

Eco-ergonomic Designing of Working Environment

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The necessity of applying new directions of ergonomics to improve safety at work is considered. The relevance is conditioned by the awareness of the problem of limited natural resources and the negative impact of human activity on the environment. It led to the necessity of rethinking the concept "security" from the standpoint of sustainable development of society. Today, safety is the procuring of harmonious relations between human and the environment in all spheres of activity. In terms of occupational safety, new areas of ergonomics such as ergoecology, green ergonomics and eco-ergonomic designing can be useful in creating such balance. The work focuses on using eco-ergonomic designing principles in matters of ensuring industrial safety. Thus, the aim is the practical application of the eco-ergonomic designing principles to improve safety at working place. At researching the basic eco-ergonomic designing principle was applied - the search of an optimal combination of working conditions and technical procuring at the workplace, which would suit modern psychophysiological, social, engineering and ecological requirements. The prime tool of researching is a practical analysis of workplaces, an essential component of which is the assessment system. Based on the study results, problematic issues at workplaces got identified, and a search for their solutions got carried out. It is shown that using eco-ergonomic designing in matters of ensuring safety at the workplace makes it possible to implement the trinity necessary to maintain and preserve human health - eco-friendliness, comfort and safety. The work results: 1) for effective management of industrial safety it is necessary to make a transition from closed systems "man-machine-working environment" to open systems "man-machine-working environment-environment" through the application of the eco-ergonomic designing principles; 2) the method of eco-ergonomic assessment got proposed as the first step to a qualitative improvement in the interaction between humans and the environment; 3) modern engineers in eco-ergonomic designing should be trained in this area, taking into account the principles of human factor engineering. The practical significance of the results is in identifying problems in the functioning of the system "man-machine-working environment-environment" and determining effective measures to eliminate them. The results of its approbation proposed assessment system at the flexo printed product's enterprise confirm the effectiveness.

Keywords: safety, ergonomics, ergoecology, green ergonomics, eco-ergonomic designing, working environment.

Introduction

Designing the human environment in the context of new technologies and requirements of ecological society is a complex organisational and creative process that involves a systematic analysis of each decision for compliance with the principles of sustainable development. This approach envisages the implementation of information technology, a theory of human activity, the concept of ecological thinking and the psychology of environmental attitude to the environment. The central notion of this approach is the analysis of the man-machine system lifecycle through the prism of eco-friendliness. It allows minimising the impact of the man-machine system on the environment. At the same time, the consequences of the designer's activity get apparent not only directly, but in the distant future also. The practical implementation of such a concept requires the designer to expand the worldview and collaboration with experts in other fields of knowledge significantly.

The working environment is a complex system of natural and artificially created environments, where there is a synergy of influences of physical, chemical, biological and psychophysiological nature. Such factors as microclimate, insolation and light, electromagnetic radiation, noise, polymer contaminants, aerosols of synthetic detergents and household chemicals, dust, viruses and bacteria always present in human being life. In turn, it stimulates the rapid progression of an eco-approach to designing of the working environment. It is the only way to slow down the psychophysiological degradation of human being and society. The use of an eco-approach in the designing of the working environment directly affects the physical, mental and social health of human being and community; this determines the relevance of the formation of ecological thinking and contributes to the development of society in a whole.

Any kind of human activity is potentially dangerous. In other words, at any level of science and technology development, safety management issues will be relevant. This fact necessitates the constant search for new means and measures to ensure human safety both during working and in everyday life. As a result, new scientific fields (for instance, risk management, psychological safety, etc.) continuously emerge. They engage in detail research and study of various aspects of the multifaceted concept "safety". A similar trend occurs in ergonomics. In recent years, new ergonomics areas emerged, such as ergoecology [1, 2] and green ergonomics [3, 4]. Their fundamental principles are the study and analysis of the relationship between the man-machine system and the environment. This moment is essential today because to ensure safety and manage by it is impossible without taking into account the principles of sustainable development of society. It should be noted that both directions arose because of the real need to revise and radically change the approach to the issue of working safety [3 - 5]. Until the early 2000s, there were four main approaches in safety management: 1) technical (increasing the level of safety of existing equipment, development and implementation of new safer types of equipment, etc.); 2) physiological (research and analysis of employee's physiological indicators, application of methods of medical professional selection, etc.); 3) psychological (research and analysis of subjective indexes employees, using methods of psychological and psychophysiological professional selection, etc.); 4) social (research and analysis of human interaction in the team, determining the impact of the team on the performance of the employee, etc.).

Shown approaches could be used both separately and in interaction. However, today the boundaries of the concept "safety" have expanded, that requires the implementation of two essential conditions: 1) comprehensive application of existing approaches in safety management, which will provide an opportunity to ensure a detailed study of safety issues and find their optimal solutions; 2) the transition from safety assessment of closed systems "man-machine-working environment" to open interconnected systems "man-machine-working environment-environment".

The principles of ergoecology and green ergonomics ensure the fulfilment of these conditions, as they have an interdisciplinary approach and have an aim at implementing the policies of sustainable development of society. Therefore, the introduction of ergoecology and green ergonomics in the safety management system is essential to increase the level of safety of the working environment and, in consequence, the safety of society in a whole.

1. Literature review

Ergoecology arose in the late 90s of the twentieth century. There are two reasons for this. Firstly, humanity realised the problem of limited natural resources, which stimulated the transition from the paradigm of “consumer society” to “green society”, in consequence, there was a need to rethink the concept of “safety”. Secondly, this period was the beginning of mass computerisation of production, which radically changed the conditions of human being activity, so there was a need to create new approaches to safety management. As a result, conditions arose in which traditional ergonomic approaches to the creation of safe working conditions became unadaptable; therefore, a new direction emerged – ergoecology, which was founded by Gabriel García-Acosta [1, 2]. Ergoecology is a product of an interaction between the ergonomic system, physical space and the environment of a system (political-legal, economic, financial, socio-cultural, techno-scientific and ecological-geographical factors). Principles of ergoecology: 1) anthropocentric approach taking into account the impact on the ecosphere; 2) focus on the principles of sustainable development of society; 3) Systematisation in the designing, analysis and evaluation of ergonomic systems. According to the founder of ergoecology, to the ergonomic system to meet modern safety requirements, it is necessary to implement steps that were not given importance in the framework of classical ergonomics (Fig. 1).

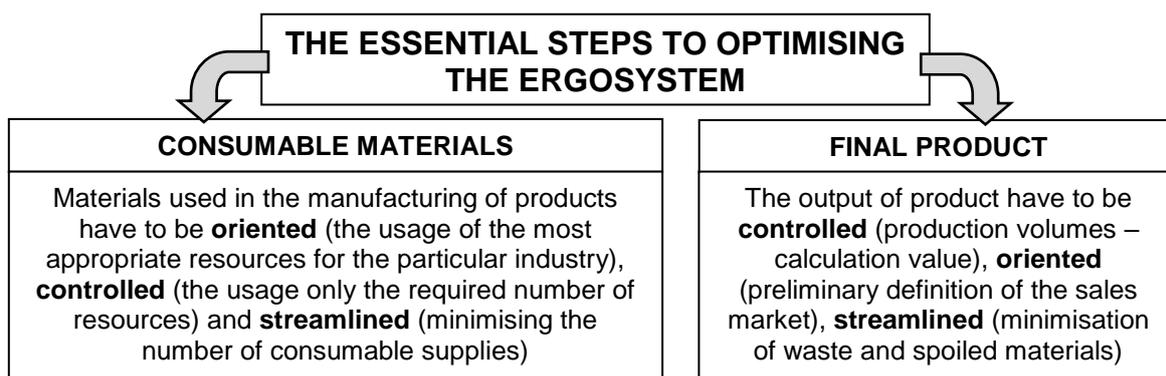


Fig. 1. Steps to optimise the ergonomic system from the ergoecology point of view

It ought to be remarked that the implementation of these steps would allow moving gradually to a new type of ergosystems (Fig. 2).

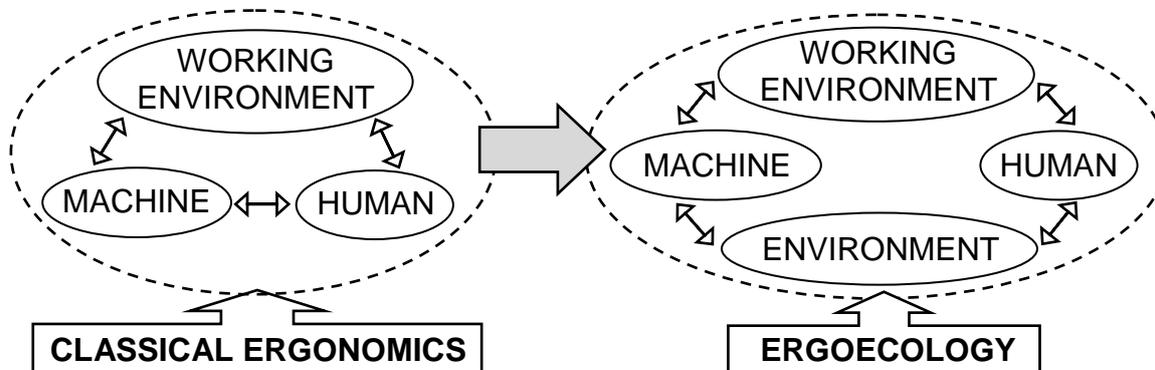


Fig. 2. Types of ergonomic systems from the classical ergonomics point of view and ergoecology one

Effective safety management requires a shift to the open systems offered by ergoecology. It will help to solve two problems simultaneously. The first problem is a natural resource scarcity (through more efficient using of them and allocation). The second one is a high level of environmental pollution (through the assessment of the risks of adverse effects on the environment and finding ways to reduce them at the stage of system designing). Besides, one of the ergoecology statements is the responsibility of the ergonomist (designer) for participating in the creation of environmental standards in the workplace, and the implementation of restore environment programs [1 - 3]. It means an active adaptation of “green” solutions in the workplace (for instance, reduction of electricity consumption during operation, shortening of waste and their efficient utilisation, using of secondary raw materials, etc.). It is also important that from the ergoecology standpoint, to increase the level of safety of the ergonomic system, it is necessary to take into account the ecological and geographical features of the region; for example, which natural resources it has, the most acute environmental problems and so on. Based on the analysis of these characteristics to determine the most effective ways to optimize (and an increase in safety) ergonomic systems.

A decade later, another direction in ergonomics emerged, which was called “green ergonomics” [4 - 8]. From the green ergonomics standpoint, today, it is impossible to achieve sustainable human well-being in conditions of constant environmental degradation, so the main emphasis is on the preservation of natural ecosystems and their restoration. According to this, green ergonomics works in three directions: the development of low-resource systems and products, designing of “green” workplace and the development of methods to orient employees to “green” behaviour. The principles of green ergonomics are: 1) ecological efficiency and eco-productivity; 2) environmental sustainability; 3) focus on the study of natural systems.

Of course, ergoecology and green ergonomics have a common goal; however, the fundamental difference is in the levels of problem assessment of the interaction between man-machine systems and the environment, and ways to solve it [4]. Ergoecology is the basis for the development of approaches such as green ergonomics and the study other macroergonomic methods related to the environmental aspects of ergonomic systems, such as “life cycle ergonomics” [7, 8] “eco-ergonomic designing” [9, 10]. Thus, ergoecology focuses on deriving concepts to create practical solutions that deal with green ergonomics, eco-ergonomic designing and others, which allow increasing the effectiveness of safety management (Fig. 3).

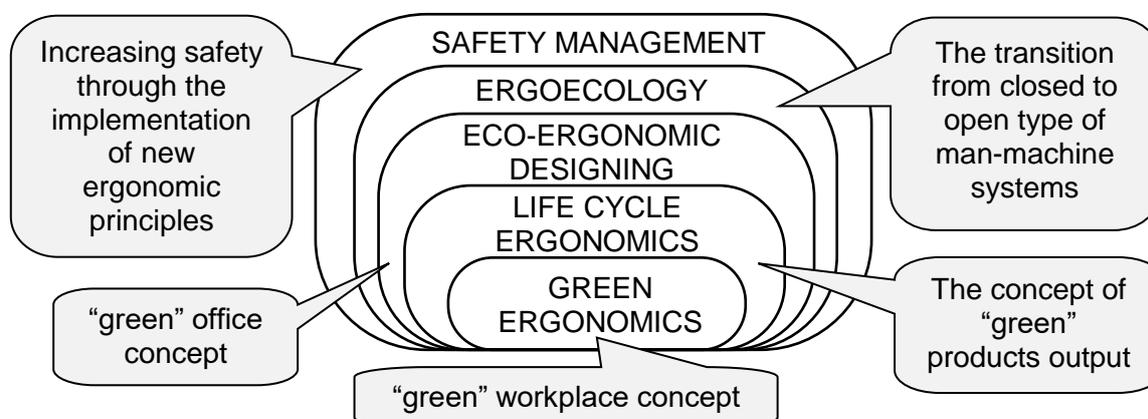


Fig. 3. The place of ergonomic trends in safety management

A separate segment in ergoecology should be eco-ergonomic designing. The essence of eco-ergonomic designing is to find the optimal combination of working conditions and technical support in the workplace that meets modern psychophysiological, social, engineering and environmental requirements. Eco-ergonomic designing has its base on the results of practical research of workplace. Therefore, its essential component is the estimate system, the results of which will identify problem issues in the working environment and implement the search of their solutions. The application of eco-ergonomic designing principles allows implementing the following components of sustainable development of society:

- 1) the environmental sphere: to reduce or even eliminate the likelihood of adverse effects on human health through the usage of eco-friendly materials;
- 2) the social sphere: to determine the ecological and ergonomic employees' priorities and, thus, to reduce the likelihood of such adverse psychological conditions as depression, stress, absenteeism, etc.;
- 3) the economic sphere: to increase financial performance through the increase of employees' performance.

Thus, there is a need to apply ecological principles for further successful ergonomics development.

However, there is another moment that also is important to provide an increase in ergonomic solution efficiency: it is the need to study and take into account the employee eco-needs. The importance of this component in ergonomics connected with the point that human being is a crucial element of any man-machine system, so the use of the eco-ergonomic designing will make sense only if the human being needs are taken into account.

Today, the notion of eco-needs is not well known and does not have a specific definition. This situation connects with the fact that this notion "eco-need" often related to the social manifestations of human behaviour. In accordance, it is not an independent category of human being needs. The existing definitions of eco-needs [11, 12] systematised as follows (Fig. 4).

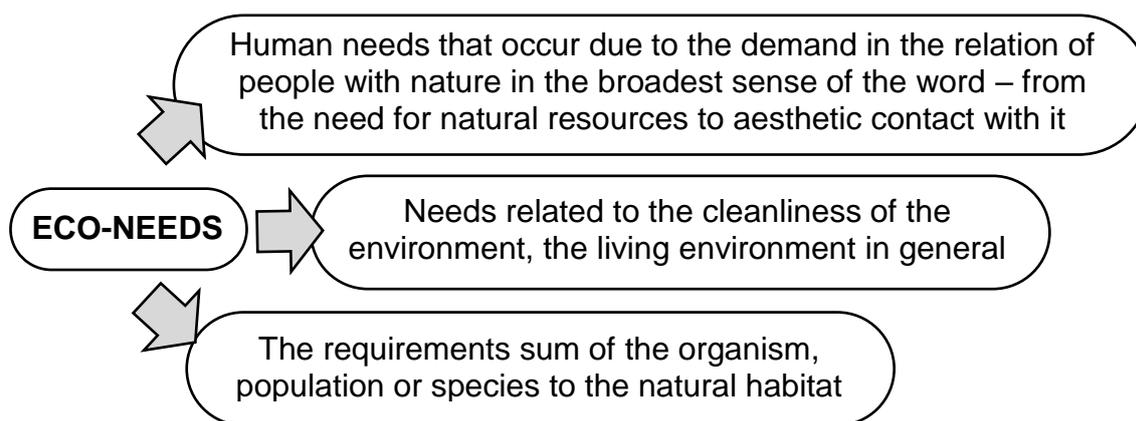


Fig. 4. The review of definitions of "human eco-needs" notion

The general disadvantage of these definitions is the vagueness, the lack of specifics that reduce their quality. The need is a category of notions that requires a clear explanation of the object or subject that is a human need. Therefore, the statement, that eco-needs are the sum of the organism's requirements for the natural

environment, is not enough, it is necessary to specify which requirements exactly: air, water, soil, food quality and so on. It similarly sounds the statement that eco-needs are human needs that stem from the people need to linkage with nature in the broadest sense of the word. The questions arise: "What are the links between human and the environment? Why are they necessary?" The use of the phrase "cleanliness of the environment, the living environment in general" is not entirely understood, because cleanliness is a subjective concept. None of the presented definitions is the basis of the notion. However, the importance of the defining mentioned notion is undeniable. Therefore, there is a sense to analyse this concept objectively and determine its role in ensuring the man-machine system safety that will allow the most accurate formulation of the definition.

2. Aims

Based on the above, we can formulate a **scientific problem**: finding ways to implement the principles of sustainable development of society in different areas of human activity. The unresolved part of the scientific problem is the application of mentioned principles in safety management through applying the principles of eco-ergonomic designing of working environment.

Researching aims to find ways of practical implementation of the principles of eco-ergonomic designing to increase safety management.

3. Methods and results

There are the following methods researching and processing of data for the achievement of the aim: a collection of statistical and experimental data, systems analysis, and the line diagrams construction.

The definition of the concept "eco-needs". The notion of "eco-needs" combines two components "needs" and "eco-friendliness". In general, the meanings of the two concepts sound as follow:

1) the need is a human psychophysiological state, which is formed in response to the absence (or insufficiency) of the primary life elements and motivates him to specific actions in the direction of their receipt;

2) eco-friendliness is the environment state in which its characteristics meet modern environmental standards and requirements [13].

Therefore, the eco-friendliness of the environment has a direct impact on human health, so it is essentially an element of his life, and consequently a need. Summarising the above and taking into account the previously mentioned shortcomings of the suggested definitions, the concept can sound as follow: eco-needs is the human being needs in an eco-safe living environment.

Let's consider the place of eco-needs in the general system of human being needs. There are many classifications of human being needs on various grounds. We apply the classification of needs by origin (or significance), according to which they can be primary and secondary. Primary ones are the essential physiological human needs (sleep, food, rest, etc.), a safety feeling, health, which are genetic. Secondary ones are the needs associated with the socio-psychological manifestations of human life, such as the need for self-realisation, success, development, communication and more.

The fundamental difference between these two types of needs is that human being physical life is possible without the implementation of the needs of the second

group, but without the first one - no. Thus, eco-needs are among the primary needs, because they directly affect human health, and determine the life quality. Other words, the preservation of human health, longevity, quality of life depend on the eco-needs implementation.

At the same time, there is a tendency to increasing the workers eco-culture. We can observe this trend in the example of employee's attention to the level of eco-safety at the workplace. For instance, they want to know which materials they contact during work, which hazard factors can affect them, the possibility to choose how to ensure individual safety, etc. It evidences that employees' eco-needs develop, and the employers have to take into account this moment to ensure the efficiency of safety management. Simultaneously, the worker eco-needs implementation means creating not only working conditions that meet regulatory requirements for labour protection, but also take into account ecological requirements, thereby improving employee safety, which is a prerequisite for a high level of performance.

Along with the theoretical issue about the definition of the "eco-needs" concept, there is also a practical one: "How to assess the degree of employee eco-needs implementation?" It is necessary to find out because it will allow us to choose the most effective measures to meet the employee eco-needs. Analysis of information on this issue showed the absence of any methods for assessing the degree of eco-needs implementation. In this case, it makes sense to start by interviewing employees about their subjective assessment of the working environment eco-friendliness.

The eco-ergonomic designing principles. A few decades ago, the safe production issue was in the application only of the labour protection principles, i.e. measures of technical, sanitary hygienic and social character. Today, safe production is a set of economic, social, technological and ecological solutions. Thus, the technical-economic approach to safe production today also includes eco-socio one aimed at preserving the environment and further advancement of the concept of sustainable development [14 - 17]. Besides, there is the emergence of new directions in other areas that also contribute to developing safe production, for example, green infrastructure and green building [10, 18 - 22]. In combination, this allows to move to a new level in the safety management at working place, and the basis of this process should be the eco-ergonomic designing principles [10], combining the basic ideas of ergoecology and green building and infrastructure. Consider in more detail the basic principles of eco-ergonomic designing:

1) designing of the eco-ergonomic workplace, namely: maximum using of eco-friendly materials, taking into account their ergonomic qualities in the creation process, which involves assessing the ecological quality of work furniture material, technical equipment one, etc., as well as ergonomic feasibility of their using;

2) using eco-friendly materials for interior decoration, which involves assessing the ecological quality of finishing materials for floors, ceilings, walls, the quality of the materials for windows, etc.;

3) assessment of ecological safety and energy efficiency of life support systems in the rooms, namely: estimating of the quality of ventilation, air conditioning, heating, artificial and natural lighting systems, etc.;

4) assessment of ecological safety of the building exteriors and infrastructure quality, including the estimate of the building materials eco-friendliness, the parking areas quality, the presence of area green landscaping, the energy efficiency of outdoor lighting, etc.;

- 5) introduction of training programs for employees on eco-culture and safety;
- 6) assessment of employees socio-psychological comfort from the implementation of the ecological solutions;
- 7) evaluation of employees ergonomic comfort of the implementation of the ecological solutions, etc.;

Eco-ergonomic designing principles can be applied both for the working environment designing and to assess the eco-ergonomic quality of the existing working environment.

The eco-ergonomic method of the working environment assessment. Consider and analyse the methods of the working environment estimating, which we used to develop of the eco-ergonomic method of the working environment assessment: the Elmer system, the Fine and Kinney method, ergonomic evaluation of the system "man-machine-environment".

The Elmer system is a reliable system for monitoring occupational safety in the industry. The Elmer system was tested at many enterprises and can be used in any industry.

The Elmer system includes the observations that cover all essential components of occupational safety, such as using protective equipment, workplace organisation, safety during the work with the machine, occupational health and ergonomics. The Elmer system estimates the enterprise level according to a safety index, the value of which can be from 0 to 100 points. Besides, the researcher can determine which issues need further improvement. Thus, the Elmer system is a means by which the company can identify opportunities to improve occupational safety, identify hazards and, at the same time, the activity on occupational safety will be more effective.

A significant disadvantage of the Elmer system is that all factors that affect safety worker are taken equal, i.e. any element has one point. This moment is contradictory because at the workplace there is always a specific differentiation of factors that affect the employee by the degree of significance that, in turn, affects the prioritisation of measures to improve safety.

To assess occupational risk in enterprises often use the Fine and Kinney method, which uses the degree of the hazard effect, the likelihood of hazard arising at the workplace and the consequences for workers health in case of hazard occurrence [23]. It can be presented in formula (1):

$$R = \text{effect} \times \text{likelihood} \times \text{consequences.} \quad (1)$$

The Fine and Kinney method varies the degree of the hazard effect from 0 (never effect) to 10 (the permanent impact). The likelihood of hazard arising varies from 0 (absolutely impossible) to 10 (the high probability). The consequences range from 1 (minimum damage) to 100 (disaster). The risks classification according to the seriousness degree: $R = 0 - 20$ a small risk, possibly acceptable, $R \Rightarrow 400$ very high one, immediate cessation of activity. The Fine and Kinney method classifies occupational risk into five groups: very mild; little; an average; high; extremely high.

In each case, the workers themselves determine how a violation of labour protection requirements can lead to occupational injury or occupational disease. They analyse all stages of the working process: from the preparation to the completion. According to the assessment, workers form the risks into a matrix that takes into account all components of risk.

The disadvantage of the Fine and Kinney method is the significant subjectivity of the evaluation results because employee carries out all researching work by yourself. Thus, the worker estimates factors that affect him during the working process by yourself and he relies, in this case, on his own experience, which is not always enough to choose the most effective means of hazards protection.

Researchers also use “the ergonomic scheme of the workplace evaluation”. According to the scheme, researchers select the workplace characteristics, which form in a table, and describe them quantitatively using two parameters α and β .

1) α is the indicator that has a range from 0 to 5 points. The characteristic that has 0 points is the most negative one, the characteristic that has 5 points is the one that ensures safe work;

2) β is the indicator specific weight. This indicator depends on the significance of the characteristic for the evaluated system and taken as a percentage. The most significant percent means that the characteristic is essential for the safety of the evaluated system.

Further, researchers determine a general ergonomic assessment of the workplace (γ) by formula (2):

$$\gamma = \Sigma((\alpha + \beta)/100). \quad (2)$$

The main disadvantage of the ergonomic scheme of the workplace evaluation is that the choice of employee’s protection means based primarily on the opinion of invited ergonomists or safety auditors, and the employee's view is not taken into account.

All mentioned methods have their advantages and disadvantages. However, to achieve the work aim, it is necessary to try to combine them into a general system. It means to choose specific elements in each method and to implement them in creating the eco-ergonomic method of the working environment assessment.

The main element should be the ergonomic scheme of the workplace evaluation because the nomenclature of indicators used for man-machine system assessment is open; therefore, it can be complemented. Elements from the inquirer used in the Elmerly method should be additional items in the scheme because they contain essential data that the scheme does not consider. Besides, along with the indicators α , β , it is necessary to add components to assess the eco-friendliness working environment, taking Fine and Kinney method as a prototype that will increase the accuracy of the results. The algorithm for eco-ergonomic assessment of the working environment can be as follow (Fig. 5).

The eco-ergonomic method of the working environment assessment includes three stages. The first one is the eco-ergonomic assessment of the working environment. The following step is the construction of linear diagrams of the eco-ergonomic assessment results and identification of problem areas. The final stage is the conclusions on the results of the evaluation, suggestions for possible improvement.

As mentioned before, the eco-ergonomic assessment combines two types of activities simultaneously – ergonomic and ecological analysis of the working environment characteristics. We used the ergonomic scheme of the workplace evaluation to assess the ergonomics of the man-machine system, and the Fine and Kinney method adapted version to determine the ecological component [23, 24]. It made it possible to assess the degree of positive or negative impact on a worker of the working environment characteristics.

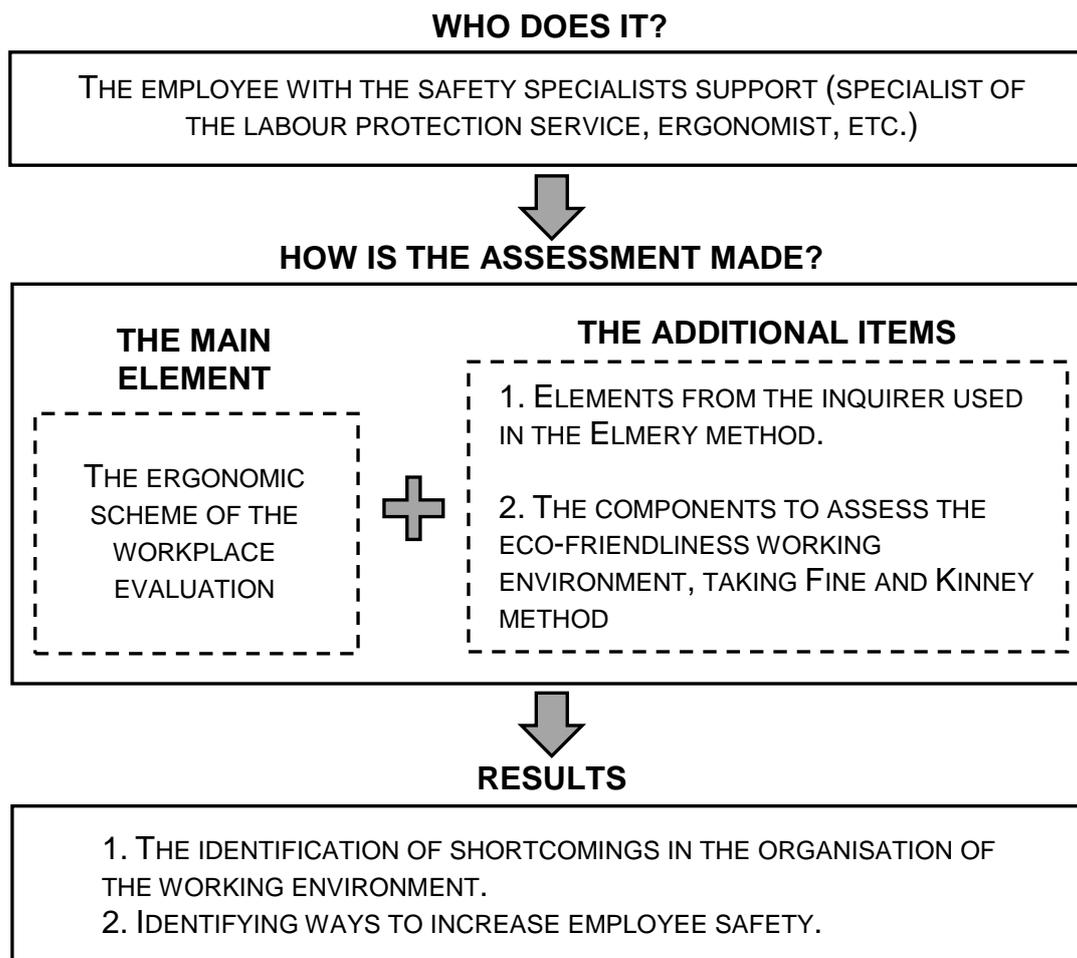


Fig. 5. The algorithm for eco-ergonomic assessment of the working environment

Eco-indicators of the working environment:

- 1) the influence frequency indicator measured in the range from 0 to 1 point (0 points – no influence, 1 point – constant one);
- 2) the influence quality indicator measured in the range from 0 to 1 score (0 points – negative meaning, 1 point – neutral one);
- 3) the consequences indicator measured in the range from 1 to 5 points (1 point – severe consequences (temporary health deterioration, occupational diseases), 5 points – no adverse effects (no deterioration signs));
- 4) e is the eco-friendliness coefficient of the element or characteristic determined according to the formula (3):

$$e = \text{frequency} \times \text{quality} \times \text{consequences}, \quad (3)$$

5) e_{general} is the arithmetic mean of the eco-friendliness coefficients of the system elements or characteristics.

The values of e and e_{general} are in the range from 0 to 5 points. In this case, the closer the indicator value of the eco-friendliness of the system to mark 5, the better its eco-friendliness quality. The generalised form of the system of eco-ergonomic assessment is in the table 1.

Table 1

The eco-ergonomic assessment of the working environment

№	Elements and characteristics of the system	Ergonomics		The eco-friendliness coefficient			
		α , points	β , %	frequency	quality	consequences	e
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
The eco-ergonomics assessment results:		$\gamma = 0 \dots 5$		$e_{\text{general}} = 0 \dots 5$			
The employee's subjective assessment of the degree of the eco-needs realisation, points						$P_e = 0 \dots 5$	
The employee's subjective assessment of the degree of ergonomic needs realisation, points						$P_\gamma = 0 \dots 5$	
The conclusion and recommendations:							

It should be noted, that the eco-ergonomic assessment contains subjective indicators of employee satisfaction with the ergonomic and ecological conditions at the workplace, thus, we paid attention to assessing the implementation of employees eco-needs, which were discussed earlier. This point is essential for obtaining objective results, because the subjective perception of the employee may differ significantly from the general indicators. The subjective evaluation has a range of 0 to 5 points (0 – inappropriate conditions, 5 – optimal ones).

The next stage in the work the construction of linear diagrams of the eco-ergonomic assessment results and the identification of problem areas (Fig. 6).

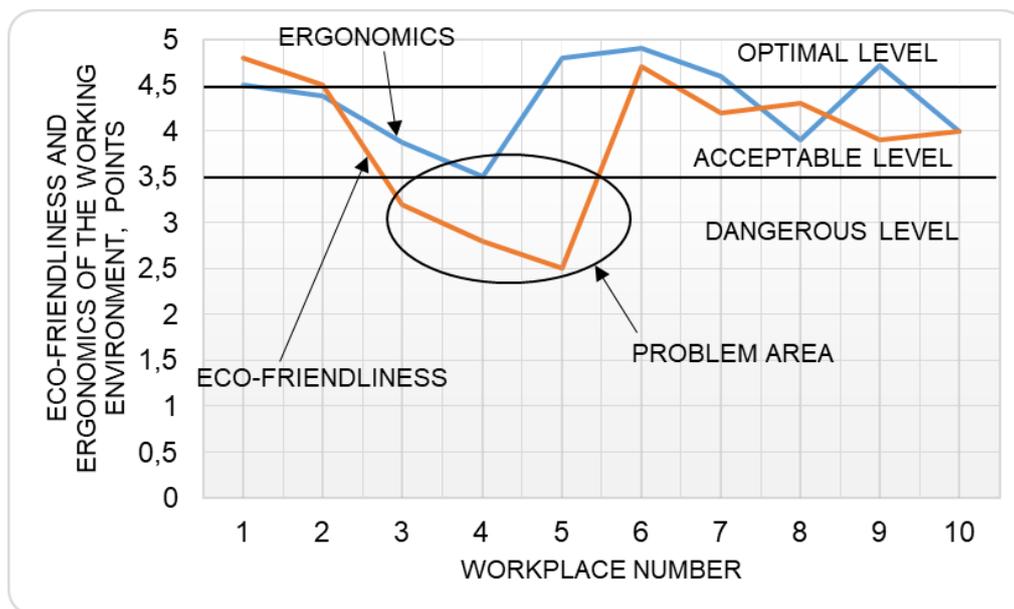


Fig. 6. The linear diagrams of the eco-ergonomic assessment results of the working environment (diagram sample).

The assessment of the working environment according to the proposed algorithm makes it possible to increase the quality of data on the level of safety production. The movement from consideration and analysis of closed systems “man-machine-working environment” to open systems “man-machine-working environ-

ment-environment” will make it possible to take adequate measures in matters of safety management in the future.

Practical implementation of the eco-ergonomic method of the working environment assessment. We realised the eco-ergonomic assessment method at the enterprise on the flexographic printed products production. The enterprise has the opportunity to apply in its activities best practices in ecological issues.

We estimated working environment of the manager and economist. The main characteristics of activities at these workplaces are computer work, document processing. During the study, employees got forms for eco-ergonomic assessment of the working environment, which they filled out independently, based on their own opinion. A simplified version of the eco-ergonomic assessment is in table 2. An ergonomist processed completed forms. The study involved 23 employees.

Table 2

The eco-ergonomic assessment of the working environment
(a simplified version)

Initial data: Enterprise name: <u>Gamma</u> Workplace: <u>manager</u>				Period: 21/09/2019 Implementer name: Ivanov, Alex			
№	Elements and characteristics of the system	Ergonomics		The eco-friendliness coefficient			
		α , points	β , %	frequency	quality	consequences	e
1	The transport infrastructure of the object	5	5	1	0,5	4	2
2	The level of landscaping	3	4	1	0,6	5	3
3	The building general characteristics	4	5	1	0,8	5	4
4	Sanitary condition of the rooms	5	5	1	1	5	5
5	Desktop	3	5	1	1	5	5
6	Work chair	5	5	1	0,8	4	3,2
7	Technical equipment	4	10	1	0,6	5	3
8	Indoor lighting	3	8	1	1	5	5
9	Indoor air exchange	5	10	1	1	4	4
10	Air conditioning	5	10	1	1	5	5
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
The eco-ergonomics assessment results:		$\gamma = 4,54$		$e_{\text{general}} = 4,2$			
The employee's subjective assessment of the degree of the eco-needs realisation, points						$P_e = 5$	
The employee's subjective assessment of the degree of ergonomic needs realisation, points						$P_\gamma = 4$	
The conclusion and recommendations: to improve the level of landscaping, indoor lighting, replace the desktop							

The assessment results are the following:

1) the indicators of eco-ergonomic assessment of working environment have an optimal or acceptable level, which indicates the awareness of employees and employers in modern society's demands on the concept of "safety" and an appropriate conscious approach to environmental and occupational safety at the workplace;

2) according to the assessment results of the realisation degree of employees eco- and ergonomic needs at the workplace, 98% of respondents determined that they have a comfortable working environment;

3) employees identified that periodic eco-ergonomic assessment of the working environment is a necessary element to ensure an appropriate level of safety and effective management.

Further, we are going to conduct an eco-ergonomic study of the working environment of a computer graphics specialist and a printing operator.

The need to train of eco-ergonomic designing principles of man-machine systems designers. Modern designers to create safe, reliable and stable man-machine systems need to be aware of the peculiarities of human existence in man-machine systems. The human factor principles should be applied to designing safe man-machine systems. The issue of the human factor in training is multifaceted and is at the intersection of psychophysiological and cognitive capabilities of workers and the influence on them of various stressors [25 - 27]. The most significant stressors are:

1) ergonomic factors related to the organisational structure of the system and statistically have a 90% influences on a safety;

2) ecological factors that often have a hidden effect, but at the same time, a significant impact on human health and functional health state.

The safety, reliability and stability of the man-machine system directly depend on the consideration of the possible influence of the human factor. Therefore, today educational institutions of engineer-technology direction pay attention to both traditional interdisciplinary natural sciences and new ones (cyber physics, bioengineering, cognitive and neuroscience). They widely use the terms viability, resilience and recoverability. In particular, the links between them are discussed in the discipline "Human factors engineering". The discipline uses interconnected complementary system principles of man-machine system development and ergonomic laws (mutual adaptation and transformation) with obligatory consideration of an ecological component. Such knowledge is necessary for designers to reduce the risks of the incident at the system designing stage yet. It is the consideration of likely changes in physical, psychological, physiological and cognitive capabilities of human under the influence of eco-ergonomic factors that will contribute to the design of safer and more stable systems.

Thus, the solution of complex ecological aspects in the designing of the subject environment directly affects the physical, psychological and social health of the individual and society in a whole. Methods of ecological factors assessment occupy a special place in the designing of the environment. Among them:

1) effective using of materials in design, production and operation;

2) the possibility of long-term using of equipment and materials;

3) secondary using of materials;

4) using of eco-friendliness materials and raw materials;

5) designing of objects based on natural analogues;

- 6) creating objects with the possibility of their updating and improvement;
- 7) designing items with rational using of energy resources during their operation and transportation;
- 8) objects design with the possibility of increasing the duration of their life cycle.

The designing process has an iterative nature, i.e. its implementation requires a consistent refinement of decisions made at the earlier stages of designing. Training of the eco-ergonomic designing principles and assessment plays a crucial role in this case. It allows refining the decision, increases the level of specification, and provides criteria for the creation of the right solution.

Conclusions

The researching results are the following:

1) ensuring the implementation of the principles of sustainable development of society is a prerequisite for any activity, and ergonomics is no exception. Moreover, in this case, ergonomics must play a crucial role because man-machine systems are a significant part of human life; therefore, they must meet modern safety requirements, and the leader in this issue should be ergonomics;

2) the principles of classical ergonomics should be supplemented by new areas such as ergoecology, green ergonomics, eco-ergonomic designing and assessment of the man-machine systems, etc. to increase the level of safety management. The introduction of these principles will allow moving from the consideration and analysis of closed systems “man-machine-working environment” to open ones “man-machine-working environment-environment”, which will take into account various aspects of interaction between human and the environment, which previously did not pay attention;

3) the method of eco-ergonomic assessment is proposed as one of the first steps to take into account the interaction of human and the environment;

4) the necessity of training modern engineers in eco-ergonomic designing, taking into account the principles of human factor engineering is shown.

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Эко-эргономическое проектирование рабочей среды

Рассмотрена необходимость применения новых направлений эргономики для повышения безопасности на производстве. Актуальность обусловлена осознанием проблем ограниченности природных ресурсов и негативного влияния человеческой деятельности на окружающую среду, что привело к необходимости переосмысления понятия “безопасность” с позиций концепции устойчивого развития общества. Сегодня безопасность – обеспечение гармоничных отношений между человеком и окружающей средой во всех сферах деятельности. В вопросах производственной безопасности инструментом для создания такого баланса могут стать новые направления эргономики такие, как эргоэкология, зеленая эргономика и эко-эргономическое проектирование. В работе акцент сделан на использовании в вопросах безопасности на производстве принципов эко-эргономического проектирования. На основании этого сформулирована цель работы – практическое применение принципов эко-эргономического проектирования для повышения безопасности на производстве. Для достижения цели применен базовый принцип эко-эргономического проектирования – поиск оптимального сочетания условий труда и технического обеспечения на рабочем месте, которое будет соответствовать современным психофизиологическим, социальным, инженерно-техническим и экологическим требованиям. Основным инструментом работы – практическое исследование рабочих мест, важной составляющей которого является система оценивания. По результатам исследований определены проблемные вопросы на рабочих местах и осуществлен поиск их решений. Показано, что применение эко-эргономического проектирования в вопросах обеспечения безопасности на производстве позволяет реализовывать необходимое для поддержания и сохранения здоровья человека триединство – экологичность, комфорт и безопасность. Результаты работы: 1) обосновано, что для эффективного управления безопасностью на производстве необходимо осуществить переход от закрытых систем “человек-техника-рабочая среда” к открытым “человек-техника-рабочая среда-окружающая среда” через применение принципов эко-эргономического проектирования; 2) предложен метод эко-эргономической оценки как один из первых шагов к качественному улучшению взаимодействия человека и окружающей среды; 3) показана необходимость обучения современных инженеров эко-эргономическому проектированию с учетом принципов инженерии человеческого фактора. Подтверждением эффективности предложенной системы оценивания являются результаты ее апробации на предприятии по изготовлению флексодрукованной продукции.

Ключевые слова: безопасность, эргономика, эргоэкология, зеленая эргономика, эко-эргономическое проектирование, рабочая среда.

Еко-ергономічне проектування робочого середовища

Розглянуто необхідність застосування нових напрямів ергономіки для підвищення безпеки на виробництві. Актуальність обумовлена усвідомленням проблем обмеженості природних ресурсів і негативного впливу людської діяльності на навколишнє середовище, що привело до потреби переосмислення поняття “безпека” з позицій концепції сталого розвитку суспільства. Сьогодні безпека – забезпечення гармонійних відносин між людиною і навколишнім середовищем у всіх сферах діяльності. У питаннях виробничої безпеки інструментом для створення такого балансу можуть стати нові напрями ергономіки такі, як ергоео-

логія, зелена ергономіка та еко-ергономічне проектування. У роботі акцент зроблено на застосуванні у питаннях безпеки на виробництві принципів еко-ергономічного проектування. На підставі цього сформульовано мету роботи – пошук шляхів практичного впровадження принципів еколого-ергономічного проектування для підвищення безпеки на виробництві. Для досягнення мети застосовано базовий принцип еко-ергономічного проектування – пошук оптимального поєднання умов праці і технічного забезпечення на робочому місці, яке відповідатиме сучасним психофізіологічним, соціальним, інженерно-технічним і екологічним вимогам. Основний інструмент у роботі – практичне дослідження робочих місць, важливою складовою якого є система оцінювання. За результатами досліджень визначають проблемні питання на робочих місцях і здійснюють пошук їх рішень. Показано, що застосування еко-ергономічного проектування у питаннях забезпечення безпеки на виробництві дозволяє реалізувати необхідну для підтримки і збереження здоров'я людини триєдність – екологічність, комфорт і безпека. Результати роботи: 1) обґрунтовано, що для ефективного управління безпекою на виробництві необхідно здійснити перехід від закритих систем “людина-техніка-робоче середовище” до відкритих “людина-техніка-робоче середовище-навколишнє середовище” через застосування принципів еко-ергономічного проектування; 2) запропоновано метод еко-ергономічного оцінювання як один з перших кроків до врахування взаємодії людини і навколишнього середовища; 3) показана необхідність навчання сучасних інженерів еко-ергономічному проектуванню з урахуванням принципів та засад інженерії людського чинника. Підтвердженням ефективності запропонованої системи оцінювання є результати її апробації на підприємстві з виготовлення флексодрукованої продукції.

Ключові слова: безпека, ергономіка, ергоекологія, зелена ергономіка, еко-ергономічне проектування, робоче середовище.

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