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EXTRACTION OF MERCURY FROM COMPACT FLUORESCENT LAMP USING INCINERATION PROCESS

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ABSTRACT

The aim of our paper is to extract mercury from the defused CFL bulbs. CFL contains a small amount of mercury. When these bulbs are disposed after their useful life to the surroundings, the mercury is released to the environment and cause pollution.
This paper deals with the extraction of mercury from the CFL bulbs using incineration process. We have designed and developed a equipment to process the defused CFL bulbs. The CFL bulbs are crushed and heated to 380℃ along with water. The mercury present in CFL is obtained and collected in mercury collecting tank, which contains aqua regia solution. The mercury obtained will be in the form of mercuric chloride.
The mercuric chloride solution can be treated chemically to extract pure form of mercury.
Keywords; *Mercury, Extraction, CFL, Poisonous.*

1.INTRODUCTION

A Compact Fluorescent Lamp (CFL) is a fluorescent lamp designed to replace an incandescent lamp; some type of CFLs fit into light fixtures formerly used for incandescent lamps. The lamps use a tube which is curved or folded to fit into the space of an incandescent bulb, and the compact electronic ballast in the base of the lamp. CFLs, like all fluorescent lamps, contain mercury in the form of vapour inside the glass tubing. Most CFLs contain 3–5 mg of mercury per bulb, whereas the bulbs labelled "eco-friendly" contains as little as 1 mg. As mercury is poisonous, these small amounts are also concern for landfills and waste incinerators where the mercury from lamps may be released contributing to air and water pollution.

Health and environmental concerns about mercury have prompted many jurisdictions to make arrangements for the proper disposal or recycle of mercury, rather than being included in the general waste stream sent to landfills. Safe disposal requires storing of the bulbs unbroken until they can be processed. The project deals with the treatment of CFL wastes in order to extract mercury by a suitable process known as incineration. Incineration is a waste treatment process that involves the combustion of organic substances from the waste materials. Incineration and other high-temperature waste treatment systems are described as "thermal treatment".

1.1 Mercury Content in CFL

Mercury is an essential ingredient for most energy efficient lighting products, including CFLs. It is the mercury that excites the phosphors in a CFL, causing them to glow and give light. When electric current passes through mercury vapour, the mercury emits UV energy. When this UV energy passes through the phosphor coating, it produces light very efficiently. Because mercury is consumed during lamp operation, a certain amount is necessary to produce light and achieve long lamp life. The amount of mercury in the most popular and most widely used CFLs, ranging between 6-3.5mg.

1.2 Toxicity of Mercury in CFL

Mercury is a metallic element that exists in one of three forms: metallic or elemental mercury (Hg0), inorganic mercury (Hg+ and Hg2+salts) and organic mercury (e.g. methyl mercury, phenyl mercury). Elemental

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mercury is a silvery liquid that can vaporize at room temperature due to its low vapour pressure (HPA, 2006) and this is the form of mercury used in CFLs. The toxicology of inorganic mercury compounds and elemental mercury are briefly summarized.

Organic mercury compounds are not known to be present in fluorescent lamps. When a CFL is broken, people may be exposed to elemental mercury (including vapour) and inorganic mercury compounds. The key exposure pathway to humans from broken CFLs is inhalation; with 80–97% of the inhaled elemental mercury being absorbed into the body through the lungs. In comparison to this, only 2.6% is absorbed from dermal exposure. Once into the body; because elemental mercury is liquid soluble; it can cross biological membranes including the blood-brain barrier and the placenta. Mercury, if circulated throughout the body can accumulate in the brain and the kidneys causing changes in neurological and renal function

2. LITERATURE SURVEY

Cristian Tunsu*et.al* [1],In this report the authors concluded that, Increase usage of fluorescent lamps around the world, environmental concerns and the rising need for raw materials make the development of an effective recycling process a high priority. Mercury is a component of all fluorescent lamps and because of this spent fluorescent lamps are classified as hazardous waste. According to environmental regulations, such waste cannot be landfilled without lowering mercury content below a certain limit. Special treatment is thus necessary. Moreover, fluorescent lamps contain REMs, elements with important applications in numerous fields.
P S Harikumar *et.al* [2],In this report the authors concluded that A study had been done on the determination of the amount of mercury present in an average CFL and the amount of mercury leached from the CFLs into the soil from where they are dumped. The extraction of the mercury from CFLs and the polluted soil was done by acid digestion. The electrochemical analytical method called Anodic stripping voltammetry (ASV) which is based on the potential dependent current measurement was used for the determination of mercury in the CFLs and the polluted soil. The determinations were done by standard addition technique in the exploratory mode. The results showed that the CFL contains 0.1175 mg/g of mercury. The soil from the spent CFLs dumped site reported a mercury concentration of 0.0149 mg/g.
Ligy Philip *et.al* [3],In this report the authors concluded thatthe feasibility of using bio trickling filters for the removal of mercury vapor from simulated flue gases was evaluated. The experiments were carried out in laboratory-scale bio trickling filters with various mixed cultures naturally attached on a polyurethane foam packing. Sulfur oxidizing bacteria, toluene degraders and denitrifies were used and compared for their ability to remove Hg0 vapor. In particular, the bio trickling filters with sulfur oxidizing bacteria were able to remove 100% of mercury vapor, with an inlet concentration of 300– 650 lg m_3, at a gas contact time as low as six seconds.
Yadong Li *et.al* [4],This article presents an original study on the releases of mercury (Hg) from broken compact fluorescent lamps (CFLs) under various environmental conditions. Leaching of Hg in liquids was examined using the U.S. Environmental Protection Agency's standard procedures Toxicity Characteristic Leaching Procedure (TCLP) and Synthetic Precipitation Leaching Procedure. Emission of Hg in vapor phase from broken CFLs was detected using an emission monitoring system. CFLs of eight different brands and four different wattages were tested.
L. Kesavarao *et.al* [5], In this report CFL Fluorescent lamps are electrical discharge lamps that contain low-pressure mercury vapour and an inert gas, usually argon. The inside of the glass is coated with a fluorescent phosphor powder. The mercury vapour is excited by an electrical current between two electrodes and emits ultraviolet (UV) light. The UV light causes the phosphor coating to fluoresce and emit visible light. Mercury (elemental or mercuric oxide) can be added to lamps in a variety of forms including liquid, solid, or pellet amalgam dosing technology.

3. WORKING PRINCIPLE

The experimental setup consists of a container in which the CFLs are broken up and treated with high temperatures. It also consists of an extraction vessel in which the mercury is extracted finally. A handle and a ram setup is provided in the container which is used to break the CFLs. The container is partially filled up with water through a water inlet. A heater is provided in order to heat up the water. The CFLs are manually fed in the container and the ram is actuated with the help of the handle such that the CFLs are broken up into pieces. These pieces are soaked in the water that is filled previously. When the CFL is broken up it releases some gas which is transferred to the extraction container with the help of the blower setup which is shown in the figure. Now the

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heater is turned on and the temperature is maintained nearly 400°C-600°C. When heated, the CFL releases more gas which is also transferred to the extraction container.

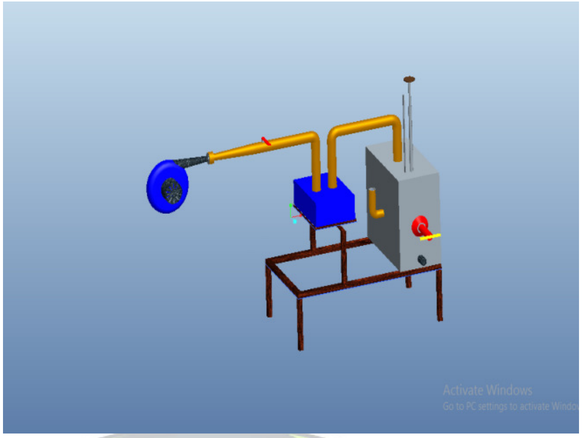

Fig 3.1 3D Diagram

The extraction container contains of a mixture hydrochloric acid and nitric acid (HCl + HNO_3). The gases released from the CFL react with this mixture and releases mercury.The mercury floats upon the acidic mixture which is extracted manually.The water in the container is drained up by opening the drain valve.This water is replaced with the fresh water and the process is repeated. The gas that is emitted from the CFL wastes is the Mercurous Nitrate ($HgNO_3$). This reacts with the aqua regia (HCl + HNO_3). The reaction between them is shown below.

$$HgNO_3 + 2HCL \longrightarrow HgCl_2 + H_2O + NO_2$$

No reactions are visible with the naked eye but the mercury is present in the form of $HgCl_2$.

4. COMPONENTS AND DISCRIPTION

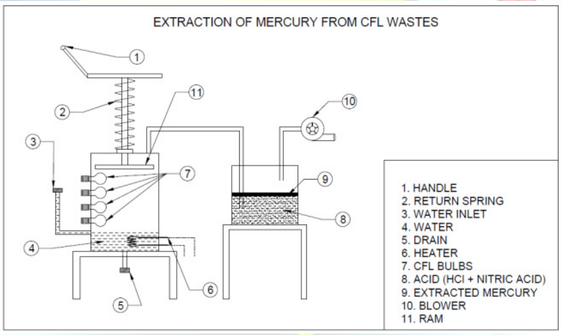

Fig 4.1 2D Diagram

4.1 Handle

This is simply a rod used to break the CFL bulbs in order to carry out the mercury extraction process. The handle is attached with the return spring rod and hence when pressure is applied on the handle, the rod along with the ram moves down. When the handle is released, the rod comes to normal position because of the return springs.

4.2 Return Spring

Fig 4.2 Return spring

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A spring is an elastic object used to store mechanical energy. Springs are usually made out of spring steel. There are a large number of spring designs; in everyday usage the term often refers to coil springs.Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication. Some non-ferrous metals are also used including phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for springs carrying electrical current (because of its low electrical resistance). Depending on the design and required operating environment, any material can be used to construct a spring, so long as the material has the required combination of rigidity and elasticity

4.3 Heater

Fig 4.3 Heater

A heater converts electricity into heat through the process of resistive or Joule heating. Electric current passing through the element encounters resistance, resulting in heating of the element. Unlike the Peltier Effect this process is independent of the direction of current flow.

4.4 Compact Fluorescent Lamps (CFL)

Fig 4.4 Compact fluorescent lamps

A compact fluorescent lamp (CFL), also called compact fluorescent light, energy-saving light, and compact fluorescent tube, is a fluorescent lamp designed to replace an incandescent lamp; some types fit into light fixtures formerly used for incandescent lamps.

The lamps use a tube which is curved or folded to fit into the space of an incandescent bulb, and compact electronic ballast in the base of the lamp.

4.5 Aqua Regia Solution

Aqua regia is a mixture of Nitric Acid and Hydrochloric Acid optimally in molar ratio of 1:3. Aqua regia is yellow orange fuming liquid.

Fig 4.5 Aqua regia solution

Aqua regia so named because it can dissolve the noble metals Gold and Platinum.However, Titanium, Iridium, Ruthenium, Rhenium, Tantalum, Niobium, Hafnium, Osmium and Rhodium are capable of withstanding its corrosive properties. This mixture of HCl and Nitric Acid is used to extract the mercury from the vapour released from the CFL wastes when they are treated.

4.6 Blower

A blower is a mechanical device for moving air or other gases. These fans increase the speed of air stream with the rotating impellers.

They use the kinetic energy of the impellers or the rotating blade to increase the pressure of the air/gas stream which in turn moves them against the resistance caused by ducts, dampers and other components. Centrifugal fans accelerate air radially, changing the direction (typically by 90°) of the airflow. They are sturdy, quiet, reliable, and capable of operating over a wide range of conditions.

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Fig 4.6 Blower

Here the blower is used to suck the vapour released from the CFL wastes from the container to the mercury extraction vessel. As the pressure inside the container will be very low and the released vapour cannot travel to the extraction vessel by itself. Hence an external aid is needed for sucking the vapour. For this purpose, the blower is used which blows air outside as a result, the vapour will be sucked from the container to the extraction vessel easily.

4.7 Ram

A RAM press is a machine that is used to press clay into molded shapes, such as plates and bowls. In operation a slice of de-aired clay body is placed in between two shaped porous mould, and vertical movement of the mould presses the body into the required shape.

This ram mechanism is used to break the CFLs in our project. This ram is controlled manually by the handle. When the handle is pushed, the ram mounted at the end of the handle is moved down which breaks the CFLs. When the handle is released, the return spring pushes the ram upwards and hence return motion is taken care by the springs.

4.8 Frame

This is made of mild steel material. The whole parts are mounted on this frame structure with the suitable arrangement. Boring of bearing sizes and open bores done in one setting so as to align the bearings properly while assembling. Provisions are made to cover the bearings with grease. The ram, handle and all the other setup are mounted on the frame.

5.CONSTRUCTION

All the components are made according to the required specification. Then the CFL crushing unit is welded to the glass collecting unit. For the proper flow of crushed CFL glasses, the bottom of the CFL crushing unit is made tapered. The rammer with a mild steel plate at bottom is welded to the top of the CFL crushing unit using a spring.

The glass collecting unit has provisions to provide heater and to pour aqua regia solution. A drain is also provided at the bottom of the glass collecting unit to remove the glass particles that settle down at the bottom of the tank after the extraction process. The inlet of the inlet suction pipe is connected to the top of the CFL crushing unit and the outlet is connected to the mercury collecting unit. The inlet of the outlet suction pipe is also connected to the mercury collecting tank and the outlet is connected to the electric blower using a ball valve.

The mercury collecting tank contains water for collecting the extracted mercury. All the components are welded together to a mild steel frame.

Fig 5.1 Model

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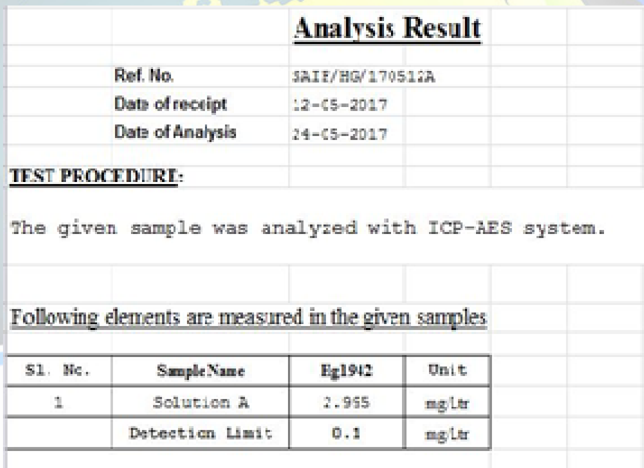
6. RESULTS AND DISCUSSION

6.1 Calculations

Amount of mercury present in each CFL = 4 mg.
Amount of mercury that can be obtained from each CFL bulb using broken glass method = 0.04-0.7 mg
Number of CFL bulb used = 20.
STIC test value obtained = 2.995mg of Hg per litre
Volume of water used in mercury collection tank = 1 litre.
Therefore, total amount of mercury extracted = 2.995×1 =2.995 mg of Hg.

6.2 Results

- Trace amounts of elemental form of mercury in the form of small spheres are found at the bottom of mercury collection unit.
- The remaining Aqua regia sample was sent for laboratory analysis of mercury to Sophisticated Test and Inspection Centre (STIC), Ernakulam for ICP-AES test.
- The test result shows the presence of 2.995 mg of Hg.
- The result shows the presence of higher amount of dissolved mercury as a result of the experiment procedures.



Analysis Result

Ref. No. SAIF/HG/170512A
Date of receipt 12-05-2017
Date of Analysis 24-05-2017

TEST PROCEDURE:

The given sample was analyzed with ICP-AES system.

Following elements are measured in the given samples

Sl. No.	Sample Name	Hg194.2	Unit
1	Solution A	2.995	mg/Ltr
	Detection Limit	0.1	mg/Ltr

Fig 6.1 Test report

6.3 Cost Estimation

SL NO:	PARTS	COST(Rs.)
i	Acids	300
ii	Blower	1500
iii	Frame Setup	3450
iv	Heater Setup	3500
v	Labour Cost	2000
vi	Machining cost	1300
vii	Miscellaneous Cost	1750
viii	TOTAL COST	13800

7. ADVANTAGES, DISADVANTAGES AND APPLICATION

8.1 Advantages

- Simplest method of mercury extraction.
- As mercury is toxic, even the small amount in the CFL wastes is a concern for landfills and by this process they are completely removed and the environment can be made free of hazards.
- The cost of the process is less.

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- The CFL wastes can be recycled without any hazards to the environment.

8.2 Disadvantages

- Need skilled persons to operate this type of systems.
- Suitable precautions are to be considered as the system deals with high temperatures.

8.3 Application

This type of extraction of mercury from CFL waste has a wide range of applications in the fields like,

- Recycling industries,
- CFL manufacturing plants,
- All industries as every industry uses CFL lamps.

8. CONCLUSIONS

In the present work we have developed an equipment and process to extract mercury from used CFL bulbs. From defused CFL bulbs we are able to obtain mercuric chloride using incineration process. The system can process 30 CFL bulbs in 3 hours. The mercury from the bulb is dissolved in the solution in the form of mercuric chloride. The solution can be further treated to extract pure form of mercury. This paper has social relevance, since mercury is toxic substance when exposed to environment.

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