EXTRACTION OF MERCURY FROM COMPACT FLUOROSCENT LAMP(CFL) WASTE

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Abstract –*The main aim of our project is to extract mercury from the waste or used CFL bulbs. When CFLs are created, manufacturers dose the bulb with a small amount of mercury. This mercury, when electrically stimulated, releases UV light, which subsequently reacts with a phosphor coating to create visible light. Thus mercury is an essential part of every CFL. The main aim of our project is to extract mercury from the waste or used CFL bulbs. When CFL; without it, the bulbs would not produce light. The typical dose of mercury is about the size of a pen tip, and these doses have been getting smaller and smaller. When these bulbs finally do reach the end of their useful life, there are several pathways they can take. In the best-case scenario, the bulbs are recycled. Even the CFLs that are discarded in the trash are unlikely to release much of their mercury. Although most of them break under current trash disposal methods, some remain unbroken, and will not release any mercury. Since the mercury is poisonous, it when released to atmosphere leads to air and water pollution. Hence, our project deals with the extraction of mercury from Compact Fluorescent Lamp (CFL) waste economically and efficiently.*

Key Words:

Mercury,Extraction,CFL,Poisonous,Pollution.

1. INTRODUCTION

In the present, two types of lamps are mainly used in lighting: mercury-containing ones (fluorescent lamps), and lamps without mercury (incandescent lamps and halogen/dichroic lamps). Fluorescent lamps are gas discharge lamps that use mercury vapours to produce light. The advantages compared to incandescent bulbs, marketing campaigns and environmental concerns have led to an increase in the number of fluorescent lamps used all over the world. Lower energy consumption (about 75% less energy consumed to produce the same light output as an incandescent bulb) and longer life expectancy (about 10 times), as well as the decisions made by some governments to phase out incandescent lighting, have greatly contributed to the rising use of compact fluorescent lamps. The principle of operation in a CFL bulb remains the same as in other fluorescent lighting: electrons that are bound to mercury atoms are excited to states where they will radiate ultraviolet light as they return to a lower energy level; this emitted ultraviolet light is converted into visible light as it strikes the fluorescent coating on the bulb (as well as into heat when absorbed by other materials such as glass).There are two types of CFLs: integrated and non-integrated lamps. Integrated lamps combine the tube and ballast in a single unit. These lamps allow consumers to replace incandescent lamps easily with CFLs. When CFLs reach their end of life, they are usually discarded as waste products. However, because all fluorescent lamps contain mercury, they are classified as hazardous waste. Once a CFL has been broken, mercury vapour, liquid mercury (if present) and mercury adsorbed onto the phosphor powder will be released. Most CFLs contain 3–5 mg per bulb, with the bulbs labeled "eco-friendly" containing as little as 1 mg. Before disposing, treatment in order to reduce the toxicity of the waste below the allowed limits is required. Recycling is one of the solutions to the large quantities of waste generated every year. While it allows decontamination of fluorescent lamps waste (mercury removal),it can also he recovery of valuable materials. So far in the world hundreds of millions of compact fluorescent lamps are sold and disposed every year. Viewed as a whole, these products contain tons of phosphorus vapour which contains, among others, high amounts of mercury. Developing an industrial process which, in a sustainable way, removes mercury from the phosphorus powders is of great importance. The purpose of this project is to effectively extract mercury from fluorescent lamps The focus will be the methods that can be applied for the efficient recovery of mercury from phosphorus vapours, in the hope of determining a viable and profitable procedure that can be scaled up to an industrial process.

1.1 Objective

- To design and develop an equipment which breaks the compact fluorescent lamp and extract mercury from it.
- Depending upon the quality of mercury obtained it is used for various applications.
- The glass breakings and ballast circuits are recycled for further use.
- To use the ballast for making LED bulbs.

1.2 Mercury content inCFL

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 ultraviolet energy. When this ultraviolet 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 is minimal, ranging between 6 mg to 3.5 mg.

1.3 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 mercury is a silvery liquid that can vaporize at room temperature due to its low vapour pressure (HPA, 2006) and is the form of mercury used in CFLs. The toxicology of inorganic mercury compounds and elemental mercury are briefly summarized here; 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 only 2.6% is absorbed from dermal exposure to elemental mercury vapour. Once in the body, because elemental mercury is lipid soluble, it can cross biological membranes including the blood-brain barrier and the placenta. Mercury is circulated throughout the body and can accumulate in the brain and the kidneys causing changes in neurological and renal function

2. LITREATURE SURVEY

L.kesavarao et. al[1] describes about the need for an environmentally acceptable and cost effective,CFL management programme that has become one of the environmental priorities. It also provides the best available technology and practices to hose who are conducting any activites related to both disposal and recycling of used CFL.

Ligy Philip et. al[2] says that Mercury (Hg) is a hazardous chemical and one of the priority pollutants. The mercury can be extracted from CFL bulbs using bio trickling filters and sulphur oxidising bacteria. By using these two methods we can extract about 99% of mercury from CFL bulbs. But this process is very expensive as compared to the extraction of mercury using thermal method.

Cristian Tunsu et. al[3] says that when fluorescent lamps reach their end of life, they are usually discarded as waste products. However, because all fluorescent lamps contain mercury, they are classified as hazardous waste. Before disposing, treatment in order to reduce the toxicity of the waste below the allowed limits is required. Recycling is one of the solutions to the large quantities of waste generated every year. While it allows decontamination of fluorescent lamps waste.

Yadong Li et.al,[4] says about the original study on the release of mercury from broken CFL under various condition. Amount of Hg in each CFL ranges from 0.1-3.6mg. Leaching of Hg in liquids can extract only less than 4% of Hg. Leaching test shows that a broken CFL continuously release Hg vapour and the release can last over 10 weeks. Total amount of Hg vapour released from a broken CFL can exceed 1.0mg.Therefore proper handling of used CFL is required.

Shyamsujan[5] says that mercury is an essential ingredient for most energy efficient lighting products, including CFL. Since the mercury is toxic, it is best to recycle the used CFL. For this the Central Pollution Control Board has decided to appoint “Lamp Recycling Units”(LRUs), where the used CFLs are collected and use very highly sophisticated machinary to retrive each part of lamps like mercury, glass particles and ballast.

3. EXPERIMENTAL SETUP

The experimental set up contains of mainly eight components- CFL Crushing Unit, Glass Collection Unit , Ballast Collection Unit , Inlet suction pipe, Mercury Collection Unit, Outlet suction pipe , Electric Blower and Heating Unit. The crushing unit, here, is designed for tubular type CFL. The feed rate is 6 CFL/ cycle .i.e 6 CFLs are crushed at a time. The upper two holes of the Crushing Unit are designed for placing tubular CFLs with three tubes while the remaining four holes are designed for accommodating tubular CFLs with two tubes. The dimensions of glass collection tank are suitably assumed for collecting maximum quantity of broken lamp glasses. Mercury content in each lamp may vary depending upon its wattage, size and shape. There is also a considerable decrease in the mercury content in used CFLs. In India a normal fresh CFL is found to have an average mercury content of 10 mg. For the sake of experiment it is assumed that 5 mg of mercury is present in each used CFL available.

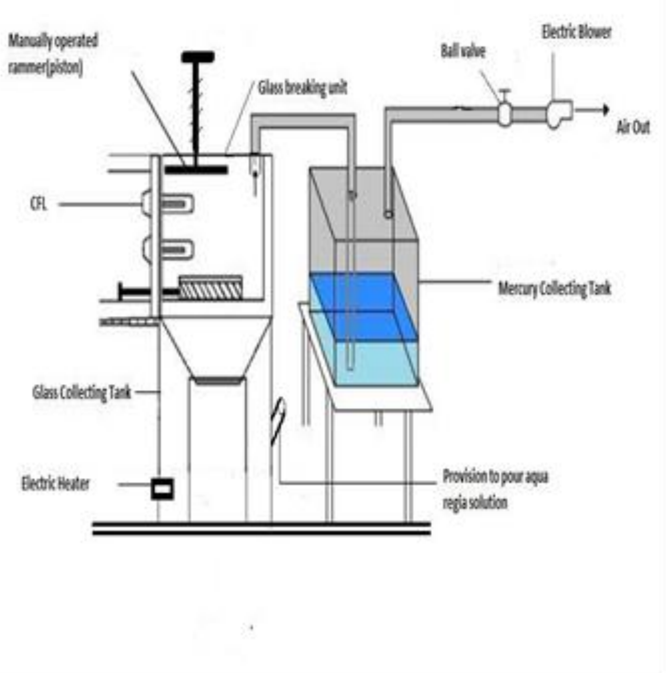


Fig -1: Experimental setup

Mercury is found in elemental state inside the tube. On breaking some of it escapes into atmosphere while the remaining stay combined with the phosphor powder. The apparatus is designed for obtaining mercury from both. The mercury which is released on breaking of lamp is captured by providing a negative pressure using a blower. Since mercury is heavier than water (density 13.546 g/cc) it settles down in the cooling medium in the mercury collection tank. Since it is very difficult to remove Mercury from phosphor powder, chemical treatment is done to separate them. Aqua regia (a mixture of HNO_3 and HCL in the ratio of 1:3) is used.It dissolves in oxidizing acids, producing Hg^{2+}. The metal is soluble in aqua regia to form $[HgCl_4]^{2-}$. No reaction is visible, but Hg will be present as $[HgCl_4]^{2-}$.

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

Mercury has a boiling point of 304°C (529°F, 549 K). It is a linear triatomic molecule, hence it has a tendency to sublime. So when heated above its boiling point it sublimes and passes through the inlet suction pipe and reaches the cooling medium (water).The obtained solution will be sent to laboratory for the ICP-AES (thermo Electron IRIS Interpid II XSP Duo) for the quantitative analysis of the obtained mercury. The glass pieces obtained are within dimensions of few millimetres. The can be sent for further recycling. The ballast consists of electronic circuit boards which can be recycled and further used.

3.1 Experimental procedure

- Place the CFLs in the crushing unit in the respective holes (3 tube lamp on the middle layer and 2 tube lamp on remaining two layers). Also the aqua regia solution should be poured in the glass collecting unit.
- Switch on the electric blower. Slowly adjust the suction ball valve till the bubbles start appearing in the mercury collection unit.
- Now manually crush the CFL by pressing the rammer from the top. Press it fully till the spring get compressed fully, so that the glass breaks into fine particles. Also the ballast falls off. This can be collected in a ballast collection unit.
- Close the shutter. It prevents the escape of fumes through the holes.
- Tilt the lower plate so that the glass pieces fall into the heating unit.
- This completes one cycle. Repeat the experiment with another set of lamps.
- When the heating unit is half filled with glass piece residues, switch on the electric heater.
- Heat the unit up to thirty to fourty minutes i.e, upto 380 °C. Make sure the entire setup is airtight.
- Continue this temperature for about five minutes so that the entire mercury sublimes out.
- The mercury will be captured in the mercury collection unit.
- Switch off the power supply and remove the glass pieces collected in the glass collection unit and repeat the experiment.

4. FABRICATION

Fig-2 Model fabrication

4.1 Components and chemicals used

- Electric Heater-2000W, 220V AC, Maximum temperature of 600 °C.

- Blower-220V AC, 6000 r/min, with a discharge of 2.5m^3/min.
- Inlet and outlet suction pipes-1 inch diameter of uPVC material.
- CFL crushing unit-10×10×10 inch mild steel sheet metal.
- Glass collecting unit-10×10×10 inch mild steel sheet metal.
- Mercury collecting unit-30×15×15 cm glass material.
- Rammer-mild steel shaft of 15mm diameter attached to a mild steel plate at the bottom.
- Nitric Acid (HNO_3)-65% concentrated.
- HydroChloric Acid (HCl)-37% concentrated

4.2 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.

5 RESULT AND DISCUSSION

- Trace amounts of elemental form of mercury in the form of small spheres are found at the bottom of mercury collection unit.
- The remaining water 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 3.33 ppm of Hg.
- The result shows the presence of higher amount of dissolved mercury as a result of the experiment procedures.

5.1 Calculation

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

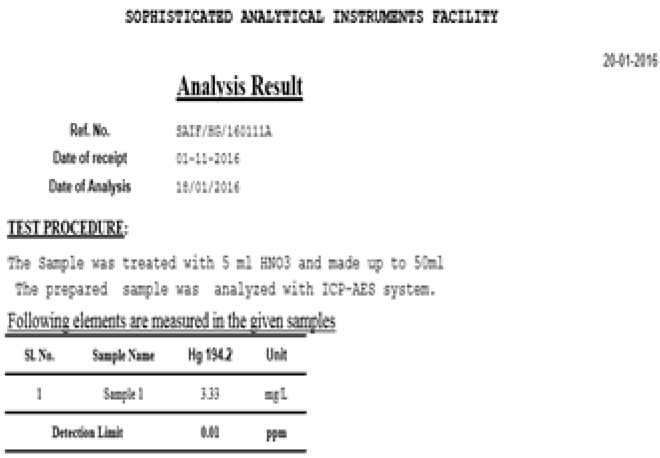
Number of CFL bulb used = 30

STIC test value obtained per litre = 3.33mg 0fHg

Volume of water used in mercury collection tank = 3 litre

Therefore, total amount of mercury extracted = 3.33×3

=9.99 mg of Hg.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20-01-2016

Analysis Result

Ref. No. SAIF/HG/160111A
Date of receipt 01-11-2016
Date of Analysis 18/01/2016

TEST PROCEDURE:

The Sample was treated with 5 ml HNO3 and made up to 50ml
The prepared sample was analyzed with ICP-AES system.

Following elements are measured in the given samples

Sl. No.	Sample Name	Hg 194.2	Unit
1	Sample 1	3.33	mg/L
Detection Limit		0.01	ppm

Fig-3 Test report

6. CONCLUSION

A new set up has to be designed and tested for mercury from CFL lamps. The commercial production of this set up can make a considerable breakthrough in the removal of mercury from CFL. This project has some social relevance, since mercury is toxic substance when exposed to environment.

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