Hazardous Waste Management in Chemical Industry

By

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- As per estimates of Organization for Economic Cooperation and Development (OECD) derived from correlating hazardous waste generation and economic activities, nearly five million tones of hazardous waste are being produced in the country annually. The Ministry of Environment and Forests, on the other hand, estimated that the figure is 4.43 (say 5.0) million MTA

- Nevertheless, this amount is quite small in comparison to that of the USA, where as much as 275 million tones of hazardous waste was generated annually.

- However, considering the fragile ecosystem that India has, even this low quantum of hazardous wastes can cause considerable damage to natural resources if untreated before releases.

India's fragile ecosystem could be seen from the following:

- India's fragile ecosystem could be seen from the following:

- Air pollution in Indian cities is highest amongst the world
- Over seventy percent of the country's surface water sources are polluted and, in large stretches of major rivers, water is not even fit for bathing
- India has among the lowest per capita availability of forests in the world, which is 0.11 ha as compared to 0.50 ha in Thailand and 0.8 ha in China

- The protection of Indian fragile ecosystem, therefore, warrants sustainable consumption of natural resources and protection from environmental degradation

- In India, there are over 13,000 industrial units located in 340 districts, out of which nearly all units have been granted authorization for multiple disposal practices encompassing incineration, storage, land disposal and other disposal (mostly recycle and reuse)options

- Small and medium sized enterprises, however, are major sources of hazardous waste

- The Environmental Impact Assessment Notification issued in 1994 requires the industry to seek environmental clearance (EC) for expansion or modernization of any activity (if pollution load is to exceed the existing one) or a new project listed in schedule of the above notification.

Significance of SMEs in Industrial Output and Pollution

- Nearly fifty percent of the total industrial output in India is contributed by SMEs. They also account for 60 to 65 percent of the total industrial pollution
- However, most of these industries generate hazardous wastes, which find their way uncontrolled into the environment
- According to the National Productivity Council, New Delhi (India), there are more than 3 million small and medium scale industries, which are spread throughout the country in the form of clusters/industrial estates.
- SMEs in India cannot afford to adopt and maintain adequate hazardous waste treatment and disposal technologies.

- **Capacity building to support increased waste reuse and recycling by the SMEs should focus on the following areas :**

  - Making operational national polices and incentives for waste management

  - Enabling SMEs to carry out waste reuse and recycling operations and undertaking waste management planning that incorporates resource recovery practices

- Alternatively the SMEs must use the available common hazardous waste treatment and disposal facility in the area

Status of Environmental Compliance by the States

- The Supreme Court has reconstituted the MoEF's Standing Committee on Hazardous Waste as the Monitoring Committee with the added responsibility of overseeing and monitoring the implementation of action programmes by the states,in a time bound schedule, as per its order dated October 14,2003.
- The States are making regular presentations to the monitoring committee about the compliances on their part and submitting the Action Taken Reports(ATRS).

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- The Hazardous Waste (Management and Handling)(HWM) Rules amended in 2003 contain definitions, responsibilities and grant of authorization for handling hazardous wastes, power to suspend or cancel an authorization, provisions for suitable and safe packaging, labeling and transport of the wastes and mandate for authorized person(s) to publish periodically an inventory of disposal sites within the state for the disposal of hazardous wastes.

- In India, biomedical wastes are regulated by the Bio-medical Wastes (Management & Handling) Rules enacted by the Ministry of Environment and Forests (MoEF) in July 1998. Biomedical wastes in this country are not considered under HWM Rules.

National Strategic Plan for Hazardous Waste Management

- **Principles**

  - Sustainability, productivity, efficiency
  - protection of public health and environment from toxic releases from industries
  - people's participation
  - decentralization
  - holistic approach.

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- **Processes**

  - Intersectoral collaboration; consultation; conflict resolution; detailed analysis of sector and interfaces
  - Outlook analysis; evaluation of alternatives; scenario setting; setting of priorities
  - Life cycle assessment (LCA) approach involving inventory analysis (raw materials, energy, emission), impact analysis, improvement analysis
  - Investment analysis; improved institutions and instruments; incentives
  - Empowerment of local structures and monitoring and evaluation.

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- **Aspects /Action areas**
  - Creation of hazardous waste testing facilities in pollution control boards.
  - Inventorization of hazardous waste generation in each state for establishing hazardous waste treatment and disposal facilities (HWTDF),
  - Ranking of best available technology not entailing excessive cost (BATNEEC)
  - Identification and listing of xenobiotics and anthropogenic chemicals commonly encountered in Indian environment with a view to set risk based remediation goals
  - Hazardous waste minimization by recycling, reuse by adopting green technologies and by applying the principles of environmentally balanced industrial complexing (EBIC)
  - Improvement in legal mechanisms, capacity building, human resources development, mobilization of investment funds, private sector & stakeholder involving.

Infrastructure for Hazardous Waste Management

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- Generally speaking, the infrastructure to be created and provided by the SPCB should include:
  - Infrastructure for hazardous waste testing facilities
  - Infrastructure pertaining to evaluate site selection criteria for HWTDF
  - Infrastructure to evaluate best available waste processing technology not entailing excessive cost (BATNEEC) pertaining to hazardous waste treatment and disposal
  - Infrastructure to evolve risk based remediation goals

Hazardous Waste Testing Facility

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- Each SPCB should have a hazardous waste testing facility to quantify corrosively, reactivity, ignitability and toxicity.
- The capacity building exercise is being undertaken by the SPCBs with the assistance of Central Pollution Control Board and NEERI to augment knowledge and skill base of the analysis along with infrastructure development to create hazardous waste testing facilities.
- The SPCB analytical laboratories must now adopt Good Laboratory Practices (GLP), a pre-requisite for establishing analytic credibility of a laboratory.
- Furthermore, since these laboratories are involved in a number of societal missions where analysis assumes a major role in determining pollution control and environmental status, it is also necessary to obtain ISO 9000 series accreditation for all monitoring activities carried out by SPCBs

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Site Selection Criteria for HWTDF

- A publication on criteria for hazardous waste landfill (revised on November 11, 1999) has also been prepared by the CPCB, New Delhi. The document was divided into eleven chapters composing: location criteria, site selection, site investigation criteria, planning and design criteria, waste acceptance criteria, landfill liner criteria and cover criteria, construction and operation criteria, Inspection, monitoring and record keeping criteria, post-closure criteria, financial assistance criteria, and contingency plan for emergencies.

Waste Minimization Programme

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- Waste Minimization through Environmentally Balanced Industrial Complexing (EBIC)

  - In environmentally balanced industrial complexes, there are more than one production units, located adjacent to one another so that the wastes of one serve as part of the raw material for another.
  - The pollution loads generated from such complexes are much less than that generated from the individual units operated in isolation.
  - Further, the production costs of all units are minimized, as these units in an EBIC are required to invest less for storage, transportation, treatment and disposal of their wastes.

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- Following are the four EBICs that are functioning in India:

  - **Vinyl Sulphone-Sulphuric and Chlorosulphonic acid Single superphosphate**
  - **H acid - Reactive Dyes**
  - **Viscose rayon - lignosulphonate - Acetylene**
  - **Phosphatic fertilizer - Ammonium Sulphate- Cement**

Incentives and Disincentive for Waste Minimization

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- A set of international green standards: ISO - 14000 has been introduced by the International Standard Organisation (ISO), Geneva to help companies, especially those trying to attain ISO 9000 standards pertaining to quality of products and services, improve environmental performance and keep environmental issues from becoming trade barriers, besides becoming a passport to international trade.

- To meet the ISO standards, companies will have to structure their processes or activities for :
  - **Organizational evaluation**
  - **Environmental Management System (EMS)**
  - **Environmental Audit/ Eco-audit**
  - **Environmental Performance Evaluation**
  - **Product evaluation**
  - **Life cycle assessment (LCA)**
  - **Environmental aspects in product standards (EAPS)**

- **These green standards are classified as follows**

➢ EMS	:	ISO 14000, ISO 14001
➢ Ecoaudit	:	ISO 14010, ISO 14011, ISO 14012
➢ Eco-labelling	:	ISO 14020, ISO 14021
➢ LCA	:	ISO 14040, ISO 14041, ISO 14043

- Waste minimization is one of the key indicators of continual improvement in implementation of ISO-14000 standards which can be effected by minimizing the use of non-renewable resource, improving the quality of raw materials, reducing energy use, avoiding materials or processes which contribute to global warming, adopting green productivity (GP) practices, minimizing the risk from hazardous materials and wastes by reducing their use and production, implementing environmentally friendly recycling and reuse of hazardous waste, and developing environmentally balanced industrial complexing (EBIC)

Conclusions

- It is evident from the above discussion that industries, especially SMEs will have a future that maintains the sustainability with recourse to waste minimisation through concepts of environmentally balanced industrial complexing (EBIC) and green productivity (GP) alternatives.

R&D Areas in Hazardous Waste Management

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R&D Areas in Hazardous Waste Management

Key Issues

- Monitoring
  - Persistent Toxic Substances (PTS)
  - Toxicity
  - Endocrine Disruptors

- Treatment / Disposal / Recycle / Reuse
  - Immobilization and solidification
  - Suitability of natural clay as liner and barrier materials
  - Newer technologies for SLF leachate management
  - Microbial leaching and metal recovery from heavy metal bearing wastes
  - Use of metal slag (non ferrous) in cement industries
  - Phosphogypsum conversion to cement

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- Disposal of hazardous waste through induction furnace and cement Kilns
  - Waste minimization
    - Environmentally balanced industrial complexing (EBIC)
    - Waste to wealth
    - Cleaner technology options
  - Remediation
    - Natural attenuation
    - Remediation through abiotic processes
    - Bioremediation
    - Phytoremediation

Monitoring

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- Monitoring of Persistent Toxic Substance (PTSs)
  - Protocols for quantification and QA/QC in emission (PICs) and waste
  - Supercritical fluid assisted PTS extraction
  - Newer techniques for arsenic and mercury monitoring
  - Speciation of metals, metalloids and PTSs
  - Development of sensors, immuno detection kits and gene probes for identification of PTSs & metals

Toxicity monitoring

- *In vitro* protocols for genotoxic and carcinogenic chemicals
- Application of flow cytometry in toxicity measurement
- Investigation on DNA polymorphism dependent response to detoxification following toxic exposures
- Biomarker identification following toxic exposures
- Natural products in mitigation of toxicity manifestation

DEFINITION OF AN ENDOCRINE DISRUPTOR

U.S. Environmental Protection Agency

"an exogenous agent that interferes with the production, release, transport, metabolism, binding, action or elimination of natural hormones in the body responsible for the maintenance of homeostasis and the regulation of developmental processes."

Kavlock et al. 1996

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DEFINITION OF AN ENDOCRINE DISRUPTOR

Considered by the European Commission

- Endocrine Disruptor is any compound that causes a change in the functionality of the uniform concept of hormone action beyond the boundaries of homeostatic control.
- Endocrine Modulator refers to all other cases of compound evoked hormonal changes.

IEH 1996

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CHEMICALS CLASSIFIED AS ENDOCRINE DISRUPTORS

PESTICIDES

Herbicides

- 2,4-D
- 2,4,5-T
- Alachlor
- Amitrole
- Atrazine
- Metribuzin
- Nitrofen
- Trifluralin

Fungicides

- Benomyl
- Hexachlorobenzene
- Mancozeb
- Maneb
- Metiram-complex
- Tributyl tin
- Zineb
- Ziram

Nematocides

- Aldicarb
- DBCP

Insecticides

- Carbaryl
- Chlordane
- Dicofol
- Dieldrin
- DDT and metabolites
- Endosulfan
- Heptachlor
- Heptachlor epoxide
- Lindane
- Methomyl
- Methoxychlor
- Mirex
- Oxychlordane
- Parathion
- Synthetic pyrethroids
- Toxaphene
- Transnonachlor

INDUSTRIAL CHEMICALS

- Alkyl phenol polyethoxylates
- Alkyl phenols
- Cadmium
- Dioxins and Furans
- Kepone
- Lead
- Parabens
- Phthalates
- PBBs
- PCBs
- Pentachlorophenol
- Penta- to nonylphenols
- Phthalates
- Styrenes

Sources, category (type) and examples of Endocrine disrupters that have been reported to cause harmful effects

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Sources	Category	Substances
Incineration, landfill	Polychlorinated Compounds (from industrial production or by-products of mostly banned substances)	Polychlorinated dioxins, polychlorinated biphenyls
Agricultural runoff / Atmospheric transport	Organochlorine Pesticides (found in insecticides, many now phased out)	DDT, dieldrin, lindane
Agricultural runoff	Pesticides currently in use	Atrazine, trifluralin, permethrin
Harbors	Organotins (found in antifoulants used to paint the fulls of ships)	Tributyltin
Industrial and municipal effluents	Alkylphenols (Surfactants - certain kinds of detergents used for removing oil - and their metabolites)	Nonylphenols - TBP
Industrial effluent	Phthalates (found in placticizers)	Diethyl phthalate, butylbenzyl phthalate
Municipal effluent Agricultural runoff	Natural Hormones (Produced naturally by animals); synthetic steroids (found in contraceptives) Cosmetic bases.	Estradiol, estrone, and testosterone; ethynyl estradiol Methyl Paraben
Pulp mill effluents	Phytoestrogens (found in plant material)	Isoflavones, lignans, coumestans

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FUNCTIONAL EVALUATION OF ENDOCRINE DISRUPTORS

- Changes in endocrine function
  - Estrogen/Anti-estrogen
  - Androgen/Anti-androgen
  - Thyroid agonist/antagonist
- Adverse effects
  - Reproduction
  - Development
  - Neurological
  - Immunological

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Animal Studies

- Thyroid effects
- Effects on Metabolic Enzymes
- Reproductive effects
  - **testicular degeneration**
  - **Reduction in GSI**
  - **Vitellogenin Induction**
- Developmental effects
  - **Behavioral effects**

Human Reproductive Studies

- Spontaneous abortion
- Lowered birth weights
- Complications
- Menstrual disorders
- Reproductive failure

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- **Diethyl Phthalate, Methyl Paraben, Tertiary butylphenol were investigated by NEERI for endocrine disruption function**

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Treatment / Disposal / Recycle / Reuse

Immobilization and Solidification

- Protocol development for heavy metal bearing wastes from industries
- *In situ* immobilization with a view to reduce availability & toxicity
- Immobilization in plant biomass

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Suitability of natural clay as liner and barrier material

- Amendment of natural clay suitable for lining in secure land fill
- Amendment of natural clay suitable for application in slurry wall construction to insulate dump sites from water (Surface & Ground) ingress

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Newer technologies for SLF leachate management

- Hybrid technology for detoxification and treatment of landfill leachate
- Production of nanosubstances for toxic metal sequestration from high sulphate bearing leachate through biotechnology route

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Microbial leaching and metal recovery for heavy metal bearing waster

- Evaluation of potential sulphur oxidizing and nitrifying microorganisms for leaching and recovery of heavy metals from landfill leachate
- Application of r-DNA techniques for producing acid resistant microorganisms capable of faster leaching of toxic metals from hazardous wastes

- Use of nonferrous metal slags in cement making
  - ➢ Evaluation of suitability of copper, zinc and lead slag for cement making and short listing of parameters required for BIS specification
- Conversion of phosphogypsum to cement & ammonium sulphate techno-economic feasibility
  - ➢ Techno-economic feasibility of Mersburg process for transformation of phosphogypsum to phosphochalk & ammonium sulphate in Indian conditions

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- Suitability of hazardous wastes having of high calorific value through induction furnace and cement Kiln
- Feasibility of environmentally sound disposal of paint bearing metal containers and drums through induction furnace
- Feasibility of disposal of hazardous waste having high calorific value through cement Kiln

Waste Minimization

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Environmentally Balanced Industrial Complexing (EBIC)

- Identification of EBIC compatable industrial consortia and establishing zero discharge criteria through material balance
- Identification of policy and legislative issues in effecing EBIC in India

Vinyl Sulphone – Sulphuric and Chlorosulphonic Acid – Single Superphosphate

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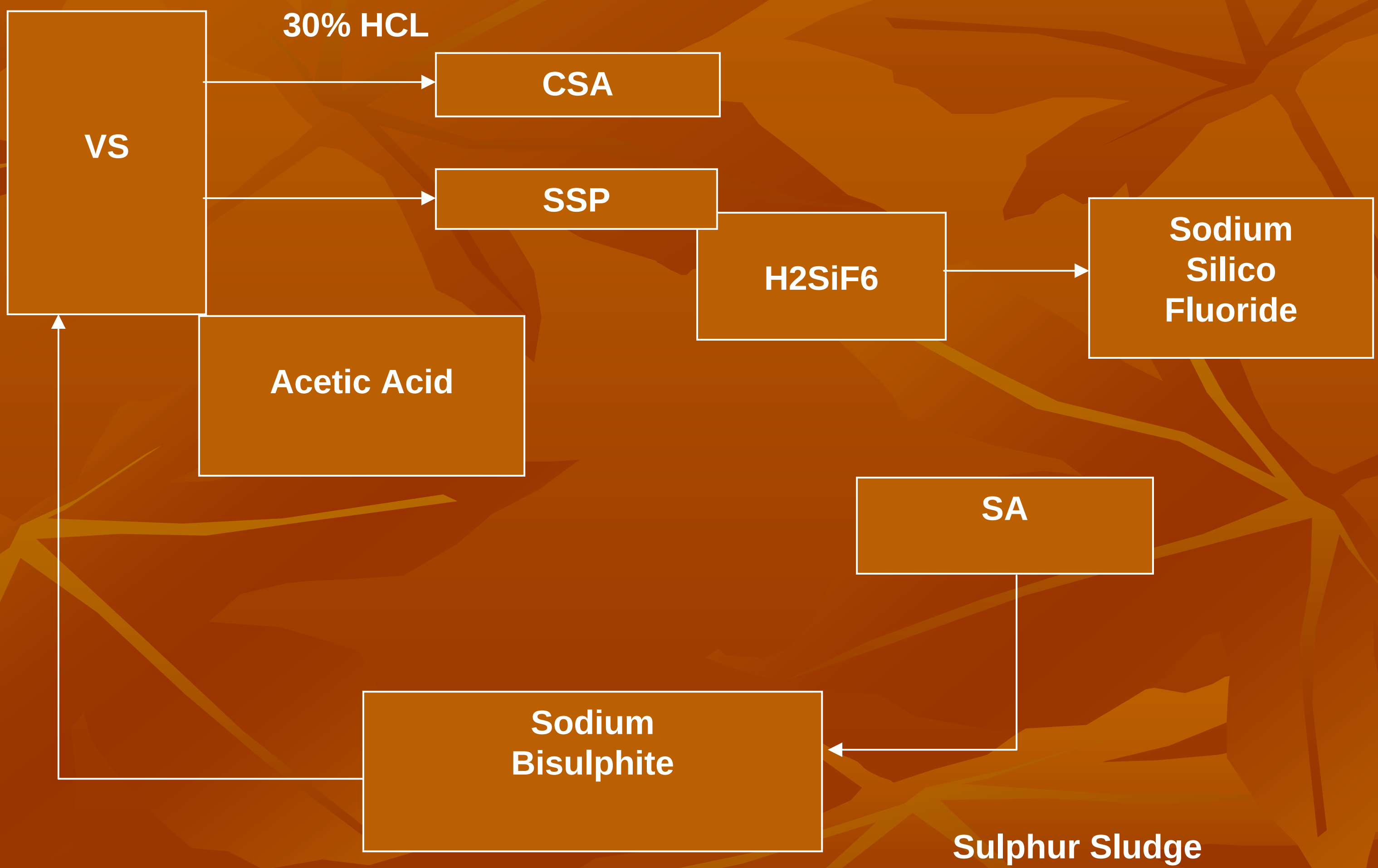

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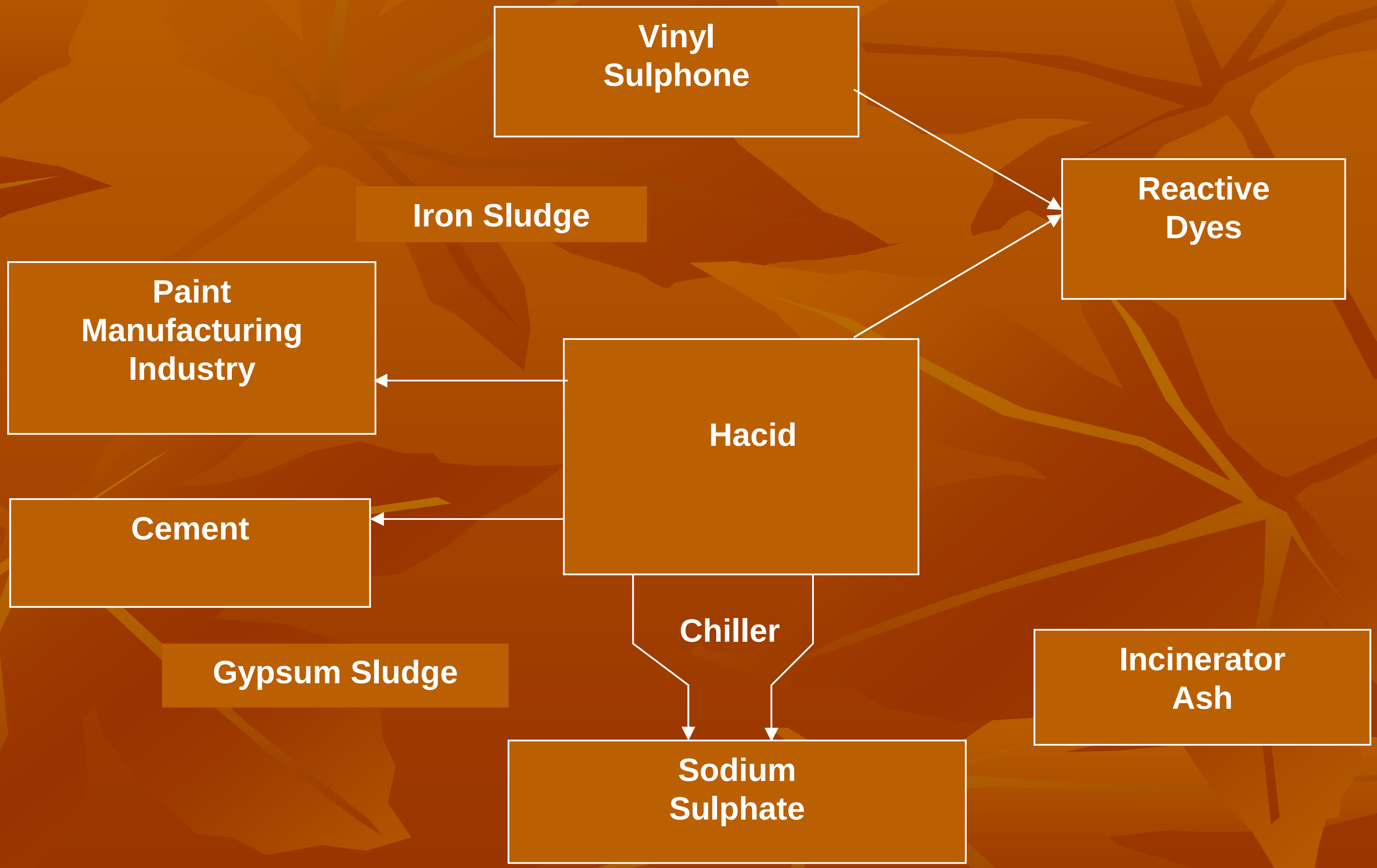
H acid - Vinyl Sulphone - Reactive dyes Complex



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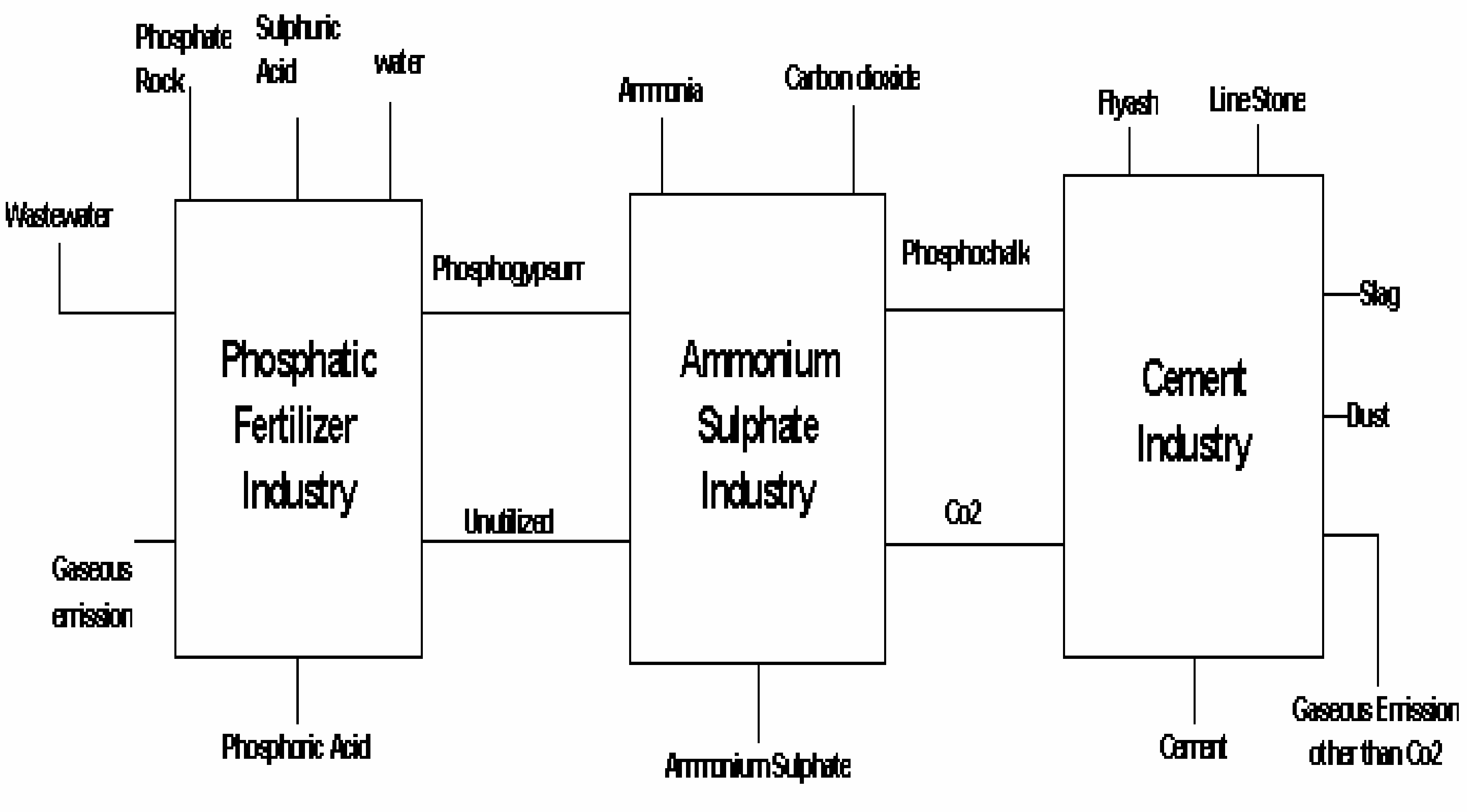
Viscose Rayon - Lignosulphonate - Acetylene Comaplex

Schematic Diagram of Environmentally Balanced Phosphoric Femilizer - Cement Industrial Complex



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Waste to Wealth

- Suitability of use of oily sludge and waste oil for power generation
- Generation of hazardous waste derived fuel and their suitability for power generation
- Suitability of metal slag unsuitable for cement manufacture for road making
- Identification of policy & legislative issues in effecting transformation of waste to wealth

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Cleaner Technology Options

- Reduction of hazardous waste generation through technology change
- Substitution of non-renewable resource base with renewable resource for chemicals and energy production

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Remediation

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- Study on environmental requirements for achieving natural attenuation *in situ*
- Use of active oxidation processes for remediation of PTSs
- *In situ* bioremediation of chemicals likely to contaminate soil and water
- Phytoremediation of contaminated sites vis-à-vis generation of ecological capital

Collaborative Institutions (Beside NEERI)

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- Agharkar Research Institute(ARI),Pune
- Central Road Research Institute (CRRI) New Delhi
- Central Fuel Research Institute (CFRI), Dhanbad
- Central Institute for Medicinal and Aromatic Plants (CIMAP), Lucknow
- Central Institute for Fisheries Education (CIFE), Mumbai
- Central salt & Marine Research Institute (CSMRI), Bhavnagar
- Council for Cement and Building Materials (NCCB), Ballabgarh
- Gujarat State Fertilizer corporation (GSFC), Baroda
- Indian Agricultural Research Institute (IARI), New Delhi National
- National Chemical Laboratory (NCL),Pune
- National Productivity Council (NPC), New Delhi
- The Energy Research Institute (TERI), New Delhi

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Thank you