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# Performance evaluation of common hazardous waste incinerator for ship scraping waste

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## Abstract

**Background/Objectives:** Hazardous waste incineration is one of the proven technologies for complete destruction of hazardous wastes. These facilities, when designed and operated properly are capable of destroying the hazardous organic components in waste along with PCBs. If these facilities are designed and not operated efficiently, could act as a significant source of such hazardous substances to the environment. Common hazardous waste incineration facilities are designed based on assumptions regarding the availability of quantity and quality (characteristics) of waste. The actual operating waste recipe and performance may differ considerably than the designed. So performance evaluation on actual operating data becomes necessary to check the operational efficiencies and levels of pollutants emitted into the environment. This implies the need for system analysis and solutions by independent assessment procedure. This study focused on the baseline performance evaluation of common hazardous waste incineration facility based on actual plant operating data located in India for Ship Scraping Waste. **Methods:** Inspection, monitoring and analysis were carried out to characterize all feed and effluent stream. Heat and mass balance were developed and actual operating efficiencies were evaluated. **Findings:** The results show that temperature and detention time achieved in the secondary chamber were 1150°C and 2.6 sec respectively, which are above the statutory requirement of 1100 + 50 and 2 seconds. The LOI in Ash was 2.5 %. The flue gas composition indicates 6.12 % Oxygen and 10.20% Carbon Dioxide levels, a good combustion efficiency and ensures sufficient amount of air needed for complete combustion. Flue gas analysis indicates PM, $SO_2$, NOx, HCl levels were well below permissible limits and absence of Dioxins and Furans. Destruction efficiency achieved for PM and HCl are 99.53% and 95.62 % respectively to meet the statutory norms. **Novelty :** Thus, from the study and analysis of results, it is inferred that the common HW Incinerator in the study is operated systematically and efficiently on actual plant operating conditions and meeting all the requirements of Central Pollution control board of India. The research findings will act as benchmarking for optimal plant operational practices for quality of incineration for ship scraping waste.

**Keywords:** Incinerator; Hazardous Waste; Mass and Heat Balance; Destruction Removal Efficiencies

# 1 Introduction

Thermal oxidation through incinerator is one of the proven technologies for destruction of hazardous waste in all the forms i.e. solid / semi-solid / liquid and gaseous, based on the feeding system, to render them innocuous in the form of non-toxic and non-hazardous residues.

From an engineering viewpoint, the basic objective of the incineration process is to efficiently; combust the material to an ash that is acceptable for land disposal while assuring that the exhaust gas products can likewise be dispersed without harm to the environment. Secondary objectives are to carry out the process with minimum energy usage and minimum system maintenance costs [1]. Under normal conditions the incineration can dispose more than 99% of organic Waste [2].

Incinerators are considered as the major technology for a waste management scheme capable of dealing with high Calorific Value (CV) waste. Hazardous waste incinerators have the potential to destroy hazardous pollutants such as Poly Chlorinated Bebzens (PCBs), Poly Chlorinated Dibenzo Dioxins (PCDDs) or Poly Chlorinated Dibenzo Furans (PCDFs). However, unless high technology emission control equipment is used and properly managed, hazardous waste incinerators could act as a significant source of such substances to the environment [3]. Incineration is thus, far the best-demonstrated available technology for waste destruction. Unfortunately, it is not a perfect technology. It may emit unwanted Products of Incomplete Combustion (PIC) or trace metals. The PICs could conceivably be equally or more hazardous than the original compounds in the waste fed to the unit [1].

Incineration process involves conversion of elemental constituents in organic waste to toxic gases and non-toxic gases [4]. Control of combustion conditions alters the composition of the various secondary substances resulting from the incineration process. The primary toxic pollutant gases from incinerator are NOx, $SO_x$, CO, HCl, dioxins and furans, their composition is influenced by combustion conditions [5]. Conditions such as oxygen concentration, residence time, temperature and mixing turbulence have big influence in formation of these pollutants [6]. High combustion temperature combined with high oxygen concentration, residence time, and mixing turbulence reduces the quantity of CO produced, due to the possibility of increase in the formation of NOx [7]. The formation of furans and dioxins is favored by low oxygen concentration, high temperature and high residence time [8]. The oxygen, carbon monoxide and carbon dioxide concentration in the effluent gas are useful indicators of the combustion performances [8].

Common Hazardous Waste Incineration Facilities are designed based on assumptions regarding quantity and quality (characteristics) of waste. The actual operating conditions may differ considerably in terms of availability and type of waste. So performance evaluation on actual operating data becomes necessary to check the operational performances, efficiencies and levels of pollutants emitted into the environment. This implies the need for system analysis and solutions by independent assessment procedure. This will need considerations of many sound engineering practices and operational factors in the waste incineration operations. The operation of the hazardous waste incinerator must meet the efficiencies and performance as regulated by the Govt. of India, such as Destruction Removal Efficiency (DRE's) of Principle Organic Hazardous Constituent (POHC), Combustion efficiencies, gas residence time, Loss on Ignition (LOI) in ash, concentration of emitted particulates, and heavy metals and HCl and other gaseous pollutants.

This paper presents the procedures and results of a case study of Test Burn (TB) conducted on Common Hazardous waste Incinerator of Ship Scraping Waste in India. The statistical data reveals that about approximately 171 ships per year, mainly cargo vessels, oil tankers, passenger liners, and war ships having about 26-27 million metric tons light dead tonnage(LDT) are scrapped every year [9]. This industry generates a huge quantity of solid waste in the form of broken wood, rubber, insulation materials, paper, metals, glass and ceramics, plastics, leather, textiles, food waste, chemicals, paints, thermocol, sponge, ash, oil mixed sponges, miscellaneous combustible and non-combustible. The combustible solid waste quantity was around 83% of the total solid waste available at the yard [10].

An energy and mass balance procedure along with actual inspection, monitoring and analysis is to be used to carry out performance test for an incinerator and identify deviations from the statutory guidelines. Thereby, identifying sensitive parameters and to evaluate whether the design specification and operating parameters are consistent with energy and mass balances and complying regulatory requirements. This will give an idea about the deviations from actual designs, statutory requirements and measures & retrofications needed to be taken to meet the regulatory requirements.

The energy and mass balance procedure is based on sound engineering principles. It has been demonstrated to be useful in evaluating the feasibility of incinerator designs and concepts and in evaluating the consistency of trial burn measurements. An Estimation of mass and energy balance of an incinerator is an important consideration towards the design and operation of the incineration process [1]. The mass and energy balance information enables the designer to calculate the amount of auxiliary fuel needed, amount of air needed for complete combustion, temperature profile across incineration system, the size and capacity of the incineration system, the flue gas composition at various stages of incineration viz. PM, $SO_2$, $NO_x$, HCl, HF, Dioxins and Furans and control efficiencies required to control them in flue gases to meet the statutory norms. Conditions such as oxygen concentration, residence time, temperature and mixing turbulence are the governing factors for performance of incinerator.

The results of the heat and mass balance calculations of fixed bed incinerator have been previously reported [8]. The most significant findings were (a) the excess air ratio to the incinerator during incineration must be optimized to minimize emissions and increase the performance of incinerator (b) to acquire more energy from incinerator, the municipal solid waste must be dried to reduce moisture contents that improve their physical structure.

# 2 Methodology

• A desk base study was carried out on available literature, site information along with Incineration process details.

• Site visit and study of the incineration system provided at the site with respect to capacity, type of waste charged, waste characteristics i.e. Approximate and Proximate Analysis

• Carry out Mass balance of each component of the Incineration system w.r.t. the mass input to the mass output and the mass of remaining or generated from the system. This shall be performed based on combustion reactions of Waste and Fuel with the Air.

• Perform energy balance of the system in accordance with the thermodynamics laws. The law of conservation of energy, which states that the total energy of an isolated system is constant. The energy cannot be created but can be transform from one form to another.

• Stack monitoring and analysis, bleed water monitoring and analysis, ash sampling and analysis, monitoring temperature profile across incineration system shall be carried out using Indian Standards (IS) and Central Pollution Control Board (CPCB) Published Methods.

• Inspection of all the components of Incineration system with respect to temperature, refractories, flow rate of scrubbing media, pressure etc.

• Performance of Incineration system shall be evaluated as per the "Protocol for Performance Evaluation and monitoring of the Common Hazardous Waste Treatment Storage and Disposal Facilities including Common Hazardous Waste Incinerator" published by Central Pollution Control Board May 24, 2010.

## 3 Case Study

The incineration facility is handling solid, semi-solid and hazardous waste with a calorific value ranging from 4000-6000 Kcal/kg or more and has incineration capacity of 5 tons/day. The main hazardous waste currently incinerated is oil sludge, cloth/sand containing oil, paint/coating material, rubber gasket, polyurethane foam, polystyrene foam, waste plastic etc.

The recipe for incineration considered is presented at Table 1. The design details of the Incineration system is presented at Table 2 and flow train of the same is presented at Figure 1

**Table 1.** Recipe for Incinerator

| Recipe for Incineration Considered | Composition (%) | GCV (kcal/kg) | C (%) | **S (%)** | H (%) | O (%) | Cl (%) | **N (%)** | Moisture (%) | Ash (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Plastic & Rubber | 15 | 5977 | 70.3 | 1.5 | 10.7 | 12.3 | – | 2.5 | 0.33 | 2.3 |
| Oily Sludge/Sand | 15 | 5399 | 67.8 | 1.1 | 1.2 | 10.2 | 0.8 | 0.1 | 8.00 | 10.8 |
| PUFF &Thermocol | 40 | 5137 | 58.7 | 0.7 | 3.1 | 16.1 | 1.9 | 1.0 | 6.24 | 12.3 |
| Miscellaneous | 30 | 4000 | 55.1 | 0.2 | 2.8 | 15.0 | 0.5 | 4.1 | 11.80 | 10.5 |
| Composition of Recipe | | 4961.1 | 60.73 | 0.73 | 3.87 | 14.32 | 1.03 | 2.02 | 7.29 | 10.04 |

**Table 2.** Design details of common hazardous waste incineration system

| **Primary combustion chamber** | |
|---|---|
| Temperature | Min.850°C |
| Auxiliary fuel | 90 kg/h LDO |
| No. of burner | 1 No. |
| Burner | 0.8 MKcal/h @ 1.35 $m^3$/KW with 20 % excess air |
| Waste Blower | 1 no. of 4800 $m^3$/h |
| Shell Volume: | 11.40 $m^3$ |
| **Secondary combustion chamber** | |
| Temperature | Min.1100+ 50°C |
| Auxiliary fuel | 24 kg/h LDO |
| No. of burner | 1 No. |
| Burner | 0.55 MKcal/h @ 1.35 m3/KW with 20% excess air |
| Waste blower | 1 No. of 4800 $m^3$/h along with PC |
| Shell Volume: | 11.40 $m^3$ |
| **Ventury scrubber** | |
| Inside volume | 8.25 $m^3$ |
| Flue gas inside temperature | 1100± 50 ° C |
| Flue gas outside temperature | 80 - 90°C |
| Circulating water flow | 10-12 $m^3$/hr. |
| **Packed bed scrubber** | |
| Inlet temperature | 80-90°C |
| Outlet temperature | 60-70° C |
| Water circulating flow | 3 - 4.5 $m^3$/hr. |
| **Monitoring and online Display requirement** | In order to monitor parameters like $O_2$, CO, $SO_2$, NOx, HCl, HF, Particulate Matter, HC & $Cl_2$ the "Online Flue gas analyzer" is installed, the result of the same are directly displayed on the computer screens. Some trace contaminant such as Dioxin (PCDD) and Furan (PCDF) can be measured manually. |
| **Ash/slag management** | Disposed of to HW TSDF |
| **Quench / scrubber liquid Management** | The wastewater from the incineration plant is mainly generated from the scrubber. Ninety percent of the scrubber liquor is recycled back and remaining is directly taken to ETP. |

The incinerator is a dual chamber-static type incinerator. The waste is incinerated in the static primary chamber at about 850° C. Hazardous Waste is charged into the primary chamber from one end and the ash is removed from the other end of the primary chamber. The flue gases from the primary chamber is combusted completely in the secondary chamber, which is further heated up to more than 1100° C by firing additional auxiliary fuel. The secondary chamber

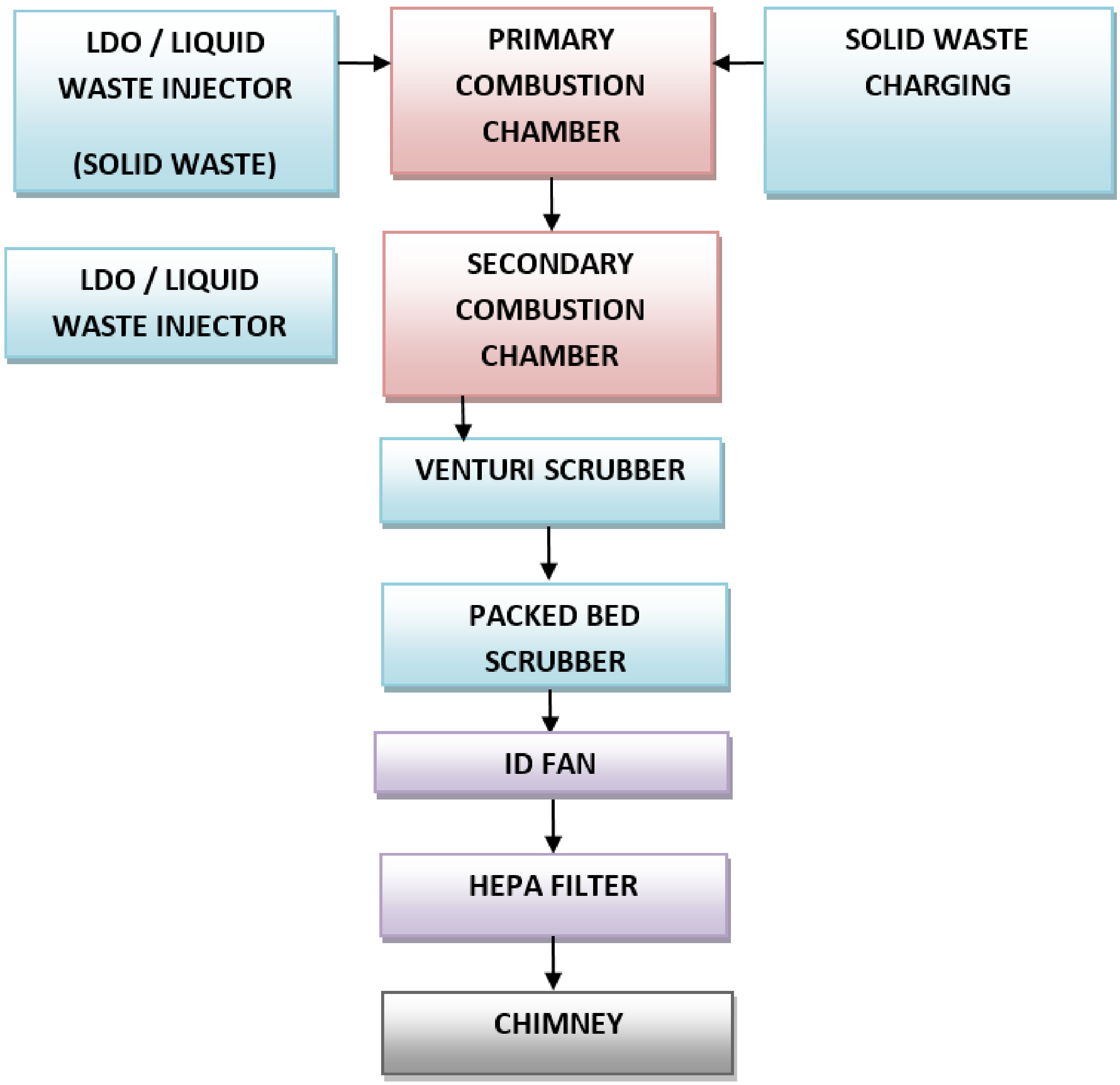


**Fig 1.** Schematic block diagram of incineration system

and the ducting is designed in such a way as to have minimum of 2 seconds residence time in order to ensure complete combustion. Exhaust gases are released to the atmosphere after treated with wet scrubbers. Scrubber water is treated in the wastewater treatment facility and ash is reclaimed in the landfill site.

## 3.1 Mass and heat balance of incineration system

A mass and heat balance is an important part of designing and/or evaluating performance of Incineration system. The procedure entails mathematical evaluation of the input and output conditions of the Incinerator viz. excess air levels, temperatures, residence time and volumetric flow rates, based on design specifications and operating conditions. The results of the same are presented at Table 3. The results of mass balance indicates that 220 kg/h of incinerable hazardous ship scrap waste at fixed recipe needs 3565 kg/h combustion air and 24 kg/h of LDO as a fuel in the secondary combustion chamber to achieve temperature of 1150$^{\circ}$C. The mass flow rate in the secondary combustion chamber works out to be 4.37 $m^3$/sec at 1150$^{\circ}$ C temperature. The shell volume provided in the secondary combustion chamber is 11.40 $m^3$. So the detention time achieved in the secondary chamber works out to be 2.6 sec.

**Table 3.** Results of mass balance

| Mass Input | | | | Mass Output | |
|---|---|---|---|---|---|
| **Mass of HW (220 kg/h)** | → | **Component of Incineration System** | → | **Mass Flow Rate to Chimney(3984 kg/h)** | |
| **Mass of Fuel (24 kg/h)** | → | | → | **Mass Flow Rate to ETP (15933 kg/h)** | |
| **Mass of Air (3565 kg/h)** | → | | → | **Mass Flow Rate to Bottom Ash (3 kg/h)** | |
| **Mass of Water (16115 kg/h)** | → | | | **Flue Gas Composition(kg/h)** | |
| | | | **Composition** | **kg/h** | **(%)** |
| | | | Carbon Dioxide | 633.00 | 15.89 |
| | | | Nitrogen | 2662.00 | 66.81 |
| | | | Sulphur Dioxide | 0.32 | 0.01 |
| | | | Oxygen | 277.00 | 6.95 |
| | | | HCl | 0.14 | 0.00 |
| | | | $H_2O$ | 412.00 | 10.34 |
| | | | PM | 0.14 | 0.004 |
| | | | **Total** | **3984.00** | **100** |
| | | | **Scrubber Effluent to ETP** | | |
| | | | The scrubber liquor generated from Ventury Scrubber, to cool the combustion gases from secondary chamber from 1150°C to 100°C is about 11719 kg/h and from pack tower scrubber is 3984kg/h. | | |

The results of heat balance indicates that combustion of 220 kg/h of incinerable HW of ship scraping waste at fixed recipe of 4000 kcal/kg generates 3620153 KJ/h heat and it further requires fuel in the secondary combustion chamber i.e. LDO @ 24 kg/h with heat capacity of 962301 KJ/h, to achieve temperature of 1150°C. The overall energy balance across the Incineration System is presented at Table 4. This indicates that approximately 4582454 KJ/h heat capacity is required to incinerate 220 kg/h of incinerable hazardous ship scraping waste at fixed recipe of 4000 kcal/kg. There works out to be 20830 KJ energy is required to incinerate a kg of waste.

**Table 4.** Results of heat balance

| Heat Input | | | | Heat Output |
|---|---|---|---|---|
| Heat with HW (3620153 kJ/h)) | → | **Component of Incineration System** | → | Radiation losses @ 5% (226832 kJ/h) |
| Heat with Fuel (962301 kJ/h) | → | | → | Heat loss to Ash (2264 kJ/h) |
| | | | → | Heat to Dry Combustion Products (260940 kJ/h) |
| | | | → | Heat to Moisture (831366 kJ/h) |
| | | | → | Energy to Heat the Chamber (3261015 kJ/h) |

## 3.2 Inspection, monitoring and analysis

### *3.2.1 **Flue gas stack monitoring and a nalysis***

The flue gas stack monitoring and analysis was carried out and results of the same are presented at Table 5. The Indicates that, the concentration of PM, $SO_2$, $NO_X$, HCl are well within the permissible limit of CPCB. The concentration of CO, $CO_2$ and $O_2$ indicates good combustion efficiency in the primary and secondary combustion chamber.

**Table 5.** Flue gas stack analysis results

| Sr. No. | Parameter | Pollutant Concentration |
|---|---|---|
| 1 | $CO_2$, (%) | 11.26 |
| 2 | $O_2$, (%) | 06.10 |
| 3 | CO, (mg/$Nm^3$) | 49.25 |
| 4 | SPM, (mg/$Nm^3$) | 28.00 |
| 5 | $SO_2$, (mg/$Nm^3$) | 112.30 |
| 6 | NOx, (mg/$Nm^3$) | 54.11 |
| 7 | HCl | 31.25 |
| 8 | Dioxin | BDL |
| 9 | Furan | BDL |

Note : #Standard $O_2$ correction @11%

### *3.2.2* ***Bleed water sampling and analysis***

Bleed water sampling and analysis were carried out from ventury and pack tower scrubber tank. The analysis results are presented at Table 6.The bleed water analysis results indicate high level of Color, Chemical Oxygen Demand (COD), Ammonical Nitrogen in the scrubber water. This is complicated and needs further investigations.

**Table 6.** Bleed water analysis results

| Parameters | Ventury Bleed Water | Pack Tower Bleed Water |
|---|---|---|
| pH @ 25°C | 7.63 | 9.18 |
| Colour | 700 | 1090 |
| Total Dissolved Solids (TDS) | 5608 | 17424 |
| Total Suspended Solids (TSS) | 582 | 234 |
| Chemical Oxygen Demand (COD) | 960 | 1607 |
| Chloride | 3650 | 11350 |
| Sulphate | 502 | 1532 |
| Oil & Grease | 20 | 26 |
| Ammonical Nitrogen | 94 | 172 |

Note: All parameters except pH and color are expressed in mg/L. Color is expressed in pt.co scale.

### *3.2.3* ***Ash sampling and analysis***

Bottom ash sampling and analysis was carried out to measure CV, LOI and metal contents. The results of the same are presented below at Table 7. The ash analysis indicates less than 5% of LOI in the ash sample as per the guidelines of CPCB.

**Table 7.** Bottom ash analysis results

| Parameters | Bottom Ash |
|---|---|
| Calorific Value(kcal/kg) | 167 |
| Loss on Ignition (%) | 2.5 |
| Arsenic (mg/kg) | <0.01 |
| Cadmium(mg/kg) | 1.06 |
| Mercury(mg/kg) | <0.01 |
| Copper(mg/kg) | 762.64 |
| Lead(mg/kg) | 479.38 |
| Nickle(mg/kg) | 182.75 |
| Total Chromium(mg/kg) | 96.48 |
| Zinc(mg/kg) | 3927.52 |

### 3.3 Performance evaluation of incinerator based on CPCB guide lines

Performance of Incineration system was evaluated based on performance criteria, monitoring requirements, emission standards and other requirements as per the guidelines of CPCB [11]. The results are presented at Table 8. From the results it is inferred that the incineration system is designed and operated as per the requirements of guidelines of Central Pollution Control Board to achieve combustion and destruction efficiencies of pollutants on actual plant operating conditions. Some of the critical findings are:

- The incinerator is properly designed with adequate pollution control measures as well as handling and storage facility as required by statutory authorities. The HW is fed manually to the incinerator. Looking to the nature of waste, there should be mechanical feeding for the safety of workers.
- The unit has provided online continuous monitoring system at Incinerator. Online parameters displayed are SPM, $SO_2$, $NO_2$, NO, CO, HC, $O_2$, $CO_2$ etc.
- The results of mass balance indicates that 220 kg/h of incinerable hazardous ship scrap waste at fixed recipe needs 3565 kg/h combustion air and 24 kg/h of LDO as a fuel, to achieve temperature of 1150°C in the secondary combustion chamber and detention time of 2.6 sec. This indicates that approximately 4582454 KJ/h heat capacity is required to incinerate 220 kg/h of incinerable hazardous ship scraping waste at fixed recipe of 4000 kcal/kg. There works out to be 20830 KJ energy is required to incinerate a kg of waste.
- The results show that temperature and detention time achieved in the secondary chamber were 1150°C and 2.6 sec respectively, which are above the statutory requirement of 1100 + 50 and 2 seconds.
- The ash analysis indicates less than 5% of LOI in the ash sample as per the guidelines of CPCB.
- The flue gas composition indicates 6.12% Oxygen and 10.20% Carbon Dioxide levels, a good combustion efficiency and ensures sufficient amount of air needed for complete combustion.
- Flue gas analysis indicates PM, $SO_2$, NOx, HCl levels were well below permissible limits and absence of Dioxins and Furans.
- Destruction efficiency of PM and HCl are achieved in the range of 99.53% and 95.62% respectively to meet the statutory norms.
- To cool the combustion gases from secondary chamber from 1150°C to 100°C requires about 11915 kg/h water in the Ventury Scrubber. The scrubber water required for pack tower is 4200 kg/h.
- The analysis result of scrubber water from ventury and pack tower indicates high level of COD and Ammonical Nitrogen in scrubbed water. This indicates condensation and is very complicated. Further, considerable amount of research needs to be done in order to ensure that they can be adequately controlled.

**Table 8. Performance Evaluation of Incinerator Based on CPCB Guide Lines**

| Particulars | As per Mass & Heat Balance | Measured Value | Criteria as per CPCB Guidelines | Remark |
|---|---|---|---|---|
| **Primary Combustion Chamber** | | | | |
| Temperature (°C) | 850 | 890 | 800± 50 | **Adequate** |
| **Secondary Combustion Chamber** | | | | |
| Temperature (°C) | 1150 | 1141 | 1100 ± 50 | **Adequate** |
| Mass Flow Rate ($m^3$/sec) | 4.37 | – | – | – |
| Detention Time (sec) | 2.56 Based Mass Balance and actual flow measurement during stack monitoring. | | 2 | **Adequate** |
| **Stack Gas Parameters** | | | | |
| Temperature (°C) | 60 | 60 | – | – |
| Gas Flow Rate ($m^3$/hr) | 4035 | 3956.4 | – | – |
| PM ( mg/$Nm^3$) | 17 | 28.0 | 50 | **Within Limit** |
| $SO_2$( mg/$Nm^3$) | 104 | 112.3 | 200 | |
| NOx( mg/$Nm^3$) | – | 54.11 | 400 | |
| HCl ( mg/$Nm^3$) | 42.95 | 31.25 | 50 | |
| CO( mg/$Nm^3$) | – | 49.25 | 100 | |
| Dioxin | – | BDL | 0.1 ng TEQ/Nm3 | |
| Furan | – | BDL | | |
| $CO_2$ (%) | 10.20 | 11.26 | – | **As per the requirment** |
| $O_2$(%) | 6.12 | 6.1 | – | |
| TOC Content in the bottom Ash | – | 2.5 % | less than 3 % or their loss on ignition is less than 5 % of the dry weight | **Within Limit** |

**Destruction Efficiency**

| Parameter | Inlet Load-Based on Mass Balance (kg/h) | Outlet Load-Based on Stack Gas Monitoring (kg/h) | Destruction Efficiency (%) |
|---|---|---|---|
| **SPM** | **18.83** | **0.088** | **99.53 %** |
| **HCl** | **2.26** | **0.099** | **95.62%** |

## 4 Conclusion

Performance evaluation of Hazardous Waste Incinerator for incinerating hazardous waste from ship scrapping was carried out with respect to its adequacy based on guidelines of CPCB, Energy and Mass Balance, Monitoring and Analysis and Inspection. It is concluded that the Common Hazardous Waste Incineration facility for ship scraping waste in the study is designed and operated as per the guidelines of Central Pollution control board to achieve combustion and destruction efficiencies of pollutants on actual plant operating conditions.

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| **Abbreviations** | |
|---|---|
| CPCB | Central Pollution Control Board |
| CV | Calorific Value |
| COD | Chemical Oxygen Demand |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| DRE | Destruction Removal Efficiency |
| ETP | Effluent Treatment Plant |
| GCV | Gross Calorific Value |
| HW | Hazardous Waste |
| HCl | Hydrogen Chloride |
| IS | Indian Standards |
| LOI | Loss on Ignition |
| LDO | Light Diesel Oil |
| LDT | Light Dead Tonnage |
| MOC | Material of Construction |
| NOx | Oxides of Nitrogen |
| $O_2$ | Oxygen |
| PT | Pack Tower |
| PC | Primary Chamber |
| PCDDs | Poly Chlorinated Dibenzo Dioxins |
| PCDFs | Poly Chlorinated Dibenzo Furans |
| PCBs | Poly Chlorinated Benzenes |
| PIC | Product of Incomplete Combustion |
| PM | Particulate Matter |
| TSDF | Treated Solid Waste Disposal Facility |
| VS | Ventury Scrubber |
| SC | Secondary Chamber |
| $SO_2$ | Sulphur Dioxide |

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