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An Overview on Fate of Mercury and Its Recovery from Spent CFL Bulbs

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Abstract-The need for an environmentally acceptable, yet cost effective, spent Compact Fluorescent Lamp (CFL) management programme has become one of the environmental priorities in South Africa. The main objective of this document is to provide practical guidelines for the best available technologies and practices to all stakeholders conducting any activities related to both the disposal or recycling of spent CFLs. Increasing environmental consciousness, the prominence of climate change concerns and energy constraints globally have prompted an intensified focus on energy efficiency measures, resulting in a significant increase in the usage of CFLs. The steps and activities for safe management of CFL waste, from separation at source to ultimate disposal at a hazardous landfill site or to a recycling facility, are outlined in the various sections on the next page. Each section is color-coded in accordance with the specific identifying icon, for ease of reading. Within each of the 'steps' the various stakeholders involved and their responsibilities are tabulated separately.

Index terms: **Compact Fluorescent Lamp, Fate of Mercury, Properties, Sources, Toxicity, And Treatment Methods.**

I. INTRODUCTION

With the fast market growth of fluorescent lamps, particularly CFLs, the associated emissions and risk of mercury, which is an essential component in all types of fluorescent lamps, have received increasing public attention and concerns. Mercury is a highly toxic heavy metal, and its toxicity depends on the chemical form and the route of exposure. Low doses of mercury exert toxicity on various human organs, including the central nervous system, renal system, reproduction system, immune system, cardiovascular system and motor system [1]. Mercury particularly impairs the neurological development of fetuses, infants and children, whose nervous system is under development and is sensitive to environmental Insults [2,3]. Mercury, in both inorganic and organic forms, exhibits toxicity to organisms in aquatic and terrestrial ecosystems [4]. Mercury toxicity in aquatic ecosystems has received great attention in particular, because inorganic mercury can be methylated in aquatic sediments, and the resulting methyl mercury is bio accumulated to a high degree in aquatic food chains [5,6]. As a result, the highest concentrations of the highly toxic methyl mercury are found in tissues of long-lived predatory fish in fresh and ocean waters [4-6]. Because of the great challenges to public health posed by mercury pollution, various voluntary and mandatory programs have been implemented in many developed countries to reduce anthropogenic mercury emissions to protect human health and the environment from the risk posed by mercury.

II. SOURCES

Chief among these mercury-containing industrial products are light sources, especially cold cathode fluorescent lamps (CCFLs), ultraviolet (UV) lamps, and high pressure mercury lamps (SHPs), which are produced and used worldwide. Mercury is used in fluorescent bulbs for converting electrical energy to radiant energy in the ultraviolet range and then re-radiating it in the visible spectrum [7]. However, the mercury concentration and the speciation in the above lamps can vary, depending on the manufacturer, lamp type and year of manufacturing [8]. According to a survey made by the USEPA, the mercury contained in one type of fluorescent lamp (produced by the Sylvania lamp manufacturer) probably consists of 0.2% (0.042 mg) elemental mercury (vapor phase) and 99.8% (20.958 mg) divalent mercury incorporated into the phosphorus powder. It is acknowledged that the speciation of mercury contained in fluorescent lamps is a controversial and complex subject [9]. Unfortunately, when such mercury-containing lamps are discarded, the mercury, which is harmful to human beings and other organisms, is released into the environment [10].

III. PROPERTIES OF MERCURY

Mercury, which has the lowest melting point of all the pure metals, is the only pure metal that is liquid at room temperature. Mercury is also one of the most toxic chemicals and has been placed on the priority list of 129

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hazardous chemical substances by the United States Environmental Protection Agency (USEPA) [11]. Mercury is a persistent environmental pollutant with bioaccumulation ability in fish, animals, and human beings. In the United States, there is already legislation aimed at controlling mercury-containing products. The European Union proposed the control mercury-containing products in their "Council Directive 76/769/EEC". However, due to its several physical and chemical advantages such as its low boiling point (357^0C) and easy vaporization, mercury is still an essential material in many industrial products.

A. Toxicity of Mercury

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 vapor pressure (HPA, 2006) [12] 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 vapor) 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 vapor [12]. Once in the body, because elemental mercury is lipid soluble, it can cross biological membranes including the blood-brain barrier and the placenta [13]. Mercury is circulated throughout the body and can accumulate in the brain and the kidneys causing changes in neurological and renal function. The absorbed elemental mercury is oxidized to Hg2+ and is excreted in the urine [12]. Mercury vapor has an average half-life in the body of two months, but the reported range is about 30–90 days [14]. The central nervous system is known to be the most sensitive target for exposure to mercury vapor. Exposure to mercury has caused neurological and behavioral disorders in humans [12], depending on the magnitude of the exposure, the exposure duration, and the age and health status of the individual, as well as the chemical species of mercury compounds [15]. Humans are also known to vary in their individual susceptibility to mercury exposure [12] with fetuses, infants, and children under the age of six known to be sensitive subgroups [16]. However, toxicity to mercury follows the expected dose–response principles; thus, at small enough doses, even sensitive members of the population are not expected to have adverse effects, as evidenced by continuing work in the Seychelles and Faroes Islands with mercury exposure to children [17]. Young children may also accumulate a higher internal dose of Mercury vapor than adults since their ventilation rate on a bodyweight basis is greater than adults. Their breathing zone is closer to the floor where mercury vapor is likely to accumulate after a CFL breakage on the floor surface [18], because such vapor is heavier than air. Exposure scenarios discussed in this analysis take these two factors into account.

B. Fate of Mercury When a CFL is Broken

Once a CFL has been broken, mercury vapor, liquid mercury (if present) and mercury adsorbed onto the phosphor powder will be released [19]. It is unlikely that any spilled liquid mercury will be visible as the volume of mercury is small and any spilled mercury would form minute droplets on impact. The phosphor powder can separate from the glass when the lamp is broken [19]. The amount of mercury released as mercury vapor or associated with the phosphor powder will depend on the age of the lamp and quantity of mercury vapor in the lamp. Fluorescent lamps will contain several species of mercury which depend on the species of the mercury added by manufacture and the age of the lamp [20]. Over time elemental mercury in the lamp will be oxidized and will form inorganic mercury compounds (predominantly HgO) [21] and will partition to lamp components including the glass and phosphor powder [22].New lamps will release more mercury vapor, whereas in older or spent (used) lamps the mercury will have been oxidized and or have partitioned to lamp components. There is an initial spike in air-borne mercury concentration following breakage of a CFL or linear fluorescent tube as mercury vapor is released [21, 23,24], followed by slower release of mercury present in solid and liquid forms (amalgams, liquid elemental mercury, inorganic mercury and mercury absorbed onto lamp components). Compared to elemental mercury, methyl mercury is much more toxic and affects the central nervous system, and may irreversibly damage brain in severe cases [6]. Mercury, in both inorganic and organic forms, exhibits toxicity to organisms in aquatic and terrestrial ecosystems [4]. Mercury toxicity in aquatic ecosystems has received great attention in particular, because inorganic mercury can be methylated in aquatic sediments, and the resulting methyl mercury is bioaccumulated to a high degree in aquatic food chains [5,6]. As a result, the highest concentrations of the highly toxic methyl mercury are found in tissues of long-lived predatory fish in fresh and ocean waters [4-6]. Because of the great challenges to public health posed by mercury pollution, various voluntary and mandatory programs have been implemented in many developed countries to reduce anthropogenic mercury emissions to protect human health and the environment from the risk posed by mercury.

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C. Capture of Mercury in the Vapor Phase

Each clean dry CFL was placed in a sealable plastic bag. One end of the PTFE tube from the peristaltic pump was attached to the bag before closing it. Once assembled, the closure of the bag was checked to ensure no air could enter or escape. The other end of the tube was left open. A vacuum was applied inside the bag using a peristaltic pump at full speed (220 rpm). It was easy to identify the moment a vacuum was reached because the plastic bag was completely adhered to the lamp. During operation of the peristaltic pump, 40 ml of a mixed acid solution were pipetted into a squeeze bottle. The mixture of acids was prepared with HCl and HNO3 at a ratio of 1:1 by volume. By using this combination of strong and oxidant acids mercury reacts to form water soluble salts [25]. Once the vacuum had been reached, the free end of the PTFE tube was adapted to a bent glass tube of a smaller diameter inserted into the squeeze bottle. The glass tubes of the lamp were then broken by hitting them with a rubber mallet. The maximum airflow rate of the peristaltic pump allowed the mercury vapor to pass through the PTFE tube and bubble into the acid mixture. This acid mixture with the captured mercury was poured into a 100 ml flask, leveled with reagent water and stored at 4 _C until it was time to analyze it. The end cap of the lamp was removed while the glass and phosphor powder were weighed and broken into smaller pieces to facilitate their separation.

D. Mercury Emissions from Fluorescent Lamp Disposal

A fluorescent lamp typically consists of electrodes at both ends of a phosphor-coated glass tube, a small amount of mercury, partly in vapor form, and an inert gas (usually argon) sealed in the tube. The mercury vapor is excited when current is applied to the electrodes, and the ultraviolet radiation emitted by the excited mercury is converted by the phosphor coating to visible light. Mercury vapor is impinged onto the glass, the phosphor powder, and the metal components during lamp operation. Thus adequate amount of mercury vapor is needed to achieve long lamp lifetimes. Depending on the types of lamps and their manufacturers, mercury in the quantities of milligrams to tens of milligrams is added. Fluorescent lamps typically last for over 6000 h, but are eventually burned-out once not enough mercury is left in the vapor form to contribute to the illumination process [26,27]. In spent fluorescent lamps, mercury is predominately bound to the glass, the phosphor and the metal end parts, with only a small fraction remains in vapor form at room temperature. Environment, while people may be exposed to toxic levels of mercury vapor released from broken lamps. Although each fluorescent lamp only contains a small amount of mercury, if millions are dumped, the cumulative mass of mercury can be significant.

The small amount of mercury sealed within the glass tubes of fluorescent lamps poses no risk as long as they remain intact. However, the spent fluorescent lamps will eventually break and release the contained mercury into the solid waste stream and the environment. It has been estimated that 1.2–6.8% of the total mercury in fluorescent lamps could be released into the air after breakage [28]. A recent study showed that CFLs continuously emitted mercury vapor once broken for over 10 weeks and the mercury level in a regular room could exceed the safe human exposure limit from breakage of a CFL under poor ventilation conditions [29]. Toxicity characteristic leaching procedure (TCLP) test showed that only 4% of the mercury in CFLs was leachable, and mercury concentrations in TCLP extracts of new CFLs were below the regulatory level of 0.2 mg/L [29]. Nonetheless, it should be noted that the TCLP test does not account for the release of mercury vapor to air and its potential impact. Mercury vapor is released when openly dumped fluorescent lamps break, while rainwater can leach the mercury bound to lamp parts or in phosphor powder from broken lamps and transport it to the soil near or under the dumping site. Measurements showed that 0.8% and 0.2% of the total mercury was released from broken fluorescent lamps with 0.5- and 1-foot of soil covers over a 20-day period, respectively [30]. Mercury content in the soil at 10 cm below the surface of a CFL disposal and solid waste dumping site in Calicut, India was as high as 14.9 mg/kg [31].

IV. WHY IS A CHOKE REQUIRED IN A TUBE LIGHT AND NOT IN A CFL?

Both conventional fluorescent lamps (usually 4ft long) and compact fluorescent lamps-CFLs (much smaller both in diameter and length of tube) used in lighting applications are low pressure mercury vapor discharge lamps. These lamps generate light by the process of flourcence (accomplishing conversion of invisible ultraviolet, UV to visible light) by electrical discharge-passage of electricity through gaseous vapor medium along the column of the tube. When electrical discharge could strike the column of the tube, lot of invisible UV radiation having wavelength dominantly at 254 nm is generated. This UV radiation when strikes the white coating inside the tube made of fluorescent material-phosphorus gets converted to visible light with wavelength in the region of 400-700nm through the process of fluorescence. The electrical resistance of the discharge column of the tube increases with dimensions and decreases with miniaturization of lamp dimensions. For a conventional fluorescent lamp, the ballast used is a choke which essentially a leak transformer (made of bulk coil windings) which momentarily produces an inductive kicks in the form of high voltage (approximately 1000 volts) so that the electrical discharge could be struck along the column of the tube. So in a conventional flourcent lamp the role of the choke is to initiate the electrical discharge process. Once the discharge is struck it can be sustained through the drop-in electric resistance of the column. But CFLs being smaller in dimensions offering much lower electrical resistance do not require such bulky chokes. Instead the discharge in CFLs is irritated by much compact electronic circuits integrated into CFL holder. Usually these electronic ballasts are small oscillating circuits producing high frequencies (approximately 10kilo hertz) facilitating flicker free quick start of lamp as electric discharge strikes faster at such high frequencies.

V. TREATMENT METHODS FOR REMOVAL OF MERCURY

CFL Fluorescent lamps are electrical discharge lamps that contain low-pressure mercury vapor and an inert gas, usually argon. The inside of the glass is coated with a fluorescent phosphor powder. The mercury vapor 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 [32]. A variety of mercury amalgams have been used in fluorescent lamps with varying combinations of iron, bismuth, indium, tin and lead [32]. Compact fluorescent lamps (CFLs) are promoted as being more energy efficient and an eco-friendly replacement for incandescent lamps. Fluorescent lamps, including fluorescent tubes and CFLs, are increasingly being used in homes around the world as part of a drive to improve energy efficiency. The key advantages of installing CFLs compared with incandescent lamps are large reductions in energy use and greenhouse gas emissions if the electricity is produced from burning fossil fuels [32]. A disadvantage of fluorescent lamps is that they contain milligram (mg) quantities of mercury. Mercury is an integral component of fluorescent lamps and a substitute chemical has not yet been identified. Internationally, concerns have been raised regarding potential mercury exposures following lamp breakage. 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 vapor pressure [12] 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.1 When a CFL is broken, people may be exposed to elemental mercury (including vapor) 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 vapor [12]. Once in the body, because elemental mercury is lipid soluble, it can cross biological membranes including the blood-brain barrier and the placenta [13]. Mercury is circulated throughout the body and can accumulate in the brain and the kidneys causing changes in neurological and renal function. The absorbed elemental mercury is oxidized to Hg2+ and is excreted in the urine [12]. Besides being expensive, fluorescent lamp recycling programs cannot achieve 100% compliance. Phasing out the production, trade and consumption of mercury-containing household products, and using alternative mercury-free technologies and products are the ultimate way to keep mercury out of the waste stream [33,34]. However, fluorescent lamps should not be subjected to such mercury bans because of their environmental and economic benefits, along with the lack of a feasible alternative. Policies, regulations and laws that deter the adoption and use of fluorescent lamps could be more detrimental to public health and the environment due to the lost energy-savings. Instead, the mercury risk from fluorescent lamps can be controlled through better product design and manufacturing by the lamp manufacturers [35]. Through collectively investing millions of dollars in new lamp manufacturing equipment and processes, the lighting industry in the U.S. has significantly reduced the use of mercury in fluorescent lamp production [36].

VI. CONSUMER RESPONSIBILITIES

Because CFLs are fragile, and broken glass and the mercury content present a health and safety risk, recovery from the waste stream after disposal is not feasible. CFLs should therefore not be thrown into the regular waste bin, but rather be kept separate and stored safely until an opportunity for disposal is available. The success of a CFL recovery initiative is entirely dependent on participation by the householder or residential consumer. A guideline for safe and effective householder participation is provided here (see Table 1):

Table-1. Consumer Responsibilities

Consumer		
	Best Practice	**Additional Information**
Objective	No CFLs are to be disposed of at a landfill for	General landfill sites are not designed to accommodate the

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	general household waste.	Release of mercury. Mercury needs to be treated (encapsulated in concrete or similar) to prevent leaching and release into the environment (e.g. atmosphere or groundwater).
Legislation	Minimum Requirements for Hazardous Waste Disposal (www.dwaf.gov.za/Dir_WQM/docs/Pol_ Hazardous.pdf) and any relevant municipal bylaws.	The Minimum Requirements state that hazardous waste must go to a hazardous landfill site. Check with the local municipality's department of solid waste management for suitable local requirements or solutions for hazardous household waste.
What to do with CFLs	Do not throw CFLs away with your domestic waste. Keep CFLs separate until you can safely take them toa drop off/collection point.	Ideally CFLs should not be broken and should be placed in their original packaging or wrapped in a plastic bag.
	In the event of breakage, special care must be taken to clean up and contain mercury powder and glass shards.	Advice on cleaning up broken fluorescent lamps is freely available on the Internet and also on Eskom's website at: http://www.eskomdsm.co.za/?q=CFL_Recovery.
Where to take your CFLs	CFLs can be taken to participating retailers and collection points in your area.	At present Woolworths and Pick 'n Pay stores offer CFL Collection points. Pick 'n Pay also accepts household batteries for disposal and recycling. Check with your local council for any other options for disposal of household hazardous wastes such as empty containers or leftover thinners, paints, poisons, batteries, etc.
How to store your CFLs	Spent CFLs should ideally arrive at a drop-off point unbroken. The lamps should therefore be securely packaged in a safe container for storage and transport	It is recommended that packaging in which CFLs are bought is kept and used for this purpose. Alternatively, packaging of replacement lamps can be used if readily available.

Municipal Responsibility

The recovery of most household hazardous wastes from the waste stream after disposal is a challenge and presents the risk of repeat exposure to any person tasked with extraction of recyclable waste (whether at a material recovery facility or less formally from bins on sidewalks or at a landfill). Municipalities should lead the drive to encourage a culture of separation of waste at the home for ALL wastes for which a recovery solution is being offered or a market exists (see Table 2):

Table-2. Municipal Responsibility

Municipality		
	Best Practice	**Additional Information**
Objective	Prevent disposal at the local general Landfill facility. CFLs must be kept away from other waste at point of generation by the homeowner.	Municipalities should proactively encourage separation at source of all recyclable and hazardous household wastes including specifically CFLs.
Legislation	Municipal functions are guided by the Municipal Systems Act, NEMA and the Minimum Requirements for general landfill and hazardous waste.	Waste separation is an important step in the Government drive for Wasteminimisation and key to achieving the waste hierarchy: Reduce, Re-use, Recycle.
How to implement in your municipal area	Educate and create awareness among the public regarding the need for waste separation and specifically the need for separating CFLs and other hazardous Wastes from the waste stream.	Have available and provide information (e.g. with billing information and/or on enquiry) of local recycling and recovery initiatives such as paper and glass banks, recycling collection services, Ewaste collection points or initiatives and particularly participating retailers that accept CFLs (refer to drop-off centre component of this guideline).

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Industry Responsibility:

A communication strategy is part of the requirements of an Industry Waste Management Plan as described in the Waste Management Bill (pending enactment, expected early 2009). Any Industry Waste Management plan for fluorescent lamps would rely heavily on participation, and hence the awareness of homeowners. The lighting industry would therefore have an obligation to collaborate with other stakeholders in creating awareness and educating the public about waste separation (see Table 3):

Table-3. Industry Responsibility

Industry		
	Best Practice	**Additional Information**
Objective	Prevent the disposal of CFLs and other fluorescent lamps with other households waste in order to facilitate recovery.	Although the Extended Producer Responsibility principle is already entrenched in existing legislation, the enactment of the Waste Management Bill and a Government request for an Industry Waste Management Plan will force active industry involvement with lighting waste.
Legislation	Industry's involvement will be most effectively governed under the pending Waste Management Bill, a subset of the National Environmental Management Act (NEMA).	
What to do with CFLs	CFL packaging should be labeled appropriately to educate consumers regarding mercury content and handling of CFL waste.	Different graphics with supporting text could be used to educate the consumer about mercury content and requirements for safe disposal or recycling as appropriate. Labels should be clearly visible and understandable.
	Call centre details to be provided on packaging and call centers should be empowered to deal with enquiries relating to safe disposal and handling of CFL waste.	A collaborative effort among lighting suppliers can address all these calls or alternatively existing call centers can be briefed to deal with these questions.
	Labeling should ideally highlight the opportunity for re-use of packaging material (assumed optimal format to prevent breakage of lamps).	Consumers should be encouraged to re-use packaging material for safe storage and transport of spent CFLs.

Department of Environmental Affairs and Tourism (DEAT) Responsibility:

National Government support for a nationwide CFL recovery mechanism is critical to the success of the initiative. More generally, the encouragement of separation at source will promote the shift towards more sustainable waste management strategies and practices, and place emphasis on the reduction; re-use and recycling of wastes (see Table 4):

Table-4. Industry Responsibility

DEAT		
	Best Practice	**Additional Information**
Objective	To encourage thorough legislation and regulations and to enforce separation at source of all recyclable and particularly hazardous household waste.	Separation at source is an essential component of all recycling initiatives and should be widely encouraged.
Legislation	DEAT's involvement is governed by the national legislative framework including: the Constitution, National Environmental Management Act and Municipal Systems Act.	
Where to enforce separation at source	Encourage and support the inclusion of the concept into Municipal Integrated Waste Management Plans and the development of bylaws to enforce separation at source by homeowners.	Emphasis should be placed on the importance of appropriate handling of hazardous household waste among all role players and every entity under legal obligation to comply.
How to support separation at source	A national education campaign. General education must be provided to the public to improve their knowledge of the impact of mercury bearing lamps on the environment. Support should also be provided to provincial departments and local municipalities in the form	Overall education relating to waste, recycling and hazardous household waste has been identified during public consultation as an imperative since existing awareness levels are extremely low. Education with regard to the benefits of using energy saver lamps should also form part of

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	of information sharing, education and empowerment.	communications.

REFERENCES

[1] F. Zahir, S.J. Rizwi, S.K. Haq, and R.H. Khan, "Lowdosemercury toxicity and human health", Environ Toxicol Pharmacol, vol. 20, pp. 351–60, 2005.

[2] T.W. Clarkson, "Mercury: major issues in environmental health", Environ Health Perspect, vol.100, pp. 31–81, 1993.

[3] R.D. Snyder, "Congenital mercury poisoning", New Engl J Med, vol.284, pp. 1014–6, 1971.

[4] D.W. Boening, "Ecological effects, transport, and fate of mercury: a general review", Chemosphere, vol. 40, pp. 1335–51, 2000.

[5] T.W. Clarkson, "Mercury: major issues in environmental health", Environ Health Perspect, vol.100, pp.31–8, 1993.

[6] P.B. Tchounwou, W.K. Ayensu, N. Ninashvili, and D. Sutton, "Environmental exposure to mercury and its toxic pathologic implications for public health", Environ Toxicol, vol.18, pp. 149-75, 2003.

[7] S. Ska˚ rup, C. Lu?beck Christensen, "Mass Flow Analyses of Mercury 2001", Environmental Project Nr. 917 2004, Danish EPA, 2004.

[8] T.C. Chang, and J.H. Yen, "On-site mercury-contaminated soils remediation by using thermal desorption technology", J. Hazard. Mater, vol. 128, pp.208–217, 2006.

[9] M. Aucott, M. McLinden, and M. Winka, "Release of mercury from broken fluorescent bulbs", J. Air Waste Manage, vol. 5, pp. 143–151, 2003.

[10] C. Raposo, C.C. Windmoller, and W.A.D. Junior, "Mercury speciation in fluorescent lamps by thermal release analysis", Waste Manage, vol. 23, pp. 879–886, 2003.

[11] USEPA homepage www.epa.gov/rcraonline.

[12] HPA (Health Protection Agency), "Inorganic mercury/elemental mercury", Toxicological Overview, HPA, United Kingdom, 2006.

[13] J.F. Risher, R.A. Nickle, and S.N. Amler, "Elemental mercury poisoning in occupational and residential settings", Int. J. Hyg. Environ. Health, vol. 206, pp. 371–379, 2003.

[14] J.F. Risher, and C.T. De Rosa, "Inorganic: the other mercury", J. Environ. Health, vol. 70 (4), pp. 9–16, 2007.

[15] ATSDR (Agency for Toxic Substances and Disease Registry), Toxicological profile for Mercury. US Department of Health and Human Services, Public Health Service, Atlanta, Georgia. 1999.

[16] S.A. Counter, and L.H. Buchanan, "Mercury exposure in children: a review", Toxicol. Appl. Pharmacol, vol. 198, pp. 209–230, 2004.

[17] K. Schoeman, J.R. Bend, J. Hill, K.M.A. Nash, and G. Koren, "Defining a lowest observable adverse effect hair concentrations of mercury for neurodevelopment effects of prenatal methyl mercury exposure through maternal fish consumption: a systematic review", Ther. Drug Monit, vol.31 (6), pp. 670–682, 2009.

[18] N.C. Johnson, S. Manchester, L. Sarin, Y. Gao, I. Kulaots, and R.H. Hurt, "Mercury release from broken compact fluorescent lamps and in situ capture by new nanomaterial sorbets", Environ. Sci. Technol. vol. 42, pp. 5772–5778, 2008.

[19] NJ MTF (New Jersey Mercury Task Force), New Jersey Mercury Task Force Volume III: "Sources of Mercury to New Jersey's Environment", Department of Environmental Protection, New Jersey, 2002.

[20] UNEP (United Nations Environment Programme), "Toolkit for identification and quantification of mercury releases": Pilot Draft Inter-Organization. Programme for the Sound Management of Chemicals, United Nations Environmental Programme, 2005.

[21] M. Aucott, M. McLinden, and M. Winka, "Release of mercury from broken fluorescent lamps", J. Air Waste Manage. Assoc, vol. 53 (2), pp. 143–151, 2003.

[22] M. Jang, S.M. Hong, and J.K. Park, "Characterization and recovery of mercury from spent fluorescent lamps", Waste Manage, vol. 25, pp.5–14, 2005.

[23] Environment Canada, "Mercury and the Environment – Sources of mercury –Mercury containing products", The Green Lane – Environment Canada's World Wide Web site, 2004.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 1, January 2013
[24] D. Stahler, S. Ladner, and H. Jackson, “Maine Compact Fluorescent Lamp Study”, Department of Environmental Protection, Maine. 2008.

[25] A. Capri, “Mercury from combustion sources: a review of the chemical species emitted and their transport in the atmosphere”, Water, Air, and Soil Pollut, vol. 98, pp. 241–254, 1997.

[26] A. Cain, S. Disch, C. Twaroski, J. Reindl, C.R. Case, “Substance flow analysis of mercury intentionally used in products in the United States”, J IndEcol, vol.11, pp. 61–75, 2007.

[27] C. Dunmire, C. Calwell, A. Jacob, M. Ton, T. Reeder, V. Fulbright, “Mercury in fluorescent lamps: environmental consequences and policy implications for NRDC”, Final report prepared for Natural Resources Defense Council. Durango, CO: Ecos Consulting; 2003.

[28] United States Environmental Protection Agency (USEPA). Mercury emissions from the disposal of fluorescent lamps, revised model, final report; Washington, D.C. 1998.

[29] Y. Li, and L. Jin, “Environmental release of mercury from broken compact fluorescent lamps”, Environ Eng Sci, vol.28, pp. 1–5, 2011.

[30] Tetra Tech/Frontier Geosciences. “Information on Fate of mercury-containing lamps disposed in landfills”, Pasadena, CA; 1994.

[31] P.S. Harikumar, A. Dhruvan, V. Sabna, A. Babitha, “Study on the leaching of mercury from compact fluorescent lamps using stripping voltammeter”, J Toxicol Environ Health- A, vol. 3, pp. 8-13, 2011.

[32] D. Parsons, “The environmental impact of compact fluorescent lamps and incandescent lamps for Australian conditions”, Environ. Eng, vol. 7 (2), pp. 8–14, 2006.

[33] H. Cheng, and Y. Hu, “China needs to control mercury emissions from municipal solid waste (MSW) incineration”, Environ SciTechnol, vol.44, pp. 7994–5, 2010.

[34] H. Cheng, and Y. Hu, “Mercury in municipal solid waste in China and its control: a review”, Environ SciTechnol, vol.46, pp. 593–605, 2012.

[35] C. Dunmire, C. Calwell, A. Jacob, M. Ton, T. Reeder, V. Fulbright, “Mercury in fluorescent lamps: environmental consequences and policy implications for NRDC”, Final report prepared for Natural Resources Defense Council. Durango, CO: Ecos Consulting; 2003.

[36]. National Electrical Manufacturers Association (NEMA).Fluorescent and other mercury containing lamps and the environment: mercury use, environmental benefits, disposal requirements; Rosslyn, VA. 2005.

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