Main hazard control and hazardous material handling in environment testing laboratory

Bungaran Saing[1], Hadita[2], Elvi Kustiyah[1], Dinda Yesika Agustin[1], Rizky Yusrina Amalia[1], Hibarkah Kurnia[3*]

[1] Department of Chemical Engineering, Universitas Bhayangkara, Bekasi
[2] Departmen of Management, Universitas Bhayangkara, Bekasi
[3] Industrial Engineering Department, Universitas Pelita Bangsa, Bekasi

*Corresponding author: hibarkah@pelitabangsa.ac.id

History: Received 06th June, 2023; Revised 09th June, 2023, Accepted 09th October, 2023

Abstract. *The increase in products from chemicals is currently growing rapidly in the Indonesian manufacturing industry. This correlates with a chemical test laboratory that is experiencing a flurry of activity. The placement of chemicals in testing laboratories still does not have problem-solving that can make it easier to search for other potential dangers. So far, the placement of chemicals is not based on hazard, but only on phase differences, namely solid and liquid phases, as well as materials that are frequently and rarely used can pose a hazard. This study aims to provide knowledge about main hazard control to all employees and propose material hazard handling in environmental laboratory testing following the material MSDS. This research method uses the concept of re-layout chemicals in the laboratory based on the type of danger they cause by collecting data obtained from MSDS, literature review studies, references from books, government regulations, and the Merck China website to see the characteristics of chemicals that will be placed in the material stock storage room. This study found a layout mapping of chemicals in the materials storage room, with 3 storage areas and 2 additional storage areas. The result of this research is that Cabinet A is filled with harmless solid phase materials and a class of toxic substances. The chemicals in cabinet B, consist of solid-phase materials that are corrosive, harmless, irritating, carcinogenic, and highly flammable. Whereas on shelf C letter L it consists of liquid phase materials which are harmless, corrosive, dangerous, flammable, highly flammable, highly flammable, carcinogenic or toxic. Whereas Container D contains chemicals that have oxidizing properties and Cabinet E contains chemicals that are highly flammable in water.*

Keywords: main hazard, control management, handling of hazardous chemicals, environmental testing laboratories

1. Introduction

Along with the increase in chemical production in various manufacturing industries that use chemicals, external laboratories also urgently need to check the quality of chemicals (Geueke et al., 2018). Testing Laboratory is a laboratory to carry out testing or separation processes both chemically and physically (Pranoto et al., 2020). In the testing laboratory, this is closely related to the several types of chemicals that will be used and their placement will determine the continuity of the examination (Beatrix & Triana, 2019). Before using chemicals, it is very important to pay attention to the properties and characteristics of these chemicals because if not paid attention to, it will indicate a work accident (Manurung et al., 2021). Basic security before using chemicals is very important and there must be management of chemical storage management (Kong et al., 2019).

Each chemical has a different level of hazard, the user must read and follow the warning label instructions (Bhuiyan et al., 2019). All chemicals used must have a Material Safety Data Sheet (MSDS). This MSDS provides information about the potential hazards of the commercial substance to be used and the safety or countermeasures that need to be followed by the user or users (Digiesi et al., 2018). Agencies or institutions must keep MSDS provided by suppliers or distributors (Rembulan & Maratama, 2022). The strategy for storing chemicals is a priority plan to achieve the goals of occupational safety and health in a test laboratory (Aprilia et al., 2023). In terms of storing materials and chemicals, a strategy is a plan that is carried out to store materials and materials correctly to reduce the risk of accidents in the laboratory (YörükoĞlu et al., 2017). Storage and arrangement of chemicals must be considered based on physical and chemical properties, especially the level of danger (Dallinger et al., 2020). Storage of chemicals can refer to the MSDS for each material that should already be owned by the agency as a supplier of basic materials for processing chemicals (Digiesi et al., 2018).

In the testing laboratory, materials are grouped based on solid and liquid and based on how often the material is used, with a material usage system using the First In First Out (FIFO) method (Bhuiyan et al., 2019). However, some chemicals should not be stored close to other chemicals because they can cause hazards such as fire, explosion, and others (Zhou et al., 2018). So that these materials must be stored specifically, separately, arranged, and controlled in storage with other chemicals (Tarnada et al., 2021). Based on these phenomena, the storage of chemicals carried out in observation laboratories is still not appropriate, because chemicals are not placed based on the hazardous nature of the materials used. So the management needs a method of storing chemicals so that accidents do not occur in the storage of materials in the laboratory.

The problem that has occurred in chemical laboratories so far is that there is no specific layout regarding the sampling of chemicals based only on the type and composition of the material. This is dangerous when picking and placing because chemicals will be mixed between harmless chemicals and dangerous chemicals. This phenomenon will result in the contamination of non-hazardous chemicals into dangerous chemicals and can potentially interfere with the collection of types of materials so that they will be mixed up during laboratory testing.

The new approach from this research is how management can control the main hazards from available chemicals if there is a mismatch in handling. In addition, how to handle hazardous chemicals in the Environmental Testing Laboratory to avoid the dangers of explosions, fires, and environmental pollution. Management must be able to control the MSDS control and the proper placement according to the type of chemical. Collecting data from literature reviews obtained from previous research, MSDS and other documents makes this research more focused and conceptual in finding new problem-solving in the handling of hazardous chemical laboratory settings. This research aims to provide knowledge about controlling the main hazards to all employees and propose handling material hazards in environmental laboratory tests according to material MSDS. The knowledge that must be obtained and understood by all employees is knowledge of the symbols for dangerous chemicals, health care to avoid chemicals, emergency response in the event of an accident exposed to chemicals, and knowledge of the placement or groups of chemicals.

2. Methodology

This research is a type of descriptive research that describes how the arrangement of material storage areas is designed based on the level of hazard and ensures it is safe to be placed side by side according to the cabinets and material shelves available in the company. Collection of research data through direct observation in the laboratory to see how things are in the field, and what things are happening and to formulate problems to be raised.

The author also conducts interviews or discussions with the person in charge of the supervisor regarding how chemical data collection is obtained from the MSDS to see the characteristics of the chemicals that will be placed in the material stock storage room. Apart from that, the research also conducted literature studies or preparatory materials by collecting and studying references from books, government regulations, and the Merck China Web. The detailed research stages can be seen in Figure 1.

Based on Figure 1 the stages of this research were carried out by mapping the hazards of chemicals in the storage arrangements for hazardous materials in the testing laboratory as follows:

- ✓ Stage 1 is to conduct interviews with the person in charge of the supervisor regarding the storage of materials in the stock room. Collecting data on lot numbers, catalog numbers, and trademarks of each available chemical.
- ✓ Stage 2 is to look for the MSDS on each website's website by entering the lot number and the material name catalog. Conduct MSDS literature for each material by recording its hazard category.

- ✓ Stage 3 is to categorize hazards, the management can use Government Regulation (GR) No. 74 of 2001 concerning Management of Hazardous and Toxic Materials, article 5 paragraph 1. Analyze the highest level of hazard for each material based on its various hazards with the book (Globally Harmonized System of Classification and Labeling of Chemicals (GHSCLC), Ninth Revised Edition, 2021) Annex 1.
- ✓ Stage 4 the storage of chemicals carried out in the observation laboratory is still not appropriate, because the chemicals are not placed based on the hazardous nature of the materials used. So the management needs a new solution for storing chemicals so that accidents do not occur in the storage of materials in the laboratory.

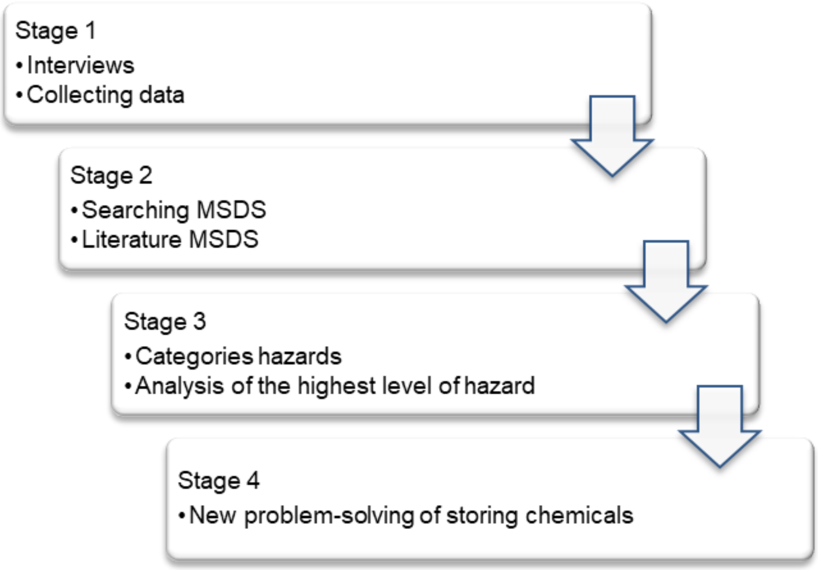

Figure 1. Research Framework

3. Result and Discussion

In this section, the results of this research will be discussed along with the discussion adjusted to the research steps that have been made and compiled in the previous section.

Stage 1 Interview results with supervisors and collected data

Interviews were conducted with the person in charge of the supervisor to find out the mechanism for preparing the placement of chemicals in the material stock room. Based on the interview results, the following information was obtained:

- ✓ The stock room is arranged based on phase differentiation, namely for 2 material cabinets containing solid phase chemicals and 1 L shelf for liquid materials and based on the frequency and infrequent use of materials.
- ✓ But there are still liquids in the cupboards and solids on the shelves because the space is no longer sufficient, so they are arranged to fit and tidy.
- ✓ The supervisor asked us to arrange the materials based on the level of hazard or hazard and then safely place them side by side.

The results of creating Hazardous Material Mapping (HMM) to be able to collect data obtained through observation, Table 1 is the result of data collection. Based on Table 1 collects data on lot numbers, catalog numbers, and brands of each available chemical by going directly to the material stock room. Other studies for the evaluation of chemicals in the laboratory are adjusted to the space and space available (Kelly et al., 2017).

Table 1. Chemical Specifications

Chemical Name	Brand	Catalog Number	Lot Number
Sodium molybdate dihydrate	Supelco	1.04874.0250	A1537674017
Kolom Cadmium Powder	Merck	1.02001,0250	K50877001926
N, N-Dimethyl-1,4-phenylenediamine oxalate	Aldrich	1002433117	MKCC4915
Sodium Nitroprusside dihydrate	Loba Chemi	595800100	B274481808
Potassium Cyanide	Merck	1.04967.0100	K50405567832
Iron (II) Sulfide	Merck	1.03956.1000	K50148656919
Potassium Chromate	Merck	1.04952.0250	57661452835
Pararosanilin	Cetisrain	1.07509.0025	FN 1395109828
1,4-difluorobenzene	Aldrich	1002775050	MKBN8571
Glycerol	Smart Lab	310719001	A-1043
Iron (III) Chloride	Sigma Aldrich	8.03945.1000	S8014545038
Chloroform	Smart Lab	250322003	A1022
Acetyl Acetone	Supelco	1.09600.0500	S6029500103
Tetrahydrofuran	Supelco	1.09731.1000	K52820031103
Dimethyl amine	Merck	8.22033.1000	S7276633636
N-Hexadecane	Merck	8.20633.0250	S7764633917
Phenol	Supelco	1.00206.1000	A1663606
Potassium Nitrate	Supelco	1.05063.0500	AM1367463010
Sodium Nitrite	Merck	1.06549.0500	A1276649811
Sodium Borohydrate	Sigma Aldrich	806373	16940-66-2

Stage 2 Searched MSDS and Literature MSDS

After obtaining the catalog number, lot number, and brand data, a search for MSDS data is carried out on the web for the brand of each chemical by entering the catalog number and lot number, then downloading each MSDS for the latest year's edition. The downloaded MSDS can be seen in Figure 2.

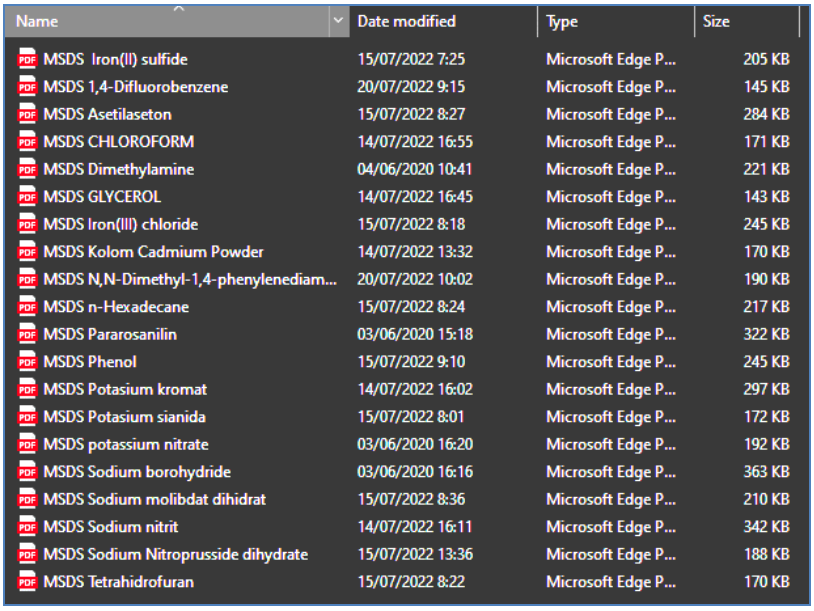

Figure 2. Downloaded MSDS of Chemical Materials

Furthermore, from the MSDS that has been downloaded, literate MSDS for each material for its hazard category concerning GR No.74 of 2001 concerning the management of hazardous and toxic materials, article 5 paragraph 1. Hazard data for each material obtained from MSDS based on GR can be seen in Table 2.

Table 2. Hazard Category Results

Chemical name	Phase	Hazard
Sodium molybdate dihydrate	Solid	Not harmful
Kolom Cadmium Powder	Solid	Very very toxic, Dangerous for the environment, Carcinogenic, Teratogenic, Mutagenic
N, N-Dimethyl-1,4-phenylenediamine oxalate	Solid	Very toxic
Sodium Nitroprusside dihydrate	Solid	Toxic
Potassium Cyanide	Solid	Very very toxic, Corrosive, Dangerous for the environment, Carcinogenic
Iron (II) Sulfide	Solid	Not harmful
Potassium Chromate	Solid	Harmful, Irritant, Dangerous for the environment, carcinogenic, mutagenic
Pararosanilin	Solid	Carsinogenic
1,4-dichlorobenzene	Solid	Very easy to ignite
Glycerol	Liquid	Not harmful
Iron (III) Chloride	Liquid	Corrosive, Irritant
Chloroform	Liquid	Irritant, Carcinogenic, Teratogenic
Acetyl Acetone	Liquid	Dangerous, Toxic, Flammable
Tetrahydrofuran	Liquid	Harmful, Highly flammable, Irritant, Carcinogenic
Dimethyl amine	Liquid	Dangerous, Highly flammable, Corrosive, Irritating
N-Hexadecane	Liquid	Dangerous, Toxic, Carcinogenic
Phenol	Liquid	Hazardous, Toxic, Corrosive, Dangerous for the environment, Mutagenic
Potassium Nitrate	Solid	Oxidizer
Sodium Nitrite	Solid	Toxic, Oxidizing, Irritant, Dangerous for the environment
Sodium Borohydrate	Solid	Toxic, Highly flammable, Corrosive, Carcinogenic, Teratogenic

Based on Table 2, the distribution of chemical hazard categories according to mapping is divided into 2, namely chemicals made from solid and liquid (Karthikeyan et al., 2018). The basis for grouping them is based on the 2 categories above and then separately arranged according to the classification of shelves available in the laboratory room.

Stage 3 Categories Hazards and Analysis of the Highest Level of Hazard

In step 3 generate the hazard category and analysis of the highest hazard level intended to classify chemicals based on the level of hazard that will affect humans and the surrounding environment. The hazards category can be seen in Table 3.

Table 3. Hazard Categories

No	Hazard Name	Remarks
1.	Explosive	The heating temperature value of a material is greater than the reference compound
2.	Oxidizing	Materials that cause other materials to oxidize
3.	Very easy to ignite	The flash point below 0°C and boiling point lower or equal to 35°C
4.	Highly flammable	Flashpoint 0-21°C
5.	Easy to ignite	Liquid phase flash point less than 60°C and solid phase flash point less than 40°C
6.	Very very toxic	LD_{50} <1mg/kg
7.	Very toxic	LD_{50} 1-50 mg/kg
8.	Toxic	LD_{50} 51-500 mg/kg
9.	Harmful	Inhalation and oral are harmful to health
10.	Corrosive	Causes skin irritation (burns) and rusting process
11.	Irritating	Mucous membranes may become inflamed by the substance

No	Hazard Name	Remarks
12.	Dangerous for the environment	Damage to the ozone layer, persistent, and materials can damage the environment
13.	Carcinogenic	Causes cancer cells or cells that damage the body
14.	Teratogenic	Affecting the formation and growth of the embryo
15.	Mutagenic	Causes chromosomal/genetic changes

After obtaining the hazard data for each material, a review of the hazard code contained in the MSDS is carried out to see the smallest hazard code. Based on the purple book, the ninth edition of the 2021 edition, seen from annex 1, it was found that the smaller the hazard code, the higher the level of danger (Oktavilia et al., 2020). To find out and determine the higher level of danger, all employees must know the danger code for each chemical. The smaller the danger code number, the higher the potential danger posed by the chemical. The smallest and highest danger codes can be seen in Table 4.

Table 4. Smallest and Highest Hazard Code Data

Chemical name	Hazard code	Highest Hazard
Sodium molybdate dihydrate	-	Not harmful
Kolom Cadmium Powder	H330	Very very toxic
N, N-Dimethyl-1,4-phenylenediamine oxalate	H300	Very toxic
Sodium Nitroprusside dihydrate	H301	Toxic
Potassium Cyanide	H290	Corrosive
Iron (II) Sulfide	-	Not harmful
Potassium Chromate	H315	Irritation
Pararosanilin	H350	Carcinogenic
1,4-dichlorobenzene	H225	Very easy to ignite
Glycerol	-	Not harmful
Iron (III) Chloride	H290	Corrosive
Chloroform	H320	Dangerous
Acetyl Acetone	H226	Easy to light
Tetrahydrofuran	H225	Very easy to ignite
Dimethyl amine	H225	Very easy to ignite
N-Hexadecane	H304	Carcinogenic
Phenol	H301	Toxic
Potassium Nitrate	H272	Oxidizer
Sodium Nitrite	H272	Oxidizer
Sodium Borohydrate	H260	very easy to catch fire in the water

Based on Table 4 there is the highest hazard that must be prioritized. The next step is to make a mapping of material placement based on 2 cabinets and 1 letter L shelf provided by the company. While in the middle of the review process, 1 cupboard for oxidizing materials and 1 small cupboard for flammable materials were added. The arrangement in the laboratory room related to the grouping of chemical materials depends on the condition and size of the room to create safety and control hazards (Bernabeu-Martínez et al., 2018).

This research provides a proposal for management to utilize the existing cabinet in the laboratory. There are 5 existing cabinets named cabinets A, B, C, D, and E. The proposal submitted is in the form of new problem-solving in mapping the layout of dangerous chemicals based on the potential dangers they cause, so it is hoped that this will prevent the emergence of something undesirable. such as explosions, fires, and pollution of the surrounding environment.

Stage 4 New Problem-Solving of Storing Chemicals

After finding the highest hazard or the hazard that should be prioritized for each material, arrange the materials in the available places, namely 2 material cupboards and 1 letter L long shelf of material concerning the Merck China table which has hazard signs. The materials can be placed side by side or cannot be placed side by side. Merck tables can be seen in Figure 3.

Figure 3. Merck China Mapping Chemical

The description of the color of the hazard lights up as follows:

- Flammable liquid
- Flammable solid
- Substances prone to spontaneous combustion
- The substance is flammable in contact with water

Based on Figure 3, the (+) sign means that the dangerous chemical can be grouped in a cabinet and conversely the (-) sign means that the chemical cannot be grouped in the same cabinet. Figure 3 makes it easier for employees to lay out hazardous chemical materials in the sample laboratory section. The composition of Merck China Mapping Chemical was obtained from previous research (Zhu et al., 2017).

After obtaining Merck China chemical mapping which can facilitate the mapping and preparation of chemical materials found in the laboratory environment (Williams et al., 2017). The next step is to generate material laying mapping data which is documented in the material placement layout database. The material layout mapping can be seen in Table 5.

Table 5. Material Laying Mapping Data

Chemical Name	Laying Mapping	Hazard
Sodium molybdate dihydrate	A cupboard	Not harmful
Kolom Cadmium Powder	A cupboard	Very very toxic
N, N-Dimethyl-1,4-phenylenediamine oxalate	A cupboard	Very toxic
Sodium Nitroprusside dihydrate	A cupboard	Toxic
Potassium Cyanide	B cupboard	Corrosive
Iron (II) Sulfide	B cupboard	Not harmful
Potassium Chromate	B cupboard	Irritation
Pararosanilin	B cupboard	Carcinogenic
1,4-dichlorobenzene	B cupboard	Very easy to ignite
Glycerol	Shelf C	Not harmful
Iron (III) Chloride	Shelf C	Corrosive
Chloroform	Shelf C	Dangerous
Acetyl Acetone	Shelf C	Easy to light
Tetrahydrofuran	Shelf C	Very easy to light
Dimethyl amine	Shelf C	Very very easy to light
N-Hexadecane	Shelf C	Carcinogenic

Chemical Name	Laying Mapping	Hazard
Phenol	Shelf C	Toxic
Potassium Nitrate	D container	Oxidizer
Sodium Nitrite	D container	Oxidizer
Sodium Borohydrate	E Cupboard	Very easy to catch fire in the water

Based on Table 5, there is a mapping of the placement and addition of material storage areas with the H272 hazard code and the H260 hazard code. On H272, it requires closed storage. Based on the Merck China hazard table, the oxidizer cannot be combined with flammable materials, while in the liquid phase, storage is placed on an open shelf so that the possibility of a reaction is quite large because the oxidizer is not stored in a closed place. Places for storage of oxidizing materials can use double containers for the first container to be kept in drums, tubs, or trays (Geueke et al., 2018). Meanwhile, for the H260 hazard code, non-flammable cupboards can be used on a small scale because this material must be isolated from other materials.

For Cabinet A, there are non-hazardous solid phase materials and a class of toxic materials, because in the Merck China table, toxic materials can be placed side by side with other toxic levels but toxic materials cannot be placed with corrosive materials. These materials consist of Sodium molybdate dihydrate, Cadmium Powder Column, N, N-dimethyl-1,4-phenylenediamine oxalate, and Sodium Nitroprusside dihydrate. For cabinet B, it consists of corrosive, harmless, irritating, carcinogenic, and highly flammable solid phase materials in the Merck China hazard table, which are safe to be placed side by side, with the materials, namely Potassium Cyanide, Iron (II) Sulfide, Potassium Chromate, Pararosanilin, and 1,4-dichlorobenzene. And finally, rack letter L consists of liquid phase materials that are not hazardous, corrosive, dangerous, flammable, highly flammable, highly flammable, carcinogenic, or toxic. In the preparation of toxic and corrosive hazards, they are separated so that they differ in end-to-end placement, and the others are safely placed side by side. The ingredients consist of Glycerol, Iron (III) Chloride, Chloroform, Acetyl Acetone, Tetrahydrofuran, Dimethyl amine, N-Hexadecane, and Phenol.

The materials above are excerpts from materials available in the testing laboratory. In the process of mapping the layout of materials, it can be observed from the highest level of hazard, so it is not recommended to place only phase differences and be neatly arranged because the chemicals in the testing laboratory have an important role (Zhou et al., 2018). Every company that uses chemicals must be replaced according to the procedure. Chemicals that are not placed based on their hazards and procedures can cause losses to analysts, resulting in work accidents or loss of company assets in the form of fire (Bhuiyan et al., 2019).

In addition to chemical mapping, it must be ensured that the room has ventilation, air conditioning, a Light Fire Extinguisher (LFE), keep it away from sources of fire, and complete personal protective equipment is available. To maintain security, the company is required to carry out room maintenance, such as checking equipment cupboards for whether they are damaged or not and making sure the storage area is suitable for use.

4. Conclusion

In this conclusion section, the conclusions from the research will be discussed to answer the research objectives. This study found that there was a mapping of hazardous materials in the testing laboratory placing materials in the available places and there were additional storage areas for Hazard codes H272 and H260. With the H272 storage type using multiple containers, the first container must be stored in a drum, tub, or tray. While the H260 uses a small cupboard that is not flammable.

This research also resulted in a new problem for mapping chemicals in laboratory test rooms. In the layout of cabinet area A, there are non-hazardous solid phase materials and toxic materials classes, because, in the Merck China table, toxic materials can be placed side by side with other toxic grades but toxic materials cannot be placed with corrosive materials. These ingredients consist of Sodium molybdate dihydrate, Cadmium Powder Column, N, N-dimethyl-1,4-phenylenediamine oxalate, and Sodium Nitroprusside dihydrate. Cabinet B consists of corrosive, harmless, irritating, carcinogenic, and highly flammable solid phase materials in the Merck China hazard table, which are safe to be placed side by side, with materials, namely Potassium Cyanide, Iron(II) Sulfide, Potassium Chromate, pararosaniline, and 1,4-dichlorobenzene. And finally, shelf C letter L consists of liquid phase materials that are non-hazardous, corrosive, dangerous, flammable, highly flammable, highly flammable, carcinogenic or toxic. In preparation for toxic and corrosive hazards, they are separated so that they differ from end to end, and the others are placed safely side by side. The composition consists of Glycerol, Iron (III) Chloride, Chloroform, Acetyl Acetone, Tetrahydrofuran, Dimethyl amine, N-Hexadecane, and Phenol.

The contribution of this research to the sample laboratory department can be to arrange or create a layout of dangerous chemicals based on the type and potential danger they will cause. So that all laboratory employees can easily search for samples of these dangerous chemicals, know how to handle these dangerous chemicals, and prevent fire accidents and other potential harm to employees and the environment. For further research, researchers recommend controlling chemicals, both incoming and outgoing materials, using a barcode system so that they are connected to the industrial digitization system 4.0. This digitization hopes that many can easily control material inventory regularly. The advantages of digitalization for chemical control reduce waste of time in the process of receiving, storing, and dispensing chemicals because everything is stored in the system.

References

Aprilia, S., Kurnia, H., Setyawan, Welly Teguh Ashar, E., & Wahyudi, A. (2023). Safety and Health (K3) Review of Employee Work Activities in Various Companies in a Systematic Study. *Industry Xplore*, *8*(2), 203–211. https://doi.org/10.36805/teknikindustri.v8i1.5102

Beatrix, M. E., & Triana, N. E. (2019). Improvement Bonding Quality of Shoe Using Quality Control Circle. *Sinergi*, *23*(2), 123. https://doi.org/10.22441/sinergi.2019.2.005

Bernabeu-Martínez, M. A., Merino, M. R., Santos Gago, J. M., Alvarez Sabucedo, L. M., Wanden-Berghe, C., & Sanz-Valero, J. (2018). Guidelines for safe handling of hazardous drugs: A systematic review. *PLoS ONE*, *13*(5), 1–24. https://doi.org/10.1371/journal.pone.0197172

Bhuiyan, M. A. R., Wang, L., Shaid, A., Shanks, R. A., & Ding, J. (2019). Advances and applications of chemical protective clothing system. *Journal of Industrial Textiles*, *49*(1), 97–138. https://doi.org/10.1177/1528083718779426

Dallinger, D., Gutmann, B., & Kappe, C. O. (2020). The Concept of Chemical Generators: On-Site On-Demand Production of Hazardous Reagents in Continuous Flow. *Accounts of Chemical Research*, *53*(7), 1330–1341. https://doi.org/10.1021/acs.accounts.0c00199

Digiesi, S., Facchini, F., Mossa, G., & Mummolo, G. (2018). Minimizing and balancing ergonomic risk of workers of an assembly line by job rotation: A MINLP Model. *International Journal of Industrial Engineering and Management*, *9*(3), 129–138. https://doi.org/10.24867/IJIEM-2018-3-129

Geueke, B., Groh, K., & Muncke, J. (2018). Food packaging in the circular economy: Overview of chemical safety aspects for commonly used materials. *Journal of Cleaner Production*, *193*, 491–505. https://doi.org/10.1016/j.jclepro.2018.05.005

Karthikeyan, L., Suresh, V. M., Krishnan, V., Tudor, T., & Varshini, V. (2018). The management of hazardous solid waste in India: An overview. *Environments - MDPI*, *5*(9), 1–10. https://doi.org/10.3390/environments5090103

Kelly, K. E., Whitaker, J., Petty, A., Widmer, C., Dybwad, A., Sleeth, D., Martin, R., & Butterfield, A. (2017). Ambient and laboratory evaluation of a low-cost particulate matter sensor. *Environmental Pollution*, *221*, 491–500. https://doi.org/10.1016/j.envpol.2016.12.039

Kong, Y., Xie, C., Zheng, S., Jiang, P., Guan, M., & Wang, F. (2019). Dynamic early warning method for major hazard installation systems in the chemical industrial park. *Complexity*, *2019*. https://doi.org/10.1155/2019/6250483

Manurung, H., Fahri, A., Purba, H. H., & Kurnia, H. (2021). Accidence Analysis Work with Failure Mode and Effect Analysis Method in the Coating Service Industry in Indonesia. *Specktrum*

Industry Journal, *19*(2), 135–144. https://doi.org/10.12928/si.v19i2.20585

Oktavilia, S., Hapsari, M., Firmansyah, Setyadharma, A., & Fajarini Sri Wahyuningsum, I. (2020). Plastic Industry and World Environmental Problems. *E3S Web of Conferences*, *202*, 1–8. https://doi.org/10.1051/e3sconf/202020205020

Pranoto, H., Adriansyah, A., Feriyanto, D., Wahab, A., & Zakaria, S. (2020). Propose Safety Engineering Concept Speed Limiter and Fatigue Control Using Slifa for Truck and Bus. *Sinergi*, *24*(3), 237. https://doi.org/10.22441/sinergi.2020.3.009

Rembulan, G. D., & Maratama, S. (2022). PDesign of Assistive Devices Using the Conjoint Analysis Method and Quality Function Deployment (Qfd) Based on Ergonomics Principles. *JIEMS (Journal of Industrial Engineering and Management Systems)*, *15*(1), 35–44. https://doi.org/10.30813/jiems.v15i1.3602

Tarnada, B., Zio, S., Nikimea, F., Tapsoda, F., Karama, J. P. B., Savadogo, A., & Yaguibou, A. G. (2021). Biological, chemical, and physical hazard control plans to ensure employees' health during dried mango production. *Journal of Life Science and Biomedicine*, *11*(6), 94–106. https://doi.org/10.51145/jlsb.2021.12

Williams, A. J., Grulke, C. M., Edwards, J., McEachran, A. D., Mansouri, K., Baker, N. C., Patlewicz, G., Shah, I., Wambaugh, J. F., Judson, R. S., & Richard, A. M. (2017). The CompTox Chemistry Dashboard: A community data resource for environmental chemistry. *Journal of Cheminformatics*, *9*(1), 1–27. https://doi.org/10.1186/s13321-017-0247-6

YörükoĞlu, K., Özer, E., Alptekin, B., & Öcal, C. (2017). Improving histopathology laboratory productivity: Process consultancy and A3 problem-solving. *Turk Patoloji Dergisi*, *33*(1), 47–57. https://doi.org/10.5146/tjpath.2016.01375

Zhou, L., Fu, G., & Xue, Y. (2018). Human and organizational factors in Chinese hazardous chemical accidents: a case study of the '8.12' Tianjin Port fire and explosion using the HFACS-HC. *International Journal of Occupational Safety and Ergonomics*, *24*(3), 329–340. https://doi.org/10.1080/10803548.2017.1372943

Zhu, L., Liang, Z., Yi, T., Ma, Y., Zhao, Z., Guo, B., Zhang, J., & Chen, H. (2017). Comparison of chemical profiles between the root and aerial parts from three Bupleurum species based on a UHPLC-QTOF-MS metabolomics approach. *BMC Complementary and Alternative Medicine*, *16*(2), 1–12. https://doi.org/10.1186/s12906-017-1816-y