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Attempts Made to Extract Mercury and Other Heavy Metals from Electric Bulbs with Special Reference to Vehicular Bulbs

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Abstract- The main aim of this research is to extract the mercury content from the crushed CFL's and vehicular bulbs. Even though the small amount of mercury is present in to the bulbs is harmful for the living being when it spilled from the broken CFL's and electric bulbs. We cannot substitute any other material with mercury so the elimination at source is quite impossible. Since the mercury is toxic it can cause the air, water and soil pollution. So it is necessary to control at the source and extracts the mercury from the CFL's and electric bulbs at the end of their useful life before they become the trash. The end users of these products directly dump the fused bulbs into the municipal solid waste. Hence the authors are trying to make and address the continuous mercury recovery equipment. This equipment consists of three main sections as heating unit, condensing unit and collection unit. Heating unit for heating the crush CFL's because mercury evaporate at the 360^{0}C and separate from the other material like glass, ceramic, metal pieces and other substances. Next section contain condenser to convert the mercury vapors into the liquid mercury this liquid mercury can be store in special storage tanks because the mercury can easily react with the any metal and make alloy hence the storage of extracted mercury is most important task. For identifying the mercury content in the vehicular bulbs we need to crush them and after that gives the aeration so all elements are separate out which may stich to the bulb glass.

Key words- Mercury, Extraction, Sedimentation, Aeration, Condensation, Municipal solid waste

I. INTRODUCTION

CFL's are energy efficient source of lighting that's why they are widely used all over the world and one more reason is that fluorescent lamp has long life with less consumption of the electricity so the performance of the CFL's is better than the incandescent lamps. In developing countries like India there is no separate collection system for the lamps so in this the lamps are usually discarded as waste product. The fluorescent lamps which contains the mercury which are classified as the hazardous material. If CFL broken, vapor and liquid form of mercury spilled out of it. Most of the CFL bulbs are contain some amount of mercury which is negligible but impact most to the environment and the bulbs labelled with "eco-friendly" containing as little as 1mg. before disposing it requires pre-treatment to reduce its toxicity because research has been shows that mercury component from one fluorescent tube or lamp can pollute 30,000 liters of water beyond safe drinking level or a tea spoonful of Hg can pollute a lake for hundreds of years. The objective of this project is to design mercury recovery equipment from brunt fluorescent tubes and lamp as an improvement in the present system. Another objective of this project is to find out the poisonous content in the vehicular bulb such as mercury and lead. The significant objective is to stop environmental pollution arising from mercury emission during recovery process and eventually develop a waste to wealth method that will eliminate the potential hazard to the environment especially ground water and ecosystem. Recycling is one of the solution to the large quantities generated every year and recycling is followed by recovery which include the valuable material such as ceramic, metal and glass. The focus will be on the process that can be applied for the efficient recovery of mercury from phosphor powder, in the hope of determining a viable and profitable procedure that can be scale up to an industrial process.

II. LITERATURE REVIEW

1. Extraction and control of mercury emission from disposed fluorescent bulb and tubes this literature show that the most of the bulbs at their end of life are thrown

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into the waste stream only 2 percent of them are recycled. Paper also tell us about the equipment design for the extraction of mercury from the burnt bulbs. This equipment simply containing the crushing unit for crush the bulbs and container for the collection of this crushed material which contain glass, ceramic, metal and mercury which is then separated.

2. Extraction of mercury from compact fluorescent lamp (CFL) waste in this paper they tell us about the working of the fluorescent lamps and how mercury is main component of the lamp. Paper also include the bad impact of mercury spill into the environment and how it leads to the air pollution and ground water pollution.
3. Shymsujan says that mercury is essential component of most of the fluorescent lamps and hence recycling is one of the best way to stop hazard occurred due to the mercury exposure because mercury is toxic in nature.
4. R.W.Serth specially focuses on the design of shell and tube warmth exchanger, air-cooled warmth and double pipe heat exchanger (hairpin). He also describes various design parameter in brief and behavior of gases and liquid at various temperatures.

III. OBJECTIVES

1. Study the collection process of the garbage and e-waste by local municipal corporations.
2. Collection of the fluorescent bulbs and tubes from both residential and industrial areas including garages where most of the vehicle bulbs are replaced by new once.
3. To find out the potential hazard from vehicular bulbs such as present of mercury and lead
4. Design equipment to recover mercury from the brunt fluorescent lamps and tubes as an improvement in the present system.
5. Develop a waste to wealth method that will eliminate the potential hazard to the environment especially ground water.
6. To study the feasibility of the model and its performance.

IV. METHODOLOGY

The process of extraction of mercury from burnt CFL's started from collection of bulbs from various collection points marks based on the field survey. The bulbs are separately collected in the given container at source because segregation after collection is quite expensive process and also the danger of mercury spill is increase. After collection of bulbs they are safely transported to the processing site is also important task. Equipment mainly containing the crusher, heater, condenser and mercury collection pot. We now briefly discuss about the heating process. The boiling point of mercury is 3600C so at this temperature mercury evaporates and converted in the vapor state and other materials are in solid state because they have higher boiling point than the mercury such as metal, glass and ceramic etc. to convert the mercury in vapor state to the liquid state we have to use condensation process. For that we select double pipe or pipe in pine condenser for the best results, another reason behind selecting double pipe condenser is that mercury and water cannot come in direct contact with each other. This double pipe condenser generally made up of stainless steel pipe which is alloy of iron and carbon. As we know that the mercury is highly reactive element that easily create bind with any metals, for that we are using here stainless steel alloy in making condenser. Water work as a cooling agent in this condensation process. The last component of the equipment is the storage container, mercury cannot be store in the ordinary metal pot because mercury react with it, we also use the glass container but the possibility of breaking the glass while handling is greater so we have to use the stainless steel alloy metal container to store the mercury.

Similarly, for vehicular bulbs first we have to find out the poisonous content if any for we collect the vehicular bulbs from the nearest garages and service centers. After studying the research area, we conclude that most of the mechanics not even know about the segregation of waste and there is no facility for collecting the burnt vehicular bulb by ULB. When we got that bulb they are in very bad condition such as bulb cover fully with dust and the oil. So we need to clean them first of all before take them for experiment. We set this bulb for 24-hour aeration to clean them well. Aeration time is varying from in 1hour, 3hour and 24 hours' batch. After aeration is completed bulbs are crushed so the inner filament of the bulbs is expose to the post aeration. In this post aeration process only crush material is aerated except metal caps which increase the volume of material and metal caps are free from any toxic substances. After aeration of bulb crushed material, water used in aeration is store in the 3 separate container as top layer, middle layer and bottom layer of water respectively. Which is then allow for settling in the container for various time period, this process is known as sedimentation. After this process we got the heavy metal at the bottom of the flask which are settle down. This sample is collected and send to the laboratory. By using the flame spectroscopy method, we test the sample for the mercury and lead content.

V. THEORETICAL CONTENT

In this section describing about the equipment that recover mercury from the crushed CFL bulbs. The first and main component of the process is heating the material that crushed in the bulb crusher, material transfer from the crusher to the recovery equipment is quite difficult task because the material from the crusher is in the solid form and powder also so it is quite possible that the phosphor powder is exposed to the air which cause another air borne disease problem so the whole process of material transfer is

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practiced in the air tight containers or equipment. Not only the process of crushed material transferred but also the whole process of mercury recovery is performed with air tight materials because process involve the mercury vapors in it.

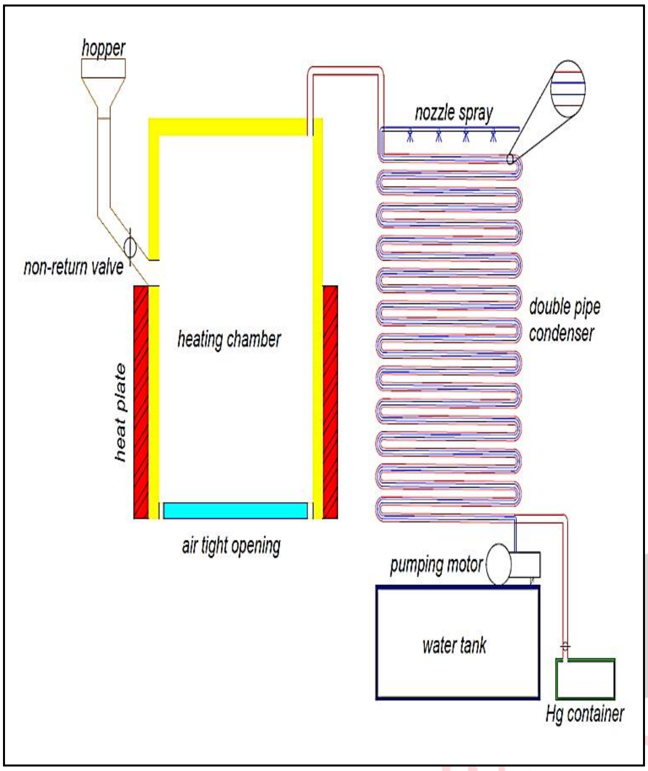

Figure 1- Mercury Extraction Equipment

At the top of the equipment we provided the hopper to collect the crushed bulbs after that non return valve is provided for control the mercury vapors that produced after the heating of the crushing material at 360^0C. for heating this material we are using oven as a heating chamber, this heating chamber are made fully air tight to perform heating of material so it could not leak the mercury vapors. Heating process is performed until the whole mercury inside the chamber is evaporates. Total three opening are provided in heating chamber that are opening for crush material intake another for vapor to travel through the double pipe condenser and last opening at the bottom of the heating chamber for the residue remain after the heating which contain the glass, ceramic and metal pieces come out through this opening. This heating chamber is generally made up of alloy material which could not react with mercury because mercury is highly reactive material. In next stage mercury vapors are inter in the double pipe condenser where the condensation process of vapor is started in which the vapors at the end of the double pipe converts into the liquid form at room temperature. In double pipe condenser the vapors are travel through the outer pipe and the cooling liquid which means water is flowing through the inner pipe in the opposite direction of vapors travelled. There is no need to force vapor through the condenser because heating process is enough to generate pressure inside the chamber which force the vapors to travel through the pipes. But there is need to force the water upside which needs water pump place on the water tank situated below the condenser and mercury collection container is place beside of the water tank. Water tank of adequate size is required for continuous supply of water through the condenser. Thinking behind choosing the double pipe condenser system is that vapor are condensed as fast as possible as it exchanges the heat with both the media water and surrounding air which boost the process of condensation. In another words we say that vapors exchange the heat with water and surrounding air. Water which pumping upward direction splash on honeycomb structure mesh by nozzle spray this water again come in use as it supplied to the water tank situated below, it means loss of water in this process is minimized. Panel 1 behind the condenser is of honeycomb structure mesh which absorbed the water sprayed through the nozzle and percolate it to the bottom channel which direct this water to the water tank. This panel also helps to decrease the surrounding temperature and supply cold breeze towards the condenser which improve the process of heat exchange. Another panel behind panel 1 is work on this equipment as supply of air to the condenser which contain exhaust fans on it. This passing air is also work as air condenser, by exchanging the heat from outer pipe. Main objective about this equipment is that both cooling agents water and air are not in direct contact with mercury so we prevent further air pollution and water pollution during the mercury extraction process.

Similarly study on the vehicular bulbs are started we problem statement and collection of vehicular bulbs. After collection they need washing as they surrounded with dust and oil. For the cleaning purpose we put them for aeration as shown in figure 2. Here we make 3 batches of bulbs set aeration, 2nd batch for 3-hours and 3rd batch for 24-hours.

Figure 2- Aeration of bulb for cleaning in tank1, 2 & 3 respectively.

As we gave different aeration for different batch the cleanliness level of bulb in each batch also differ from the other and we can also conclude that what happens with over aeration. Neat and clean bulbs is taken for crushing. After crushing the bulbs, they get segregated in two parts as glass and metal caps. Metal caps from crushing material is

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separate out. Only glass material is now set for aeration at constant time of 24-hours for all batch. Now each batch of aeration is separated in three sample as top layer, middle

Figure 3- Sample set for post-aeration

layer and bottom layer of sample in which most of heavy particles. The presence of suspended particles in the water make water turbid, we can clearly see that color of sample 3 darker than other two samples. This sample are now set for sedimentation process in which the particle is allow to settle down over period of time. This time for sedimentation is also different for each batch of sample, so on that we can find out the settling rate of the particles.

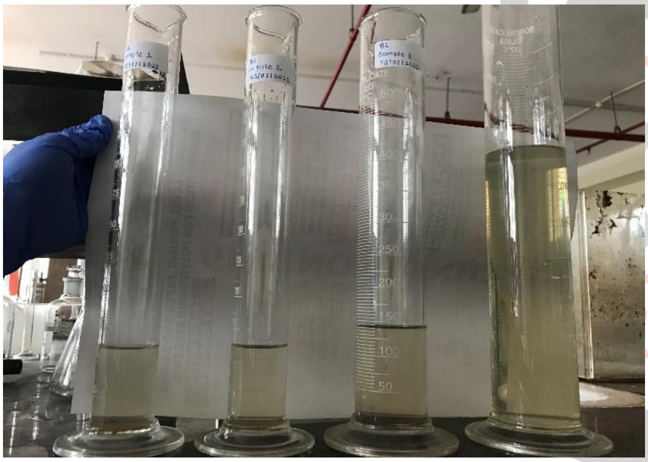

Figure 4- Sample set for sedimentation

After sedimentation period is completed the sample are extracted again. The top layer water extracted in such way that in flask 1 we get bottom 30ml water, from flask 2 upper layer of water is extracted so we get 70ml sample from bottom and flask 3 which is our sample 3 extracted in way that we got 150ml bottom layer sample. It means that from flask 1 we get 30ml sample, from flask 2 we get 70ml sample and from flask 3 we get 150ml sample, by adding all this sample we finally get 250ml of sample from batch1.

Figure 5- Sample after extracting top layer

This extraction quantities and process is keep similar for further batch-2 and batch-5. After extracting bottom layer samples from each flask mix them and prepare final sample which is send to the laboratory for testing. After few days of settling process batch-2 is prepare for lab testing. Here we see in figure 5 that 4th flask is filled with water extracted from top layer of the sample 1, 2 and 3. We name it sample-4 (B1) similar sample is obtained from batch-2 which is sample-4 (B2). This sample sample-4 from batch-1 and batch-2 is mixed after few days settling period now we get the new sample which is B5. By applying similar process of extraction upper layer water id extracted and remaining 250ml water at bottom send to the laboratory testing.

VI. RESULT & DISCUSSION

Section 1:

After designing the condenser (double pipe heat exchanger) we got optimum length of the that is 2.197 feet which is sufficient for mercury vapors condensation.

Section 2:

Sample send to the laboratories for checking the presence of Mercury (Hg) and Lead (Pb) by conducting experiment of Atomic Absorption Spectroscopy (AAS). So the result of B1, B2 and B5 sample are mentioned below.

Table 1- Indicative lab test result for Batch-1

Sr. No.	Sample Name and ID	Parameters	Obtained Result	Remark
1	Water sample Batch-1 (B1)	Lead (Pb)	1 ppm	Present
		Mercury (Hg)	2 ppm	Present

Table 2- Indicative lab test result for Batch-2

Sr. No.	Sample Name and ID	Parameters	Obtained Result	Remark
1	Water sample Batch-2 (B2)	Lead (Pb)	1 ppm	Present
		Mercury (Hg)	2 ppm	Present

Table 3- Indicative lab test result for Batch-5

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Sr. No.	Sample Name and ID	Parameters	Obtained Result	Remark
1	Water sample Batch-5 (B5)	Lead (Pb)	3.7 ppm	Present
		Mercury (Hg)	3.1 ppm	Present

From the experimental analysis we observed that the B1 and B2 are allowed under pre and post aeration of crushed material into 1000ml beaker for the cycle of duration ranges from 3 hours as minimum and maximum of 90hours. It is further observed that B1 and B2 samples has final settling thickness of the particles in cylindrical jar is minimum 1mm and 4mm maximum. The concentration of lead (Pb) in B1 and B2 samples is observed around 1ppm and that of for mercury (hg) is 2ppm. The settling of B3 and B4 is under observation and yet to analyze. The concentration of lead (Pb) in B5 sample is observed as 3.7ppm and that of for mercury (hg) is 3.1ppm. as per WHO recommendation for the permissible limit for mercury (Hg) and Lead (Pb) in drinking water is 0.002 ppm and 0.00001 ppm respectively.

Figure 6- Crushed material of vehicular bulbs

When bulbs are crushed we get glass and metal caps, the metal caps are get separated from glass to reduce the volume of the aeration material, so only glass set for post aeration. This glass, metal caps and tungsten wire get recycle, reuse from that we can generate the revenue and protect environment from its bad impact.

VII. Conclusion

There is so many substances that pollute our earth every day and mercury is one of them but hazard of mercury to the human and environment is quite large. So for controlling the spillage of mercury from broken fluorescent lamps the only way is to recycle it. The equipment that we have use for the extraction of mercury is extract mercury from crushed bulbs and we got mercury in liquid form. When we come to the vehicular bulbs experiment we conclude that in initial aeration process 6hours is optimum time for cleaning the bulbs and excess aeration cause corrosion of the bulbs. Also the result is varying with settling time of samples because B5 sample has more settling period than samples of B1 and B2 we got higher proportion of Lead (Pb) and Mercury (Hg) in B5 sample.

By performing Atomic Absorption Spectroscopy (AAS) experiment in the lab we observed the presence of both lead and mercury in the sample which conclude that vehicular bulbs can poses hazard to living being. The remaining material such as glass and stainless steel metal caps and tungsten in vehicular bulbs are also recycled and reused. If there any ceramic part in it that can be used in the making of LED's.

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