Risk Monitoring and Assessment System for Accidents, Occupational Diseases and Work-Related Injuries for Enterprises with Chemically Hazardous Sites

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Abstract: There are, currently, numerous different methods and software products available for conducting industrial safety studies. The weakness of most of them is that they do not completely address all the sets of components for the industrial safety management system of the studied objects. The presented analytical information system (AIS) is developed for the assessment of risks associated with the activities of the chemically hazardous sites (CHSs) in industrial enterprises. It considers the specifics of manufacturing processes and the hazardous chemicals (HCs) used in them. The developed software is made on a client-server architecture and has a user-friendly interface for working with applications on the main server. The output, generated by the analytical information system, enables specialists to make informed decisions for reducing the risk of emergencies in enterprises with CHSs and also provides feedback to the employees of the labor safety services in the enterprises.

Keywords: analytical information system; risk assessment; chemically hazardous site; hazardous chemical

Introduction

Potential threats at enterprises with CHSs are quite serious. Man-made emergencies at these sites can result in serious consequences, which primarily affect the employees of the enterprise. Additionally, hazards at sites utilizing chemical technologies can arise even during regular operations, as chemicals used in manufacturing processes can have adverse effects on the health of staff.

Occupational diseases are the dominant cause of worker fatality. According to statistics from the World Health Organization [1], hazardous substances cause more than 650 thousand deaths per year. Data from the International Labor Organization [2] demonstrates that, over the past 20 years, in the world as a result of accidents that occurred at chemical manufacturing plants, the health of more than 6 thousand people was damaged, every third of whom died. The most severe consequences are typical for developing countries.

The passports and safety catalogs developed by EMERCOM of the Republic of Kazakhstan (RK) for both certain regions of Kazakhstan and the country as a whole contain a rather extensive list of technogenic threats. According to official information posted on the portal of the same ministry, over the past three years in the country about 30 thousand different kinds of man-made emergencies were registered. As a result of these accidents, 2 thousand enterprise employees were injured, nearly half of them died. These facts highlight the urgent need to develop operational, methodological, and informational tools, as well as preventive measures, to forecast and prevent such situations.

The study and consideration of each of the numerous factors affecting labor safety require a holistic approach. A similar approach is required for developing management systems to address each of the risks associated with the operation of a CHS.

The development of digital technologies facilitates more effective implementation of measures to improve occupational health and safety management systems at enterprises through the use of specialized information systems. The advancement and implementation of AISs for monitoring and assessing the risks of accidents, occupational diseases, and work-related injuries at enterprises with CHSs have become especially pertinent.

1 Literature Review

Automated information systems applied for managing labor system at the enterprise, unlike other types of information systems, have a number of specific features, due to their special purpose, operating conditions, information processed in them and requirements imposed on their functional part. The main distinguishing feature of these systems is their ability to monitor and control the physical processes and subsystems, in real time, that directly affect the safety of processes and the livelihood of the staff.

The most advanced systems carry out several processes:

- Collecting large volumes of information, expressed through a set of parameters with various characteristics and structure
- Calculating indices, that characterize the functioning of the enterprise's industrial safety system
- Analyzing and sharing the results, for all interested parties

The output of these systems greatly facilitates the critical analysis of potentially hazardous situation management systems used in companies.

S. Bradbrook et al. [3] presented a detailed justification of the implementing various information technologies to promote risk reduction in the work environment of enterprises across various industries. J. Díaz [4] sees the solution to reducing occupational risks in the use of both traditional methods (development of software applications) and innovative approaches (use of nanotechnology in occupational health and safety). M. Takács [5] showed that the application of traditional software products (Matlab Fuzzy Toolbox, Simulink) to solve risk management problem is quite difficult. The Quentic website [6] outlines promising trends in the development of information technology to ensure occupational safety. Every year modernization of the manufacturing process has an increasing impact on the working environment. F. Brocal et al. [7] developed a method for identifying and assessing the risks arising from the application of new technologies, in particular, the automation of manufacturing processes. The authors note the high efficiency of this method at the enterprises of processing industry. The report [8] describes perspective directions for occupational safety development from the perspective of digitalization. It considers digitalization as a very promising basis for innovative advancements in workplace safety. When managed properly, digitalization can significantly reduce occupational risks due to faster information processing. The authors [9], by analyzing occupational health and safety prevention strategies in Spain, have shown, based on a reliable sample of companies, how the implementation of advanced management systems contributes to accident prevention.

One of the main functional tasks that these automated information systems should address is the continuous monitoring of the 'safety climate' within the concept of workplace safety management [10]. It is worth noting that these software products should be adaptable for use at multiple levels, depending on the level of authority available and the degree of aggregation [11].

Currently, there are many automated information systems that fulfill similar tasks and allow the user to simplify the management of documents related to occupational safety [12-17].

In recent years, many enterprises in Kazakhstan have introduced automated labor safety management systems aligned with state and international standards. This trend is driven by the fact that on the one hand, it is required to reduce the costs associated with health and safety at work, on the other hand, it is necessary to improve the production efficiency of enterprises.

For example, Mazhkenov S. A. and Dalakyan S. A. [18] [19] present *Automated Risk System (ARS)*, a software which is the basis of the *Safety, Health, and Environmental Protection Management System (SHEPMS)* of JSC *Azimut Energy Services*. In *SSOE RRCSCI RSE NRC MES RK* (Shymkent city), a calculation methodology was developed, along with the TOXI TABLE software, which is designed for the quantitative assessment of potential contamination zones in man-made disasters at CHSs, transport, and for forecasting the scale and consequences of these accidents [20].

In *SSOE KarRIIS RSE NRC* of the Ministry of Emergency Situations of the Republic of Kazakhstan (Karaganda city) a methodology was developed, along with a computer system based on it, that monitors hazard level of mining industry enterprises. This software also carries out risk assessment based on multifactor analysis of data on accidents, work-related injuries, and occupational sickness rate [21] [22]. The multifactor models presented in this methodology provide a reliable assessment of the accident hazard level based on a set of criteria parameters.

Thus, our analysis notes a great number of national and specialized company-developed automated information systems, for monitoring and analyzing workplace injuries. The information systems in different countries are developed in accordance with their national legislation. This fact determines the differences in analytical information systems. Therefore, the effective operation of such AISs, is impossible, without adaptation to the certain enterprise, taking into account technological processes and peculiarities of the national regulatory framework.

2 Methodology used in Creating the Analytical Information System

The Ministry of Emergency Situations of the Republic of Kazakhstan is working on the development of *Corporate Information Communication System of the State System for Prevention and Elimination of Emergency Situations (CICS SES)*. The main purpose of this system is to ensure a high level of communicative interaction between departments, model various emergencies, analytical support for management decision-making in forecasting and mitigating consequences of emergencies of different nature.

The main goal of the CICS SES is to monitor industrial safety at hazardous industrial sites, ensure the prompt response of the Ministry of Emergency Situations in the case of emergencies at plants, and develop management measures to prevent such situations. The functioning of the system is aimed to enhance the protection for both the working staff and the population living near the enterprises.

The information provided by the system is highly valuable for specialized departments within enterprises, the Ministry of Emergency Situations and relevant public organizations.

The structure of the CICS of the State Emergency Situations Service includes 12 interrelated subsystems. One of the central subsystems is *Supervision*, which fulfills the functions of automation (informatization) of state supervision and control in the field of emergencies and manages the interaction of the MES RK subdivisions.

It is planned to integrate the *Risk Monitoring and Assessment System for Accidents, Occupational Diseases, and Work-Related Injuries at Enterprises with Chemically Hazardous Sites of the Republic of Kazakhstan* developed by the authors into this *Supervision* subsystem as a standard model. Previously, a similar project of the authors [22] developed for mining enterprises, has already been integrated into this subsystem.

The presented AIS is based on the *Methodology for the Analysis and Assessment of the Risk of Accidents, Work-Related Injuries, and Occupational Diseases of Personnel at Chemically Hazardous Sites of Enterprises in the Republic of Kazakhstan* developed by the authors [23]. The creation of the AIS based on the original methodology [23] confirms the undoubted scientific novelty of the development.

The above-mentioned methodology results from analyzing data on accidents at chemically hazardous sites, evaluating the reliability of technological processes, and risk modeling and assessing of various types of accidents at enterprises with CHSs. The methodology is based on the methods of expert assessments (for accident risk assessment) and statistical analysis (for work-related injuries and occupational diseases among staff). [24-26]

The necessary input data for calculations are provided as survey questionnaires, which are filled out by specialized departments of industrial enterprises with CHSs. The data are grouped into clusters based on certain areas of assessment for the state of the industrial safety management system of the enterprise. The methodological approach [23] allows the user to consistently calculate the risk of accidents, work-related injuries, and occupational diseases, as well as to determine the class of accidents rate, injury rate, and occupational sickness rate at the enterprise.

The developed AIS enables automatic data collection, processing, and calculations for each unit (workshops or sites) and for each hazardous chemical used in the industrial enterprise's workshops.

For creation of the AIS, we used a popular and quite widespread nowadays programming language Python. Python is commonly applied in developing programs that handle large amounts of data, websites and web applications related to artificial intelligence, various desktop console, graphical programs, as well as mobile applications.

2.1 Architecture of the Analytical Information System

The AIS architecture is designed as a 'client-server' model, as a variant of 'thin client fat server', i.e., all the databases, logic of their processing, and specialized software are stored on the server.

The software includes two main parts:

- **Server Part:** This is the complex of applied programs stored on the server with the database. The administrative server part is designed as a centralized repository for collecting, storing, and processing incoming system information in electronic form.
- **Client Part:** It is designed as a software application accessed via a web browser using an Internet connection to the server (Figure 1). The protocol of data exchange used is TCP/IP. The client part is responsible only for initial data presentation and user interface. No specialized software is installed on the client part.

2.2 Requirements for System Structure and Operation

The main tasks performed by the client part of the system are as follows: visualization of the user interface of the AIS; input of initial data by the user; formation of necessary queries; processing of answers to queries and transferring them to the user.

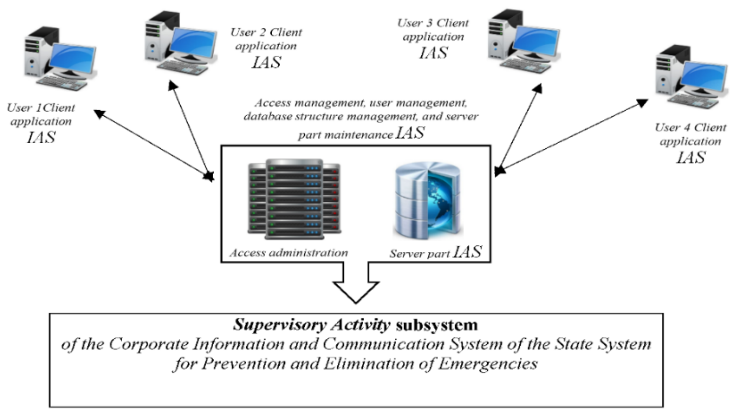

Figure 1

Scheme of users of the analytical information system, and their information links and functions

Since this product is a specialized software with a limited user base, no significant load is planned. The scheduled number of users will not exceed 3,000.

The developed system can be scaled up when the number of users increases. To do this, it is enough to install the software for the primary data collection subsystem on the end user's computer and register it on the database storage server.

During testing, load average of the system indicated parameters of 0.96 0.71 0.34, i.e., the system did not experience significant process load. This demonstrates the sufficiency of its computational resources. Data on the state of objects are transmitted in text form, the size of the data packet does not exceed 1-2 MB. Minimum speed of data transmission over the communication channel (bandwidth) is 512 kbit/sec.

The main tasks of the database management system are as follows: storage of the system's database; fulfillment of necessary queries on the information recorded in the database (DB); maintenance of the proper condition and structural integrity of all system database elements; backup and recovery of the database after incidents. Table 1 presents the AIS subsystems created from their purpose and realized functions.

Table 1
Subsystems of AIS

No.	Title of subsystem
1	Managing Operation with Clusters and Classifiers
2	Weight and Score Distribution of the Values of the Criterion Parameters
3	Managing the Branch Structure of the Industry and Types of Enterprises with CHS
4	Managing the Initial Data on Industrial Enterprises (Subdivisions)
5	Managing the Questionnaire
6	Calculating the Hazard Index of a CHS Located at an Industrial Enterprise (Subdivision)
7	Calculating the Vulnerability Index of the Staff of an Industrial Enterprise (Subdivision) from a CHS
8	Calculating the Risk of Accidents and Determining the Accident Hazard Class at an Industrial Enterprise (Subdivision) with CHSs
9	Calculating the Work-Related Injury Frequency Index at an Industrial Enterprise (Subdivision) with CHSs
10	Calculating the Index of Severity of Harm to Staff Health at an Industrial Enterprise (Subdivision)
11	Calculating the Risk of Work-Related Injuries and Determining the Injury Hazard Class at an Industrial Enterprise (Subdivision)
12	Calculating Vulnerability Indicators of Working Conditions at the Industrial Site
13	Calculating the Frequency of Occupational Diseases Firstly Detected at an Industrial Enterprise (Subdivision)
14	Calculating the Risk of Occupational Diseases and Determining the Hazard Class at an Industrial Enterprise (i-th subdivision)
15	Evaluation and Analysis of the Results of the Research of Accidents, Work-Related Injuries and Occupational Diseases
16	Preparing the final report on the enterprise

2.3 Modules of the Analytical Information System

The presented AIS consists of 3 main parts by functional purpose: service modules, auxiliary modules, and basic modules.

The service modules of the AIS provide the user with the possibility to view the information from clusters describing the operation of the enterprise safety management system (by criterion parameters) and various specialized classifiers.

Service modules of AIS contain the following clusters and classifiers:

- Organizational criteria parameters for evaluating the industrial safety management system at the enterprise
- Catalog of HCs
- Parameters of HCs by physical and chemical properties. It contains information on classification of HCs in accordance with Directives 67/548/EEC and 1999/45/EC, as well as qualifying quantities of mentioned chemicals and groups of chemicals in accordance with Directive 96/82/EC
- Parameters of the equipment used at the industrial enterprise
- Indicators of staff qualification and the organization of work within the industrial enterprise (subdivision)
- Parameters describing the vulnerability index of the staff at the industrial enterprise (subdivision) to CHS
- Indices by labor conditions classes.

The program realization of the service modules block is carried out by Subsystem 1 of the AIS (Table 1). The functions fulfilled by this subsystem are presented in Figure 2.

Auxiliary modules of the AIS are designed to support the work of the main modules that directly fulfill the functions of calculating the accident hazard indices, the vulnerability of industrial enterprise staff to accidents, the frequency of work-related injuries, the severity of harm to health, the insalubrity of labor conditions of an industrial site, the frequency of newly detected occupational diseases, as well as the risk of accidents, work-related injuries, occupational diseases, as well as the class of accidents. Subsystem 2 (Table 1) performs program implementation of the block of auxiliary modules. It functionally transfers the values of criterion parameters and their weight coefficients to the main AIS modules. The functions performed by this subsystem are presented in Figure 3.

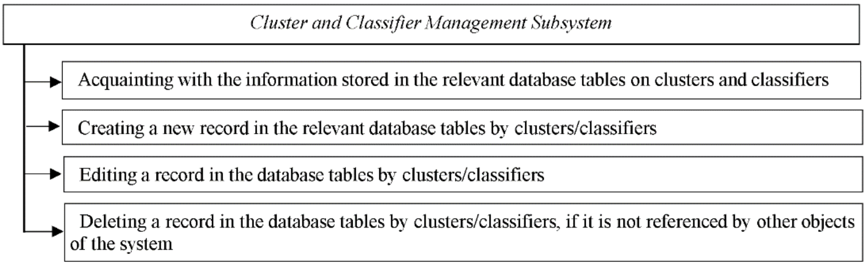

Figure 2

Functions of the *Managing Operation with Clusters and Classifiers Subsystem*

The group of basic modules of the developed AIS includes the Initial Data Input Module (data correction if necessary). It handles the initial information for the industrial enterprise under study. This module is also responsible for the input of questionnaire data on HCs used in the technological process, equipment, qualification, and organization of the staff work. In addition, this module serves the functions of entering information on organizational measures within the enterprise's safety management system, parameters describing the index of staff vulnerability to accidents at CHSs, parameters describing the indicators of work-related traumatism frequency, severity of health impact, insalubrity of working conditions in the industrial site, and frequency of newly detected occupational diseases.

The main goal of the module for analyzing and assessing the state of an enterprise's (or subdivision's) industrial safety system is to provide:

- Objective information on the state of industrial and occupational safety at the enterprise.
- Information on the most problematic sites in terms of accident and injury hazard, and insalubrity assessment within the industrial enterprise (subdivision), and the determination of criteria parameters most influencing these indicators.

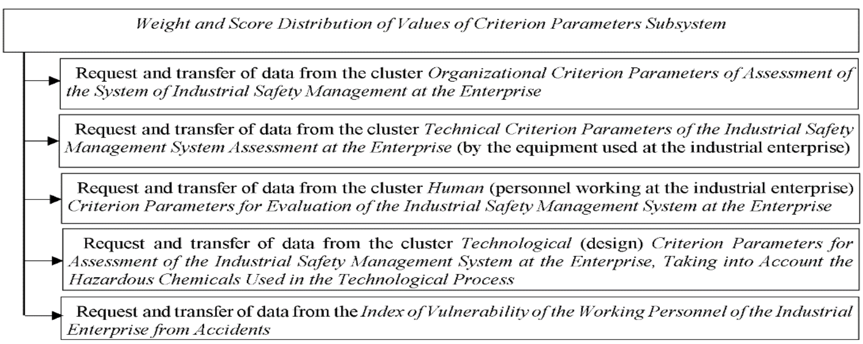

Figure 3

Functions of the *Weight and Score Distribution of Values of Criterion Parameters Subsystem*

- Justified recommendations and measures to reduce the risk of accidents, industrial injuries, and the development of occupational diseases, as well as to reduce their consequences.
- Module for Outputting the Resulting Information on the carried-out research. The information is presented in output forms (tables) in the final report. The report can be exported both in short and full format as a file with the user's choice of extension (*.docx or *.pdf). The brief format contains the information displayed directly in the user's window, while the full format includes all the consolidated information on the enterprise with the CHS as a whole.

The structural scheme for the operation of the main modules of the presented AIS is shown in Figures 4 and 5.

The implementation of the basic modules block is handled by Subsystems 3 through 14, as detailed in Table 1. Figures 6-11 show the main functions fulfilled by the subsystems of the basic modules block.

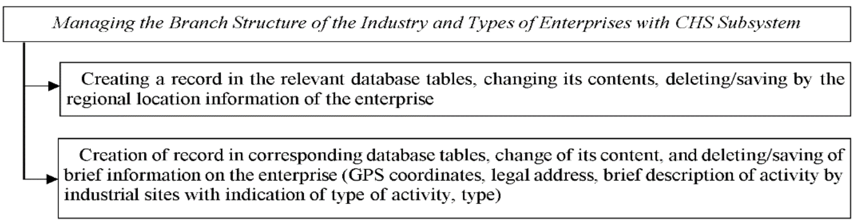

Figure 6

Functions fulfilled by the *Managing the Branch Structure of the Industry and Types of Enterprises with CHS Subsystem*

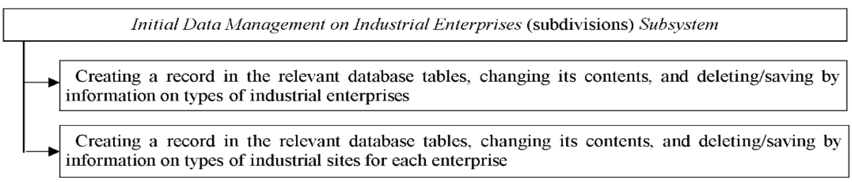

Figure 7

Functions fulfilled by the *Initial Data Management on Industrial Enterprises* (subdivisions) *Subsystem*

Deletion of a record from the database tables is possible only if it is not referenced by other objects in the system.

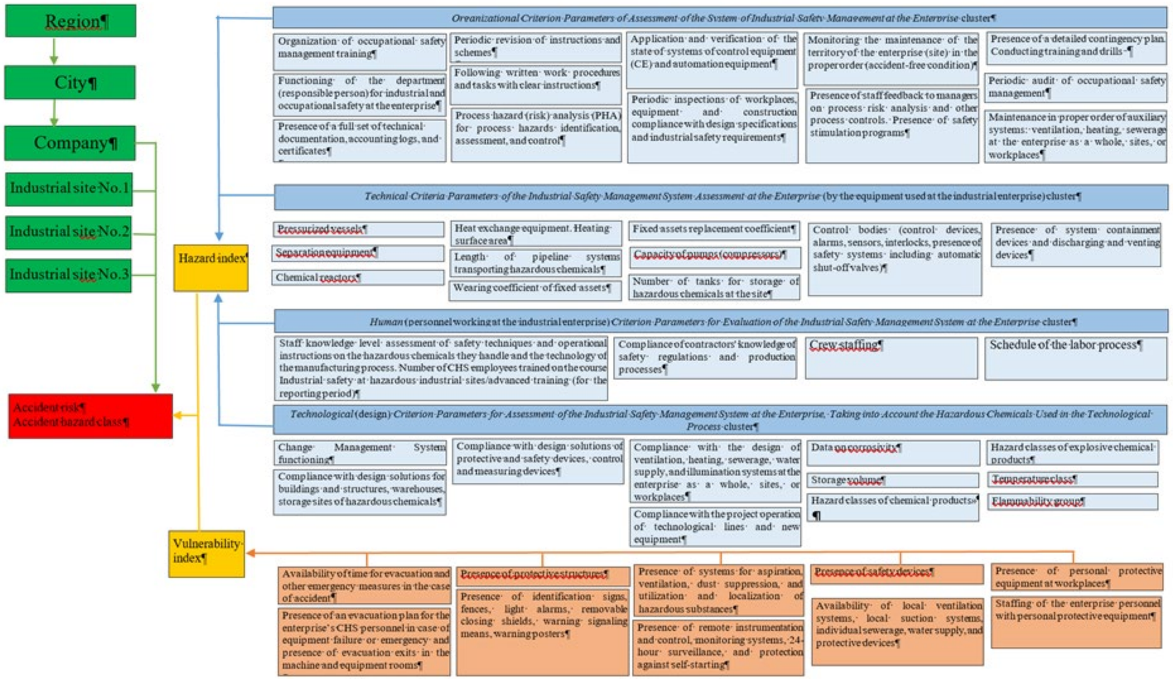

Figure 4

Block diagram of the main modules operation of the *Risk Monitoring and Assessment System for Accidents, Occupational Diseases, and Work-Related Injuries at Enterprises with Chemically Hazardous Sites of the Republic of Kazakhstan* for assessing accident hazards

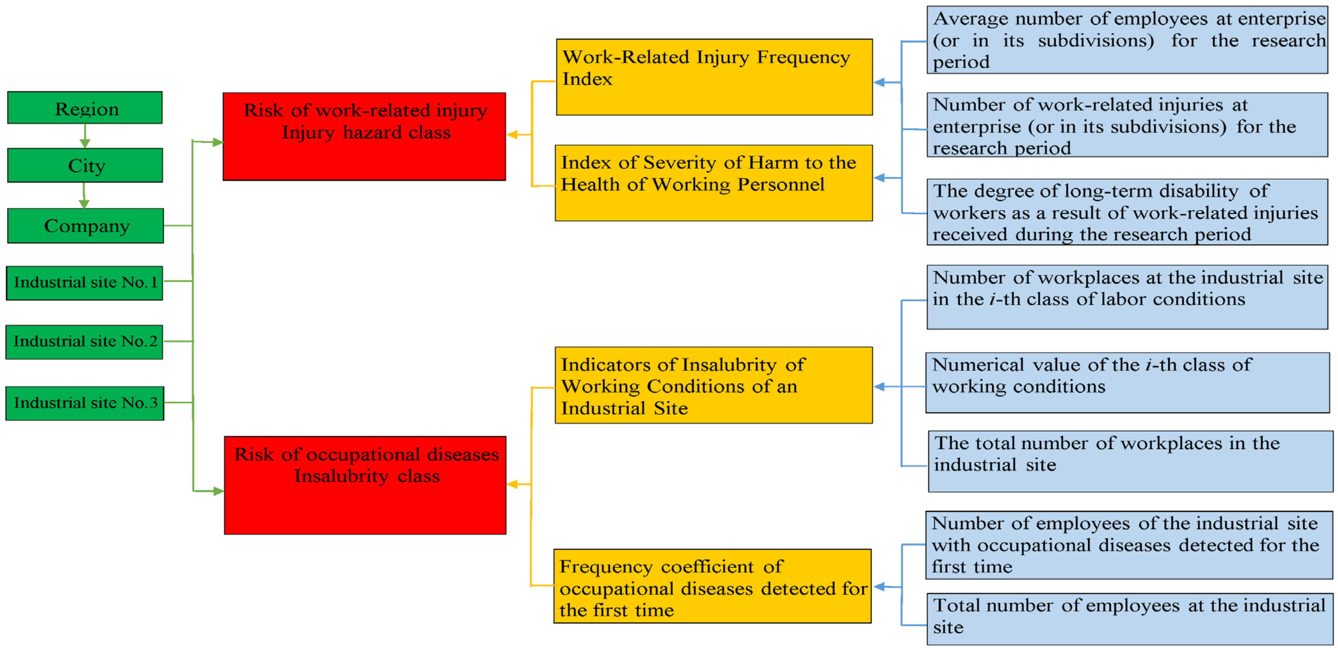

Figure 5

Block diagram of the functioning of the main modules of the *Risk Monitoring and Assessment System for Accidents, Occupational Diseases, and Work-Related Injuries at Enterprises with Chemically Hazardous Sites of the Republic of Kazakhstan* for the assessment of work-related injuries and occupational diseases

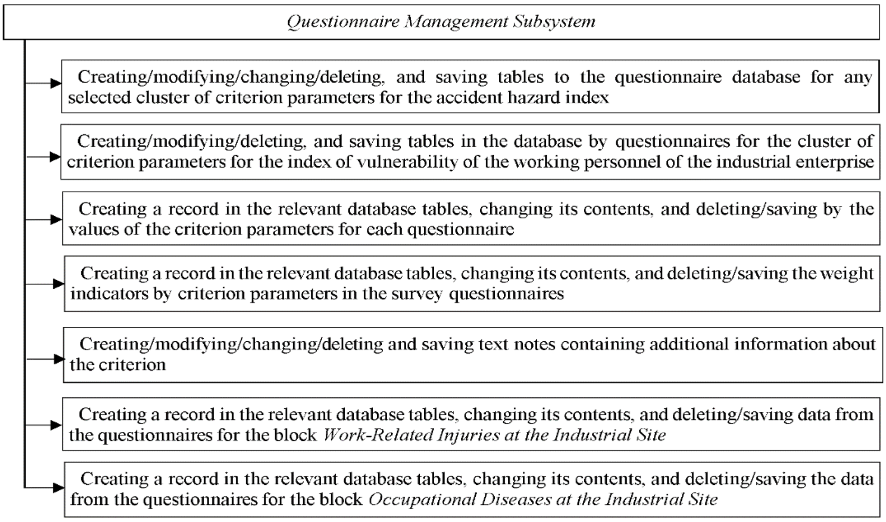

Figure 8

Functions fulfilled by the *Questionnaire Management Subsystem*

According to Table 1, subsystems 6 - 8 are responsible for realization of the following functions:

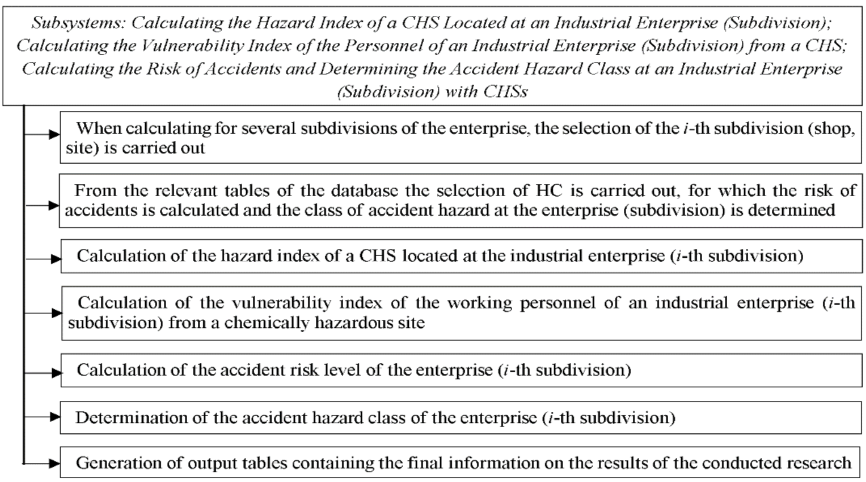

Figure 9

Functions fulfilled by subsystems 6-8 of the AIS

According to Table 1, subsystems 9 - 11 are responsible for realization of the following functions:

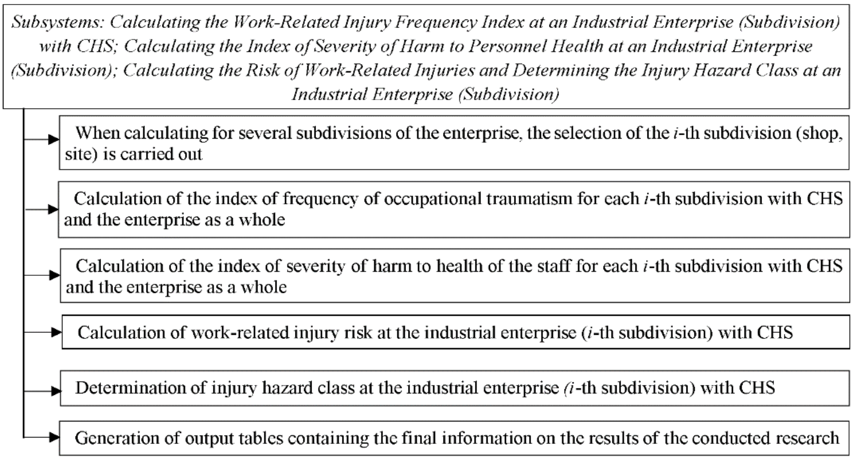

Figure 10

Functions fulfilled by subsystems 9-11 of the AIS

According to Table 1, subsystems 12 - 14 realize the following operations:

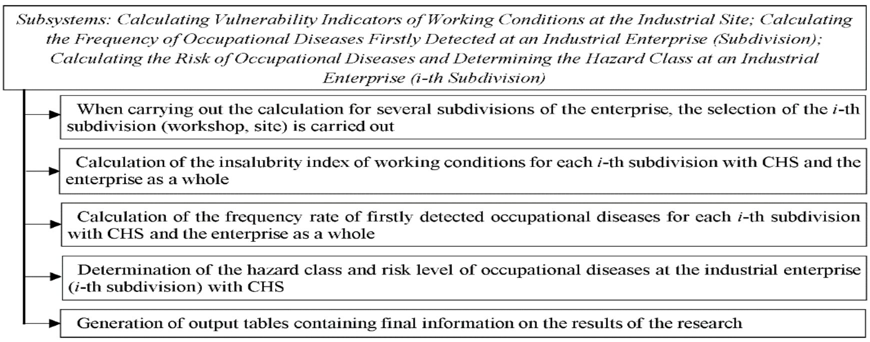

Figure 11

Functions fulfilled by subsystems 12-14 of the AIS

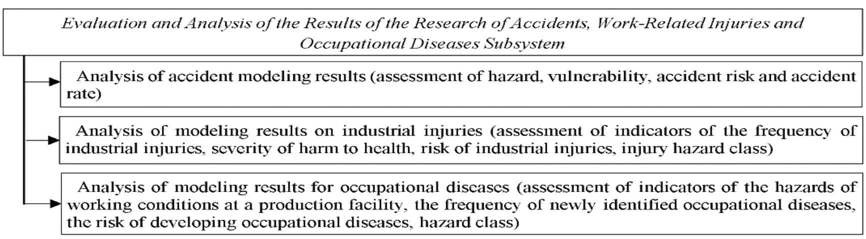

Figure 12

Functions fulfilled by the *Evaluation and Analysis of the Results of the Research of Accidents, Work-Related Injuries and Occupational Diseases Subsystem*

Based on the results of the calculations carried out for each area of research, the output information is presented in the form of output tables of the summary analytical report. The information presented in the tables allows specialists to visually and thoroughly assess the state of the safety system at the industrial enterprise, both at certain industrial sites and for the enterprise as a whole. As an example, summary tables for the research and assessment of accident rates (Tables 2-7), work-related injuries (Table 8), and occupational diseases (Table 9) at the *Copper Electrolysis* workshop of LLP *Kazakhmys Smelting* in Balkhash city are represented. When analyzing, attention should be paid primarily to criteria parameters with a score of 3 or more points. In the tables below, these criteria parameters are highlighted in yellow (3 points), orange (4 points), and red (5 points).

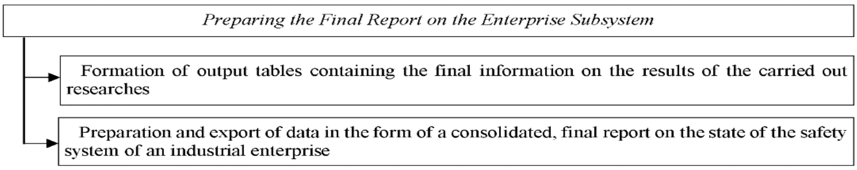

Figure 13

Functions fulfilled by the *Preparing the Final Report on the Enterprise Subsystem*

The information presented in the output tables and the final report of the AIS will allow controlling authorities, enterprise management (and other interested parties) to obtain:

- Objective information on the state of the industrial enterprise's safety system
- Information on the most vulnerable areas from the point of view of industrial safety, work-related injuries, and occupational diseases within the industrial enterprise
- Data on the most influential criteria parameters affecting the state of the enterprise's safety system
- Comparative analysis of the safety system's functioning at the industrial enterprise over the reporting period (month, quarter, year) to assess the dynamics of changes in the system operability over time
- Substantiated recommendations to reduce the risk of accidents, work-related injuries, and the development of occupational diseases at the enterprise with CHSs

Table 2

Data on the Organizational Cluster

Title of the criterion parameter	Score	Weight
Organization of occupational safety management training	1	0.047
Functioning of the department (responsible person) for industrial and occupational safety at the enterprise	1	0.034

Presence of a full set of technical documentation, accounting logs, and certificates	1	0.015
Periodic revision of instructions and schemes	3	0.015
Following written work procedures and tasks with clear instructions	1	0.065
Process hazard (risk) analysis (PHA) for process hazards identification, assessment, and control	3	0.068
Application and verification of the state of systems of control equipment (CE) and automation equipment	1	0.021
Periodic inspections of workplaces, equipment and construction compliance with design specifications and industrial safety requirements	1	0.047
Monitoring the maintenance of the territory of the enterprise (site) in the proper order (accident-free condition)	1	0.02
Presence of staff feedback to managers on process risk analysis and other process controls. Presence of safety stimulation programs	1	0.056
Presence of a detailed contingency plan. Conducting training and drills	1	0.01
Periodic audit of occupational safety management	1	0.007
Maintenance in proper order of auxiliary systems: ventilation, heating, sewerage at the enterprise as a whole, sites, or workplaces	3	0.025

Table 3

Data on the Technical Cluster

Title of the criterion parameter	**Score**	**Weight**
Pressurized vessels	0	0.023
Separating equipment	0	0.014
Chemical reactors	5	0.011
Heat exchange equipment. Heating surface area	2	0.011
Length of pipeline systems transporting hazardous chemicals	5	0.046
Wearing coefficient of fixed assets	5	0.035
Fixed assets replacement coefficient	4	0.025
Capacity of pumps (compressors)	5	0.02
Number of tanks for storage of hazardous chemicals at the site	5	0.029
Control bodies (control devices, alarms, sensors, interlocks, presence of safety systems including automatic shut-off valves)	2	0.026
Presence of system containment devices and discharging and venting devices	3	0.01

Table 4

Data on the Human Cluster

Title of the criterion parameter	**Score**	**Weight**
Staff knowledge level assessment of safety techniques and operational instructions on the hazardous chemicals they handle and the technology of the manufacturing process. Number of CHS employees	2	0.034

trained on the course Industrial safety at hazardous industrial sites / advanced training (for the reporting period)		
Compliance of contractors' knowledge of safety regulations and production processes	5	0.01
Crew staffing	2	0.031
Schedule of labor process	3	0.015

Table 5

Data on the Technological Cluster

Title of the criterion parameter	Score	Weight
Change Management System functioning	5	0.038
Compliance with design decisions for buildings and structures, warehouses, storage sites of hazardous chemicals	1	0.023
Compliance with design decisions of protective and safety devices, control and measuring devices	2	0.016
Compliance with the design of ventilation, heating, sewerage, water supply, and illumination systems at the enterprise as a whole, sites, or workplaces	1	0.017
Compliance with the project operation of technological lines and new equipment	1	0.021
Data on corrosivity	5	0.013
Storage volume, ammonia	0	0.024
Storage volume, chlorine	0	0.024
Storage volume, carbon sulphide	0	0.024
Storage volume, sulphur dioxide	0	0.024
Storage volume, butane-1-ol	0	0.024
Storage volume, sulfuric acid	1	0.024
Storage volume, potassium amyl xanthate	0	0.024
Storage volume, hydrochloric acid	1	0.024
Storage volume, nitric acid	0	0.024
Hazard classes of chemical products that are flammable liquids	0	0.015
Hazard classes of chemical products that are flammable solids	0	0.015
Hazard classes of chemical products that are flammable gases	0	0.015
Hazard classes of explosive chemical products	0	0.02
Temperature class (Auto-ignition temperature of the mixture)	1	0.01
Flammability group	0	0.013

Table 6

Data on the vulnerability of the working staff of an industrial enterprise

Title of the criterion parameter	Score	Weight
Availability of time for evacuation and other emergency measures in the case of accident	1	0.4

Presence of an evacuation plan for the enterprise's CHS staff in case of equipment failure or emergency and presence of evacuation exits in the machine and equipment rooms	1	0.1
Presence of protective structures	1	0.1
Presence of identification signs, fences, light alarms, removable closing shields, warning signaling means, warning posters	1	0.03
Presence of systems for aspiration, ventilation, dust suppression, and utilization and localization of hazardous substances	1	0.07
Presence of remote instrumentation and control, monitoring systems, 24-hour surveillance, and protection against self-starting	1	0.05
Presence of safety devices	1	0.05
Availability of local ventilation systems, local suction systems, individual sewerage, water supply, and protective devices	3	0.09
Presence of personal protective equipment at workplaces	1	0.05
Staffing of the enterprise staff with personal protective equipment	1	0.09

Table 7

Modeling results by accident rate

Hazard index	2.162
Vulnerability index	1.18
Accident risk	Minor
Accident hazard class	IV

Table 8

Modeling results by work-related traumatism

Work-related injury frequency index	0.0015
Index of severity of harm to the health of working staff	15%
Work-related injury risk	Moderate
Injury hazard class	III

Table 9

Modeling results by occupational sickness rate

Indicator of insalubrity of working conditions of industrial site	2.37
Indicator of frequency of occupational diseases detected for the first time	0
Risk of occupational diseases development	Low
Insalubrity class	IV

3 Results (Implementation)

Step-by-step testing of the developed AIS, showed the operability of all subsystems and functional capabilities of the system's program modules (service modules, auxiliary modules, and main modules). The operation with the user interface demonstrated the software product's structural flexibility and the convenience of operation at all stages of the research cycle for assessing the industrial safety system of the enterprise with CHSs.

The operability of the developed AIS was assessed at thirteen sites (enterprises and workshops) with CHSs situated in Central and Southern Kazakhstan. Enterprises with CHSs across different industries with various technological processes and HCs, in the cities of Balkhash, Zhezkazgan, Pavlodar, Taraz, Taldykorgan, Aktau, were chosen as research objects.

The results of testing and validation at enterprises with CHSs in the Republic of Kazakhstan fully confirmed the accuracy of calculations made in accordance with the *Methodology for the Analysis and Assessment of the Risk of Accidents, Work-Related Injuries, and Occupational Diseases of Personnel at Chemically Hazardous Sites of Enterprises in the Republic of Kazakhstan*, as well as the operability of the developed AIS.

The developed methodology and AIS received positive feedback from control and supervisory organizations in the Republic of Kazakhstan working in the field of occupational health and safety, as well as industrial enterprises (*Kazakhmys Smelting* LLP, *KazAzot* JSC, *Mineral Fertilizers* Plant *Kazphosphate* LLP, *Kainar* LLP and others).

Conclusions

The developed AIS functions as a centralized data storage and supports data integrity, as well as various methods of automated data processing. The analytical information system allows users to easily enter input data, make necessary calculations, work with the subsystem of normative and reference documentation, and form the final analytical report in a convenient format.

The implementation and operation of the AIS within the *Supervision* subsystem will allow various categories of users to benefit from the system's results as follows:

Controlling and supervisory departments in the field of occupational and industrial safety: To obtain reporting information on the current safety status of CHSs taking into account features of technological processes, if necessary, to promptly develop a set of actions focused on reducing the risk of man-made emergencies.

Responsible representatives of local executive authorities in the field of civil protection: To obtain reliable information regarding the occupational safety of working staff at enterprises with CHSs.

Enterprise management and departments responsible for accident prevention: To improve the efficiency of the existing industrial safety management system (to conduct comprehensive studies to assess the indicators affecting the risk of accidents, work-related injuries, and occupational diseases among staff at the enterprise with CHSs), to reduce financial losses related to eliminating the consequences of accidents at CHSs.

In the future, it is planned to expand the analytical information system to work in other industries, such as the food, oil and gas, processing, metallurgical and others.

Acknowledgements

This research is funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP09259869). The authors would like to thank Kuandyk Almukhambetov, Leading Specialist, National Certification Committee for Welding Production LLP, Karaganda, Kazakhstan for his assistance with the preparation of this article. The authors would like to thank the editors and anonymous reviewers for their insightful comments and suggestions.

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