and renewable parameters and there must be different indicators.

In conformity with artificial urban system there are other parameters used for assessment of environment quality in cities. As the central object in the urban systems are population of citizens the main general indicator of environment quality must be people's health parameters[Михайлова, 1990]. Nevertheless this indicator is postindicator – it is too late to control quality of environment when human life is in danger. It means that in cities must be controlled main factors possible to exert influence on the health of citizens. Urban indicators must include among others such factors as the level of industrial development and ecological safety of plants and the quantity and composition of wastes and systems of their disposal and treatment technology.

These factors have double influence on the man – physically chemical (pollution) and psychical (distress and discomfort). Straight physical and chemical influence is connected with air, water, earth and food quality. It is well known that estimation at air, water and soil quality may be accomplished through concentration of pollutants in these substances.

THEORETICAL ANALYSE OF INDICATORS

Maximal level of allowed concentration of matter can be achieved with the small quantity of pollutants and at the some time it is possible that large quantities of pollutants will not give such effect.

But if we consider that the main way to eliminate pollution of nature and protect environment is to reduce and to stop in creating pollutants it is necessary to use quantity of total emissions of pollutants as a main indicator of the environmentally sound technology [Strategy for Sustainable development, 1977].

Anthropogenic pressure indicator on atmosphere (air) I_g: depends on density of population in city B (population per 1 km^2) and quantity of emissions in air on the area 1 km^2 – $M_s(kg/km^2)$. M_s must be calculated for each pollutant independent and then summarized taking into account the danger coefficient of matter D_s.

$$I_g = kB\sum_j (M_{sj}/D_s)$$

where: k – special coefficient on geological and climate conditions (between 1-6).

Anthropogenic pressure indicator on the surface of water reservoirs I_h must be calculated taking into account the quantity of pollutants M_h discharged in the water

$$I_h = \sum_j (M_{hj}/D_h \sum (K_{fj} V_j))$$

where: $K_f = 1/R_f E_f$ – stability factor of water reservoirs (0,1-1,0),
R_f – factor of resistivity,
E_f – elasticity factor.

Anthropogenic pressure indicator on the earth surface I_T must be estimated taking into account the area of degraded territories S_{degr} and quantity of the solid pollutants M_T.

$$I_T = \sum_j (D_{ej} M_{Tj}) \Big/ \sum_j (S_{degr} S_{ter})$$

where: D_{ej} – danger coefficient of pollutants,
S_{ter} – the total square of cities territory.

THE PARAMETERS OF ECOLOGICALLY SAFE TECHNOLOGIES

The paradigm of environmentally sound technology is clearly formulated in UN program "Sustainable Development – Agenda-21", Chapter 34.

These technologies include not only tasks for elimination of pollution, but also using all resources in a more sustainable manner and producing the products with less influence on the environment and nature during their exploiting and after exploiting – so called ecologically safe life – cycle of products [Беляев, Пупырев, 1996].

These technologies – ecotechnologies must be estimated by the next indicators [Noviks, 2000]:

1. Capacity of materials (resources) M – total quantity of all raw materials necessary for producing one unit of product.
2. Coefficient of pollution P_m – quantity of pollutants produced during processing per one unit of product.
3. Coefficient of pollution utilization R_m – quantity of utilized pollutants per one unit of product.

As complementary indicators may be used complex parameters:

1) $\alpha_m = P_m/M$ – part of resources transformed into pollutants;
2) $\beta_m = R_m/M$ – part of utilized pollutants from total amount of resources ;
3) $\gamma_m = R_m/P_m$ – coefficient of utilization – part of utilized pollutants from total amount of pollutants.

Integral parameter ω_m comprise the main parameters mentioned above

$$\omega_m = (P_m - R_m)/M$$

ω_m indicates the final part of used natural resources, which is lost and form pollutants and waste products.

Industrial process in terms of material and energy flows comprises the next parts:

First group includes basic resources **A** and additional resources **a**, used in the technological process, final industrial product **B** and resources **b**, necessary for exploiting the product.

Second group includes wastes produced in industrial sphere $\boldsymbol{\alpha}$; during exploiting the product $\boldsymbol{\beta}$ and the remnants of used product $\boldsymbol{\delta}$.

Third group includes additional resources **e** for utilization of wastes, additional products **E** created from wastes and final summarized nonutilized wastes ε generated during manufacturing, exploiting and processing.

On the base of these parameters may be constructed two complex environmental reliability indicators – the useful exploiting of resources indicator [Noviks, 2001a, 2001b]:

$$R = \frac{B + E}{A + a + b + e}$$

the effectiveness of waste products utilization indicator

$$\omega = \frac{\varepsilon}{\alpha + \beta + \delta}$$

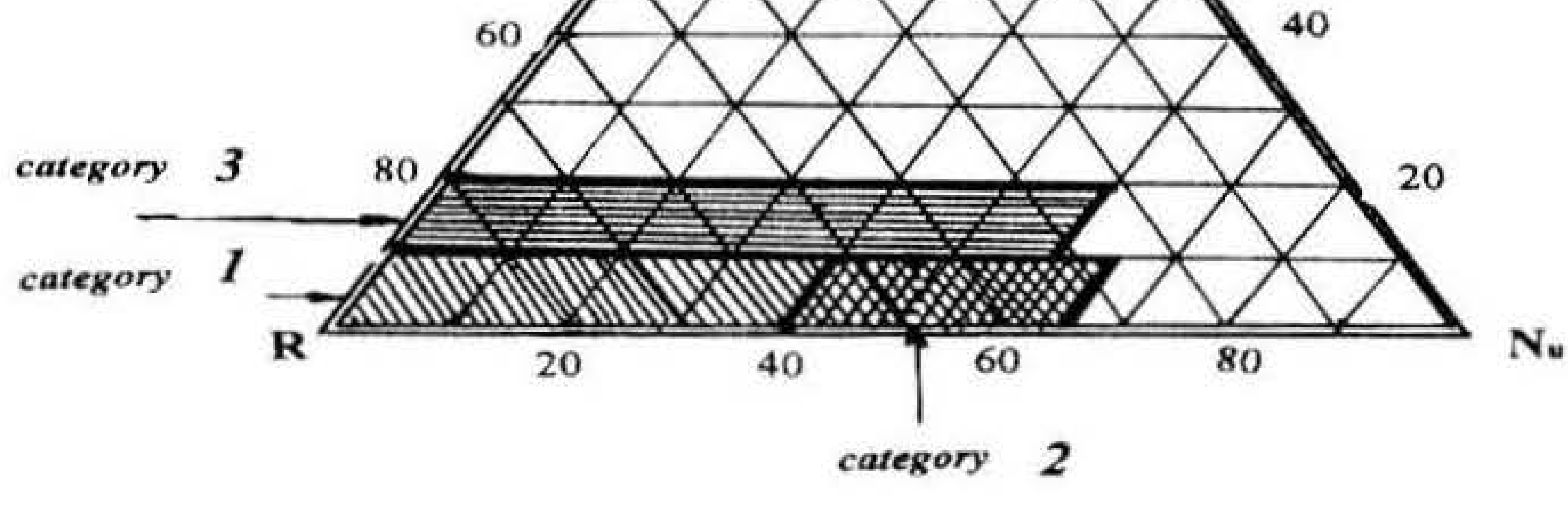

Fig. 1. The fields of environmentally sound technology

The level of environmentally sound technology may be evaluated on the base of structural triangle diagram (Fig. 1), where the main three parameters are used:

1) Non utilized final wastes coefficient

$$N_N \leq 10\%$$

$$N_N = \frac{\varepsilon}{A + a + b + e} 100, \%$$

2) Useful part of resources coefficient

$$R = \frac{B}{A + a + b + e} 100, \%$$

3) Utilized part of wastes coefficient

$$N_u = \frac{E}{A + a + b + e} 100, \%$$

The technologies of highest I category has on the diagram square in the next limits

$$N_N \leq 10\%$$
$$R > 50\%$$
$$N_u \leq 40\%$$

The technologies of middle II category:

$$N_N \leq 10\%$$
$$R = 25 \ldots 50\%$$
$$N_u \leq 65 \ldots 40\%$$

The lowest III category technologies:

$$N_N \leq 10 \ldots 20\%$$
$$R \geq 20\%$$
$$N_u \leq 50\%$$

The other technologies cannot be considered as ecotechnologies.

The analyse of theoretical equations proves, that progress and sustainable development can be achieved only by developing environmentally sound technologies on the basis of industrial ecology.

THE METHODOLOGY OF TECHNOLOGY PROCESSES ANALYSE

The predication of future development of Latvian economy after crisis in the last century 90-ths is based on growth of variable industrial branches in the regions with existing high-level quality of environment (for example, in Latgale) as well as in the most industrialized cities. At the same time our researches showed that in Latgale are relatively low ecological capacity parameters of nature and the every industrial addition in the impact of nature will be possible to destroy natural systems and to decrease quality of human life.

It means that reconstruction of the industrial objects in Latvia must be based on the modern environmentally sound technologies-ecotechnologies.

The main principles of the Ecotechnology are pollution prevention at the source, complete and complex exploiting of material and energetic resources, utilizing, recycling, recovering residuals, remains and pollutants, manufacturing ecologically safe production during its all life-cycle.

The construct such technology is complex and integrated task, which requires to work out appropriate methodology.

Our theoretical investigations showed that the main features of the methodology are the next. As the technological process is influence of physical or chemical fields and energies on raw materials and the result of this influence is a new useful product, it is necessary to begin analyse the corresponding physical effects on materials and to choose among them the most appropriate effect from the view of impact on the environment.

So we can to indicate theoretically and technically possible field S_T of the technological process (Fig. 2).

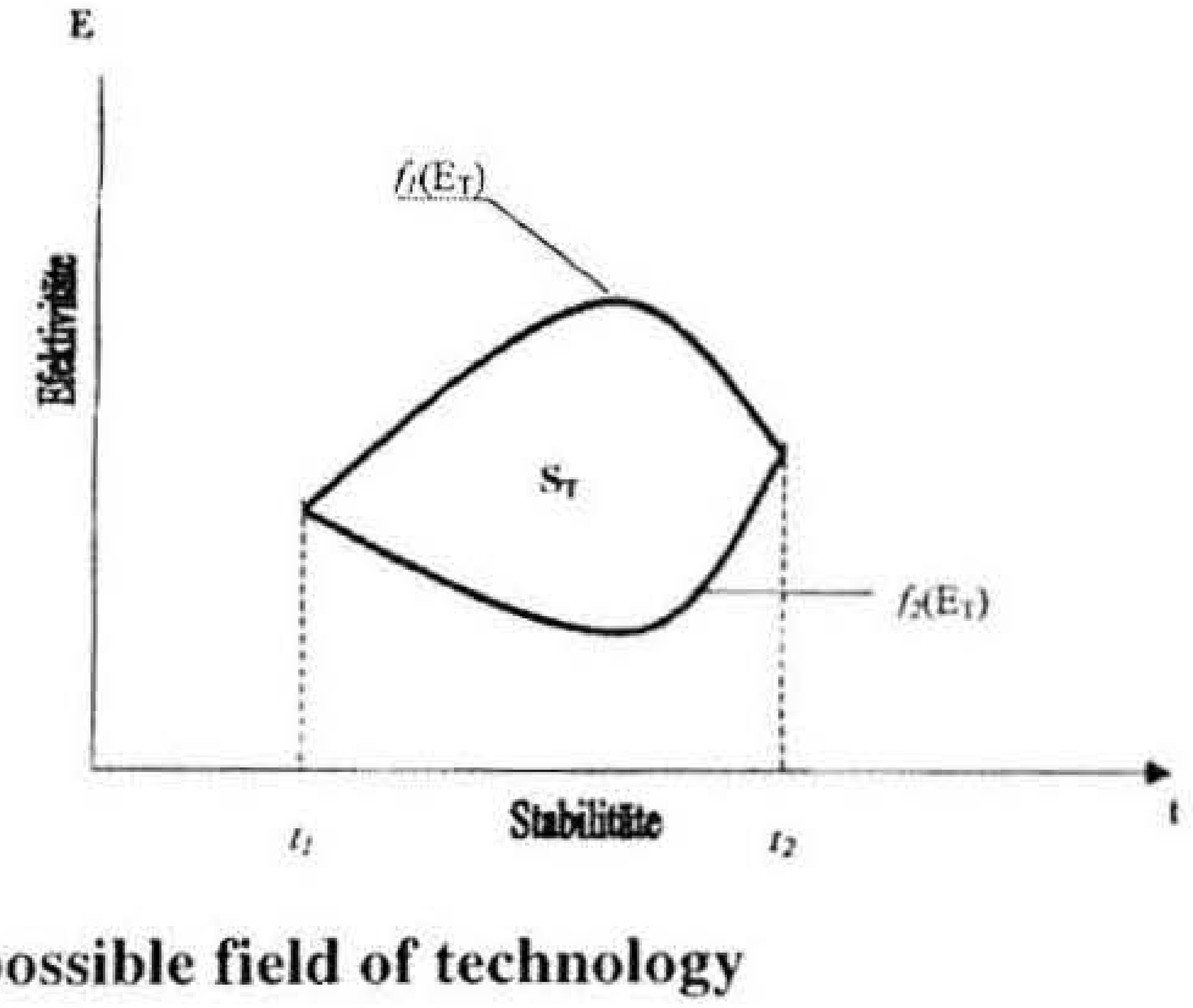

Fig. 2. Technically possible field of technology

$$S_T = \frac{1}{2}\oint\left(E_T^{'}\frac{dE^{''}}{dt} - E_T^{''}\frac{dE^{'}}{dt} \right)$$

where: E'_T and E''_T – effectivities of the physical field;
t – the stability time of the physical field.

The next step is indication the borders of ecologically safe field in the S_T.

$$S_E = \frac{1}{2}\oint\left(E_E^{'}\frac{dE_E^{''}}{dt} - E_E^{''}\frac{dE_E^{'}}{dt} \right)$$

The last step must be to indicate the borders of social-economical usefulness field S_S in the frames of mentioned S_T and S_E fields.

$$S_S = \frac{1}{2}\oint\left(E_S^{'}\frac{dE_S^{''}}{dt} - E_S^{''}\frac{dE_S^{'}}{dt} \right)$$

$$S_E = \frac{1}{2}\oint\left(E_E^{'}\frac{dE_E^{''}}{dt} - E_E^{''}\frac{dE_E^{'}}{dt} \right)$$

The summarized ecologically safe field of ecotechnology (Fig. 3) possible to predict by the next formula:

$$S_O^{E_T} = \int_{t_6}^{t_3}\left[f_1(E_E)dt - f_2(E_E)dt\right] - \int_{t_5}^{t_3}\left[f_4(E_T)dt - f_2(E_E)dt\right] - \int_{t_6}^{t_4}\left[f_1(E_E)dt - f_3(E_T)dt\right]$$

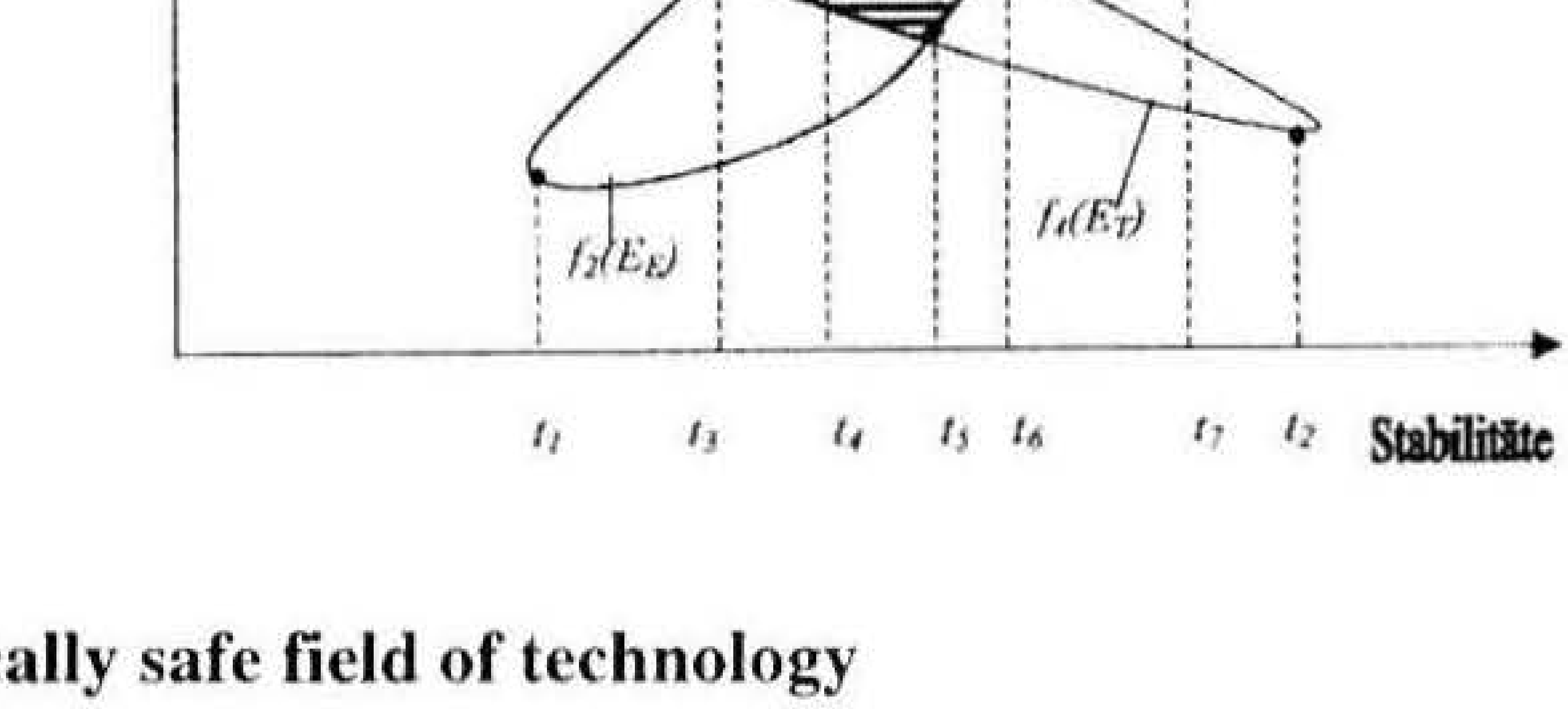

Fig. 3. Ecologically safe field of technology

Such detached zone is the base for the further analyse. The analyse process consist from dividing all technology in separate blocks connected each with other through energy and material flows and optimising each block in the direction of minimizing inputs of materials and energy, minimizing outputs of residuals and maximizing outputs of useful products, which in the most cases when analysing technological process is the input for next technological block. It is necessary not only optimise each block separately but to unite partial effects to find the best common solution to the whole plant (Fig. 4).

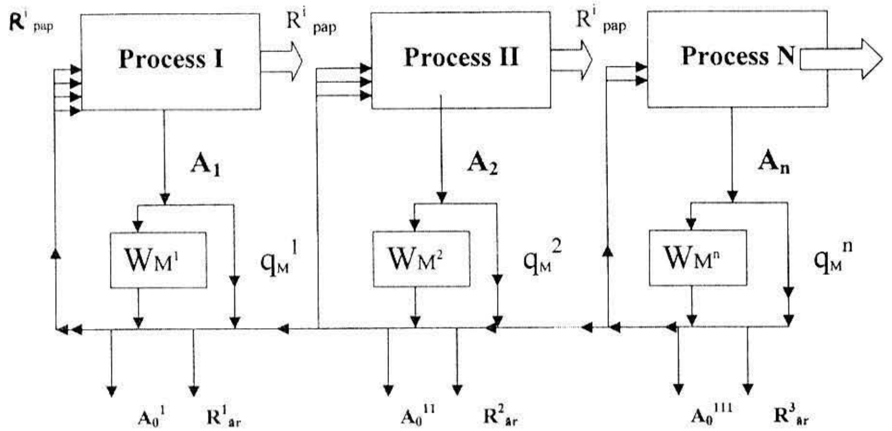

Fig. 4. The flow of material in technological processes

In the figure 4: R^i_{pap} – additional resources for technological operations;
$A_1 - A_n$ – the primary losses of materials and energy;
W_{M^1} - W_M^n – the final product of technology;
$q_{M^1} - q_M^n$ – residuals of materials;
$A_0^I - A_0^{III}$ – the secondary losses of materials and energy;
$R^1_{ar} - R^3_{ar}$ – the complete quantity of resources in technology.

INVESTIGATION OF PYROLYSIS TECHNOLOGY

Solid wastes keep the first place among other waste products due to their quantity – total volume and mass. The main feature of solid wastes– especially of municipal wastes is their complicated composition– diversity in chemical composition and structure as well as in physical and chemical properties. Additional difficulty is that all these parameters are not constant in the time and space.

These factors create difficulties in the utilization of solid wastes. Problem is in the selection the most suitable method of solid wastes treatment and creating proper technology from the ecological and economic point of view. To solve this task it is necessary to obtain knowledge about composition, structure and properties of wastes and their diversity. Indispensable information level of wastes chemical composition depends on projected technology and its influence on matter. The separation process for example, may be rest upon information about content of components, biochemical processing demands knowledge about molecular composition, thermochemical technology – molecular and atomic composition. Structural features as well as chemical must be analysed in the different levels too. When choosing the processing technology it is necessary to analyse feasible parameters of ecological danger for man and nature in addition.

There may be two steps in investigation of proper technology. At first, must be analysed mutual influence between physical-chemical fields and raw materials and its results. Then, as a second step, chosen technologies must be evaluated by ecological effects.

On the bases of constructed methodology there may be analysed theoretical and technical aspects of a new municipal solid wastes processing technology. The pyrolysis is one of the most prospective among different utilization methods of residuals. Usually the heating process of materials is accomplished by contact with heaters and the process is limited by thermal convection and thermal conductivity of materials [Винтовкин, 1998]. So the process is very slow but burning of fuel has important impact on environment. We investigated the possibility to apply for heating organic mass in the pyrolysis process up to 550°C high frequency and high intensity electromagnetic fields [Noviks].

It is necessary to analyse relationships between waste electrical parameters and frequency of electromagnetic field to achieve optimal parameter of electromagnetic heating. For this purpose was worked out a device for measuring dielectric permittivity and dielectric losses in the range of electromagnetic frequencies between 0,05-50 MHz. The measurements were accomplished on the samples composed of different quantity of organic and inorganic (dielectrics and conductors) materials.

The methodology of calculation optimal physical and technical squares for implementation of suggested technology was applied and experimental data were analysed. The best parameters of electromagnetic field for pyrolysis of solid wastes is frequency $f = 1{,}5\text{-}4\ 10^6$ Hz and electric intensity $E = 180\text{-}220$ kV/m and $E = 390\text{-}400$ kV/m for waste of different composition (Fig. 5).

The advantages of such technology are next:

1. Every organic material may be exposed to pyrolysis and as a result may be obtained worth production – gas, resin and coke;
2. It is not necessary to separate waste materials;
3. High-frequency electromagnetic field generate thermal energy (equation 11-13) in the internal layers of waste mass and so its heating up to 550°C takes much less time (theoretically about 2-3 min) to complete the pyrolysis process.

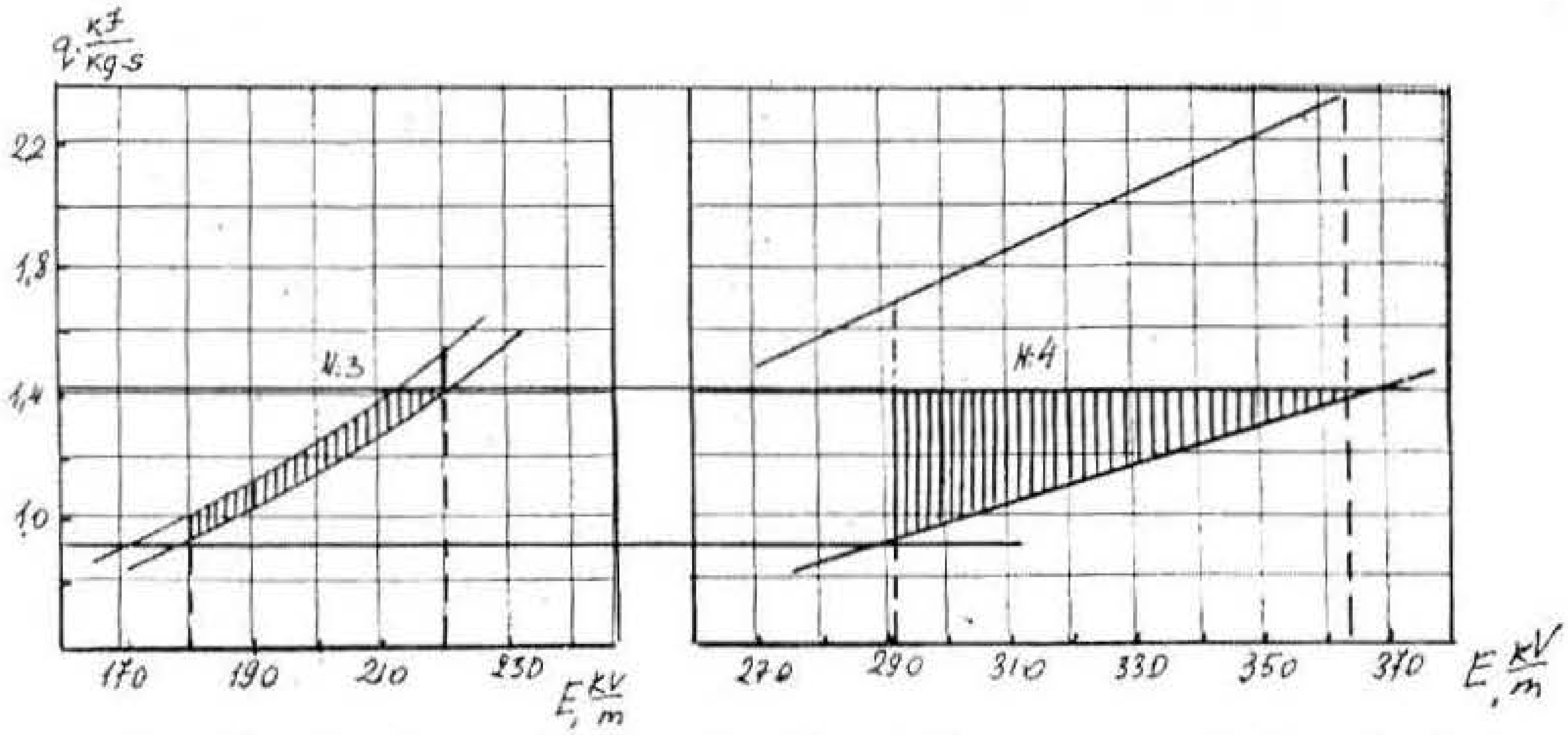

Fig. 5. The most optimal values of intensity E and frequency of electrical field

Besides there is not combustion with smoke, pyrolysis reactor is compact, isolated from environment, adjustable and easy to control the regimes of external and internal action. The impacts on the environment at the case are minimized. As a result of pyrolytic processing of wastes there may be obtained such worthy products as resins, combustible gaze, fuel, coke breeze and building materials. The non-organic materials after processing may be used in construction and highway engineering.

SUMMARY

1. Complete solution of the environment pollution problem may be achieved by implementation ecologically safe pollution prevention technologies – ecotechnologies.
2. There are many indicators for assessment quality of environment. Special indicators for evaluation of industrial plants' ecological quality was obtained.
3. Indicators include complex parameters of quality of residuals, pollutants at each technology process.
4. The methodology of environmentally sound fields of technology was created.
5. The methodology was used for establishing the most optimal parameters of solid waste pyrolysis process by high frequency electromagnetic heating.

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