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POSITION OF THE SUSTAINABLE DEVELOPMENT IN THE SYSTEM OF SODA PRODUCTION AUTOMATION

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ABSTRACT

The work of the United Nations and other international organizations towards the establishment and implementation of the Statement on Sustainable Development has been considered. The indicators for assessing the state of the environment characterizing sustainable development in the areas of economics, ecology and sociology are presented. The necessity to consider these indicators in the development and operation of automation systems by technological processes is substantiated. The example of absorption processes and calcination of soda production technology shows how to take into account the requirements of each of the areas of sustainable development in the tasks of optimal control. The method of interaction of international organizations' documents, technological documentation and results of technological processes provides for the creation of appropriate databases and special expert groups working with them, is described. We examined Saati's method for considering the importance of each document. The algorithm scheme has been developed for solving multicriterial problem of optimal control of technological processes with consideration of documents related to sustainable development. The conclusions about expediency and possibility of taking into account international documents while designing and operation of automation systems are presented.

Keywords: sustainable development, automation, soda production, sustainable development indicators, optimization criteria, expert assessments.

INTRODUCTION

Topicality: An analysis of the trends in the development of resources surrounding humanity has led to the need to recognize the significant depletion of the planet and its ozone layer. The main reason for such a situation is the people's activity. The characteristics of the environment are constantly changing, influencing people's needs according to the inverse action principle. In order to reduce negative environmental impacts, the global community needs to work on a very wide range of tasks in various subject areas.

The development in this sphere started with the introduction of the special concept of "sustainable development". The definition of such a development of society was given in the report by Gra Hurlem Brundtland [Symbol], chairman of the International Commission on Environment and Development, who worked in 1984-1987 [1]. Among the most important publications declaring tasks and partially solving the problems of sustainable development, the Framework Convention on Climate Change [2] and the Kyoto Protocol attached to it stand out, the Gothenburg Protocol on the Abatement of Oxidation, Eutrophication and Ground-level Ozone [3)] to the Convention on Long-range Transboundary Air Pollution, the Rio Declaration on Environment and Development [4], the Land Charter [5], the Millennium Declaration [6], UN and Sustainability [7].

The abovementioned documents suggest solving the tasks of estimating and forecasting the state of the environment, society, etc., as well as determining the necessary actions for the formation of their future state. Further actions require a coherent international formalization of system descriptions and impacts on them.

The search for ways to implement international projects in environmental, economic and other areas can be considered very relevant in the long run, and the harmonization of international indicators of sustainable development with the objectives of each production in general and automation systems in particular - is a perspective area of research for specialists in automation and computer- integrated technologies.

Automation systems can be technologies able to help in the implementation of the concept of sustainable development. They can be give the industry the following benefits:

- with the help of technical means of automation it is possible to measure the value of separate indicators included in the general indicators of sustainable development;
- automation systems allow us to use raw materials and energy resources optimally;
- automation is aimed at increasing social standards of life, reducing the physical and mental burden on people.

Analysis of Recent Research and Publications: The ways of implementing the strategy of sustainable

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development are considered in numerous publications. The following scientists devoted their researches in particular to them: Zgurovsky M.Z. [8, 9], Melnik L.G. and DegtyaryovaI. B. [10], Daly H. [11], Pearce D. W., Warford J. J. [12], Ashok Sahai, ClementK. Sankat, Koffka Khan [13], Hrechanyk N. Yu. [14], Bozheneva I. M. [15], Pakulin S. L., Pakulina A. A. [16], Atkinson G., Dubourg, R., Hamilton K. and others [17], Michael H. Huesemann [18], Kristina Oskarsson, Fredrikvon Malmborg [19], Heksel L.K. [20], Zhuchenko A.I., Yaroschuk L.D., Makarov T.V. [21, 22], Shubchik O. A. [23], Zhuchenko A. [24, 25], Osipa R. [26].

In the works [8, 12] the theoretical foundations of the strategy of sustainable development and ways of their realization in terms of society as a whole are considered. In [13] it is suggested to assess the state of the region in the national context. The question of implementation of the statements of sustainable development at the enterprise level is considered in [14-21]. The paper [21] addresses the integration of environmental and social requirements through management systems in engineering. The authors of these papers explore ways of introducing sustainable development for enterprise management, but not in terms of the requirements for managing technological processes, but from the point of view of enterprise management as a whole.

The studies described in [22] allowed the author to substantiate the change in the soda production technology based on reconciling the sustainable development of the economic, environmental and social components. In addition, the author considers the creation of an integrated management system for a set of quality, personnel, environment, health and safety management systems.

Publications [23, 24] were the authors' first attempts to find ways to bring sustainable development problems closer to enterprises creating problems for ecology and are closely related to the economy and social sphere of populated areas. In the works [23, 24], the problem of implementation of the statements of sustainable development in the automation system was not considered comprehensively and in detail. Materials of these works require further in-depth study and presentation.

In [25-28] the analysis of the trends of system automation of balanced enterprise activity indicators is carried out. But both recent works do not cover the automation methods of technological processes based on consistency of criteria inherent in sustainable development.

To implement such a global concept, automation systems should be more complex than they are now, because they need to add components responsible for measuring indicators related to sustainable development.

The Statement of the Research Problem: The objectives of the study are to determine the ways of introducing the main provisions of the concept of sustainable development into documents related to the design and operation of automation systems for technological processes.

The obtained results will also allow us to conclude how appropriate this activity is for different productions. Soda production was selected to solve this problem. Soda being a very common and important substance. This production is sufficiently researched and automated.

PRESENTING OF THE BASIC MATERIAL

Due to peculiarity of the study industrial production, should be described as a subject area in the concepts of sustainable development on the one hand, and in the concepts of automatic control on the other hand. Let's first consider the model of the subject area in terms of sustainable development.

Sustainable development is based on certain environmental, economic, social and institutional indicators. These are indicators of living standards and human health, environmental pollution in a certain area, the rate of human impact on the environment. The index is the general indicator based on several other indicators [29, 30]. Since sustainable development is still a relatively new concept, the unified final system of indicators and indices for it has not yet been created. Many influential organizations are working on their development. Conferences on this issue take place. The United Nations, the World Bank, The Organisation for Economic Co-operation and Development (OECD), the European Commission, the Scientific Committee on the Problems of the Environmental (SCOPE) and others work proactively on the creation and unification of the indices. For example, the United Nations Commission on Sustainable Development (DAC) has developed a system of 132 indicators of sustainable development; the *OECD* has developed a system of environmental indicators, etc.

Since the automation system should take into account the legislative documents of sustainable development, we will investigate what type and amount of information support of this system is being considered.

For an example, let us consider the definition of one of the indexes, namely the index of environmental measurement (I_e) [31]. Obviously, this index is related to the environment. It includes 3 policies (upper level), 13 indicators (average level) and 44 special indicators (lower level). The ecological measurement index was developed to assess the ecological sustainability of countries. Methodologically, it is based on the ESI-2005 index (Environmental Sustainability Index - Sustainability Index) [32], created by the Center for Environmental Law and Policy of the Yale University (USA) and calculated for 146 countries as of 2005. The ESI index was formed from 21 environmental indicators calculated from 76 environmental indicators. The ESI determines the probability of country maintaining the available resources of the environment over the next few years, assesses the country's potential for preventing environmental degradation.

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$I_e$consists of the following policies: Ecological Systems (I_{SYS}), Ecological Stress (I_{STR}) and Regional Environmental Management (I_{REG}).

Eachofthesepoliciesincludesseveralindicators.

The I_{STR} policy, forexample, consistsofemissions in to the atmosphere indicator (I_{EMS}), ecosystem stress (I_{ECO}), waste generation and use (I_{WST}), water stress (I_{WAT}).

Eachof the seindicators includes several parameters. Emissions in to the atmosphere I_{EMS}, volatile organic compounds (I_{VOC}), roadvehicle emissions (I_{CAR}), as well as stationary and mobile sources emissions based calculation by 1 km^2 (I_{EKM}), static and mobile sources emissions in airpercapita (I_{EPC}). The indicator "Emissions in to the atmospheri cair" is calculated as the equilibriumavera geoftheparameters of emissions of in trogenoxide, sulphur compounds, volatile organic substances, pollutants frommotor vehicles, as well as emissionsper $km^2$and percapita:

$$I_{EMS} = I_{NOX}/6 + I_{SOT}/6 + I_{VOC}/6 + I_{CAR}/6 + +I_{EKM}/6 + I_{EPC}/6;$$

$$I_{NOX} = (I_{NOX\_STA} + I_{NOX\_MOB})\cdot 10^3/I_{AREA};$$

$$I_{SOT} = (I_{SOT\_STA} + I_{SOT\_MOB})\cdot 10^3/I_{AREA};$$

$$I_{VOC} = (I_{VOC\_STA} + I_{VOC\_MOB})\cdot 10^3/I_{AREA};$$

$$I_{CAR} = I_{EM\_AT}\cdot 10^3/I_{AREA},$$

where I_{NOX} - emissions of nitrogen oxide in certain area for the reported year, t/km^2; I_{NOX_MOB} -emissions of nitrogen oxides from stationary sources in the reported year, ths. Tons; I_{NOX_STA}–emissions of nitrogen oxides from mobile sources in the reported year, ths.Tons; I_{SOT}–emissions of sulphur dioxide in certain area in the reported year, t/km^2; I_{SOT_STA}–emissions of dioxide and other sulphur compounds from stationary sources in the reported year, ths.Tons; I_{SOT_MOB}–emissions of sulphur dioxide from mobile sources in the reported year, ths.Tons; I_{VOC}–emissions of volatile organic compounds on certain area in the reported year, t/km^2; I_{VOC_STA}–emissions of volatile organic compounds from stationary sources in the reported year, ths.Tons; I_{VOC_MOB}–emissions of volatile organic compounds from mobile sources in the reported year, ths.Tons; I_{CAR}–emission of pollutants from automobile transport in the area of the territory in the reported year, t/km^2; I_{EM_AT}–emission of pollutants from automobile transport in the reported year, ths.Tons; I_{ECM}–emission of pollutants into the air from stationary and mobile sources in certain territory in the reported year, t/km^2; I_{EPC}–emissions of pollutants into the air from stationary and mobile sources per capita, kg; I_{AREA}–area of the region, km^2.

The remaining indexes, policies, as well as the index of the environmental measurement (I_e) are determined in a similar manner:

$$I_e = I_{SYS}/3 + I_{STR}/3 + I_{REG}/3.$$

Evaluating weight of environmental parameters is a challenge for experts. Often, the weight factors in the formulas for calculating indicators of the index of environmental measurement are the same, since statistical studies have shown them to be almost equivalent.

Such a calculation technique is proposed by World Data Center for Geoinformatics and Sustainable Development (WDC Ukraine) - part of the World Data System International Institute Council for Science ICSU WDS including about 50 centers in 13 countries of the world at the current moment. WDC is conducting a calculation of indicators of sustainable development in many countries of the world.

These calculations show that the volume of information collected and then provided by international organizations is substantial. The information of these organizations should be taken into account when operating a variety of industries.

Now let's show how to consider soda production in terms of sustainable development without changing the structure of technology and technological lines.

To assess the indicators of sustainable development of any production, it is necessary to analyze its technological features. Let us consider a simplified scheme for the production of soda ash in the ammonia method (Figure-1) [33].

Plants producing soda can be characterized as multi-tonnage, with a significant amount of waste. Soda production has a high level of automation. The use of soda in everyday life is well known.

Purified from the salts of magnesium and calcium brine comes by gravity from the pressure tank 1 in the bubble absorption columns 2. Saturation of brine with ammonia and partially carbon monoxide happens in it. Here, regenerated ammonia is used from distillation column 10, as well as waste gases from various apparatus of the workshop (carbonization columns 3, absorbers, filters 5) containing ammonia and carbon monoxide residues. Ammonized brine is distributed on carbonization columns 3. Concentrated carbon monoxide from the furnaces of calcination of soda 6, and diluted 40% gas from the lime kilns are supplied by the compressor in the lower part of the column and in the middle of the column, accordingly. 5-hydrocarbonate suspension is moved to the drum vacuum filters from the column 3 by gravity.

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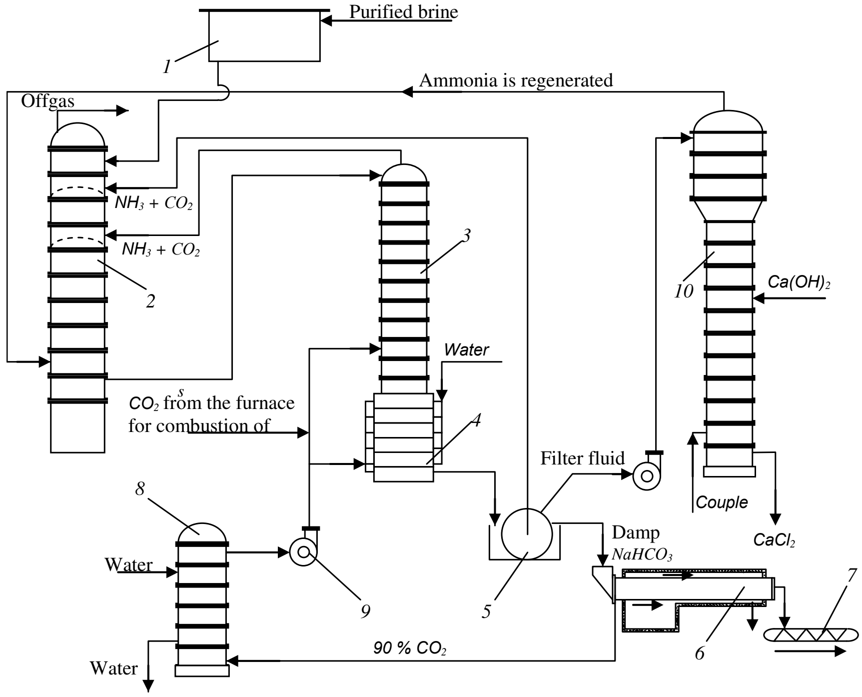

1- pressure tank; 2- bubble absorption column; 3- bubble carbonization column; 4- cool part of the column; 5- drum vacuum filter; 6- a furnace of calcination; 7- conveyor; 8- washerof sulphur oxide; 9- compressor; 10- bubble distillation column

Figure-1. Simplified scheme for the production of soda ash in the ammonia.

Vacuum filters are rotating, and wet bicarbonate is separated from the mother liquor. Carriers in the calcine furnace 6 (rotating drum drier) are supplied with bicarbonate. Furnaces produced external heat by combustion gases. The temperature in the middle of the furnace is 1400 ° C - 1700 ° C. The screw conveyor 7 move soda ash on to the packaging. Calcination gases (containing up to 90% of CO_2) after being washed with water in the apparatus 8 go to the compressor 9 for carbonization. The mother liquor is fed into the bubble distillation column 10 from the filters 5 for the ammonia regeneration. The lime milk enters the irrigation of the distillation column 10. Water vapor (as a heat-carrier) is fed in the lower part of the column 10. Regenerated ammonia comes back into absorber 2, and a solution of calcium chloride goes to the dump.

The production of soda ash releases harmful substances into the environment and is one of the largest environmental pollutants in any country.

The most harmful discharge is distilled slurry [34] formed in the amount of 8-10 m^3 per 1 ton of soda. This is a solution of calcium and sodium chloride, hydroxide and calcium sulfate with a total mass content of 15-16%.

The most harmful gases out of all gases are flammable ones (containing sulphur dioxide) and air from the filters (containing hydrogen sulfide), carbon dioxide CO_2 and ammonia. The latter is hazardous to human health, even atlow concentrations. It is also explosive in certain concentration ratios in the mixture with air.

Let us analyze the points of contact between the soda industries and the trends of sustainable development. Soda is very important for the country, corresponding to the economic trends of sustainable development. Production of soda produces quite a lot of emissions to the environment, and this is due to the ecological trend of sustainable development. The social trend of sustainable development embraces this production because, in places of its location, it is perhaps the most important production providing the population with jobs. So the welfare of people depends on the welfare of the enterprise.

So, the analysis of soda production shows its close connection with all trends of the concept of sustainable development.

Let us consider the emissions of soda production in terms of documents. At first we should refer to the Kyoto Protocol to the Framework Convention on Climate Change. This document regulates emission quotas for greenhouse gases, including carbon dioxide. It is worth mentioning the Gothenburg Protocol on the Abatement of Oxidation, Eutrophication and Ground-level Ozone to the Convention on Long-range Transboundary Air Pollution over the long distances.

The Rio Declaration on Environment and Development, the Earth Charter, the Millennium Declaration, and others also emphasize the need to reduce industrial emissions and improve people's lives. However they do it in a more generally.

According to the documents of sustainable development, monitoring of the environment is necessary. According to its results, effective management, timely

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prevention of violations and public awareness must be implemented. Some environmental indicators are necessary to monitor the environment. Thus one can see trends in development and make conclusions, in particular regarding management actions.

Since the research objective is to create indices for assessing the ecological, economic and social sustainability of the soda company, consistently consider the formation of these indices.

Since sustainable development is a new concept, many influential organizations are working on developing a unified metrics system. During the consideration of this issue, it was proposed to form the index of sustainable development of production (denoted with I_{sdi}) from the index of ecological sustainability of production (I_{ecolsi}), the index of economic sustainability of production (Ieconsi) and the index of social sustainability of production (I_{socsi}). Organization for Economic Cooperation and Development while developing I_{sdi} suggested these components to be equally important. Therefore, the authors also gave them the same weight coefficients to begin with (we isolate them with brackets on purpose):

$$I_{sdi} = (1 / 3) \cdot I_{ecolsi} + (1 / 3) \cdot I_{econsi} + (1 / 3) \cdot I_{socsi}.$$

Indicators of the environmental sustainability index can be obtained from the information component of the automation system (AS). Additional technical means of automation should be introduced to the system. They will receive emission signals not only from the devices, but also on the adjacent territory. Information on the volumes of various emissions can be aimed at adjusting the work of the control circuit (as a task for regulators). Computer hardware AS should calculate indicators and indices of sustainable development of the enterprise.

In order to determine the performance of the production technological system, less indicators are required than for a region or a country. Instead of a set of key figures such as indicators and indices, you can use economic, environmental and social criteria. They unambiguously characterize functioning of the chemical and technological system.

The criterion of economic sustainability Ieconsi can be calculated as the gross domestic product of production per employee of the enterprise.

The authors suggest the criterion of social sustainability to be defined as the equilibrium sum of the indicators of average wages and social costs per employee of an enterprise:

$$I_{socsi} = (1 / 2) \cdot I_{as} + (1 / 2) \cdot I_{scpw},$$

where I_{as}–an average salary at the enterprise; I_{scpw}–the company's social costs per worker.

Whereas the criteria of economic and social sustainability can be formed in the same manner for all industries, the criterion of environmental sustainability I_{ecolsi} must be formed for each production individually, based on its emissions to the environment. Authors suggest to form it as follows for soda production:

$$I_{ecolsi} = (1 / 4) \cdot I_{dist} + (1 / 4) \cdot I_{SO2i} + (1 / 4) \cdot I_{CO2i} + +(1 / 4) \cdot I_{NH3i},$$

where I_{dist} is the amount of distilled fluid, t / year; I_{SO2i}– amount of sulphur dioxide, t / year; I_{CO2i}–the amount of carbon dioxide; I_{NH3i}–amount of ammonia, t / year.

Algorithms for process control should be aimed at increasing the efficiency of production, reducing emissions and improving the lives of the workers of the enterprise. While developing the criteria for the effectiveness of the required processes, experts in the field of AS must take into account the constraints imposed by the technological regulations (a document defining the parameters of technological processes).

The economic efficiency of production in general can be achieved with the cost-effectiveness of each of its technological subsystems. The authors have developed criteria for optimality and limitation for the basic processes of production of soda ash. The principles of their development are shown in two examples.

The first one relates to one of the main processes of soda production - the absorption of ammonia occurring in the bubble absorption column 2. According to the technology description, brine purified from the salts of magnesium and calcium is delivered to it. In the column brine is enriched with ammonia. Ammonized brine flows out of the column and offgas is released. The purpose of the system of automatic control is determined by the target of the process, namely achieving maximum ammonisation of brine coming out of the column in the following apparatus - an absorber. The input values in the absorber are the water use G, the initial concentration of ammonia in the gas mixture X_{pr}, the initial concentration of ammonia in water Y_{pr}, and the output values are the concentration of ammonia in the throttling gas Y_{end} and the ammoniated brine X_{end}. Figure-2 shows an absorber scheme.

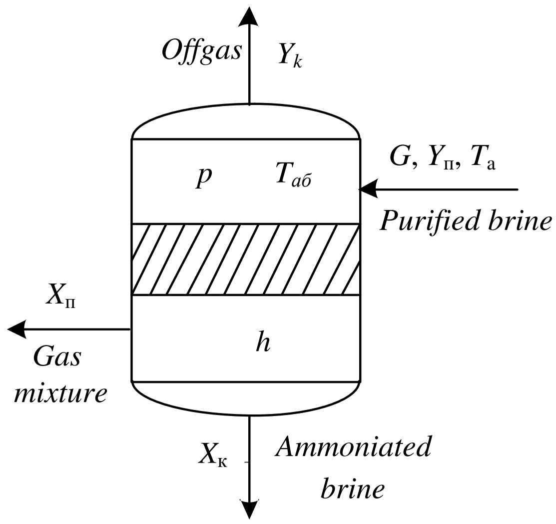

Figure-2. Absorber scheme.

The processes of ammonization are also influenced by pressure and temperature in the absorber,

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water temperature at the inlet, water level in the column. So the output values are functions of many factors:

$X_{end} = f(X_{pr}, G, p, T_{ab}, T_{wat}, h, Y_{end})$
and $Y_{end} = f(X_{pr}, G, p, T_{ab}, T_{wat}, h, X_{end})$,

where X_{end} is the concentration of ammonia in the ammoniated brine; X_{pr}– initial concentration of ammonia in the gas mixture; G–consumption of purified brine; p - pressure in the column; T_{ab}–temperature in the absorber; T_{wat}–water temperature (purified brine) at the entrance to the column; h–water level in the absorber; Y_{end}–ammonial concentration in the offgas.

In terms of economic feasibility, you need the highest possible profit. Therefore, it is necessary to obtain the highest possible concentration of ammonia in the ammoniated brine at certain costs:

$K_{ab\_econ} = X_{end}/ C_{ab}$,

where K_{ab_econ} is the economic criterion of optimality for the ammonia absorption process; C_{ab}–the ammonia absorption in the column cost.

Ammonia absorption expenditures in the column are the energy costs of heating the incoming brine, the cost of electricity for the operation of compressors pumping the ammonia stream in the pipeline at the inlet to the absorber. Technological regulations may impose restrictions on the concentration of ammonia in the offgas, pressure in the absorber, as well as the minimum concentration of ammonia in the ammoniated brine. So you can formulate the optimization problem in the form of an optimization criterion:

$K_{ab\_econ}= X_{end}/ C_{ab} \rightarrow \max$

and restrictions:

$$\begin{cases} Y_{end,\min} \le Y_{end} \le Y_{end,\max}; \\ p_{\min} \le p \le p_{\max}; \\ X_{end,\min} \le X_{end}, \end{cases}$$

where the minimum allowed values are indicated by the index *min* and the maximal ones by the index *max*.

In terms of environmental feasibility it is necessary to minimize the concentration of ammonia in the offgas:

$K_{ab\_ecol}= Y_{end}$,

where K_{ab_ecol} is an ecological criterion of optimality for the ammonia absorption process.

The technological regulations may impose restrictions on the concentration of ammonia in the ammoniated brine and the pressure in the absorber. So you can formulate the optimization problem in the following way:

$K_{ab\_ecol} = Y_{end} \rightarrow \min$

$$\begin{cases} X_{end,\min} \le X_{end} \le X_{end,\max}; \\ p_{\min} \le p \le p_{\max}. \end{cases}$$

Another important process of soda ash production is the drainage of sodium bicarbonate (soda) in the calcining furnace. The stove is a rotating drum dryer. In the middle of the furnace the temperature should be in the range of 140 - 170 ° C.

Gaseous fuels G_{fuel} and primary air G_{pr_air} are fed into the furnace 1 (see Figure-3). The drying agent is prepared in a mixing chamber 2 also feeding the secondary air G_{sec_air}, reducing the temperature of the combustion products at the inlet of the drum.

Wet soda enters the drying drum 3. The material moves along the drum, it is dried to a certain humidity ω_{end} and enters the hopper 4. Dry soda G_{dry_soda} is transported from the hopper 4. The exhausted drying agent (offgas) G_{offsas} is discharged into the atmosphere after a certain purification.

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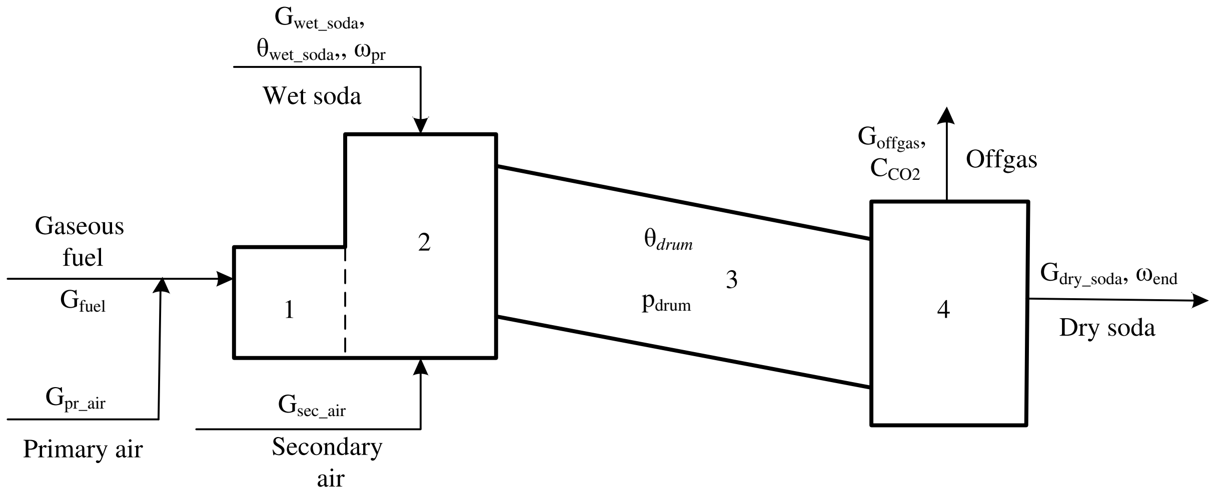

1 - firebox; 2- mixing chamber; 3 - drying drum; 4 – bunker

Figure-3. Calcining furnace scheme.

According to the scheme, many factors influence the process of drainage. In general, the connection between them and the output technological variables can be presented as follows:

$G_{dry\_soda} = f_1(G_{fuel},\alpha,\ G_{wet\_soda},\ \Theta_{wet\_soda},\ \omega_{pr},\ G_{sec\_air},\ \Theta_{drum},\ p_{drum});$

$\omega_{end} = f_2(G_{fuel},\alpha,\ G_{wet\_soda},\ \Theta_{wet\_soda},\ \omega_{pr},\ G_{sec\_air},\ \Theta_{drum},\ p_{drum});$

$C_{CO2} = f_3(G_{fuel},\alpha,\ G_{wet\_soda},\ \Theta_{wet\_soda},\ \omega_{pr},\ G_{sec\_air},\ \Theta_{drum},\ p_{drum});$

$G_{offgas} = f_4(G_{fuel},\alpha,\ G_{wet\_soda},\ \Theta_{wet\_soda},\ \omega_{pr},\ G_{sec\_air},\ \Theta_{drum},\ p_{drum});$

where G_{dry_soda}– is consumption of dry soda; G_{fuel}– gaseous fuel consumption;α – the ratio between the primary air flow rate G_{pr_air} and gaseous fuel G_{fuel}; G_{wet_soda} – wet soda consumption; ω_{pr}– primary moisture content of soda; ω_{end}– the final moisture content of the soda; G_{sec_air}–secondary air consumption; Θ_{drum}– drying drum temperature; P_{drum}– dilution in the drying drum; G_{offgas} – offgas consumption; C_{CO2}–CO_2 concentration in the offgas.
Note that the automation system must maintain a given ratio
$\alpha = G_{pr\_air}/ G_{fuel}$.

The purpose of the automation system of this technological subsystem is determined by the target of the process - drying of sodium hydrogen carbonate to the given humidity.
The economic criterion is determined based on the profitability of the head unit. The greatest profit will be obtained with the highest consumption of dry soda per unit of raw materials and energy resources expenditures:

$K_{calc\_kiln,econ} = G_{dry\_soda} / C_{calc\_kiln},$

where $K_{calk_kiln,econ}$is the economic criterion of optimality for the soda drying process; C_{calc_kiln}– the cost of draining soda in a calcining furnace.
The main costs for thecalcining furnace are energy-related. They consist of the spent fuel cost and the cost of electricity consumed by the furnace rotation, the operation of the pumps' engines for supplying primary and secondary air and the offgas output, and so on.
Technological regulations may impose restrictions on fuel consumption, secondary air, offgas, the ratio between fuel and primary air consumption, the offgas temperature, the temperature and dilution in the drum, the final moisture content of the soda. So, we can present the task of economic optimization in the form of an optimization criterion:

$$K_{calc\_kiln,econ} = G_{dry\_soda} / C_{calc\_kiln} \to \max$$

and restrictions:

$$\begin{cases} G_{fuel,\min} \le G_{fuel} \le G_{fuel,\max}; \\ G_{\sec\_air,\min} \le G_{\sec\_air} \le G_{\sec\_air,\max}; \\ \Theta_{drum,\min} \le \Theta_{drum} \le \Theta_{drum,\max}; \\ p_{drum,\min} \le p_{drum} \le p_{drum,\max}; \\ G_{offgas,\min} \le G_{offgas} \le G_{offgas,\max}; \\ \omega_{end,\min} \le \omega_{end} \le \omega_{end,\max}; \\ \alpha_{\min} \le \alpha \le \alpha_{\max}. \end{cases}$$

According to the ecological criterion, it is expedient to use the consumption of the offgas containing carbon dioxide and other harmful components in its composition, if the harmful substances concentrations are approximately constant values or they are not measured individually:

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$K_{calc\_kiln,ecol} = G_{offgas}$,

where $K_{calk\_kiln,ecol}$–isecological criterion of optimality for the soda drying process.

The total amount of harmful substances can be used as the criterion, if all their concentrations are measured:

$$K_{calc\_kiln,ecol} = G_{offgas} \sum_{i=1}^{L} c_i ,$$

where c_i–concentration$i$ hazardous substance in the offgas; L-is the total amount of hazardous substance in the offgas taken into account.

The technological regulations may impose restrictions on the expense and composition of the offgas (in particular, on the concentration of CO_2).

Let us present the task of ecological optimization as one of the optimization criteria:

$$K_{calc\_kiln,econ} = G_{offgas} \rightarrow \min$$

or

$$K_{calc\_kiln,ecol} = G_{offgas} \sum_{i=1}^{L} c_i \rightarrow \min,$$

and restrictions:

$$\begin{cases} G_{fuel,\min} \le G_{fuel} \le G_{fuel,\max} ; \\ G_{\sec\_air,\min} \le G_{\sec\_air} \le G_{\sec\_air,\max} ; \\ \Theta_{drum,\min} \le \Theta_{drum} \le \Theta_{drum,\max} ; \\ p_{drum,\min} \le p_{drum} \le p_{drum,\max} ; \\ G_{offgas,\min} \le G_{offgas} \le G_{offgas,\max} ; \\ \omega_{end,\min} \le \omega_{end} \le \omega_{end,\max} ; \\ \alpha_{\min} \le \alpha \le \alpha_{\max} . \end{cases}$$

Choosing a social criterion is a rather difficult task. In the past no one actually tried to develop it. But the modern attitude to social problems requires consideration of this criterion for the production work. The social criterion for a separate technological subsystem of production is even more complicated. The authors propose to consider a single social criterion of optimality for all production for the present-day issue.

However, this criterion could be designed for each technological subsystem separately, and thena general social criterion with its weight coefficient could be introduced into the formula. In other words, we could use synthesis:

$$K_{hum\_aggr} = \sum_{j=1}^{N_{ss}} \gamma_{subsys,j} K_{hum\_subsys,j} \quad (1)$$

where $K_{hum_aggr}$is the value of the social optimality criterion for all production;Nss–number of dedicated subsystems in the production; $\gamma_{subsys,\ j}$– weight coefficient for j – technological subsystem; $K_{hum\_subsys,j}$ –is the value of the social optimality criterion for the j subsystem.

The authors suggest using as a social criterion for the soda production optimal quality, the criterion taking into account the workers profits, payments to the local budget and the production harmful effects on employees. Employees' profits can be determined through their wages and bonuses. Whereas payments to the local budget can be determined through taxes paid by the enterprise. The harmful effects of production can be determined through sick leave payment. Obviously, such payments will be made not only for professional but also for other diseases and injuries. But the amount of non-professional diseases in many respects depends on the ecological state of residence area. And soda production affects the ecology of the area to a large extent. Therefore, the use of such a measure of the production harmful effects on workers is appropriate.

If the abovementioned social criterion components are calculated additively and their different importance for production and the environment due to weight factors is taken into account, then $K_{hum\_subsys,j}$ can be presented as follows:

$$K_{hum\_subsys,j} = (k_{1,j} S_j + k_{2,j} T_j - k_{3,j} HS_j) / Q_{work,j} , \quad (2)$$

where $k_{1,j}$, $k_{2,j}$ and $k_{3,j}$ – are weight coefficients of the social optimality criterion components; S_j– total salary and bonuses paid to employees; T_j– the total amount of taxes paid; HS_j– the total amount of sick leave payments; $Q_{work,j}$– the number of employees j technological subsystem.

The question of assigning the weight coefficients to processes ($\gamma_{subsys,j}$) and parts of the social optimality criterion components ($k_{1,j}$, $k_2$jandk$_{3,j}$) can be solved exclusively with experts' help.

Payments to workers (wages and bonuses) and tax payments are taken with a positive sign, because these funds are used to improve people's lives. Sick leave payments are taken with a negative sign, because they are a kind of deterioration of life, negative impact of the enterprise.

So, takingintoaccount (1) and (2) we can formulate a generalized social criterion of production optimality:

$$K_{hum\_aggr} = \sum_{j=1}^{Nss} (k_{1,j} S_j + k_{2,j} T_j - k_{3,j} HS_j) / Q_{work,j} , \quad (3)$$

The limitations for setting the K_{hum_aggr} (3) minimization task may be that each of its elements must be non-negative, and the sum S_j must be at least the amount of the minimum salary set in the enterprise, $S_{\min}$. The $Q_{work,j}$ value can not be less than the number of employees at the current time, Q_{work}.

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According to the above studies, the mathematical support of automation systems will become much more complicated than it is now. This will happen not only because of increased measurements, but mainly due to the transition from stabilization systems to multi-criteria optimal systems.

In addition, the need to obtain subjective data follows from the equations (1-3). Technological processes automation experts, technologists, economists and environmentalists should become their sources. For this reason, the system will become too complicated, and its conclusions may be controversial.

Experts may misplace the priorities. Thus, the production efficiency may deteriorate and its work can be disrupted. In order to mitigate the influence of incorrect expert decisions, it is suggested to use the processes simulation model. However, this will also increase the intellectual component and the automation system design cost.

Thus, the documents should be created by skilled workers, who should process the different institutions requirements for the results of the production work in economic, environmental and social spheres.

Harmonization of documents related to the production conditions. Understanding the technology industries need to integrate in life saving processes on our planet forces international, government and local authorities to accept documents imposing a variety of restrictions on the functioning of these industries. Each of these documents contains certain emission limitations, economic or social indicators, but does not include methods for managing technologies and recommendations for automated technological complexes design. At the present stage of human development, the main document for the production process is the technological regulation. Documents of international organizations are still declarative.

The number of documents related to sustainable development is significant. The authors propose to enter and store all enterprises documents containing the statements of sustainable development (and others related to the problem of environmental problems globalization) in a special database (DB) with the designation DB_1.

New documents will complement the DB_1 as they arrive. Each document displays one or more-social, economical or ecological trend. According to this article, an optimality criterion has to be determined for each of the trends. For soda production, for example, it would be economically advantageous to use energy efficiently, to reduce the emission of harmful substances (for example, ammonia), and to increase the employees profits.

If the same document will deal with several trends, it can be divided into several relevant parts. For each document it is necessary to take into account the validity period and the fact it can be approved by international organizations, but not ratified by the country. Thus, a document can be displayed in DB_1, but it should not be used for calculations.

There should also be a DB_2 with the technological regulations requirements and information on the production parameters state. Such DB_1 will be suitable for work with *SCADA*-system [35].

Obviously, the documents contained in DB_1 and DB_2 have a different degree of importance. In addition, some international documents put forward requirements impossible to meet by means of automation systems. In order to take into account these circumstances in the management system, it is necessary to establish a mechanism for determining the degree of importance of each document for a specific production. Since the aggregate operating conditions of the enterprises may change, the degree of the importance correction is also required.

Therefore, developers of automation systems need to create data models for both databases and algorithms for their joint use.

The authors developed a generalized algorithm for the production management system taking into account the application of the sustainable development provisions (Figure-4). The following sequence of operations follows from it:

- maintenance of documents database (DB_1) created by international or state organizations for the implementation of the sustainable development provisions (these documents relate to the country, region and production in general); This operation is carried out by a group of experts "Experts 1";
- selection of numerical characteristics of sustainable development for the country and region; this is done by a group of experts "Experts 1";
- introducing database DB_2 containing data on the technological regulation requirements and the results of the production operation ;
- determination by means of DB_2 of current production indicators related to sustainable development;
- assessment of each of the sustainable development areas importance for the current situation and the trends in production and environment changes indicators (coefficients a, b, c); This operation is carried out by a group of experts "Experts 2" based on information from the DB_1 and DB_2;
- solving tasks of technological processes optimization : the tasks for regulators are calculated separately for each sustainable development area -Task 1,Task 2, Task 3;
- calculation of generalized tasks for regulators according to the importance degree of each of the sustainable development areas;
- tasks conduction by regulators of local control systems, influence on management objects, calculation of current indicators of technological objects functioning.

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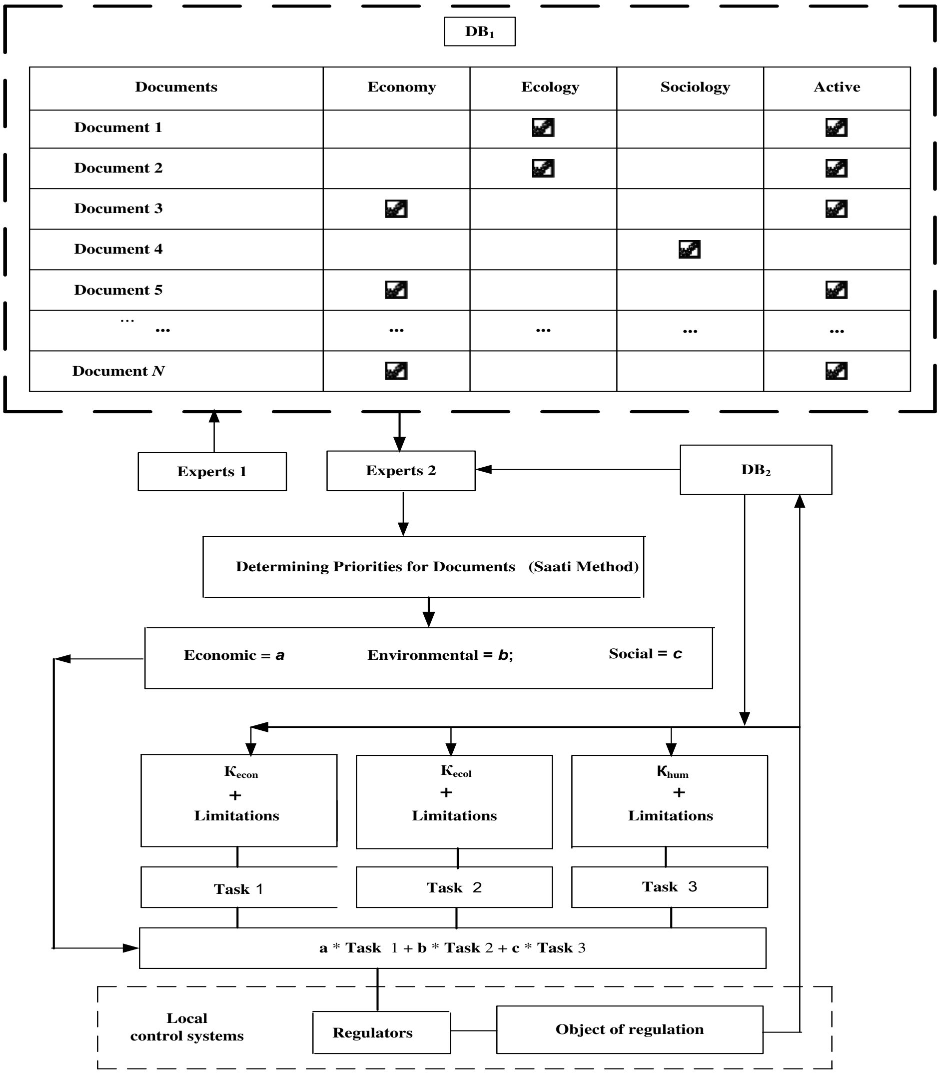

Figure-4. Scheme of the generalized algorithm of the production management system, taking into account sustainable development documents.

The algorithm clearly shows the possibility of individual operation performance with the help of the experts' intellectual abilities. The authors propose to involve several groups of experts.

To work with DB_1 you need international law specialists (in the sustainable development), experts in the legislation of the country, the region and the basic requirements for production (in the environmental and social problems and requirements area). Experts of this group (group Experts 1) should fill the DB_1, classify the documents by directions, provide the necessary legal advice. According to the work results of the DB_1, the company managers should also receive information on indicators of country and region sustainable development (indices, indicators, etc.).

The task of another experts group (Experts 2) - is to determine the degree of importance of documents for technological processes management. They receive information from the DB 1, the recommendations of Experts 1 and the operation results of the production technological system from DB2. Expert Group Experts 2 requires the introduction of specialists in various subject areas - of technologists, experts in the technological processes automation, environmentalists, economists, lawyers. According to the authors all of them must be employees of the very enterprise where the provisions of sustainable development are implemented.

There are suggestions for document processing systems, in particular [36, 37], which allow for coordinating their information, as well as decision-making methods for a plurality of criteria [38].

Obviously, the experts’ opinions will not coincide. A method of ranking these areas should be applied in order to develop a joint decision regarding the priority of individual areas of sustainable development for the technological system management.

There are many expert methods for determining priorities among multiple factors [39-56]. The authors, for example, chose a method for analyzing the Saati hierarchy [41]. In this method information about the relative importance of the criteria is presented as pair comparisons matrix. The *EXPERT CHOIC*E package for decision

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support recognized in the whole world was developed on its basis. This package is successfully used by such large corporations as General Motors, Lockheed, Ford Motor Company, Ferrari, General Electric and many others.

Let us consider using this method for our task. There is a set of objects A1, A2,..., An (object - document). It is necessary to compile a matrix A of pairwise comparisons of each of the documents importance based on the results of expert surveys (Experts group 2).

$$\mathbf{A} = (a_{ij})_{nxn} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix},$$

where a_{ij} is a matrix element, showing how many times the document A_i importance is greater than the document A_j importance.

The result of the Saati method is the vector of document importance, **w**. In our case, it is the coefficients a, b, c.

Such a situation is possible when the local system failed to find the optimality criterion for all classes of tasks. For example, it will always be difficult to formulate an optimality criterion and limitations for social tasks. The experts' work should help again.

At the stage of starting and debugging the system it is not necessary to submit the calculated task directly to the regulator. It is advisable to check the configuration of control systems on simulation models of management technological objects. You can submit tasks calculated separately for each sustainable development area for the same model and compare the results. Thus, experts get an opportunity to understand how to better adjust the comparisons matrix of the documents importance. If there are no simulation models, you can involve experts to predict the behavior of objects with calculated driving influences.

RESULTS

a) The generalized society development directions and relevant quantitative characters of social state envisaged by the conception of sustainable development (SD) are observed.

b) Examples are given on how each sector (economic, environmental and social) can be related to the technological processes, in a point of fact in the soda production. It is shown that the concept implication of SD requires choosing not only economic criteria for tasks of self-optimizing control of technological objects as well as environmental and social ones.

c) The environmental criteria application (related to the amount and composition of hazardous waste) will expand the research space for an optimization task (not only the technological device, but also the operational zones of the technological division, zones within the production territory, zones outside the production).

d) The social criteria application connected with the number and severity of diseases caused by the influence of production hazardous substance exposure. In such a case, the research space may be also different: workers (a production zone) and the public (those who live beyond the production).

As a result, it has been established that it is necessary to organize complementary measurements of the environmental and social production indicators for environmental and social criteria application.

e) It was found that the control impacts on technological control objects, defined at solving optimization problems by three different criteria will distinguish. In this regard, there is a coordination problem of three different optimization results. It is shown that this object can’t be solved by a formal way and it is suggested to use peer inspections of experts in the field of certain production.

f) It is determined that expert opinions should depend on several factors such as the current correlation between economics, ecology and social problems of the world and regional society development states and also from the production state. To track these states, there should be arrays of related information and constantly update them. The authors proposed to establish an appropriate database, which will contain the required data. The directing and usage of this date base should be included into the production automatic technological process control system.

g) The research shows that exist two main problems that will arise when commercial manufacture is involved in the sustainable development concept.

The first of them is the tasks number increase which should be solved by the automatic technological process control system. Moreover, these tasks will be associated with an increase in the amount of information involved in managing technological processes. The part of the information will come from international and public offices; the rest of the information should be provided by the production itself. That means, both the power of computer aids and the number of personnel should increase.

The second problem resides in the necessity to use intelligent information, in other words, the need for

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professionals will increase in environmental, social and international directions, and there will be tasks of carrying out relevant examinations.

h) It follows from the article materials that the implementation of the sustainable development concept in production is a long complex process, and it is expedient to implement it gradually solving separate tasks.

CONCLUSIONS AND DISCUSSIONS

Such a conclusions can be drawn, from the following study materials:

- the structure of the automation system becomes rather complicated, as the normative base of technological processes, the number of measurements and calculations increases;
- the automation system becomes very complicated as more people are involved in the management process;
- the requirements of each document, generally, cannot be fully implemented; Exceptions are situations where a document is the main or match results of calculations for all optimization criteria. Consequently, the regulators task should be considered as an optimal option for a multicriterial task;
- the reliability of the decisions taken in relation to determining the management effects on technological processes decreases, because, firstly, the automation system acquires a considerable complexity, and secondly, failing to take into account a document can cause a transition to the limit values of technological processes;
- the uncertainty of social and environmental requirements for individual production leads to the growing role of subjective factors in the quality and decision-making timing;
- the automation system becomes an essential intellectual component.

The conducted research allows us to make such recommendations for technological processes automation system designers.

At the beginning of automation system design or modernization, it is necessary to determine the significance of the production environmental impacts (by volume and level of emission harmfulness, by the distance between production and residence areas and important places of the plant world and reservoirs, etc.). If the impact of production on the environment is significant, the indicators proposed by the international community to characterize production as an object of sustainable development should be defined.

It is important to create a special team of specialists who will develop algorithms for sustainable development documents implementation in the process control algorithms. According to the authors, it is expedient to create and use expert systems [43] for the dissemination of specialist knowledge.

According to the research, it is necessary to attract specialists of a very high level and increase the funds for creation and operation of the automation system for the effective implementation of sustainable development provisions.

Hopefully, the results of the study will enable the implementation of sustainable development concept and other international documents into the production activities of people.

REFERENCES

[1] Our Common Future: Report of the International Commission on Environment and Development (ICRD). 1989. Tr. with English. S.A. Evteev, R.A. Perelet. - Moscow: Progress, 371 p.

[2] United Nations Framework Convention on Climate Change. http://unfccc.int/essential_ background/convention/items/6036.php

[3] Protocol to the 1979 convention on long-range transboundary air pollution to abate acidification, eutrophication and ground-level ozone https://www.unece.org/fileadmin/DAM/env/lrtap/full %20text/1999%20Multi.E.Amended.2005.pdf/.

[4] Rio de Janeiro Declarationon Environment and Development Adopted by the United Nations Conferenceon Environment and Development, Rio de Janeiro, 3-14 June 1992. http://www.un.org/ru/documents/decl_conv/declarations/riodecl.shtml/.

[5] The Earth Charter. http://earthcharter.org/ discover/the-earth-charter/.

[6] The United Nations Millennium Declaration. Adopted by General Assembly resolution 55/2 of 8 September 2000. http://www.un.org /ru/documents/decl_conv/declarations/ summitdecl.shtml/.

[7] UN and Sustainability. http://www.un.org/en /sections/general/un-and-sustainability/ index.html/.

[8] Zgurovsky M.Z. 2008. Sustainable Development Global Simulation: Quality of Life and Security of the World Population (2005-2007 / 2008) / M.Z. Zgurovsky, A.D. Gvishiani. -K.: NTUU KPI. p. 140.

[9] Zgurovsky M. Z. 2008. Assessment of Sustainable Environmental Development at a Sub national Level

©2006-2021 Asian Research Publishing Network (ARPN). All rights reserved.

in Ukraine / Zgurovsky M.Z., Statyukha G.O., Dzhigirey I.M. // System Research and Information Technologies. No. 4. 7-20. http://dspace. nbuv.govua/handle/123456789/11999.

[10] Melnik L.G. 2012. EU experience in building innovative strategies for sustainable development/ Melnik LG, Degtyaryova I. B. // Marketing and management of innovation. (1): 190-200. http://mmi.fem.sumdu. edu.ua/sites/default/files/mmi2012_1_190_200.pdf/.

[11] Daly Herman. 2002. Out of growth: the Economics of Sustainable Development/ H. Daly. - Trans. from eng., Institute Sustainable Development. - K.: Intelsfera, p. 312. http://library.kpi.ua:8991/F?func=find-b&request=000266503&find_code=SYS/.

[12] Pearce D. W., Warford J. J. 1993. World without end: economics, environment, and sustainable development. - p. 451. https://www.cabdirect.org/cabdirect/abstract/ 19926714828/.

[13] Ashok Sahai, Clement K. Sankat, Koffka Khan. 2012. Decision-Making Using Efficient Confidence-Intervals with Meta-Analysis of Spatial Panel Data for Socioeconomic Development Project-Managers, International Journal of Intelligent Systems and Applications. 4(9): 92-103, DOI: 10.5815/ijisa.2012.09.12.

[14] Hrechanyk N. Yu. 2014. Environmental Dimension of Sustainable Development: Marketing Approach. Sustainable development of economy. 1(23): 94-101.

[15] Bozheneva I. M. 2012. Theory of Steady Development and its Role in the Process of Management Enterprise/ I. M. Bozheneva // Collection of scientific works VNAU. Series: Economic Sciences. 3(80): 21-28. http://econjournal.vsau.org/files/pdfa/2096.pdf/.

[16] Pakulin S. L., Pakulina A.A. 2016. Management of sustainable development of modern enterprises. TraektoriâNauki. 2(3): 21-217.

[17] Measuring sustainable development: macroeconomics and the environment. 1997. Atkinson G.; Dubourg R.; Hamilton, K.; Munasinghe M.; Pearce D.; Young C. // Measuring sustainable development: macroeconomics and the environment. 252 pp. ref.23 pp. https://www.cabdirect.org/cabdirect /abstract/19981806027/.

[18] Michael H. Huesemann. 2003. The limits of technological solutions to sustainable development. Clean Technologies and Environmental Policy. 5(1): 21-34| https://link.springer.com/article/10.1007/ s10098-002-0173-8/.

[19] Kristina Oskarsson, Fredrik von Malmborg. 2005. Corporate Social Responsibility and Environmental Management. 12(3): 121-128.

[20] Heksel L. K. 2008. Methodology for improving soda production on the basis of a systemictrip. Thesisfor a scientific degree of the Doctor of TechnicalSciences, Moscow State Academy of Fine Chemical Technology. M. V. Lomonosov Moscow State University, Moscow. p. 259.

[21] Zhuchenko A. I. 2011. System management of technological processes in the mentality of the bagatovectorality of Wimog / A. I. Zhuchenko, L. D. Yaroshchuk, T. V. Makarov // Automatics / Automatics - 2011: Materialofthe XVIII International Conference of Automatic Control, 28-30 veresnya 2011 inthecity of Lviv / National Academy of Sciences of Ukraine [та інші]. - Lviv: Publishing House of Lviv Polytechnic, 344-345. https://core.ac.uk/download/pdf/ 67645215.pdf/.

[22] Zhychenko A. I. 2012. Development of criteria for automation in the production of soda in the conditions of multidirectional requirements [Text] / A. I. Zhuchenko, L. D. Yaroschuk, T. V. Makarov / Automation / Automatics - 2012. XIX International Conferenceon Automatic Control, September 26-28, 2012: Conferencematerials. - K: NUKHT, 359-360.

[23] Shubchik O. A. 2013. Analysis of the directions of automation of the system of balance dindicators of enterprise a ctivityon the basis of moderns of twaretools / O. A. Shubchik // Sustainable development of the economy. 3(20): 114-118.

[24] Zhuchenko A., Kvasko M., Osipa R. 2011. The use of microprocessor technology in wastewater treatment control systems Bulletin of the National Technical University of Ukraine Igor Sikorsky Kyiv Polytechnic Institute ser. Chemical Engineering, Ecology and Resource Saving. 1.2(.8): 143-145.

[25] Zhuchenko A., Osipa R., Osipa L. 2016. Optimization tasks, which are solved in the integrated automated

©2006-2021 Asian Research Publishing Network (ARPN). All rights reserved.

control system of water saving processes Bulletin of the National Technical University of Ukraine KPI named after I. Sikorsky ser. Chemical Engineering, Ecology and Resource Saving. 15(1): 108-110.

[26] Osipa R. 2019. Statics Simulation of the Buffer Wastewater Neutralization Process. International Journal of Engineering and Manufacturing(IJEM), 9(4): 1-14, DOI: 10.5815/ijem.2019.04.01

[27] Indicators of Sustainable Development: Guidelines and Methodologies: [Text] / United Nations publication. 2007. -Third edition. - NY.: United Nations, Sales No: E.08.II.A.2, October, -99 p. 2300 copies.

[28] Tarasova N.P. 2006. The Indices and Indicators of sustainable Development / N.P. Tarasova, E.B. Kruchina // International Conference Proceeding Sustainable development: Nature, Society. 2006. Man, Moscow. 1: 127-144.

[29] Environmental Performance Index [Electronic resource] / http://www.epi.yale.edu /downloads/.

[30] Environmental Sustainability Index: Benchmarking National Environmental Stewardship: [Electron. resource]. - Access link: http://www.yale.edu/esi/.

[31] Shokin I. N., Krasheninnikov S. A. 1975. Technology of soda. -M.: Chemistry. p. 288.

[32] Zaitsev I. D., Tkach G. A., Stoev N. D. 1986. Production of soda. -Moscow: Chemistry. p. 311.

[33] [33] Anatolii I. Zhuchenko, Liudmyla V. Osipa, Evgeniy S. Cheropkin. 2017. Design Database for an Automated Control System of Typical Wastewater Treatment Processes. International Journal of Engineering and Manufacturing (IJEM), 7(4): 36-50, DOI: 10.5815/ijem.2017.04.04.

[34] Ahmad Ashari, Mardhani Riasetiawan. Document Summarization using TextRank and Semantic Network. 2017. International Journal of Intelligent Systems and Applications. 9(11): 26-33, DOI: 10.5815/ijisa.2017.11.04.

[35] Rasim M. Alguliyev, Ramiz M. Aliguliyev and Gulnara Ch. Nabibayova. The Method of Measuring the Integration Degree of Countries on the Basis of International. 2017. International Journal of Intelligent Systems and Applications. 7(11): 10-18, DOI: 10.5815/ijisa.2015.11.02.

[36] T. K. Das, D. P. Acharjya, M. R. Patra. 2015. Multi Criterion Decision Making using Intuitionistic Fuzzy Rough Set on Two Universal Sets. International Journal of Intelligent Systems and Applications. 7(4): 26-33, DOI: 10.5815/ijisa.2015.04.04.

[37] Grabovetskii B. Ye. 2010. Methods of expert assessments: theory, methodology, directions of use: monograph. - Vinnitsa: VNTU. p. 171.

[38] Beshelev S. D., Gurvich F. G. 1980. Mathematico-statistical methods of expert evaluations. - Moscow: Statistics. p. 263.

[39] Saati T. 1993. Decision-making. The method of analyzing hierarchies. - Moscow: Radio and Communication. p. 320.

[40] Geerthik S., Rajiv Gandhi K., Venkatraman S. 2017. Category based expert ranking: a novel approach for expert identification in community question answering. ARPN Journal of Engineering and Applied Sciences. 12(1): 194-200, ISSN 1819-6608.

[41] Waterman D. A. 1989.Guide to expert systems / Trans. from English. - Moscow: Mir. p. 388.

[42] Zhulynskyi A. A., Ladieva L. R., Korniyenko B. Y. 2019. Parametric identification of the process of contact membrane distillation. ARPN Journal of Engineering and Applied Sciences. 14(17): 3108-3112.

[43] Korniyenko B. Y., Borzenkova S. V., Ladieva L. R. 2019. Research of three-phase mathematical model of dehydration and granulation process in the fluidized bed. ARPN Journal of Engineering and Applied Sciences. 14(12): 2329-2332.

[44] Kornienko Y. M., Liubeka A. M., Sachok R. V., Korniyenko B. Y. 2019. Modeling of heat exchangement in fluidized bed with mechanical liquid distribution. ARPN Journal of engineering and applied sciences. 14(12): 2203-2210.

[45] Bieliatynskyi A., Osipa L., Kornienko B. 2018. Water-saving processes control of an airport. Paper presented at the MATEC Web of Conferences, 239. doi:10.1051/ matecconf/ 201823905003

[46] Korniyenko B., Galata L., Ladieva L. 2018. Security estimation of the simulation polygon for the protection of critical information resources. Paper

©2006-2021 Asian Research Publishing Network (ARPN). All rights reserved.

presented at the CEUR Workshop Proceedings. 2318, 176-187.

[47] Galata L. P., Korniyenko B. Y., Yudin A. K. 2017. Research of the simulation polygon for the protection of critical information resources. Paper presented at the CEUR Workshop Proceedings. 2067, 23-31.

[48] Galata L., Korniyenko B. 2020. Research of the training ground for the protection of critical information resources by iRisk method. Mechanisms and Machine Science. 70: 227-237. doi:10.1007/978-3-030-13321-4_21

[49] Korniyenko B.Y., Osipa L.V. 2018. Identification of the granulation process in the fluidized. ARPN Journal of Engineering and Applied Sciences. 13(14): 4365-4370.

[50] Korniyenko B., Galata L. 2019. Implementation of the information resources protection based on the CentOS operating system. 2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering, UKRCON 2019 - Proceedings 2019, 1007-1011.

[51] Zhuchenko A.I., Cheropkin Y.S., Osipa R.A., Korniyenko B.Y. 2020. Features of mathematical modeling of the first stage of paper web drying. ARPN Journal of Engineering and Applied Sciences. 15(5): 647-656.

[52] Kornienko Y.M., Haidai S.S., Sachok R.V., Liubeka A.M., Korniyenko B.Y. 2020. Increasing of the heat and mass transfer processes efficiency with the application of non-uniform fluidization. ARPN Journal of Engineering and Applied Sciences. 15(7): 890-900.

[53] Korniyenko B., Galata L., Ladieva L. 2019. Research of Information Protection System of Corporate Network Based on GNS3, 2019 IEEE International Conference on Advanced Trends in Information Theory, ATIT 2019 -Proceedings 2019, 244-248.

[54] Korniyenko B., Galata L., Ladieva L. 2019. Mathematical model of threats resistance in the critical information resources protection system. Paper presented at the CEUR Workshop Proceedings. 2577, 281-291.

[55] Kornienko Y.M., Sachok R., Tsepkalo O.V. 2011. Modelling of multifactor processes while obtaining multilayer humic-mineral solid composites. Chemistry. 20(3): E19-E26.

[56] Kornienko Ya. N., Podmogilnyi N.V., Silvestrov A.N., Khotyachuk R.F. 1999. Current control of product granulometric composition in apparatus with fluidized layer. Journal of Automation and Information Sciences. 31(12): 97-106.