A REPORT

ON

CSIR- Harnessing Appropriate Rural Intervention and Technologies

(CSIR-HARIT)

AcSIR

Project Theme

Environmental Management within CSIR-Indian Institute of Petroleum: To Improve Sustainability within the Campus

(Solvent and Solid Waste Management)

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Introduction

For the development of the nation, Industries and Chemical laboratories have become an essential part. The waste generated from these industries and laboratories is an inescapable outcome of its developmental activities. Chemical laboratories majorly produce (1) liquid waste like oils and solvents (2) solid waste, which includes paper, packaging material, kitchen waste, and waste chemicals (3) gaseous emissions from the laboratory fume hood. In general practice, these laboratory wastes are disposed into the atmosphere, water bodies, and land *via* evaporation, sewage system, landfilling, respectively.

Among all kinds of waste generated from a chemical laboratory, solvent waste is the most heavily generated waste. Since organic solvents are ubiquitous in chemistry and thus a large proportion of the solvent waste comes from the organic solvents, contaminated by reactants and products of the reaction. A considerable amount of these solvent wastes are potentially hazardous to both the environment and living beings. Before facing any irreparable damage, safe and secure disposal of these wastes is required. So, in this regard, we have assessed the solvent waste generated from the campus for the development of an effective laboratory waste management plan. In addition to solvent waste, solid waste, including paper, plastic, kitchen waste, and e-waste, is also generated in a considerable amount from the campus, and thus, the solid waste has also been assessed.

The main objective of this work is to quantify the solvent, and solid waste generated from the campus, to know its composition and the initiative taken by the institute to dispose of in an eco-efficient way. This work also focuses on the methods to improve sustainability inside the campus and to reduce the resource utilization pattern.

Waste Categorization

For proper waste management and recycling, waste categorization is an essential requirement. So, in this direction, the survey was done on the entire campus and based on observations made during the field trial, the solvent and solid wastes generated from the campus are categorized as shown:

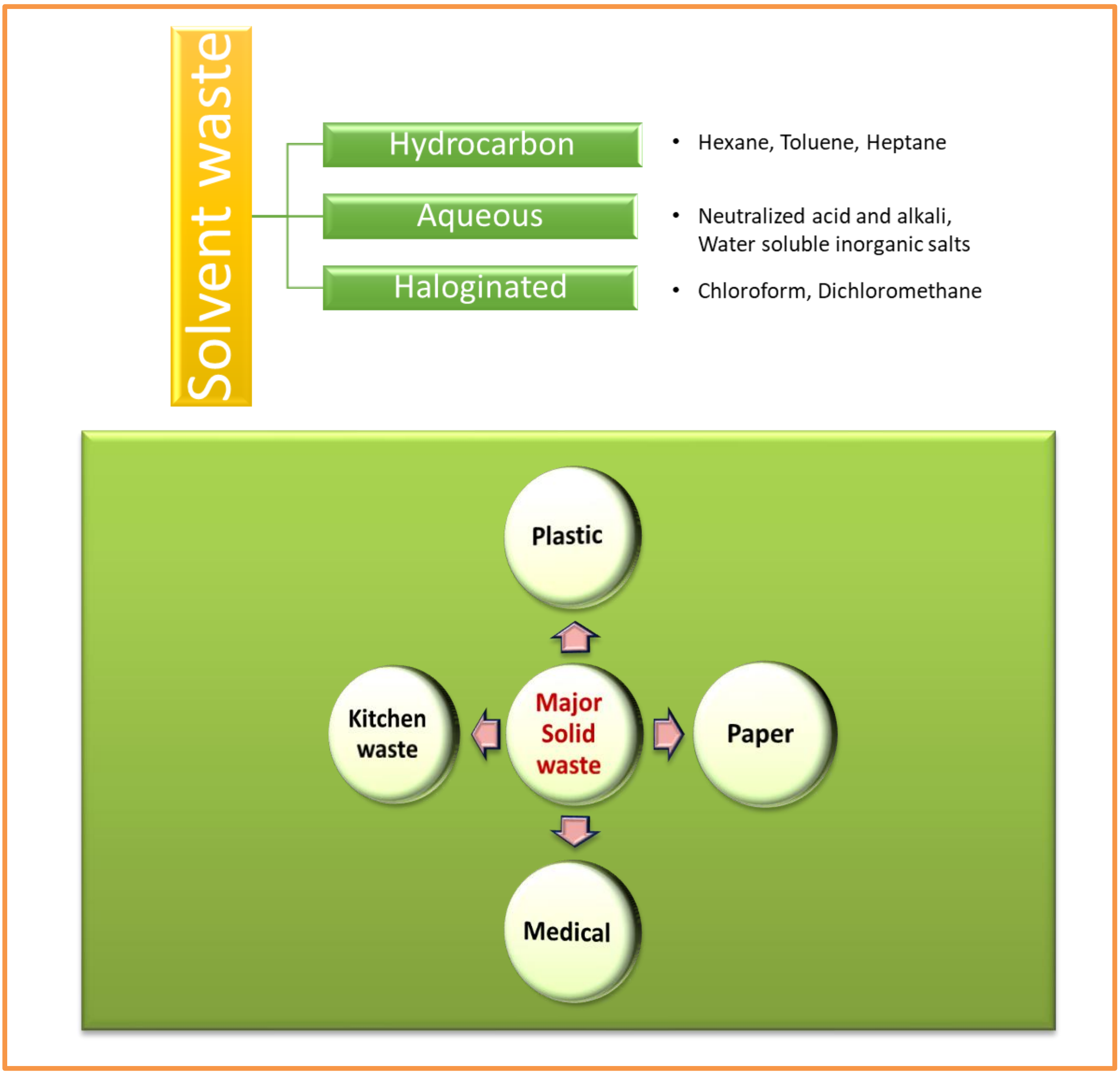


Fig1: Types of solvent and solid waste

Segregation of Waste in the Institute

In a chemical laboratory, it is very important to manage and reduce the waste generated from the laboratories. Dealing correctly with laboratory wastes is an important issue for all who are working in a chemical laboratory.

In a chemical laboratory, a wide range of waste arises like liquid waste and solid chemical waste, which should be segregated aptly. In our campus, liquid waste and solid waste are being segregated; also, liquid chemical waste is further segregated as aqueous waste and hydrocarbon waste in different containers in each lab and then it is sent for further treatment.

Solid waste is also being segregated and treated properly to reduce potential hazards. At our campus use of plastic is banned, only unavoidable plastic waste (e.g., Packaging materials, plasticware used in labs) is there; also, the use of disposable paper utensils has been banned to minimize the paper waste. There are separate containers for paper waste, plastic waste, and medical waste in every lab and also in the corridor. Glass waste is stored in robust bin separately from the other solid waste, broken glasses and unbroken glass waste are also kept separately. At the end of the week, all segregated paper and glass wastes are sent for recycling; plastic waste is sent to the “waste plastic to diesel plant,” established in the campus itself where plastic is converted into diesel, waste kitchen oil is utilized for fuel production in Biofuel Division of the institute, and the other organic kitchen waste is being used as animal feed.

Fig 2. Separate Bins placed in campus for solid and liquid waste segregation.

Estimation of Waste Generated from the Campus

An estimation of waste on the campus is done to have an idea of total waste generated from campus. We have estimated the solvent waste generated weekly from each division of the institute, as shown in table 1, and total solid waste generated per day from the campus is shown in fig3.

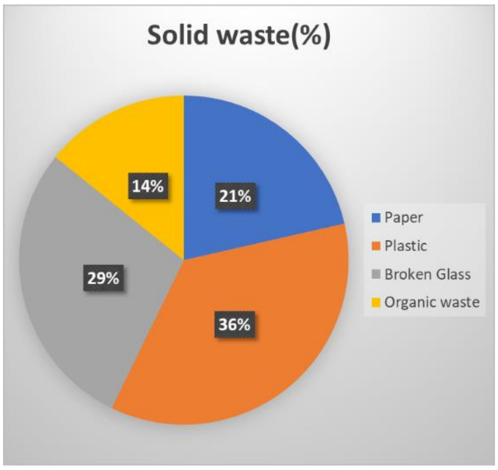
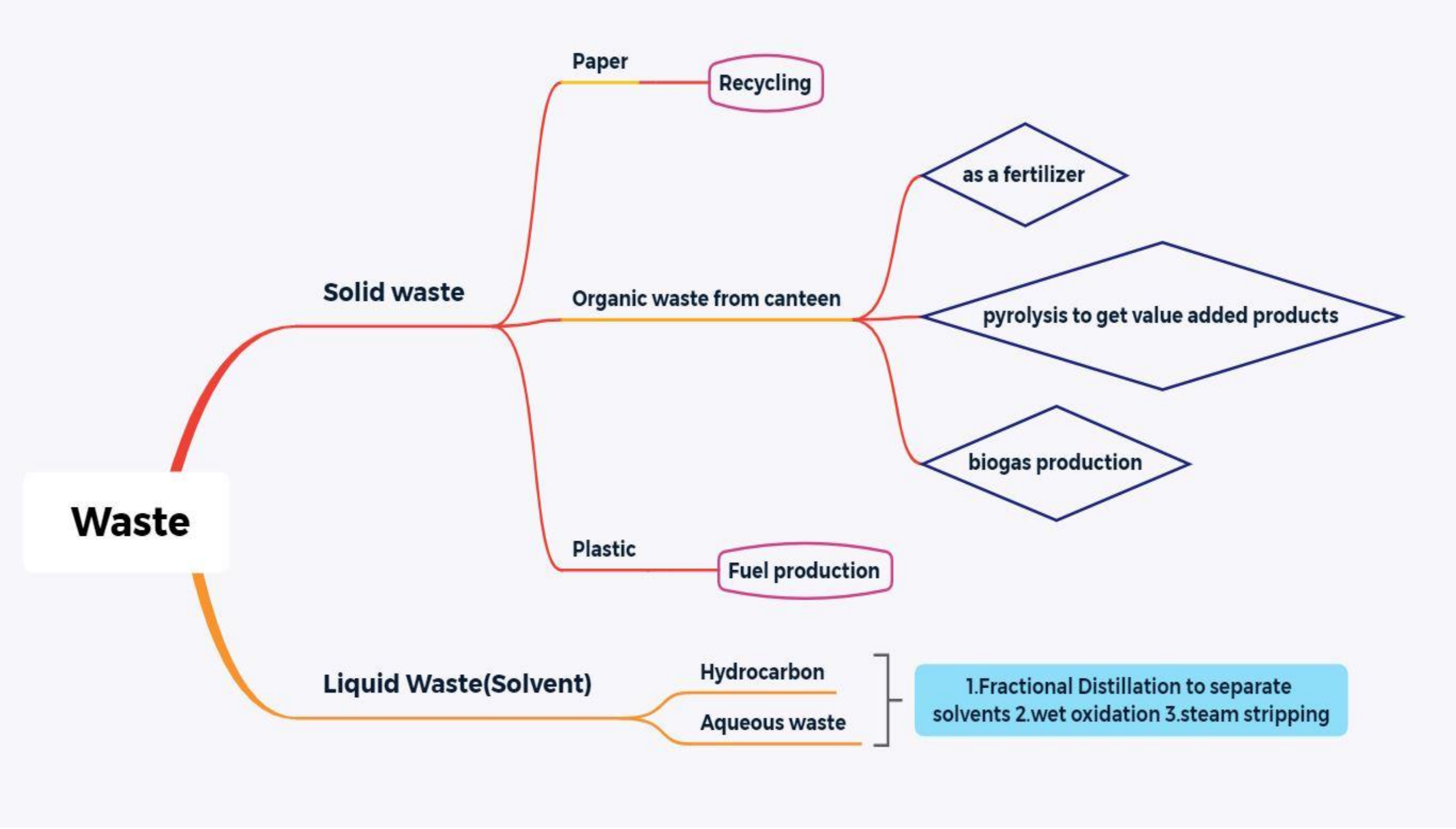


Fig3: Solid waste generated per day from the campus.

Division	Hydrocarbon waste(L)	Aqueous waste(L)
CMSD	1.5	2
Biofuels	2	2
Light stock processing	2	5
Materials resource efficiency	0.5	1.5
Separation Processes	0.5	0.8
Tribology and Combustion	0.75	1.25
Upstream and Wax Rheology	0.5	0.5
Distillate and Heavy Oil Processing	1	1.5
Automotive fuels and lubricants application	-	-
Analytical Sciences	0.5	1

Table1: Waste generated weekly from each division of the institute.

Waste Minimization And Its Treatment



(A) Solvent Waste

- **Minimization**

Every individual of the laboratory can contribute to waste minimization if they practice the following:

1. Before using any chemical, refer to Material Safety Data Sheet for its handling and storage.

2. Before disposing of any solvent, ask other lab members, if they can utilize that.

3. Excess storing of solvents, particularly extremely toxic and flammable solvents, just because it can be used in the future, should be avoided.

4. All the chemicals used and synthesized by a person working in the laboratory should be labeled and should be stored well once he completes his research work.

5. Recycle the solvent if possible, the recycled solvent can be used for rinsing the glassware, sterilizing biosafety cabinets.

How to dispose of a specific solvent:

Ether- Six-month-old ether stored in metal cans should be transferred to plastic coated or glass bottles, and also, it should be diluted with water before its disposal. However, if the metal can is expired, it should not be opened or used again, and it should be disposed of as per the methods given in its Safety Data Sheet.

Biological liquid waste- The biological liquid waste that may contain alive viruses must not be sent to the waste chemical storage area. These types of solvent should be disposed of as per the procedures that have been established by the Environmental Medical Services.

- **Treatment**

1. Fractional Distillation

Fractional distillation- the most widely used non-destructive process for solvent recovery. It is a process of separating a mixture of chemical compounds, having a difference of less than 25 °C in their boiling points. The mixture is boiled in the Fractionating column, and each component is caught in a container as a pure compound, that can be reused. Compounds having high boiling point condense at the bottom and substances with low boiling point condense at the top.

2.Steam Stripping

Stream stripping is a type of distillation where volatile organic matter is removed from the water. Thich involves the injection of steam into waste for the separation of more volatile components from dischargeable wastewater. The steam injection results in the production of turbulence and the volatilization of low boiling components from the waste. Substances, well dissolved in water, can also be removed by this method.

3.Wet Oxidation

Wet oxidation is a method for the treatment of waste stream, which is too toxic for the direct disposal and to dilute for the incineration process. There are four types of wet oxidation processes: wet air oxidation, catalyzed wet air oxidation, super-critical fluid oxidation, and high-temperature wet oxidation. This method involves the oxidation of the organics and inorganics, basically non-chlorinated toxic organics, present in the waste stream [1].

(B) Solid Waste

- **Minimization**

Several initiatives have been taken by the institute to curtail the solid waste. Still, some measures can be taken by individuals to minimize the waste, e.g., the use of duster instead of tissues for cleaning the workbench in the laboratory. Avoid excessive use of paper for weighing the chemicals.

- **Treatment**

The solid waste, including plastic, kitchen waste, animal litter, and agricultural residue, can be converted to energy and valuable chemicals through various thermochemical (pyrolysis, gasification, hydrothermal carbonization) and biological process (anaerobic digestion). The details of all the conversion processes are illustrated below.

1) Thermochemical Process

a) Pyrolysis

Pyrolysis is a method involving thermal decomposition in the absence or limited supply of oxygen at the temperature ranging from 400-700 °C. Depending upon the process parameters, i.e., vapor residence time and heating rate, pyrolysis is further categorized into slow (low heating rate; 5-7 °C/min. and high vapor residence time; >1h) and fast pyrolysis (high heating rate; more than 200 °C/min. and low vapor residence time; <10s) [2]. Pyrolysis results in the production of solid (biochar), liquid fuel (bio-oil), and a lower amount of non-condensable gases. However, fast pyrolysis majorly produces liquid fuel, bio-oil whereas, slow pyrolysis majorly produces solid fuel, biochar. The biochar produced can be used as an adsorbent, or it can be used as a catalyst/catalyst support [3][4]. The biochar also has a significant contribution to increasing soil fertility. Similarly, the bio-oil produced is abundant in aromatics and various valuable chemicals.

b) Gasification

Gasification is another thermochemical process for the conversion of waste to valuable fuels. The process involves the partial oxidation of the feedstock at a higher temperature (600-900 °C) in the presence of various gasifying agents like CO_2, air, oxygen, steam, or a mixture of these gases. Gasification majorly produces syngas/ producer gas, and a very low amount of solid product biochar, 5-10 % of the feedstock [5].

c) Hydrothermal Treatment

The thermochemical methods discussed earlier are efficient for the decomposition of dry waste. For the conversion of wet waste, these thermochemical methods are highly energy-intensive as prior drying is required, which only adds up to the process cost [6]. The conversion of wet waste to valuable fuel and chemicals can be achieved through hydrothermal processes. One of the biggest advantages of the hydrothermal process is that the moisture content of the wet waste acts as the solvent and catalyst. Depending upon the temperature and pressure condition, the hydrothermal processes are classified into (1) Hydrothermal pre-treatment (2) Hydrothermal carbonization (HTC) (3) Hydrothermal liquefaction (HTL) (4) Hydrothermal gasification (HTG). HTL and HTC majorly produce liquid (bio-oil) and solid product (biochar) whereas, HTG majorly produces a gaseous product.

2) Biological Processes

The conversion of waste to wealth can be achieved through the utilization of micro-organism, in addition to thermochemical processes. Bio-chemical conversions are achieved mainly through two processes, i.e., fermentation and anaerobic digestion.

a) Aerobic Composting

Aerobic digestion is a biochemical process involving the conversion of waste in the presence of an oxygen-rich environment by microbes. In this process, waste is consumed by bacteria, which convert it into carbon dioxide, water, and manure. Manure has a high nutrient value, and thus, it is used as the fertilizer.

b) Anaerobic Digestion

Anaerobic digestion involves the conversion of the organic waste directly to biogas and digestate. The process involves the conversion of high moisture waste in an anaerobic environment by bacteria [7]. This bio-chemical conversion process is carried out by several bacteria like methanogens, facultative, acidogenic, and actogenic bacteria. Facultative bacteria carry out the hydrolysis of waste, actogenic bacteria are involved in the metabolization of intermediary metabolites. Methanogens are involved in the removal of hydrogen for the successful operation of anaerobic digestion. The biogas produced from anaerobic digestion comprises 50-60 % methane so, it can be used as fuel, whereas digestate produced can be converted to liquor and fibrous material.

Conclusions

The total solvent waste generated per week from the campus is about 25L, in which hydrocarbon waste is 9L, and aqueous waste is 16L approximately. And paper waste, plastic waste, broken glass waste, organic waste generated per day from campus is 21%, 36%, 29%, and 36% respectively of the total solid waste.

Recommendations

- A person working in the laboratory should pay more attention to the segregation and disposal of the solvent and solid waste generated from the laboratory.
- One should always think of reducing both the volume and hazards of laboratory waste to have environmental benefits as a result.
- Methods, by which materials, once thought of as a waste can be reused to conserve the resources should be formulated.

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