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Hexane: Industrial Applications, Health Risks, and Regulatory Frame work in India

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Abstract

Hexane (C_6H_{14}) is a critical solvent used in various industrial applications, notably in the extraction of edible oils and the synthesis of chemicals in the pharmaceutical industry. Despite its effectiveness, hexane poses significant health risks and environmental concerns. This paper explores the chemical properties of hexane, its industrial applications, health hazards associated with its use, and the regulatory frameworks governing its production and handling in India. An analysis of supply and demand trends is also included to highlight the importance of hexane in the Indian market.

1 INTRODUCTION

Hexane is a highly volatile and flammable hydrocarbon that plays an indispensable role in modern industries. As a non-polar solvent, it is primarily used to dissolve oils, fats, and other lipophilic compounds. Its applications range from food processing, particularly in the extraction of vegetable oils, to the pharmaceutical industry, where it is used in the formulation and purification of active pharmaceutical ingredients (APIs).

Due to its widespread use, hexane production and handling must be carefully managed. In India, hexane is produced by several large petrochemical companies. With a growing demand in various sectors, there is a need to understand hexane's chemical behavior, safety precautions, and regulatory frameworks. This paper aims to provide a detailed overview of hexane's applications, risks, and regulations.

2 PHYSICAL AND CHEMICAL PROPERTIES

Hexane is a simple alkane with the molecular formula C_6H_{14}, and it consists of six carbon atoms bonded to fourteen hydrogen atoms. As a member of the alkane family, hexane is relatively inert, meaning that it does not readily react with other chemicals under standard conditions. However, it is highly volatile and flammable, making it dangerous if handled improperly.

2.1 Hexane's Molecular Structure and Properties

Hexane's linear structure can be described as:

C6H14 = CH3(CH2)4CH3

The molecule consists of a chain of six carbon atoms, with each carbon bonded to the necessary number of hydrogen atoms to satisfy the octet rule.

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Property	Value
Molecular Weight	86.18 g/mol
Appearance	Colourless liquid
Density	0.659 g/cm³ at 20°C
Boiling Point	68.7°C
Melting Point	-95°C
Flash Point	-9.4°C
Autoignition Temperature	225°C
Vapor Pressure	150 mmHg at 20°C
Solubility	Insoluble in water

Table 1: Physical and Chemical Properties of Hexane

2.2 Combustion and Flammability

Hexane is extremely flammable, and its vapors can form explosive mixtures with air. The flash point of hexane is -9.4°C, which means that it can ignite at relatively low temperatures. In the presence of an ignition source, such as a spark, hexane can burn rapidly, producing carbon dioxide, water, and potentially hazardous byproducts, such as carbon monoxide.

$$C_6H_{14} + 9.5O_2 \rightarrow 6CO_2 + 7H_2O$$

3 INDUSTRIAL APPLICATIONS OF HEXANE

Hexane's industrial applications are vast, owing to its non-polar characteristics, which allow it to dissolve various organic substances.

3.1 Edible Oil Extraction

Hexane is extensively used in the extraction of vegetable oils from seeds. This process involves dissolving the oil in hexane and then separating it from the solid material (the seed husks). The oil is then recovered by evaporating the hexane.

Seeds + Hexane → Oil + Residue

In India, hexane plays a pivotal role in the edible oil industry, which continues to expand due to the growing demand for soybean, mustard, sunflower, and other oils.

Seed Type	Oil Yield (%)
Soybean	99.5
Sunflower	98.9
Canola	99.2

Table 2: Oil Yield for Different Seeds Using Hexane Extraction

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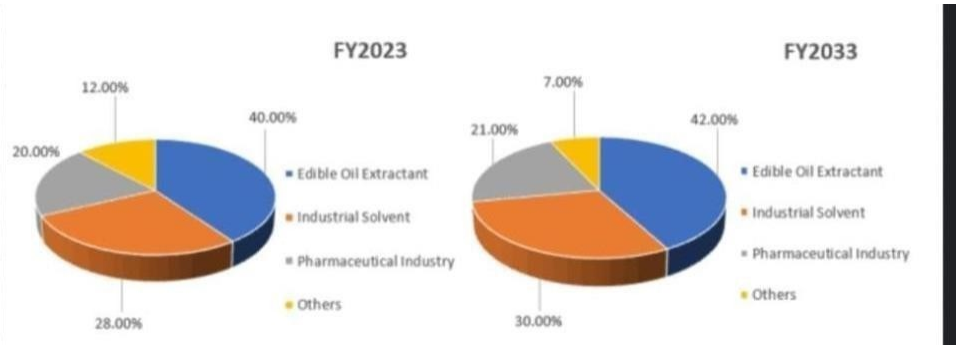

Fig 1:-India n-Hexane Market Share, By End-Use, By Volume, FY 2023 & FY2033 (From CHEMANALYST)

3.2 Pharmaceutical Applications

In the pharmaceutical industry, hexane is used to formulate drugs and purify pharmaceutical ingredients (APIs). Hexane's ability to dissolve non-polar compounds makes it suitable for the extraction and purification of oils, fats, and other hydrophobic drugs.

3.3 Chemical Industry

Hexane plays a significant role in the chemical industry, primarily due to its non-polar nature and ability to dissolve organic compounds. It is widely used as a solvent in polymerization processes, aiding in the production of polymers like polypropylene and polyethylene.

Additionally, hexane serves as a precursor in the synthesis of other chemicals and compounds, including different isomers of hexane that are important for various chemical reactions. Its utility as a reaction medium further enhances its application in chemical processes, where it facilitates organic syntheses by dissolving non-polar substances effectively.

4 HEALTH RISKS ASSOCIATED WITH HEXANE

Hexane exposure, especially over long periods, can pose significant health risks. These include both acute and chronic effects, which must be managed carefully in industrial environments.

4.1 Acute Effects

Short-term exposure to hexane vapor can result in dizziness, headaches, and nausea. Higher concentrations can lead to more severe effects, such as unconsciousness and respiratory distress. Skin contact can cause irritation, while eye exposure may result in redness and pain.

4.2 Chronic Effects

Chronic exposure to hexane can lead to more serious health issues, such as peripheral neuropathy, which involves the degeneration of nerve tissue in the hands and feet. This condition is often accompanied by symptoms such as numbness, tingling, and muscle weakness. Hexane has been classified as an aspiration hazard, meaning that it poses risks if inhaled into the lungs.

4.3 Carcinogenicity

Hexane is not considered carcinogenic to humans based on current evidence, although certain compounds formed during its combustion may pose carcinogenic risks.

5 RISK ASSESSMENT

5.1 Monitoring Data

Hexane exposure in industrial settings necessitates comprehensive risk assessment due to its potential health hazards. Airborne hexane concentrations can vary significantly, ranging from below 50 ppm in well-ventilated areas with proper controls to over 500 ppm in poorly controlled environments. To ensure worker safety, biological monitoring of 2,5hexanedione, a hexane metabolite, in urine helps assess exposure levels. Additionally, monitoring programs should be established to track hexane levels in workplaces and the environment, ensuring the effectiveness of control measures. Regular reviews of risk assessments are essential, incorporating new scientific data, regulatory updates, and changes in industrial processes to manage ongoing risks effectively.

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5.2 Risk Characterization

Risk characterization for hexane involves evaluating both its flammability and neurotoxic effects from chronic exposure. The process integrates hazard data with exposure information to estimate the potential risks to human health and the environment.

-Risk Quotient Calculation: This step compares estimated exposure levels with established toxicity thresholds, such as occupational exposure limits (OELs) and environmental quality standards, to determine the likelihood of adverse effects.

-Margin of Safety: The margin between actual exposure levels and toxicity thresholds is assessed to determine whether it is sufficient to protect exposed populations. This analysis considers uncertainties in data and variations in exposure scenarios.

Risk Characterization Data:

-Fire and Explosion Risk: Hexane presents a high risk of fire and explosion due to its low flash point and high volatility. Stringent controls are required to minimize ignition sources in environments where hexane is used.

-Health Risk: Chronic exposure to hexane poses moderate to high health risks, primarily affecting the nervous system. Inadequate controls can lead to neurotoxic effects, but these risks can be significantly reduced through regular monitoring, the use of personal protective equipment (PPE), and proper ventilation.

5.3 Risk Management for Hexane Exposure

Effective risk management for hexane exposure involves implementing a combination of engineering controls, administrative controls, and the use of personal protective equipment (PPE) to mitigate identified risks.

Engineering Controls:

-Ventilation: Utilize local exhaust ventilation systems to capture hexane vapors directly at the source, reducing airborne concentrations.

-Containment: Employ closed systems for the handling and storage of hexane to minimize vapor release and potential exposure.

Administrative Controls:

-Training: Ensure that all workers are adequately trained in the safe handling of hexane, including emergency response procedures in the event of accidental exposure or spills.

-Exposure Monitoring: Perform regular air monitoring to measure airborne hexane levels and biological monitoring (e.g., testing for hexane metabolites like 2,5-hexanedione) to track worker exposure.

Personal Protective Equipment (PPE):

-Respiratory Protection: Use NIOSH-approved respirators equipped with organic vapour cartridges in situations where ventilation is insufficient to control hexane vapours. -Skin Protection: Wear chemical-resistant gloves and protective clothing to prevent skin contact with hexane.

-Eye Protection: Use safety goggles or face shields to safeguard against splashes and accidental contact with hexane.

Safe Handling and Storage:

-Storage: Store hexane in tightly sealed containers in a cool, well-ventilated area away from heat, sparks, and open flames.

-Labelling: Ensure containers are properly labelled with hazard information.

-Transfer Procedures: Use bonding and grounding techniques to prevent static discharge during transfer operations.

Emergency Procedures:

-Spill Response: Have spill control materials readily available. Use non-sparking tools and absorbent materials to clean up spills.

-Fire Response: In case of fire, use foam, carbon dioxide, dry chemical, or water spray. Ensure that fire extinguishers are accessible and personnel are trained in their use. -First Aid: In case of exposure, move the affected person to fresh air immediately. For skin contact, wash the area with soap and water. Seek medical attention if symptoms persists.

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6. SAFETY STANDARDS AND REGULATIONS

Hexane use is strictly regulated due to its health hazards and environmental impact. In India, hexane is regulated by several government agencies, including:

- Central Pollution Control Board (CPCB): Enforces emission limits for industries using hexane.
- Ministry of Environment, Forest and Climate Change (MEFCC): Sets environmental guidelines.
- Food Safety and Standards Authority of India (FSSAI): Regulates hexane residue limits in food products.

Regulatory Agency	**Standard or Regulation**
CPCB	Emission standards for industries
FSSAI	Limits on hexane residues in food
OSHA	PEL of 500 ppm
NIOSH	REL of 50 ppm

Table 3: Regulatory Standards for Hexane Use and Exposure Limits

7. MARKET ANALYSIS

India is one of the leading producers of hexane, with major companies like Bharat Petroleum Corporation Ltd (BPCL), Indian Oil Corporation Ltd (IOCL), and Reliance Industries Ltd (RIL) playing a critical role.

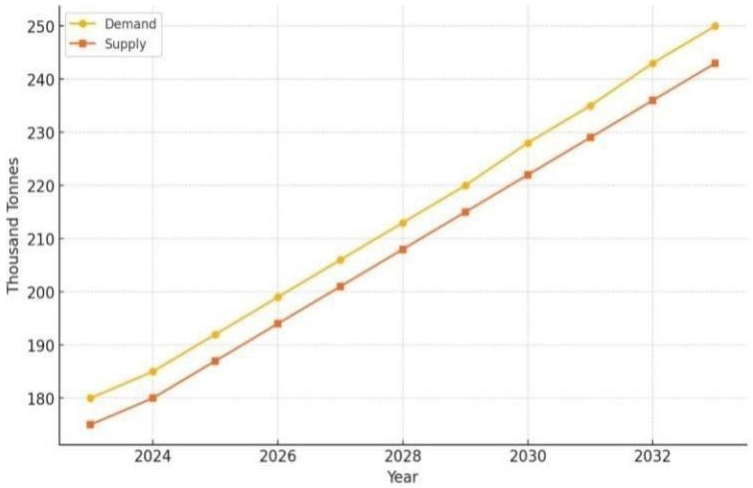

Fig 2: Hexane Market in India: Supply and Demand Forecast (2023-2033)

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7.1 Production Capacity

The production capacity of hexane in India has been steadily increasing to meet the growing demand across industries.

Company	Production Capacity (tonnes/year)
Bharat Petroleum Corporation Limited (BPCL)	50,000
Indian Oil Corporation Ltd (IOCL)	40,000
Reliance Industries Ltd (RIL)	30,000
Hindustan Petroleum Corporation Ltd (HPCL)	20,000
Mangalore Refinery and Petrochemicals Ltd (MRPL)	15,000

Table 4: Hexane Production Capacities of Major Indian Companies

8. ENVIRONMENTAL IMPACT AND MITIGATION STRATEGIES

The use of hexane poses environmental risks, primarily through the release of volatile organic compounds (VOCs) into the atmosphere. These VOCs contribute to air pollution and can have detrimental effects on ecosystems.

8.1 Environmental Risks

Hexane is classified as a hazardous air pollutant (HAP) under the Clean Air Act due to its potential to form ground-level ozone (smog). Prolonged exposure to high levels of hexane can also contaminate soil and water supplies, affecting plant and animal life.

8.2 Mitigation Strategies

To reduce the environmental impact of hexane, industries are encouraged to adopt greener technologies and implement solvent recovery systems. Vapor recovery units (VRUs) and thermal oxidizers are widely used to capture hexane vapours before they are released into the environment.

9 CONCLUSION

Hexane is a versatile solvent with widespread applications in industries such as food processing, pharmaceuticals, and chemicals. Despite its benefits, hexane's health and environmental risks necessitate strict adherence to safety regulations and the use of mitigation strategies. As the demand for hexane continues to rise, particularly in India, the need for sustainable production and responsible usage becomes more crucial.

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