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The Role of Systematic Safety Analysis in Reducing Occupational Risk in Industry

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Abstract

This article examines the role of systemic analysis in reducing occupational risk in industrial settings by clarifying the nature of hazards, their types, and the underlying causes of potential hazardous conditions. It aims to explicate the logical development process linking "hazard – cause – unintended consequences," to illustrate this process through practical examples, and to elaborate on the "Cause and Risk Tree" as a structured tool for identifying and evaluating risk pathways. Using an analytical and conceptual approach, the article systematizes key concepts of hazard and safety, describes the structure and purpose of systemic analysis in safety management, and outlines the logical processes involved in constructing and interpreting cause–consequence relationships. The discussion highlights how the integration of systemic analysis and the Cause and Risk Tree framework enables more comprehensive identification of causal chains and unintended outcomes, thereby supporting targeted risk reduction strategies in industry. The article concludes that a rigorous, system-oriented approach to safety analysis enhances the effectiveness of occupational risk management and provides a methodological

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basis for improving safety decision-making and preventive measures in industrial practice.

Keywords: Occupational Risk; Systemic Safety Analysis; Industrial Hazards; Cause and Risk Tree; Safety Assessment Methods

Introduction

In modern industry, ensuring safety has become one of the most essential components of sustainable development and effective production management. Among the theoretical and practical approaches to achieving safety, systemic analysis occupies a central place. This method allows for a comprehensive examination of processes, equipment, environments, and human factors that may contribute to potential hazards. Systemic analysis considers safety not as an isolated event, but as a complex interaction between technical, organizational, and human subsystems that together determine the level of risk within a production system.

A hazard is generally defined as a situation, process, object, or means that directly or indirectly threatens human health or life during professional activity. In other words, it refers to any condition that can lead to undesirable or harmful consequences. The number and nature of indicators that characterize hazards can vary depending on the purpose, depth, and scope of analysis being conducted. Therefore, for practical application in occupational safety and industrial hygiene, hazards are classified into a unified category known as "dangerous and harmful production factors."

These dangerous and harmful factors can be divided into several groups according to their origin and mechanism of influence. From this perspective, they are classified as physical, chemical, biological, and psychophysiological factors. Physical factors include noise, vibration, radiation, temperature extremes, and mechanical movement of equipment. Chemical factors are represented by toxic, flammable, or explosive substances that can enter the human body or the environment. Biological factors include microorganisms, viruses, and other living agents that can cause diseases. Psychophysiological factors, on the other hand, are associated with overstrain, stress, monotony, or improper work-rest regimes that affect the mental and physiological state of a worker.

Risk, as a core concept of safety science, is defined as the probability of occurrence of a hazardous event combined with the severity of its consequences. In industrial environments, risk is generally divided into potential (latent) and real (manifest) types. A potential risk exists under normal operating conditions and depends primarily on the nature of the production process and the preventive measures in place. The realization of a potential risk transforms it into a real risk — that is, an actual event leading to injury, damage, or environmental harm. Evaluating potential risk involves identifying and analyzing the underlying causes that could trigger hazardous situations.

The causes of accidents and incidents associated with hazards are conventionally divided into four main categories: technical-technological, sanitary-hygienic, organizational, and psychophysiological.

- *Technical-technological causes* relate to equipment failure, design flaws, or process violations.
- *Sanitary-hygienic causes* include poor ventilation, excessive noise, lighting problems, or exposure to harmful substances.
- *Organizational causes* arise from insufficient training, violation of labor discipline, or poor safety management.
- *Psychophysiological causes* involve human errors, fatigue, stress, or reduced attention levels.

In the process of ensuring industrial safety, risk management plays a vital role. The first stage is the identification of risks, which involves registering hazardous processes, evaluating production conditions, and analyzing the causes of potential risks. The second stage is risk assessment, where the probability of occurrence and the severity of consequences are quantified, often using a risk matrix. This matrix allows decision-makers to prioritize risks based on their significance.

The third stage is developing and implementing risk management strategies. Depending on the level of risk, different approaches are used:

- Risk acceptance is appropriate for low-level risks that do not require immediate intervention.
- Risk redistribution can be achieved through insurance or transferring responsibility.
- Risk reduction (mitigation) involves implementing preventive or protective measures to lower the likelihood or severity of adverse events.

- Risk avoidance means completely eliminating the hazardous process or replacing it with a safer alternative.

In conclusion, systemic analysis serves as a methodological foundation for identifying, assessing, and managing industrial hazards. It enables an integrated understanding of the relationships between equipment, environment, and human behavior. Through continuous monitoring, data analysis, and preventive strategies, industries can significantly reduce occupational injuries and ensure safe working conditions. Therefore, the systemic approach to safety not only protects human health and life but also contributes to the economic stability, productivity, and sustainability of industrial enterprises.

Methods

The study used analytical, predictive, comparative and statistical analysis methods, as well as empirical methods: questionnaires, observation, test questions, interviews, open-ended ideas, and analysis of experimental test results.

Main Part

Throughout the history of humankind, the issue of safety has always been one of the most important social, economic, and moral values. Along with technological progress, the expansion of production, and the acceleration of life pace, various accidents—in production, transportation, domestic life, or as natural disasters—have also increased in number. Accidents are an inseparable part of human life, and preventing them or minimizing their consequences is one of the key tasks facing modern society.

An accident is defined as an unexpected event that occurs during human activity and causes harm to human health, property, the environment, or the production process. Such incidents often result from the realization of potential hazards or dangerous factors. Therefore, they should not be viewed merely as coincidences, but as systemic socio-technical phenomena with identifiable causes.

The Role of Accidents in Human Life

Accidents play a certain role in various aspects of human life. On the one hand, they are important in shaping a culture of safety, developing awareness of risks, and

learning how to reduce them. On the other hand, they have negative impacts on human health, psychology, and social well-being.

1. Educational and social significance:

Accidents serve as important lessons for the development of safety culture in society, improvement of labor protection systems, and the formation of vigilance and responsibility among citizens. Each incident is analyzed, its causes are studied, and as a result, new safety measures are introduced. Thus, every accident becomes a source of experience for preventing similar events in the future.

2. Technical and scientific importance:

Accidents also drive progress in technology and science. After every major failure or disaster, technical systems are re-examined, their reliability is improved, and safety standards are updated. For example, large-scale accidents in aviation, nuclear energy, the chemical industry, or construction have led to fundamental changes in safety regulations.

3. Psychological and social aspects:

Accidents develop a deep sense of risk awareness in people's minds, strengthening individual responsibility and caution. Humans learn to be prepared for emergencies and to protect themselves and others. Therefore, accidents can have preventive or educational value in certain contexts.

Nevertheless, by their very nature, accidents are events that negatively affect human life and societal development, and their consequences are often irreversible.

Negative Aspects of Accidents

Accidents affect all spheres of human life—physical, psychological, economic, social, and environmental. The main negative aspects are discussed below.

1. Danger to health and life

The most serious consequence of accidents is the threat to human life and health. Every year, millions of people around the world suffer injuries of varying degrees, and thousands lose their lives. Industrial accidents, traffic collisions, fires, and natural disasters lead to severe physical harm, disability, or death. Such situations cause not only physical suffering but also psychological trauma such as fear, stress, depression, and loss of

confidence. Moreover, accidents negatively affect the emotional and financial well-being of victims' families.

2. Economic losses

Every accident brings significant economic damage. For instance, an industrial accident may not only destroy equipment but also halt production, increase product costs, and reduce labor efficiency. On a national scale, such incidents lead to a decrease in labor productivity, higher medical and insurance costs, and economic instability. Sometimes, a single major industrial accident can disrupt an entire economic sector.

3. Social and psychological consequences

Accidents also affect the social and emotional atmosphere within society. During large-scale disasters, people experience fear, insecurity, and instability, which may result in stress, social depression, unemployment, or migration. Frequent workplace accidents undermine workers' trust in safety systems, leading to reduced discipline and the creation of new risks.

4. Environmental impact

Some accidents, especially in chemical, oil and gas, or nuclear industries, have catastrophic effects on the environment. The release of toxic substances into the air, water, or soil harms ecosystems and biodiversity, indirectly affecting human health. For example, the Chernobyl and Fukushima nuclear accidents rendered vast areas uninhabitable, forcing mass evacuations and causing long-term health problems for thousands of people.

5. Strategic damage to the state and society

In some cases, accidents can have national or even international consequences. Large-scale industrial or transport accidents may damage a country's image, reduce foreign investment, and negatively influence political stability. Governments are often forced to allocate huge sums of money to eliminate the consequences of such events, which slows down economic development and social programs.

The Need to Prevent Accidents

The widespread and severe consequences of accidents demonstrate the need for effective preventive measures. Today, the main directions in ensuring safety include:

1. Systemic analysis and risk assessment: Continuous evaluation of production processes, technical equipment, and working environments to identify potential hazards.

2. Development of safety culture: Promoting responsibility and adherence to safety rules as part of daily behavior.

3. Technical modernization: Replacing outdated equipment with advanced systems and increasing automation levels.

4. Preparedness for emergencies: Establishing efficient systems for first aid, evacuation, medical response, and psychological support.

Accidents are inevitable yet preventable outcomes of human activity. They encourage societies to reconsider safety systems and introduce new standards and technologies. However, their negative impacts on human life, health, economic stability, mental well-being, and the environment are profound and far-reaching.

Therefore, safety must be regarded as a top priority in every sector. It is essential to deeply analyze the causes and effects of accidents and to consistently implement preventive measures. Human life is the highest value, and protecting it is the most important duty of every state and society

Results And Discussion

The conditions under which potential hazards arise and are realized are called the causes of accidents. Accidents can be of various types, namely injuries, damages, diseases and other forms.

Hazard, cause and consequence are the main characteristics of accidents, emergencies, fires and other similar unpleasant events.

“Hazard - cause - unpleasant consequences” is a logical development process that leads to the emergence of a hidden danger and the infliction of real damage. As shown, this process is multi-factorial. Therefore, identifying their causes plays an important role in preventing accidents.

Here are some examples of "risk-causation":

Electric current (danger) – short circuit (cause) – burn (consequence);

Pesticides (danger) - non-use of pesticides (cause) - poisoning (consequence).

Any human activity is a potentially dangerous process. Of course, although this statement is axiomatic in nature, it has important methodological significance.

Studying risks based on the principles of systematic analysis and developing measures to eliminate them play an important role in ensuring safety.

Systems analysis is a set of methodological tools used to prepare and justify decisions on complex problems, including security systems.

A system is a set of interconnected components, as a result of their interaction, a certain goal is achieved, that is, work is performed.

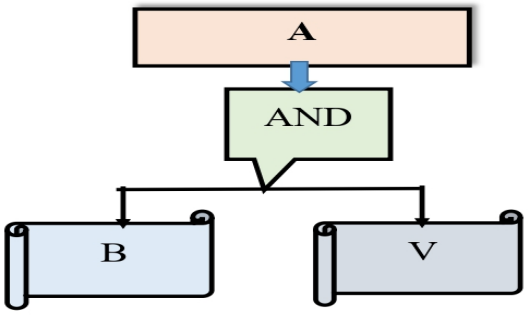
In addition to materials and objects, the components of a system also include their interconnections and the relationships between them. Any machine can be an example of a technical system. If a component (element) of the system is formed by a person, such a system is called an “ergatic system”. Examples of ergatic systems include “man-machine”, “man-environment”, “man-machine-environment”, etc.

Along with the fact that the elements that make up the system have their own characteristics, the system also has its own characteristics. The characteristic that arises in the system is not present in any of the elements that make it up. For example, “combustible substance - oxygen - fire source” forms a single system. If any of these elements is absent, the combustion process will not occur. Here, the combustible substance has the property of burning, oxygen has the property of creating conditions for the occurrence of fire, and the source has the property of carrying out fire. Of course, the absence of any of these elements in this system will lead to the breakdown of the system, the result, the goal (in this case, combustion) will not be achieved.

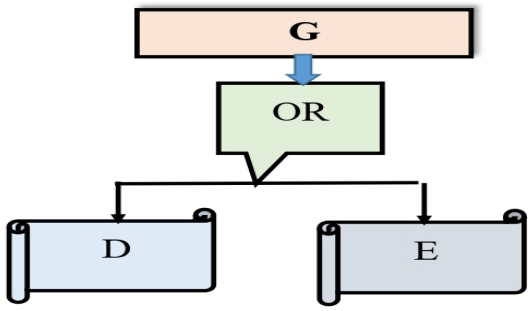
The construction of cause-effect "trees" is one of the main stages in determining the causes of accidents. Since the construction of the "tree" is a multi-stage, endless process, it requires the acceptance of certain limitations. These limitations depend on the purpose of the study and must be logically justified.

Logical processes in system security analysis are defined by the expressions "AND" and "OR". The "AND" sign indicates that all of the initial processes must be performed to achieve the result. For example, to perform process A, both processes B and C must be performed. The "OR" sign indicates that at least one of the initial processes must be

performed to achieve the result, i.e., to perform process G, either process B or process C is required.



A=B*V (logik ko‘paytma); R(A)=R(B)xR(V)



G=D+Ye (logical sum); (G)=R(D)+R(Ye) –R(D)*R(Ye)

Logical processes in the analysis by the "tree of denial" method

It consists of identifying the causes that lead to accidents (accidents) and, on this basis, developing measures that ensure the possibility of reducing them.

A security system can be analyzed in two ways, namely a priori and a posteriori methods. In both cases, the method used is carried out in a forward or reverse order.

A priori method. In this method, the researcher identifies a potential hazard (undesired event) for the system being analyzed and studies the sequence of other hazards that may arise under the influence of this hazard or determines the type of circumstances and causes that lead to this unwanted event. This method is performed by logical analysis before the activity is carried out.

A posteriori method. This method is performed after the activity is carried out, that is, after the event has occurred. In this case, based on the trace of this unwanted event, its

causes are determined and, based on the results of the analysis, a plan of work to be carried out in the future is developed.

These two methods are also called the direct and reverse methods, respectively.

In the direct method, the causes and types of hazards leading to accidents are studied, and possible accidents are analyzed in advance. In the reverse method, the accidents that have already occurred are studied and their causes are identified.

Any risk arises as a result of a certain cause or causes and causes undesirable consequences. There is no real risk without a cause. Therefore, the elimination or prevention of a risk depends primarily on studying the cause of its occurrence, and this is explained by the "cause-effect" connection. A risk is a consequence of some cause or causes, which in turn causes another cause, that is, a risk that arose under the influence of a certain cause may cause the emergence of another risk, which in turn may cause another risk, and as a result this process may take the form of a chain or system.

The graphic representation of such a connection resembles a tree with many branches. Therefore, in some literature devoted to security analysis, expressions such as "Cause Tree", "Negativity Tree", "Threat Tree", "Consequence Tree" are often found. Of course, such graphic representations-"trees" contain branches of causes and branches of consequences, which indicate the full dialectical nature of the "cause-effect" connection. Therefore, it is appropriate to call such a graphic representation, built on the basis of the results of the analysis, the "Tree of Causes and Effects".

Conclusion

One of the main problems in safety analysis is the correct determination of its main indicators and the boundaries of the system. If the system is analyzed too narrowly, some dangerous situations may be overlooked, and as a result, various accidents may occur. Also, if the system is taken too broadly, the analysis will result in uncertainties and confusion. Therefore, before determining the boundaries of the analysis, it is necessary to determine the exact purpose of the analysis. In general, all economic, technical, organizational, sanitary-hygienic and other measures developed on the basis of the analysis should ensure the complete prevention of possible hazards in this system, that is, the elimination of the occurrence of accidents.

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