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To cite this article: A Ishchenko *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **915** 012032

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Chemical safety in the context of environmental goals of sustainable development

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Abstract. Abstract. The aim of the article is to carry out a systematic analysis of the components of chemical safety in the context of the environmental aspect of sustainable development goals and to identify those components with the help of competent health professionals. Hazardous chemicals can travel for long distances, be accumulated in the environment as well as cause adverse effects on human health through food chains. The action of toxicants of inorganic and organic nature occurs due to the violation of metabolic processes, inhibition of enzymes, and biotransformation of xenobiotics into more toxic compounds. Physicians must be clearly aware of the relationship in the "toxicant-pathology" system; understand the molecular mechanisms of the hazardous chemicals action; use terminology regarding toxicological characteristics of toxicants; conduct educational, treatment, and prevention activities among the population; acquire information on regulations governing the management of chemical compounds. The next component of chemical safety is the knowledge of approaches to chemical labeling and safety measures for working with chemical products throughout their life cycle. Proper interpretation of the type and level of hazard will enable taking necessary precautions and following relevant safety rules while working with chemical products.

1. Introduction

Chemical safety and managing chemical products are priority areas that integrate the international community and are the components of sustainable human development characterized by the principles of international strategy in the field of chemical safety. This means understanding of a chemical factor as an integral danger to the environment and human health, creation of institutions at the international and national levels that specialize in the study of chemical safety, enhancement and expansion of risk assessment activities for the production and use of chemical compounds, creation of a unified system of classification and labeling of chemicals, development of programs that will help reduce the negative impact of chemical compounds, prevention of illegal international toxic and hazardous substances trafficking, exchange of data on toxic compounds and related risk factors to the environment and human health [1]. These goals were achieved through the adoption of international legal instruments of Basel (1989) [2], Rotterdam (2004) [3], Stockholm (2007) Conventions [4], Globally Harmonized System of Classification and Labeling of Chemicals (2003) (GHS) [5], International Chemical Safety Program (1980) [6] and Strategic Approach to International Chemicals Management (SAICM) (2006)



[7]. At the governmental level, the state of Ukraine has adopted the Concept of Increasing the Level of Chemical Safety (2008), which states that one of the key factors to solving this problem is continuous education, namely modernization of educational programs of teaching specialists in accordance with international standards, improvement of protocols for providing medical and toxicological care to persons affected by exposure to chemicals, and conducting educational activities on the management and use of household chemicals [8].

2. Related Works

Chemical safety is considered in the context of measures for managing chemicals, which are regulated by international legal instruments: Basel, Rotterdam, and Stockholm Conventions; Globally Harmonized System of Classification and Labeling of Chemicals; International Chemical Safety Program; Strategic Approach to International Chemicals Management; Global Action Plan; United Nations Environment Program.

Based on the analysis of legal acts, the following priority areas are identified in the field of chemical safety:

- principles of unification of norms, rules, and procedures for the management of transportation and disposal of hazardous waste at the national and international levels (Basel Convention) [2];
- requirements for the international trade of hazardous chemical products and pesticides, the exchange of information about toxicological and ecotoxicological properties (Rotterdam Convention) [3];
- reduction of the use and complete elimination of persistent organic pollutants (Stockholm Convention) [4];
- establishment of the unified rules for classification and labeling of hazardous chemicals (GHS) [5].

The international community has developed a model that regulates the management and minimizes the negative effects of chemicals during their production, storage, transportation, sale, use, and disposal. Thus, the successful implementation of the programs involves coordinated work in the fields of legal, economic, environmental, and educational activities. Here is an interpretation of the "chemical safety" concept in the context of international and domestic regulations (Figure 1).

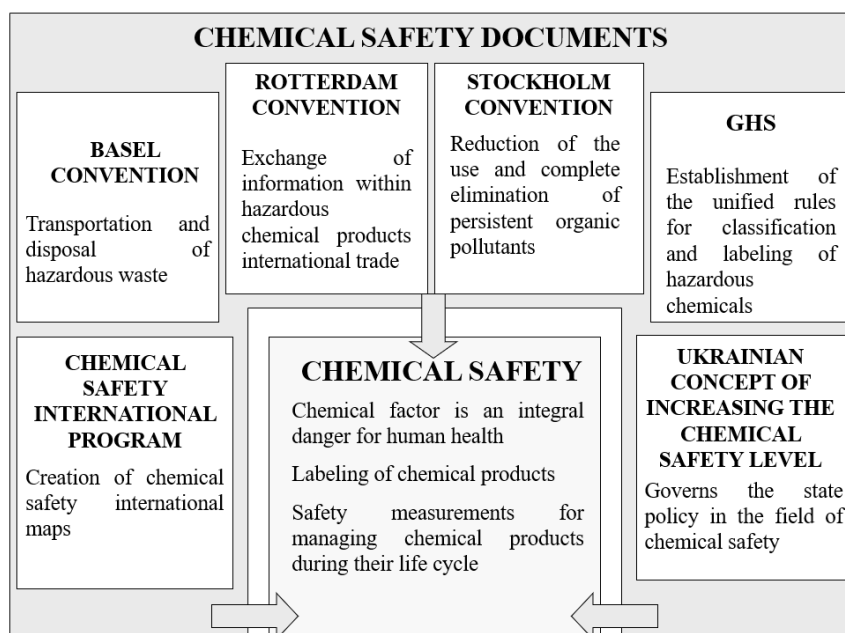


Figure 1. Components of chemical safety in the context of international and domestic regulations.

The main components of chemical safety are:

1. Chemical factor, which is an integral danger to human health. The chemicals are an integral part of human life and activity. Hazardous substances can travel for long distances through food chains, be accumulated in the environment (bioaccumulated), and subsequently cause adverse effects on human health. The action of toxicants of inorganic and organic nature occur due to the violation of metabolic processes, inhibition of enzymes, biotransformation of xenobiotics into more toxic compounds. It is necessary to conduct educational activities among the population to understand the relationship in the "toxicant-pathology" system, explain the mechanisms of action of hazardous chemicals, provide the information of legal documents governing the management of chemical compounds [9].





2. Labeling of chemicals and safety measures for working with chemical products throughout their life cycle. Understanding the hazards described on chemical labels is an integral part of chemical safety competence. Therefore, correct interpretation of the type and nature of hazard will allow the necessary precautions to be taken and the relevant safety rules to be followed when working with chemical products (household chemicals).






Apparently, the labeling of chemicals is one of the most important components of chemical safety, it is a universal "language". Correct interpreting the information indicated on the labels of chemical products (household chemicals, pesticides) will allow to follow the necessary measures in terms of first aid, safety during work, use, storage, transportation, and disposal of these materials.

At the international level, the approaches to the classification and labeling of chemicals are regulated by the standard – Globally Harmonized System of Classification and Labeling of Chemicals. Based on the provisions of the GHS, the "Preventive Labeling of Chemical Products. General requirements" DSTU GOST 31340:2009 was implemented in Ukraine, which entered into force on January 1, 2010 [10, p. 2]. The sphere of the standard is the requirements for warning labeling and its application to chemical products. The elements of labeling are an icon or sign of danger, a signal word, a brief description of the danger and measures how to prevent it.

The description of the hazard (labeling elements) is indicated taking into account the type of danger. According to GHS and in accordance with DSTU, "Preventive labeling of chemical products. General requirements", all hazards are divided into three types: physical danger; danger to human health, and the environmental danger.

Table 1. Characteristics of icons in accordance with GHS and DSTU "Preventive labeling of chemical products. General requirements".

Icon / Danger Characteristic	Icon / Danger Characteristic
<i>Physical Danger</i>	
 <p>GHS01 – Explosion</p> <ul style="list-style-type: none"> • Explosive chemical products • unstable explosives • organic peroxides 	 <p>GHS02 – Flame</p> <ul style="list-style-type: none"> • Flammable materials • pyrophoric compounds • organic peroxides • materials capable of self-decomposition • materials capable of self-heating • products that emit flammable gases
 <p>GHS03 – Flame over a circle</p> <ul style="list-style-type: none"> • Oxidizers 	 <p>GHS04 – Gas container</p> <ul style="list-style-type: none"> • Pressurized gases

<i>Danger to Human Health</i>			
 GHS05 – Liquids spilling from two test tubes	<ul style="list-style-type: none"> • Corrosion of metals • skin lesions • significant eye damage/irritation 	 GHS06 – Skull and crossbones	<ul style="list-style-type: none"> • Acute toxicity (dangerous)
 GHS07 – Exclamation mark	<ul style="list-style-type: none"> • Skin/eye irritation • acute toxicity (harmful) • skin sensitization • danger to the ozone layer 	 GHS08 – Health risk	<ul style="list-style-type: none"> • Carcinogenicity • respiratory sensitization • mutagenicity • reproductive toxicity • danger in case of aspiration • toxicity to target organs
<i>Environmental Danger</i>			
 GHS09 – Dry tree and dead fish	<ul style="list-style-type: none"> • acute toxicity to aquatic organisms; • chronic toxicity to aquatic organisms 		

Presumably, understanding the elements of labeling of chemical products and basic measures for work, management, and disposal of chemicals are the basic components of the ecological worldview of a human. The consideration of chemical safety must be formed throughout people's lives and in the context of their professional activity.

3. Method

The researches on the level of training of specialists in the field of medicine and pharmacy are analyzed [11-15]. Moreover, the questionnaires and tests have been developed to assess the degree of shaping chemical safety components. A survey and testing of 147 first- and second-year students attending 222 "Medicine" special course at the Bohomolets National Medical University have been conducted. The study examined the motivational-value, cognitive and activity components of competence in chemical safety of future physicians. The motivational-value component reflects the formation of stable internal motives for the application in further professional activity of the culture of safe management of chemicals during their life cycle, understanding the practical value of interpreting modern data on the biochemical mechanisms of the chemical effects on human health as a part of successful treatment and prevention activities.

The cognitive component of chemical safety competence of future doctors consists of two semantic blocks: labeling of chemicals and biochemical aspects of chemical safety. The activity component of the competence reflects its application during educating processes in the field of chemical safety. According to the described components of competence in chemical safety of future doctors, these three criteria have been identified: motivational-value, cognitive, activity. The level of formation of the motivational-value criterion of chemical safety competence was considered by the results of students' self-assessment in terms of the questionnaire questions № 1-2, 4-8 (Fig. 2).

Dear students, answer the questions in this questionnaire please!

*Assess your answer by the score from 0 to 4
(where 0 is the lowest and 4 is the highest motivation)*

Date _____, Group, Faculty _____

1. Do future doctors need knowledge of chemical safety?	0	1	2	3	4
2. Do future doctors need to know modern approaches to hazard labeling (label elements, risk phrases)?	0	1	2	3	4
3. Do future doctors need to know the rules of managing chemical substances during their production, transportation, storage, and disposal?	0	1	2	3	4
4. Will you use the toxicological characteristics of chemicals during your professional activity?	0	1	2	3	4
5. Do future doctors need to understand the mechanisms of inhibition of enzymatic reactions by toxicants?	0	1	2	3	4
6. Do future physicians need to understand the molecular mechanisms of chemical mutagens action?	0	1	2	3	4
7. Do future physicians need to understand the effects of organic and inorganic toxicants on the human body at the molecular level?	0	1	2	3	4
8. Do future physicians need to know the processes underlying the biotransformation of xenobiotics and endogenous toxins?	0	1	2	3	4
9. Will you take preventive measures applying your knowledge of chemical safety during your professional activity?	0	1	2	3	4
10. Will you use the knowledge of chemical safety in your daily life?	0	1	2	3	4
Your total points					

THANK YOU FOR COOPERATION!

Figure 2. Example of the developed questionnaire to establish the levels of formation of motivational-value and activity criteria within competence in chemical safety.

The motivation for the need to understand the abovementioned aspects of chemical safety (answer to the question) was assessed by future doctors with scores of 0, 1, 2, 3, 4 (where 0 is the lowest motivation and 4 is the highest motivation). The coefficient certifying the level of shaping the motivational-value criterion of competence in chemical safety among the interviewed future doctor was established by the formula [15], which is adapted to this study:

$$C_{m-v} = \frac{\sum p}{\sum n}, \quad (1)$$

where C_{m-v} – coefficient of forming motivational-value criterion; $\sum p$ – the points scored for answers to questions; $\sum n$ – the maximum possible points.

To diagnose the degree of forming the levels of cognitive criteria, the students are offered to perform test tasks for understanding modern approaches to labeling of chemicals and biochemical aspects. The analysis of test results was carried out by means of mathematical statistics [16-18].

Evaluating the degree of forming the levels of the activity criterion regarding competence in chemical safety was carried out by respondents' self-assessing their work in the context of solving the given tasks (№ 3, 9-10). The students are asked to assess their readiness to perform such activities using points 0, 1, 2, 3, 4 (where 0 is the lowest and 4 is the highest level of readiness). The coefficient certifying the level of shaping the activity criterion of the surveyed future physicians was determined by the formula [15], which is adapted to this study:

$$C_a = \frac{\sum p}{\sum n}, \quad (2)$$

where C_a – coefficient of formation of activity; $\sum p$ – the points scored for answers to questions; $\sum n$ – the maximum possible points.

4. Results

Evaluating the shaping of the cognitive criterion within competence in chemical safety of future doctors was carried out by testing in accordance with the developed indicators. For diagnostic purposes, a final test, which consists of 50 test tasks, was developed. Accordingly, the levels of forming the cognitive criterion of competence are distributed: low – up to 70% (0-35 test tasks completed); average – 71-80% (36-40 test tasks completed); sufficient – 81-90% (41-45 test tasks completed); high – 91-100% (46-50 test tasks completed).

The levels of building motivational-value and activity criteria of competence in chemical safety were determined by the value of the calculated coefficients C_{m-v} and C_a .

Accordingly, the levels of creating motivational-value and activity criteria of competence in chemical safety were: low – the value of C_{m-v} or C_a varies from 0 to 0.25; average – the value of C_{m-v} or C_a varies from 0.26 to 0.50; sufficient – the value of C_{m-v} and C_a varies from 0.51 to 0.75; high – the value of C_{m-v} and C_a varies from 0.76 to 1.0.

According to the developed criteria and indicators, the following levels of competence in chemical safety of future doctors were demonstrated (Fig. 3): motivational-value (high – 37.67%; sufficient – 46.58%; average – 10.27%; low – 5.48%), cognitive (high – 10.46%; sufficient – 34.39%; average – 46.77%; low – 8.38%), and activity (high – 23.97%; sufficient – 50.69%; average – 21.25%; low – 4.11%) criteria.

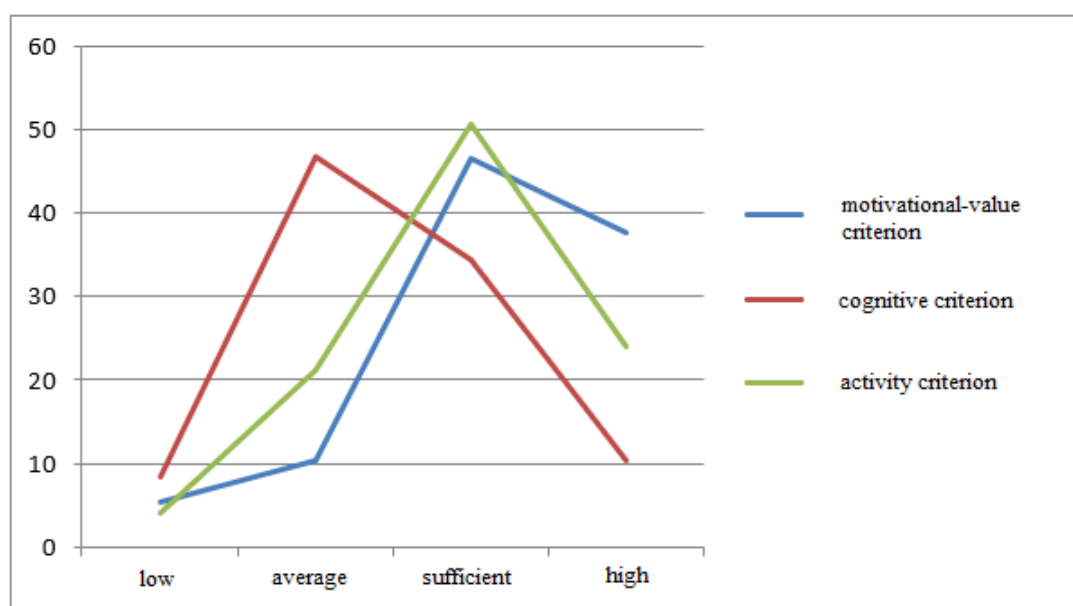


Figure 3. Levels of forming the criteria of competence of future doctors within chemical safety.

The obtained results proved the need for reviewing the content of medical students' training, more detailed study of the issues of chemical labeling, new approaches to the rules of management and disposal of chemicals.

5. Conclusions

A comparative analysis of domestic and international legal documents in the field of chemical safety of the systems of classification and labeling of chemicals was conducted at the global level (namely International Chemical Safety Program; Strategic Approach to International Chemicals Management; Concept of Increasing the Level of Chemical Safety in Ukraine). It was established that chemical safety is a set of legal and practical measures that minimize the negative impact of chemical compounds during their production, transportation, storage, use, sale, utilization through coordinated work in the fields of legal, economic, ecological-hygienic, and educational activities. The global consideration of chemical safety must be formed throughout people's lives in the context of their professional activity. The components of chemical safety are identified: the measures for transportation and disposal of hazardous waste; dangerous chemicals trade; reduction of use and complete elimination of POPs; implementation of unified rules for hazards classification and labeling of chemicals.

Considering the obtained results, the following is stated: the issues of chemical safety in the system of training medical students need paying more attention, developing special courses (to choose from), and strengthening the safety component in the study of fundamental natural and specialized disciplines.

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