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Review Paper

Chemical Hazards in Pharmaceutical Industry: Impact and Implications for Industrial Safety

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ABSTRACT

Chemical hazards expose significant risks in Pharmaceutical Industries and laboratories. This topic mainly examines the types, sources, routes of exposure, and effects of chemical hazards commonly encountered in these settings. Major categories discussed include irritants, sensitizers, carcinogens, corrosives, mutagens teratogens, reactive chemicals, and flammables, Common hazardous chemicals like methanol, ethylene glycol and heavy metals are explored in detail, along with their toxicities and treatment approaches. This topic outlines key preventive measures, including engineering controls, administrative practices and personal protective equipment. Proper handling, storage, labelling and disposal procedures are emphasized. A systemic approach to hazard identification, risk assessment and implementation of control measures is recommended to minimize chemical exposures and worker health protection and safety. This content provides guidelines for managing the chemical hazards through a combination of organizational, technical and personal protective strategies in laboratory and pharmaceutical environment.

INTRODUCTION

Chemical hazards are produced by manufacturing, processing, chemical synthesis, transportation and their effect on human and environmental conditions. A chemical hazard a type of occupational hazard caused by exposure to chemicals in the workspace. Hazardous materials a wide range of substances, including agricultural

and industrial chemicals, cosmetics, pharmaceuticals, pesticides and food additives. To ensure the safe handling of these substances, its crucial to have comprehensive knowledge about their characteristics, potential health and environmental impacts and appropriate control measures. There are many types of hazardous chemicals including carcinogens, systemic toxins, dermatologic agents, neurotoxins, immune agents and sensitizers.

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Some chemicals can cause severe burns if they come in contact with living tissues or other routes, like inhalation

Living tissues may be destroyed by chemical reactions such as digestion, oxidation, dehydration.

Chlorinated hydrocarbons, benzene, chloroform and low boiling point fractions of petroleum are some of the common organic solvents used in the pharmaceutical industry

The eye and mucus membranes of the throat are particularly susceptible to the effects of corrosive dust, mist and gases etc.

TYPES OF CHEMICAL HAZARDS

Mutagens

Corrosives

Carcinogens

Teratogens

Flammables

Irritant chemicals

Sensitizers

Asphyxiants

Reactive chemicals

Mutagens: Chemicals classified as mutagens cause genetic changes to a cell's DNA and. Genetic changes can cause cancer, prevent normal biological functions or result in the malfunction of a particular organ. Some examples of mutagens include benzene, ionizing radiation and hydrogen peroxide.

Corrosives: Chemical corrosives cause visible and irreversible changes to the composition of a material due to direct contact. Similarly, these can also cause a localized reaction in the human body at the point of contact. However, corrosive chemicals also have potential to produce systemic chemical exposures away from point of contact when mixed with other substances. Some of the examples of corrosives include sodium hydroxide and sulfuric acid.

Carcinogens: carcinogens are cancer causing chemical substances, and a small amount of such a chemical is enough to severely harm human health. The hazards of such chemical substances will only appear many years after exposure. There are over 200 known human carcinogens

Some examples of carcinogens are benzene, cadmium, formaldehyde and vinyl chloride

Teratogens; Chemical teratogens can disrupt the normal development of a fetus, causing birth defects and even the healthy advancement of pregnancy. Some examples of teratogens include thalidomide, ionizing radiation and organic mercury compounds.

Flammables: Many chemicals characterized as flammable because they can easily burn to innately when exposed to oxygen. Some examples of flammable chemicals are methanol, Acetone, propane and butane.

Irritant chemicals: Chemical substances that cause a chemical hazard, such as an explosion, when mixed or combined with other chemical or non-chemical substances, such as water or air. Some examples of reactive chemicals include nitric acid, benzoyl peroxide and silane.

Sensitizers: Sensitizers are also known as allergens, meaning they cause an allergic reaction in people who face repeated exposures over time to certain chemicals. Reactions to chemicals deemed sensitizers vary from person to person and can be either acute or chronic. Chemical exposures can manifest as swelling of the airway or develop into dangerous illness such as lung disease. Some diseases such as asthma and contact dermatitis, become common among people due to over exposures to chemicals

Some examples of allergens are chlorine and alkalis

Asphyxiants; Chemical asphyxiants deprive the body of oxygen, interrupting the transfer and use of oxygen by the blood stream. Some examples of asphyxiants are carbon monoxide and cyanide.



SOURCES OF CHEMICAL HAZARDS

Chemical hazards are toxic corrosive, carcinogenic, to flammable and mutagenic. According to workplace hazardous, material information, Hazards can be classified in to

Class A:

Compressed gases

Dissolved gases or liquified gasses

Class B

Flammable gases

Flammable and combustible liquids

Flammable solids

Flammable aerosols

Reactive flammable materials

Class C

Oxidizable material--- Oxidizer and organic peroxide

Oxidizer---Chlorates, nitric oxide, peroxides, nitriles

Organic peroxide---Tetrahydrofuran, diethyl ether, Dioxane and Methyl isobutyl ether

Class-D

Poisonous and infectious materials

Eg: Cyanide, tea salts and asbestos.

Sources of hazards in pharmaceutical industries

Handling and storage of huge quantity of hazardous chemicals

Transferring, loading, and unloading of solvents and chemicals to reaction vessels.

Emission of hazardous air pollutants from reaction vessels

Volatile organic compounds release from uncontaminated vessels

Reaction vessels and most common VOCs include methanol, dichloromethane, toluene, ethylene glycol, n-dimethyl formaldehyde and acetonitrile

Leaks of effluents from waste water treatment plants or from effluent collection sumps from process areas.

Routes of chemical exposure: The use of chemicals in processes, production and goods has benefited people in many ways, these chemical substances are also the cause of chemical hazards. There are several routes of chemical exposure they are described below.

Inhalation – That is breathing in toxic vapors or small chemical particles.

Absorption – such as direct exposure to the skin by touching a chemical substance without any protection such as wearing gloves.

Ingestion - that is when toxins are accidentally swallowed.

Injections: That is when a sharp contaminated object or needle accidentally penetrates a worker's body.

Effects of Chemicals on exposure

Cancer

Ache

Ulcer in hand, nose etc.

Skin burn

Many chemicals can cause severe burns when they come in contact with living tissues

Living tissues may be destroyed by following chemical reactions.

- Dehydration by strong dehydrating agents
- Dehydration by strong acids and bases
- Oxidation by strong oxidizing agents

Common chemical exposures and their Heavy metals

- Metals comprise three- fourths of the element in periodic table
- Most of the known metals are quite toxic to living organisms when present excess

Treatment Strategies:

- Removal of the subject from the sources of exposure
- Treatment with chelating agents such as EDTA, cysteine e N-acetyl cysteine.
- Administration of some antioxidants, vitamin C, E



Methanol

- Methanol is used as a pharmaceutical and industrial solvent
- Methanol is also used as an extraction solvent in food

Treatment of methanol toxicities

- Gastric c may be considered if the patient presents within 1 hour of ingesting methyl alcohol.
- Activated charcoal is probably of little use as it does not absorb significant amounts of methyl alcohol.
- Hemodialysis may be indicated in increase the removal of methyl alcohol and its toxic metabolites

Methanol toxicity

- Characteristic symptoms of methyl alcohol poisoning are caused by toxic metabolites and develop after a latent period of about 12 to 24 hours.
- Metabolic acidosis with rapid shallow breathing
- Severe abdominal pain, gastrointestinal disturbances, pain in the back and extremities.
- Coma which is severe cases may terminate in death due to respiratory failure or rarely to circulatory collapse.

Ethylene glycol

- Ethylene glycol is commonly encountered in antifreeze solutions and has been used illicitly to sweeten some wines.
- Ethylene glycol is absorbed from the gastrointestinal tract and is metabolized. Chiefly in the liver, by alcohol dehydrogenase

Ethylene glycol toxicities

- Toxic effects arising from the ingestion of ethylene glycol results from its major metabolite: Aldehydes, glycolates, lactates.

- Clinical features may be divided in to 3 stages depending on the time lapses since ingestion:
 - 0-12 hours the patient may show signs of drunkenness, nausea, vomiting.
 - 12-24 hours tachycardia, mild hypertension and heart failures'
 - 24-72 hours protein urea, renal failure, respiratory failure, cardiovascular collapse and sometimes coma and death.

Treatment of ethylene glycol toxicities

- The stomach should be emptied by lavage if ingestion of ethylene glycol was within the preceding hours.
- Metabolic acidosis should be corrected with sodium bicarbonate intravenously hypocalcemia corrected with calcium gluconate.
- Hemodialysis or peritoneal dialysis may be of value. Some other chemicals that show hazardous effect on exposure include benzene, formaldehyde, vinyl chloride etc.

Preventive measures

- Solvent used in extraction, purification of synthetic drugs and chemical analysis should be handled with care.
- Flammable and explosive chemicals should be kept at proper distance.
- Tolerance level for toxic chemicals set by federal regulation have to be followed.
- Suitable label to the chemicals for proper handling.
- Personal protective personal cloth
- Application of cream before commencement of work
- Use of goggles

Management to over exposure to chemicals

- Removal from exposure



Prompt removal of the person from the exposure site is the first step and air respirators and lifelines are also mandatory first aids

- Resuscitation

Resuscitation means restoration of life of one who is apparently dead further supportive care should be provided as with any other medical emergency.

- Decontamination

A victim whose skin or clothing has been contaminated requires immediate removal of garments and shoes, it is advised.

- Symptomatic treatment

Acute over exposure may result in a variety of signs and symptoms that require general supportive medical management regardless of the specific agent. Examples include the control of convulsive seizures, treatment of bronchospasm.

Controlling chemicals hazards in the workspace

There are three general methods for controlling one's exposure to hazardous substances:

- Engineering controls
- Work Practices and Administrative controls
- Personal protective Equipment.

In the laboratory, these methods or a combination of them can be used to keep exposure below permissible exposure limits.

ENGINEERING CONTROLS

Engineering control include the following:

- Substitution of a process or operation
- Change in process to minimize contact with hazardous chemicals.
- Isolation or enclosure of a process or operation.
- Use of wet methods to reduce generation of dusts or other particulates
- General dilution ventilation
- Local exhaust, including the use of fume hoods.

Work Practices and Administrative Controls

Work Practice changes can include rotation in assignments and also by adjusting work schedules so that workers are not overexposed to hazardous chemical. Administrative controls are changes in work procedures with the goal of reducing the duration, Examples of administrative controls are Elimination ---Eliminate the hazard whenever possible to eliminate the risk.

Substitution--- Use less dangerous, more stable chemicals when possible

Modification--- Before conducting the actual procedure, always perform a dry run to identify and resolve possible safety hazards. Modify the process to reduce risk.

Segregation--- Establish a designated, restricted access work area.

Personal Protective Equipment

When engineering controls are not sufficient to minimize exposure, personal protective equipment, including gloves, eyes protection, respirators and other protective clothing should be used.

Some of the important steps used to controlling chemical hazards in the workplace are:

- Reduce or eliminate the use of hazardous chemicals whenever possible
- Maintain adequate ventilation systems to reduce concentrations of air borne chemicals
- Practicing good personal hygiene (e.g.: Washing hands) and maintaining regular workplace cleaning routines.
- Learn how to avoid carrying hazardous substances home.
- Use personal protective equipment and devices.
- Perform maintenance work in off hours so that accidental release of toxic substances will affect fewer workers



- Maintain equipment in good order to prevent leaks and breakdowns that may release toxic substances,

Picture			
Indicating words	EXPLOSIVE	Oxidizing	DANGER Highly flammable or extremely flammable
Name of the symbol	E Explosive	O Oxidizing	F, F+ Highly flammable or extremely flammable
Picture			
Indicating words	T, T+ Toxic or very toxic	Xn, Xi Harmful or irritant	B Harmful or irritant
Name of the symbol	T, T+ Toxic or very toxic	Xn, Xi Harmful or irritant	B Harmful or irritant
Picture			
Indicating words	B Biohazards	N Dangerous for the environment	R Radioactive
Name of the symbol	B Biohazards	N Dangerous for the environment	R Radioactive

Chemical safety: What to do and what to avoid

- **Know the hazard before using the chemicals**

Before using the chemicals, the hazardous properties of all chemicals involved and the possible hazardous at every stage of the process should be fully understood. Appropriate safety measures can then be taken.

- **Use appropriate control measures and personal protective equipment**

Measures Appropriate control (such as engineering control) should be used to reduce the exposure to the hazard to the lowest level. Personnel protective equipment should only be a supplement to, and not in lieu of, control measures, and should be selected appropriate to the hazards to be encountered.

- **Keep the work area well ventilated, or even work under local exhaust ventilation**

Always keep the work area well-ventilated to avoid accumulation of hazardous gas/vapor. Increase the ventilation by mechanical means if necessary. In case where more hazardous chemicals or processes are encountered, work under local exhaust ventilation.

- **Keep away from any ignition source when handling flammable substances.**

Ignition source may ignite the vapor of the flammable substances and even lead to explosion

- **Don't eat, drink and smoking**

Dangerous substances can easily enter in the body while eating, drinking or smoking during use of chemicals, and would be injurious to health.

- **Don't touch chemicals with bare hands. wearing protective gloves**

Dangerous substances can easily enter the body through the skin while touching chemicals with bare hands, and should be injurious to health. If the chemical is corrosive, the hands will suffer from chemical burn. Appropriate protective gloves should be wearing.

- **Don't such chemicals with your mouth. Use appropriate liquid delivery tools.**

Dangerous substances can easily enter the body during sucking chemicals with mouth, and would be injurious to health. If the chemical is corrosive, the mouth will suffer from chemical burn.

Appropriate liquid delivery tools such as hand pumps should be used.

- **Don't use container with narrow openings for a process that evolves heat and/ or gases.**

As the opening of the container is narrow, the releasing gas bubble may carry along hot liquid out of the container. At the same time, the heat and gas generated may tremendously increase the pressure inside the container which consequently burst. It will be more hazardous if dangerous substances are involved.

- **Don't mix oxidizing agents with flammable/ combustible substances**

When oxidizing agent such as potassium permanganate is in contact with flammable/ combustible substances, including Sulphur powder, carbon powder, zinc dust, wood dust etc. Vigorous oxidation reaction may occur spontaneously evolving large amount of heat and possible gases. This may be leads to fire and explosion

- **Don't mix acids with bleaching solutions**

When bleaching solution is mixed with acid reaction occurs spontaneously liberating toxic gases.

Table-1 : Clinical symptoms and hazardous causing chemicals

Organ	Symptoms	Chemicals
Eyes	Corneal and conjunctival disturbances	Sulphur dioxide, hydrogen sulphatic.
Nervous system	Drowsiness	CNS Depressants
Mouth	Green tongue	Vanadium
Throat	Salivation	Mercury
Lungs	Shortness of breath, chest tightness or pain	Asbestos, Bauxite dust

Safety Aspects :

- Disposable gowns made up of fabric that has low permeability to the agents in use with closed fronts and cuffs, intended for single use.
- Powder free gloves, labelled and tested for drugs used with chemotherapy. Made up of latex, nitrile, neoprene.
- Face and eye protection when splashing is possible.
- Substitution of more harmful material by one that is less dangerous to health.
- Approved respirator when there is a risk inhaling drug aerosols. The labelling of solvents to indicate their properties and health and fire hazards, is an extremely important method for controlling the hazards.
- To prevent or reduce dangerous exposure to toxic materials.

CONCLUSIONS

The prevalence of chemical hazards in the pharmaceutical industry necessitates stringent measures to protect workers the environment. This topic underscores the diversity and severity of chemicals hazards, highlighting their sources, exposure routes and health effects. The study reveals the main cause of these of risks, Particularly in pharmaceutical environments where significant volumes of dangerous components are handled, processed and stored on a daily basis. Particularly those proposed chemical substances. The primary approach begins with engineering and work practice controls, which, aim to physically alter the workplace or procedures to reduce exposure, these measures should be implements. Respiratory protection becomes necessary when engineering controls are

impractical or still in progress. Personal protective equipment (PPE), while less preferable due to its reliance on consistent use and potential limitations in fully eliminating risks, remains viable measure when other controls.

Effective diagnosis and control of chemical hazards are critical to preventing harm to people, the environment, and the workspace. By identifying potential hazards, assessing risks and implementing controls such as substitution, isolation, ventilation and personal protective exposure and prevent accidents. equipment, industries can minimize exposure and prevent accidents. Regular monitoring, training and maintenance are also essential for ensuring the continued effectiveness of control measures. A proactive approach to diagnosing and controlling chemical hazards is essential for creating a safe and healthy work environment, and for promoting a culture of safety and responsibility.

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