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Digital Software of Industrial Enterprise Environmental Monitoring

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Abstract

The relevance of the article is due to the need to develop and improve the environmental management of industrial enterprises in conditions of high environmental risk and the continued irrational use of natural resources. The purpose of the article is to develop new mechanisms of environmental monitoring using mathematical methods and the potential of modern digital smart systems of manufacture management. The authors consider the goals and objectives of industrial enterprises' environmental monitoring, the idea of using environmental restrictions in new opportunities for growth of manufacture activities and its quality improvement. The authors developed a module of data statistical analysis of manufacture processes, allowing new information obtaining about their condition and to use it for solving problems of environmental management and improvement of the industrial enterprise's manufacture activities as a whole; showed the possibility of this module's integration with the existing manufacture management system. The article is intended for managers of industrial enterprises, employees of quality management and environmental management departments, developers of management digital smart systems.

Keywords: environmental management, environmental monitoring, digital software, industrial enterprise, manufacturing execution system

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INTRODUCTION

Manmade development caused a contradiction between cultural and civilizational achievements, natural appropriateness and use of natural resources and actualized the phenomenon of specific environmental management as a system of reasonable and conscious consumption and recreation of natural components of the environment (Gulak 2013, Kobeleva 2012, Makholava and Akhmatova 2015, Podprugin 2012). Modern philosophy emphasizes: ecology becomes a philosophy of survival, considering man as a subject of moral responsibility for the consequences of his actions for his own life and the lives of other creatures living in the biosphere (Crass 2010, Danilov-Danilyan and Losev 2000, Doroshenko 2012, Yanickii 2014).

Health and safety of the modern person living in the metropolis, largely depends on the level of environmental safety of operating industrial enterprises, despite the fact that the commercial purpose of their operation, regardless of the industry (oil, gas, chemical, water, metallurgical, etc.), is to maximize profits, to preserve and enhance competitive advantages. The management of environmental processes – the interaction of man, manufacture and nature, taking into account numerous territorial, landscape, industrial, socio-cultural and other factors, condition the provision

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of social responsibility and guarantees to the society by the industrial enterprise.

Many researchers note that the task of the economy, in the broadest sense, is the need to find ways to meet the ever – growing needs of people with limited resources, while there are two more important issues-self-recovery and the further potential of the environment, taking into account manmade and industrial needs (Buletova 2013, Khabarova 2011, Medvedev 2015, Pakhomova et al. 2013) These factors determine the significance of the environmental management system of the enterprise, implementing its environmental policy, and actualize the need to improve and develop environmental monitoring systems of industrial enterprises, including, taking into account modern achievements of digital smart systems (Pakhomova and Khorochavin 2016, Salim'yanova and Treiman 2017). In order to eliminate routine operations that inhibit the intensity of processes, as well as the integration of real-time information flows based on the digital smart system of the enterprise, the authors propose to use the potential of manufacturing execution system (MES) in the implementation of environmental policy and objectives of the enterprise (Galushkin 2015, Kudinov, Markov and Ostrast 2013, Sudarikov and Merkulova 2017).

MATERIALS AND METHODS

The Role and Functions of an Industrial Enterprise's Environmental Monitoring

The policy of industrial manufacture safety, preservation of life, health of citizens and territories explains the priority of environmental management. As a rule, the control of target and planned environmental indicators: the level of air pollution, water resources, soil surrounding areas, as well as the method of disposal of industrial waste carries out organization of environmentally safe production processes and prevention of negative anthropogenic impact on nature in the process of production, consumption and disposal of products.

Environmental monitoring is a toolkit of environmental management aimed at the formation of a production complex that minimizes the consequences of its industrial activities relative to the environment (Bocakova 2014, Chkhutiashvili 2017, Dobrolyubova 2016, Sartigan 2007).

In this context, the objectives of environmental monitoring include:

Observation of processes and phenomena occurring in the environment of an industrial enterprise and identification of changes associated with both manufacture activities and a variety of natural phenomena and conditions;

Assessment of the company's emissions (water, air, waste, soil) from the standpoint of the actual impact of manufacture activities on the environment in the area of the facility;

Forecast of the consequences of the actual impact of manufacture activities on the environment;

Assessment of the effectiveness of environmental measures carried out at the industrial enterprise.

The analysis of these positions led us to the conclusion that along with the systematic monitoring of manufacture activities' impact on the environment and compliance with environmental legislation, there are reserves for environmental restrictions' transfer into new opportunities for the growth of manufacture activities, quality control, improvement of the environmental monitoring system and forecasting possible changes in the quality of the environment. The essence of the proposed innovations is to use the potential of modern information software and digital smart systems already implemented in industrial enterprises.

Information software of environmental monitoring is a part of information software of environmental management of the enterprise and includes a system of databases evaluated in terms of the environmental component of manufacture processes' indicators that affect the overall environmental performance. Work with them-monitoring, analysis, forecasting determines further regulation of quantitative parameters (volume of emissions, concentration of substances, etc.). The need for such information is particularly acute in industrial enterprises in the context of environmental management systems' formation.

Application of Manufacturing Execution System in Environmental Monitoring of Industrial Enterprise

Considering the industrial enterprise as a system, one can attribute it to socially active, dynamic systems, when its controlled elements can affect the overall state of the system, or change their state by their own. Management of systems of any type, as well as any other object, is aimed at changing its current state and trajectory of development for the implementation of the

goals. Thus, goal setting is a reporting point and involves setting parameters, conditions and control mechanisms.

Modern organizations automate their activities – management functions (document management, accounting, controlling, and management decision-making support) and manufacture functions (manufacture lines, machines with digital software control, quality control). Automated industry systems (MES – manufacturing execution system) allow you to monitor daily changes in processes and product lines. Such systems provide a platform for improving management processes and therefore provide a direct route to increased profitability. MES is a digital smart system that supports the implementation of all functional tasks for planning, control, accounting and analysis of the entire manufacture process at all its stages and aimed at achieving the maximum economic effect from manufacture activities. Then it is obvious that not only environmental management, but also the safety of the enterprise and surrounding areas largely depends on the reliability of the MES operation.

The composition of the problems solved by MES is significant, they include:

– monitoring the state and allocation of resources – RAS) - loading of manufacture resources (on what equipment, what operations are performed or were performed, the personnel and tools involved);

– production dispatching (DPU) - managing the sequence of production tasks, redistribution of individual operations between specific instances of equipment, teams of workers in accordance with the current situation in the workshop;

– Management of material flows on operations, orders, batches, series, through work orders with full visualization of the entire production process;

– Document management (DOC – - ensuring paperless workflow of production, technological and licensing documentation of manufacturing processes;

– data collection and storage (DCA) - interaction of information subsystems in order to obtain, accumulate and transmit technological and control data circulating in the production environment of the enterprise;

– personnel management (LM –monitors and changes the load of personnel in relation to production tasks, equipment used, processed batches of materials and raw materials;

– product quality management (QM) – analysis of product quality measurement data in real time based on information coming from the manufacture level, ensuring proper quality control, identification of critical points and problems that require special attention.

The type and priorities of manufacture determine the choice of the implemented MES functions. Each type of manufacture has its own character, its own *painful points* and its own *places of additional profit*, which impose special *industry* requirements for the functional tasks of MES.

Systematic registration of production process indicators in terms of environmental management provides critical information about the production process, including analysis of downtime and production efficiency using the following digital technologies:

– InTouch HMI/SCADA – SCADA system and data visualization;

– Industrial SQL Server-real-time relational database and Active Factory-reporting tools;

– Down Time Analyst-system for tracking and recording downtime

– Suite Voyager-industrial digital portal;

– In Track – materials flows management of discrete manufacturing;

– I/O-servers.

The collection of all process data and information on the quality from all manufacture units in a Central database provides all users with a solid and reliable basis for decision-making. This helps to avoid wrong steps and product quality problems due to *late response*. Examples are regular management reports with key performance indicators and the *information center for all factory users*, which are the basis for the analysis of deficiencies in any manufacture process. Regular assessment of work and material quality from the standpoint of environmental management will allow the company to improve manufacture processes from a global point of view, not limited to the operation of individual units. This practice not only achieves separate positive results, but also optimizes the work of the entire enterprise.

<table>
<tr><td colspan="5">Stage 1</td></tr>
<tr><td rowspan="2">input→</td><td colspan="2">TECHNOLOGICAL PROCESS
↓</td><td colspan="2" rowspan="2">→output
↓</td></tr>
<tr><td colspan="2">Technological line</td></tr>
<tr><td colspan="3"></td><td colspan="2">Indicators' sensors</td></tr>
<tr><td colspan="5">Stage 2 ↓</td></tr>
<tr><td>Process tolerance definition</td><td>←</td><td colspan="2">Process event analysis</td><td>←</td><td>Receive data by Manager Scada</td></tr>
<tr><td colspan="6">↓ Stage 3</td></tr>
<tr><td colspan="2">Setting the logistics of the events and MES process States</td><td>→</td><td colspan="3">Messages about the current state of the process for MRP to make management decisions</td></tr>
</table>

Fig. 1. Step-by-step operation of MES-technologies in the implementation of environmental monitoring of manufacture processes of petrochemical enterprises

The Mathematical Apparatus of the Study

For the purpose of manufacture regulation processes and implementation of ecological control tasks, we apply:

1. *The method of three Sigma*, based on the calculation and analysis of statistical characteristics of the process - interpretation of the standard deviation, which allows to assess how the diagnosed values of the parameters of the process differ from the *reference* average. This makes it possible to estimate the permissible variability of the process with respect to its main characteristics.

2. *Correlation analysis,* allowing to study the relationship between variables (process indicators) and to simulate time series with a given type of correlation function. This method helps to determine the normalization of the values of the process indicators by studying the correlation coefficient between the levels of the original time series and the levels of this series shifted by several steps in time. This makes it possible to establish links between successive levels of the series caused by the action of any long-term causes, which leads to the presence of such components of the series as the long-term trend and the periodic component, which allows deeply assess the essence of the process under study in dynamics.

3. *Spectral analysis* that allows you to select and amplify signals with *useful* frequencies and suppress *harmful* frequencies characteristic of noise and disturbances. It is based on the study of spectral density, which demonstrates the distribution of signal power according to information about useful signals, noise and disturbances.

RESULTS

One can consider the step-by-step operation of MES-technologies in the implementation of environmental monitoring of manufacture processes of petrochemical enterprises (**Fig. 1**).

At the initial stage, data collection from sensors during the technological process is automated. At the second level, the data obtained from the automation systems of the first level are transmitted for processing and control in software systems – SCADA (Supervision Code and Data Acquisition). At the third level, MES systems are created, which form information about the manufacture process, using the data of the previous level in a convenient and understandable form for making management decisions, and then bring the decisions to the management of departments. Further integration of MES with automated management functions – Manufacturing Resource Planning (MRP), including automation of accounting and management accounting, General document flow in the enterprise, planning is possible.

Comparing planned and actual MES performance allows you to analyze equipment operation and work shifts in terms of performance and efficiency. Therefore, in the aspect of the question considered on the flow control of technological processes and ensuring a high level of reliability and safety of petrochemical manufacture the MES functioning is based on the principle of control and coordination of flows in real time, and the emphasis is on the technological process monitoring and its stable performance maintenance. MES accumulates all information flows that characterize the current state of the manufacture process – data on the acceptance of raw materials and shipment of products, stocks in warehouses and tanks, the current load of technological plants and workshops, data on the quality of semi-finished products and the consumption of heat and energy resources.

The task of operational control includes the following functions:

– Control of technological modes violations;

– Control of the plan's fulfillment, the calculation of the deviation of the fact from the plan for the change of day;

– Control of consumption and distribution of material and energy resources;

– Control of operation of technological equipment and safety ensuring;

– Recording and control of the dispatcher's orders execution;

– accounting for the movement of raw materials, semi-finished products and manufacture products;

– Formation of dispatching and manufacturing reporting.

Thus, one of the most important conditions for the use of MES potential in environmental management is the definition of key process parameters based on the readings of device sensors, their interaction, interdependence, process tolerances (variability of boundaries). Normative data on permissible deviations of technological parameters and quality parameters enter the system, which allows to signal about going beyond them and to investigate the process, its risks in an intensive mode to prevent possible extreme situations.

From the standpoint of mathematical data processing, MES allows not only to collect the necessary production and technological data, but also to manage the processes, for example, to set the technological parameters of the equipment operation; to track the history of the product (PTG) – visualization of information about the place and time of work for each product, to perform performance analysis (PA) – providing detailed reports on the actual results of production operations. The information may include reports on performers, technological routes, components, materials, batch and serial numbers, changes made and current production conditions, etc.

In addition to the above-mentioned standard variable functions of MES, we propose to integrate dynamic diagnostics of measuring devices with the help of a mathematical apparatus into an automated control system. All available information, in our opinion, can be used to implement the tasks of environmental management and ensuring the industrial safety of the enterprise as a whole, if we introduce the author's module of statistical analysis of data coming from the sensors of the production line (processes). The proposed module will enhance the functionality and practical usefulness of production processes' monitoring, providing automatic adjustment or management interactive support.

The content of this module includes:

Analysis of statistical data by the method of three Sigma in order to identify the permissible limits of the current process based on retrospective information and statistical analysis of data; Simulation of time series with a given type of correlation function, analysis of methodical errors of pseudorandom sequence generation with a given type of correlation function and spectral analysis, allowing timely detection of breakdowns and inaccuracies of measuring instruments.

InTouch HMI/SCADA, a package for the development of HMI (Human Machine Interface) was used to create a module for the environmental manufacturing monitoring system of an industrial petrochemical enterprise. This software product supports animation, master objects, historical trends and real-time trends, has a built-in programming language, a library of functions. The InTouch SCADA system is a powerful human-machine interface (HMI) for industrial automation, process control and control by the dispatcher. The world-famous human-machine interface software InTouch HMI from Wonder ware, designed for visualization and control of production processes, provides an easy-to-use development environment and a set of graphical tools. The package offers a number of significant advantages that can significantly improve manufacture productivity and efficiency. Powerful development tools and implementation of the new Wonder ware Smart Symbols technology provide extensive functionality for the rapid creation and deployment of custom automation applications that communicate and transmit real-time information to the graphical representation of industrial processes. For application development, an environment with Window Maker is used. These Windows can be connected to industrial systems or other Microsoft Windows applications. InTouch applications can be viewed using a variety of digital devices, and information about the process flow is provided to the tracking operator in the form of graphs, process tolerance is analyzed here by means of the author's module (**Fig. 2**).

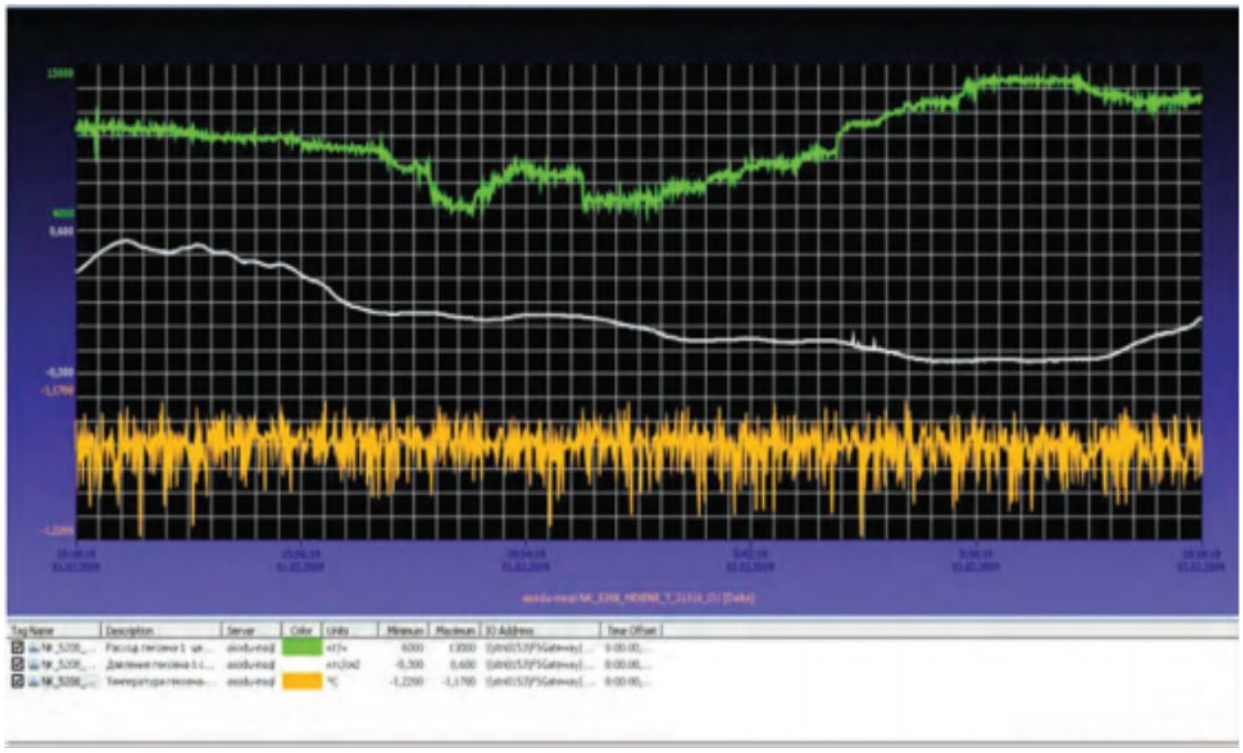


Fig. 2. An example of production processes technology progress (analysis of resources' consumption, pressure and temperature)

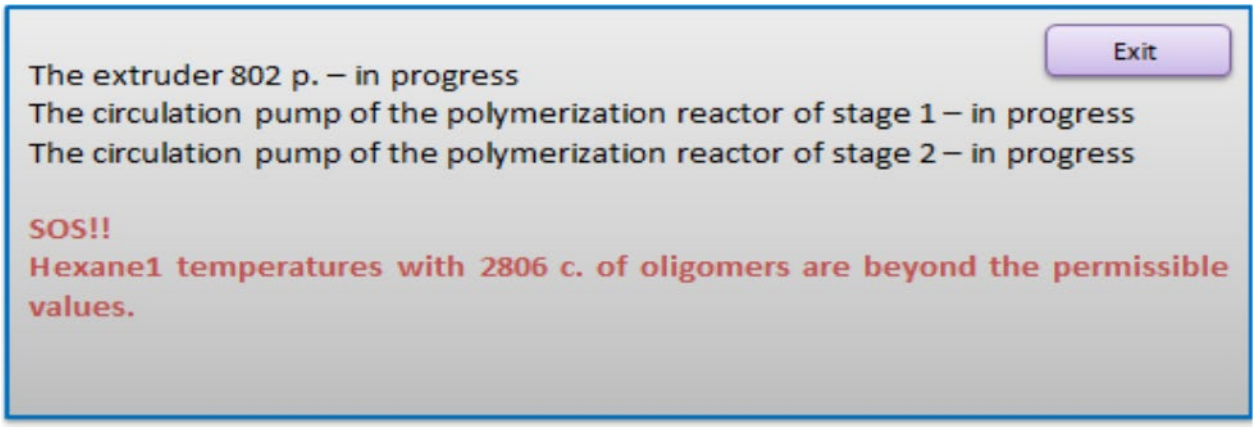
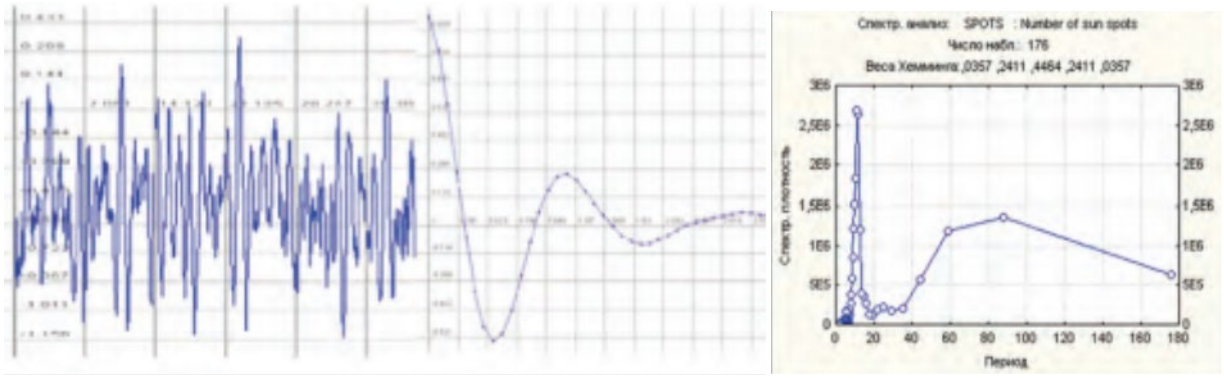


Fig. 3. The kind of a sensor signal in excess of the parameters values (going beyond the established interval of ±3δ)

Further, when obtaining the type of correlation function, the search for safe boundaries of the process was carried out based on statistical analysis of the data, the descriptive indicators of the processes were calculated and the values of the standard deviation (δ) were established. The set interval ±3δ allows with a high degree of reliability to "keep" the current production process in normal condition by means of special equipment - customizable process sensors installed on the production line and visualized with MES. Each sensor has a window with a graphical representation of the flow data (flow, pressure and temperature, or only flow). In case of any problems in the production, the alarm system lamp turns red (in normal operation, the lamp is green) and a description of the process conditions is displayed (**Fig. 3**).

The alarm system gives a signal to start the dynamic diagnosis of measuring instruments, or rather to diagnose the device that is responsible for measuring of the data of the flow, the parameters of which are beyond. The mathematical processing Windows look like **Fig. 4**.



a) a Random signal and a graph of the correlation function

(b) graph of spectral density dependence on time period (spectral analysis)

Fig. 4. Example of the author's module of statistical data analysis

The analysis of the above-mentioned example allows us to determine that there is a pronounced 11-minute cycle of temperature excess; moreover, there are signs of the existence of a longer, approximately 80-90-day cycle, this follows from the form of the curve obtained from spectral analysis. The obtained data need further processing and analysis, construction of forecast data by specific specialists in order to identify new patterns, and possibly to make changes in the production process to study the level of impact on the safety of the entire facility

That is, the inclusion of environmental control through MES into the active production system allows also diagnosing measuring devices using a mathematical apparatus, which includes the primary diagnosis of sensors based on statistical parameters and diagnostics of sensor faults measuring devices through spectral analysis, which contributes to the safety of the industrial facility as a whole. As a result, there is a continuous improvement of all production processes not only from the standpoint of environmental management, but also from the standpoint of the functioning of production lines, debugging equipment, tracking system, data forecasting, etc. (in accordance with the requirements of the quality management system).

Continuous monitoring of all sensors of industrial production technological processes provides a high level of environmental control and safety of industrial production lines with visualization of the process. In case of deviation of the normalized parameters, the system gives a signal about the approximation of the values of the process indicators to the critical values, which allows either to quickly correct the situation, or (in extreme cases) to stop the flow process production to prevent a possible industrial disaster.

As recommendations when connecting additional calculation modules to MES, the need should be noted for digital filtering of data flows, which determine the speed of their processing. In a narrow sense, a digital filter is a frequency-selective circuit that provides selection of digital signals by frequency (Kaplun 2012). After performing digital filtering, we usually get the signal we are interested in, i.e. the signal carrying the information we need, in a form convenient for further processing. Accordingly, with a significant amount of processed information filter orders increase dramatically, which seriously affects the hardware costs, since during the synthesis of digital filters the greatest time and equipment costs fall on the multiplication operation.

Theoretically, the problem of processes formation with a given type of correlation function is solved by filtering and is reduced to determining the characteristics of the forming filter with known characteristics of the input and output signals. The study of algorithms of non-recursive filter (direct convolution, a moving spectrum and inverse Fourier transform) demonstrates that the sampling frequency of the samples at the output of the filter in accordance with the provisions of the theory of sampling from the continuum images is uniquely associated with the width of its stripe. Violation of this position in the traditional implementation of digital filtering, when the frequency f is assumed to be equal to the sampling rate of the input sequence, leads to information redundancy of discrete representation of the filter reaction and is accompanied by unproductive computational cost, reducing the efficiency of computing facilities; in this regard, the paper proposes to increase the slip step of input information.

CONCLUSION

Our findings allow us to draw the following conclusions and recommendations:

1. The system of environmental control, of course, should be included in the environmental management system and the overall enterprise management system. In addition to the typical tasks of environmental control, we offer preventive measures – analysis of production process indicators in order to identify their deviations from the normalized values, and therefore, the prevention of dangerous environmental situations and reducing of the likelihood of their occurrence at the early stages of production.

2. The introduction of environmental control through MES into the active production system and its connection to the General enterprise management system demonstrates their significant usefulness and the possibility of multi-faceted use with insignificant financial and resource costs for its development for the industrial enterprise.

3. The use of mathematical statistics methods and their integration with MES allows identifying the cycles of potential hazards of production, carrying out modeling of processes and their analytical analysis in order to solve the problems of environmental control.

4. Implementation of diagnostics of production lines and measuring devices directly in the process of production allows determining and investigating the painful points of production processes from the standpoint of environmental management and from the standpoint of safety in General. The data obtained serve as the basis for predicting possible events and developing the necessary security measures, schedules of additional checks, etc.

Thus, the improvement of mechanisms of environmental management and safety of industrial production based on modern computer systems for monitoring the state of the equipment state during its operation using systems that measure the parameters of various physical and industrial processes meets the current challenges of ensuring the safety of life activity and environmental protection on a national scale (Khaliy 2015, Spiridonov 2010, Titarenko 2015). The result of all the above-mentioned tasks of MES in the framework of environmental control is an analytical analysis that runs through all its functions. The MES projects use an approach to production management based on key performance indicators, allowing several aggregate criteria to monitor current trends in all areas of the production process.

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