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A Comparative Analysis of the Total Mercury Content of CFL brands sold in the Philippine Urban Market

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Foreword

Executive Summary

A compact fluorescent lamp (CFL), also known as compact fluorescent light or energy-saving light, is a type of fluorescent lamp which can replace incandescent lamp as it can fit into most lighting fixtures. It can last between 6,000 to 15, 000 hours, which is 8x to 15x higher than the conventional ICL. Replacing ICLs with CFLs in the global scenario is estimated to reduce the lighting sector's demand for energy by nearly 40%, thus eliminating 900 million tons of CO_2 emissions annually. Due to its energy- saving character, portability and ability to produce soft white light, a shift in the production and use of CFLs in the global consumer market is seen, with most governments such as the United States and European Union pushing for this energy- saving scheme.

At the National Energy Summit in 2008, the Philippine government announced the country's shift from ICLs to energy- efficient CFLs by January 2010. To achieve this goal, the Department of Energy (DOE), through a US$46.5 million worth of loan and grant agreement with the Asian Development Bank (ADB), has launched the Philippine Energy Efficient Project (PEEP) which includes, among others, the distribution of 13 million compact fluorescent light bulbs nationwide.

The implementation of the PEEP has claimed to save US$90 million from avoided fuel costs, and US$1.3 billion deferred investments in power generation. However, the advantages of using CFLs have eclipsed its other environmental implications. Since CFL bulbs invariably contain mercury in differing amounts, concern over the switch to mercury- containing lamps for energy efficiency has become prevalent. Without a corresponding adequate consumer education on toxic risks and a functional system for managing lamp wastes, the adverse health and environmental impacts of toxic mercury exposure may ensue. Mercury in CFLs, while "small" in numbers, may pose a major health risk to the whole population, especially to its vulnerable sectors-- children and pregnant women. CFL wastes are commonly improperly disposed off by dumping, burning or recycling in unregulated conditions, thus causing the dispersal of the toxic metal into the environment. Exposure to high levels of mercury can cause permanent brain damage, central nervous system disorders, memory loss, heart disease, kidney failure, liver damage, vision and sensation loss and tremors.

The DOE, through the PEEP, has allocated US$1.5 million to set up a mercury waste management facility to recover mercury from used fluorescent lamps. Also, they are developing a plan on Extended Producer Responsibility (EPR) in consultation with CFL producers, but what is missing in this effort is how to pressure manufacturers to ratchet down the mercury content in their CFLs. Since most product labels do not provide information about the product's mercury content, its quantity and the necessary steps to be followed for disposal, consumers are left unaware and unprepared on how to manage the ensuing CFL waste.

BAN Toxic's proposed CFL study does not touch on end-of-pipe problem with CFL, but more on the manufacturing side. Inspired by the ToxicsLink study, "CFL: Poison in the Glow", BT aims to replicate the study by ToxicsLink and give it a Philippine context. Thus, the study aims to:

1. Determine CFL Hg content in the local market and develop a report outlining the mercury content of each CFL;
2. Pressure manufacturers and distributors to address Hg content in their product and proper labelling.
3. Present findings to the government and media and create pressure on manufacturers to clean up their act on mercury.

A total of 88 samples from 6 CFL brands were randomly collected, procured and recorded accordingly. The CFL samples were sent to Delhi Test House for mercury content analysis. The key findings and conclusions are as follows:

a. CFLs sold in the Philippine market considerably falls under the 5mg limit set by international standards such as the European RoHS and US EPA. Even though the average content value for CFLs fall under the 5mg limit (3.258mg Hg), some units still have a record high of 17.47mg, which exceeds the standards three folds. Of the samples analyzed, 20.45% were found to have mercury content higher than the EU RoHS standard of 5mg. 28.57% of Philips samples have higher contents than the standard, whilst CATA/ Otaca and Osram only recorded 13.33% of the samples.
b. The average mercury content values per wattage category across brands are: 3.612mg for 5W, 4.516mg for 7W, 4.561mg for 8W, 2.661mg for 9W, 3.429mg for 11W and 2.733mg for 14W.
c. The variance on mercury dosing per brand is highest for GE 8W, with a standard deviation (SD) value of 9.018. The lowest variance value was Osram 13W, with SD value of 0.474.
d. Over- all, the mercury content per watt decreases with increasing wattage category. The highest average Hg/ watt value is 0.722mg Hg/W for 5W and the lowest is 0.056mg Hg/W for 13W.
e. Mercury dosing in Philippine CFLs seem to be quite random. Higher wattage units tend to have slightly lesser mercury content compared to those with lower wattage.
f. In a scenario where each Metro Manila household consume 1 CFL unit per year, the mercury input or consumption may range from 0.234 Kg/ year to 2.848 Kg/y. These values would have a devastating effect on the ecology if improperly disposed or discarded in the waste stream. 0.5 to 1.5g of elemental mercury is known to contaminate a 20- acre lake to an unsafe level.

Given these results, the following recommendations are made:

a. The creation of a regulatory framework or standard for limiting mercury dosing in CFLs and end- of- life management practices must be initiated and implemented. These will provide the proper disposal mechanism or infrastructure that will deal with the discarded and used-up lamps, and thus prevent the imminent danger of mercury getting released into the environment and affecting vulnerable populations.
b. Since the Philippines import CFLs from other countries, stricter mandatory standards must be in put into place to force manufacturers to cap mercury dosing in their products. The government must come up with a maximum limit for mercury dosing in CFLs, and they can do so through exploring policies being implemented at the international level such as the European RoHS. Technically, mercury dosing can be limited to 2-3 mg/ CFLs with less than

20 watts. This value is present and available in the market, and thus will also encourage manufacturers to standardize their production process, and to innovate green design.

c. Proper labelling must be made mandatory, which includes a mercury cautionary mark with specific amount present in CFL. The proper regulatory agency must be capacitated with the skills and equipment necessary to undertake random testing for products imported into the Philippines to check compliance of products to limits.

d. Extended producers responsibility (EPR) can be tapped to finance the infrastructure for CFL/ mercury management. This should be done through the joint efforts of the manufacturers, government, regulatory agencies, NGOs and CSOs and other stakeholders. Consumers have the responsibility for the proper disposal of broken and used- up lamps, as set by Philippine laws. They should be informed of the information on how to manage their lamp wastes and the accredited facilities that will do so.

Chapter I: Introduction

What is a CFL?

National and local efforts to promote energy efficiency as a mechanism to reduce climate change impacts have been gathering strength in the Asian region and other countries around the globe. Of the many available technological options, the use of compact fluorescent bulbs as an alternative for incandescent lights in the residential sector serves to be one of the mainstays of most energy efficiency campaigns [1]. This promotion has led to an accelerated increase in global demand for this robust energy- efficiency measure.

A compact fluorescent lamp, also known as compact fluorescent light or energy- saving light, is a type of gas- discharge, fluorescent lamp that is designed to fit light fixtures formerly used for incandescent lamps [2]. Aside from the easy switch from traditional light bulbs to CFLs due to structural considerations, CFLs give the same or more amount of visible light and have longer rated life as compared to general service incandescent lamps [3, 4]. Wattage wise, CFLs consume at least two- thirds less energy and generate 70% less heat, thus, they are safer to operate and can also reduce energy costs associated with cooling homes and offices [4].

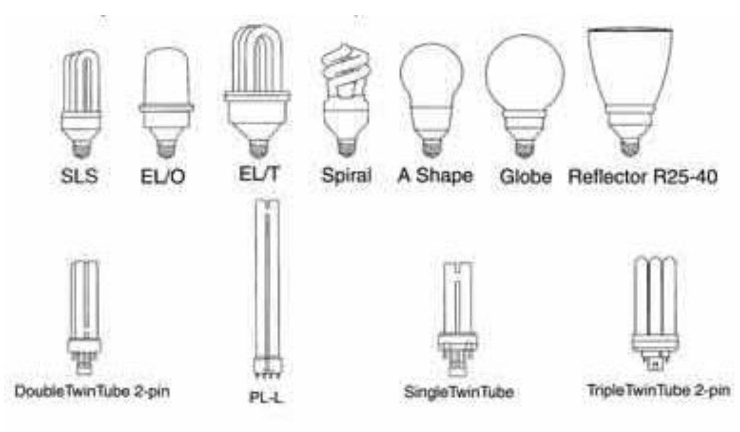

Figure 1. *Types of Compact Fluorescent lights according to bulb shapes [5]*

There are many types of CFLs, each constructed differently, but with technology that is similar [5]. Their wattage normally ranges between 5 and 50 watts and generally comes in U- bar or spiral shapes. A good CFL would last between 6,000 to 15,000 hours, 8 to 15 times higher to that of a conventional incandescent lamp. The light output of a CFL is roughly 4 times higher per watt compared to an ICL [3, 4]. Initially, CFLs tend to be more expensive than ICLs but because it lasts longer and costs so much less to run, it proves to be a better bargain over time. Replacing a 100W incandescent bulb with a 20 W CFL will save a household 4, 215.50 PHP, which is also equivalent to 5 ICL units used over time [15].

SAVINGS CHART - QUALITY CFL vs. QUALITY INCANDESCENT BULB

	INCANDESCENT BULB	COMPACT FLUORESCENT LAMP
Input Power, watts	100 W	20 W
Cost of First Lamp, Php	21.00 Php	150.00 Php
No. of Lamp Replacements, units	5 units	0
Replacement Cost	105.00 Php	0
Energy Cost	5,298.00 Php	1,060.00 Php
Total Energy & Lamp Cost	5,424.00 Php	1,210.00 Php
Net Savings		
Cost, Php		4,214.50 Php
Demand, kW/unit		0.080 kW/unit
Consumption, kWh		480 kWh
Greenhouse Gas (GHG)		285 kg CO2e

Figure 2. Quality CFL savings chart [15]

Under a global scenario, substituting incandescent lights with CFLs would reduce the lighting sector's energy demand by nearly 40% and save 900 million tons of CO_2 annually by the year 2030 [2, 6]. In the United States alone, replacing just one regular ICL with a CFL would prevent greenhouse gas emissions from power plants amounting to 90 billion pounds, which is equivalent of taking 7.5 million cars off the road [4].

With its energy- saving character, portable size and ability to produce soft white light, the CFL markets in almost every country in the world is experiencing extremely rapid growth. As of 2005, the annual volume of CFL sales in the Philippines have reached 25 million units, compared to the 4.5 million sold in 2001 [1].

Mercury and/ in CFLs

Anatomy of a CFL

Unlike incandescent bulbs, energy- saving lights save energy by converting ultraviolet (UV) light to visible light. This is similar to the one used by creatures like fireflies, whose bodies contain chemicals that make cool light without any heat [7].

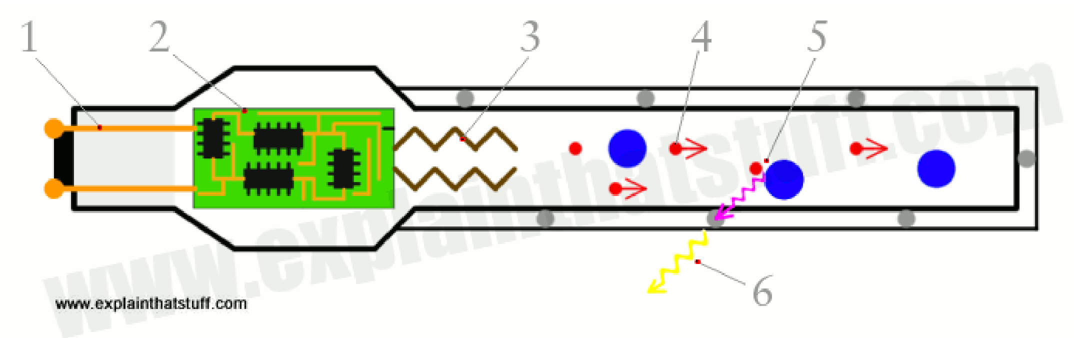

Figure 3. Anatomy of a CFL [7]

Like all fluorescent lamps, mercury is an integral component of CFLs. When electricity flows into the electrodes, electrons are elevated into an excited state and shoot off down the white thin tubes and collide with atoms of mercury. The presence of mercury greatly increases the ultraviolet light produced, as well as the amount of current that can flow through the gas. The UV light produced is then converted to visible light when it passes through the phosphor coating at the inside of the glass tubes [2, 7, 8]. Since a small amount of mercury in energy- saving fluorescent lamps is needed to convert electricity into light more efficiently, it is very crucial to approach the whole debate on mercury in lamps in a holistic, rather in an isolated approach. So far, no other materials have been discovered to replace mercury and reach comparable energy- efficiency, lifetime and light quality [9]. Thus, stakeholders and the lighting industry must continuously work toward greater mercury reduction and eventual elimination.

Manufacturing Process of Fluorescent Lamps

Manufacturing CFLs is more complex and expensive than incandescent bulbs. The process begins with the cutting of straight glass shells which are then bent into a U shape. These tubes are washed in chemically- purified water at a temperature of 65 to 75^{o}C and dried for about 25 minutes at a temperature of about 80^{o}C. A fluorescent powder coating, consisting of a combination of phosphor (containing calcium phosphate, aluminium oxide) and polyethylene oxide and dispersion agents, is prepared with a binder and purified water is then applied to the glass shells. The tubes are dried and put in a baking machine that maintains a temperature of 550^{o}C. After 3 minutes, the tubes are taken out and a fluorescent- whitening agent is applied. The filament is slipped inside the tubes, which is then mounted and locked in a sealing machine. The tubes are vacuumed in an exhaust machine, and mercury and argon are introduced into the tubes while the cathodes are heated. The mercury can either be in the form of pellets or liquid, depending on the mercury dosing technique employed by the manufacturers. The heated cathodes turn the mercury into gas. The tubes are sealed using a tipping machine and the electrical components are soldered with the tubes. The CFLs are capped with a plastic base and sent for quality- checking that involves grading of CFLs based on their luminescence [10].

Theoretically, the amount of mercury required in vapour form in the discharge to energize the lamp is 50µg, which is about 0.5 to 2.5% of the total mercury placed in the lamp when manufactured [11]. Thus, there must be enough initial elemental mercury in the lamp so that at least

50μg is available in vapour form at the end of the lamp's rated life. Mercury dosing techniques have evolved since 1927, with average mercury dose being reduced by about two- thirds by 1985 [11, 12]. In 2005, mercury dosing was performed manually by hand using precision syringes, but by 2007, this technique was abandoned by all large manufacturers involved in US imports and was replaced by amalgam pellets [12]. In its solid form, mercury that is chemically combined inside a metal alloy in the amalgam cannot escape in the event of a lamp breakage. The amalgam technology also enables minimal dosing of mercury to even less than 2mg per amalgam [13]. It is claimed that approximately 70% of all Chinese CFLs adopted amalgam dosing techniques by 2007 [13].

Mercury content of lamps

The adoption of the European Union's RoHS (Restriction on Hazardous Substances) standards has propelled the development of improved techniques which allow precise mercury dosing in CFL units. In 2007, the National Electrical Manufacturers Association (NEMA) in the US has agreed on a mercury content standard of 5mg per unit for CFLs that use less than 25 watts of electricity, and 6mg for CFLs that use 25 to 40 watts [12]. These values are then lowered in 2010, with the espousal of a mercury content standard of 4mg per unit for CFLs that use less than 25 watts of electricity, and 5mg for CFLs that use 25 to 40 watts [2]. The EU RoHS directive even envisions to limit mercury content per CFL to 2.5 mg by 2013 [2]. Mercury content standards are influenced by a variety of factors [9]. For example:

- Age matters: Modern lamps contain less mercury than older models due to the advancement on mercury dosing techniques employed by CFL manufacturers;
- Lamp life doesn't matter: Long- life lamps do not tend to have more mercury. CFL lifespan is dependent on factors such as operating voltage, manufacturing defects, exposure to voltage spikes, mechanical shock, frequency of cycling on and off, lamp orientation and ambient operating temperature-- mercury is rarely a determining factor [14];
- Shape often matters: Circular and U- bent fluorescent lamps often have more mercury than linear models of the same wattage due to the difference in surface areas of the units;
- Size matters: Bigger fluorescent lamps tend to have more mercury than more commonly used smaller fluorescents because manufacturers have often reformulated their most-popular lamp production lines with low- dosing technology. For instance, the 2001 US average ranges from 7 to 9mg for 4ft T8 linear lamps, while 8ft T12 lamps have approximately 12mg of mercury.
- Brand matters: There is sometimes a significant variation in mercury content among equivalent lamps offered by different manufacturers. Depending on the dosing technique used, manufacturers have competitively designed their units based on national and international standards.

Considering both mercury content and energy efficiency, there is usually a "win- win" situation since the most efficient types of fluorescent lamps often have the lowest mercury content.
Some CFL models marketed in the US have less than 5mg, as reported by the manufacturing companies. These include Philips (1.23 to 2.7mg), Osram- Sylvania (1.5 to 3mg), MaxLite (1.2 to 2.5mg) and Litetronics (1mg) [9]. Report from the EEB conference in 2008 saw industry proposal to

set higher allowable levels of mercury of 3.5mg of mercury per lamp, while NGOs proposed 2mg of mercury per lamp since lamps containing 1.4mg are already available in the market [9].

Mercury emissions due to electricity consumption

Apart from the mercury which may be released from a mercury- containing lamp, mercury is a trace element in coal burned in power plants to produce electricity. Thus, the energy consumed in a light bulb's lifetime causes mercury releases in the atmosphere. Lower energy consumption through the use of energy- saving lamps leads to less mercury emissions, as compared to using incandescent lights. Since mercury releases vary with the percentage of coal and the mercury content of the coal in the fuel mix, reductions of mercury emissions due to the use of CFLs may vary depending on the region and country. For instance, computations made by the US Environmental Protection Agency showed that a typical CFL is responsible for releases of about 1.7mg of mercury from electricity generation and disposal, while an incandescent lamp is responsible for releases of about 5.8mg. The European situation on the other hand showed that a typical CFL is responsible for releases of about 2.4mg of mercury from electricity generation and disposal, and 3.5mg for incandescent lamps [9].

In August 2008, DENR conducted an inventory of mercury emissions in the Philippines. The study identified the extraction and use of fuels and the use of products, including CFLs, as major contributors totalling to 21% and 23% of annual mercury emissions respectively [16]. As a result, it is imperative that mercury content be reduced to its absolute minimum, as well as to maximize the lifetime and lumens of all mercury lamps.

Chapter II: Rationale of the Study

CFL's Growing Market Demand

Concerns on energy security, air pollution and climate change have prompted national policymakers to focus on the need to have energy conservation and clean energy promotion programs in their countries. These programs include the use of CFLs as an alternative to the incandescent lighting technology, which triggered the dramatic increase of CFL production and sales at the global level. Earlier this decade, 1 billion units of CFLs were purchased, with the trend increasing to 2 billion units annually. With plans to phase out incandescent bulbs, the global trend may increase to up to 4 billion units annually by the end of this decade [1].

The Asian region reflects similar CFL production growth, with China leading the region, and the world, in the number of CFL manufacturers. For instance, in 2007, there were at least 150 CFL manufacturers and 200 suppliers of special CFL materials and components in China, where more than 90% of the CFLs sold worldwide are currently manufactured [17]. In contrast to China's growth in CFL manufacturing, the number of CFL manufacturers in other Asian countries has dwindled in the past 5 years, with the Philippines having no domestic manufacturing plants [1]. Thus, CFL units available in the Philippine market are imports, with the majority of them having Chinese origins. As of September 2011, 22 CFL brands spanning wattage categories of 3W to 55W have passed the Philippine National Standard (PNS) for compact fluorescent lamps [PNS IEC 969:2006 and PNS 2050-2:2007] [18]. *Insert data on CFL market share in the Philippines.* The majority of these brands are manufactured in China.

Several factors have contributed to the success of CFLs in the Philippine market. Some of these are the [19]:

- Proliferation of information dissemination campaigns which demonstrate the economic benefits of switching from incandescent lamps to CFLs;
- Repositioning of CFLs as an energy- saving, resource- conserving and environment-friendly product;
- Increased number of CFL imports and the emergence of sidewalk vendors and door-to door peddlers bring CFLs closer to the customers;
- Participation of different stakeholders, such as Filipino NGOs, consumer groups and cause- oriented groups, in relating energy and environment benefits which support the lighting transformation program;
- Promotion of optimum mix of lighting technology which further increases the opportunity for households, commercial and industrial sectors to avail proper lighting designs;
- Recognition of the different Philippine market segments and their purchasing power or ability to pay, with the majority of the urban households belonging to the D and E market segments choosing to buy the most affordable lighting available.
- Recognition of the market's basic needs and preferences, with the less affluent households sacrificing measures of CFL performance over brand name or price.

A survey made in 2007 showed that the market shares of high quality, well- known brands in the Philippines have reached 68% whilst poor and very poor quality brands claim 32% [1]. These high- quality brands have evidence of testing and quality registrations, whilst the "shoddy" ones have no proof of testing. However, the results of the study may have been limited due to the fact that the available data analyzed do not adequately represent the number of "black market" CFLs- products that are not tested and therefore not registered in the formal product control system. Thus, low- quality CFL products may occupy a larger share of the market than the surveys were able to capture [1, 17].

Philippine Energy- Efficient Projects

Initially, the Philippines was one of the 7 pilot countries for the Efficient Lighting Initiative (ELI) program funded from the Global Environmental Facility (GEF) and administered globally by the International Finance Corporation (IFC). For the program duration spanning from May 2000 to December 2003, a total budget of USD 2.5 million was used to sustain ELI's goal of reducing GHG emissions by accelerating the growth of the market for energy- efficient lighting technologies and services. Prior to the ELI- marketing assessment, approximately 6 out of 10 CFL brands were found to be traded illegally, having no import commodity clearances (ICCs). This reveals a wide and deep penetration of low- cost, low- quality CFLs which left the consumers vulnerable to fake, substandard and unreliable products [23]. In response, the global ELI program developed voluntary technical specifications that addressed product efficiency and reliability. The lighting product testing capability of the Department of Energy- Lighting and Appliance Testing Laboratory (DOE-LATL) was strengthened through provisions of equipment and training for CFL energy performance testing.

Further initiatives made through political commitments to reduce GHG emissions have helped shine a spotlight on CFLs, with the government of the Philippines announcing at the 2008 National Energy Summit the country's shift from energy- wasteful incandescent bulbs to energy-efficient CFLs by January 2010, the first country in Asia to do so on a national scale [20, 21].

The United Nations Development Programme (UNDP) and DOE developed the Philippine Efficient Lighting Market Transformation Project (PELMATP) in 2002, which aimed to promote the application of energy- efficient lighting in the country's public sector. Through the financial support from GEF, PELMATP's strategic components included the [21]:

1. Establishment and/ or enhancement of policies, standards and guidelines, which included, among many others, the issuance of Administrative Order No. 183 or the retrofitting of government buildings with energy- efficient lighting (EEL);
2. Development of EEL institutional and technical capacities on EEL applications, such as the acquisition of ISO certification for DOE- LATL;
3. Improvement of EEL consumer awareness through *Palit- Ilaw* (Switch to EELs) for the public sector;
4. Implementation of financing assistance programs for EEL initiatives, and;
5. Development of EEL systems waste management

The Philippine government's energy efficiency project (PEEP) has an estimated total cost of USD 46.5 million. A special report by the Department of Energy, PEEP's implementing agency, published in the Philippine star (July 24, 2009) claimed annual savings of about USD 90 million from avoided fuel cost with the introduction of energy- efficient CFLs and the implementation of other project components [20, 21]. Though the implementation has proceeded satisfactorily, activities for the 5th component of the program has been proven to be a challenge for its implementing agency. This component consists of [21]:

- Awareness creation on the proper disposal of CFLs, as well as the proposed expansion of waste recycling facility;
- Development and distribution of guidebooks on lamp waste management through the Department of Environment and Natural Resources- Environmental Management Bureau (DENR- EMB), and;
- Implementation of information campaigns and directory of lamp waste generation.

Though the switch from inefficient incandescent bulbs to EELs has brought a tremendous amount of benefit for the environment, government and the society, the move came with a price. Mercury in CFLs, when not properly disposed off, poses a hazardous risk to the environment and to humans.

CFL's Quality, Environment and Health Concerns

CFL Regulations, Testing Programs and Cost of Compliance

Several countries, including the Philippines, have responded to the extreme growth of the CFL markets by implementing a number of measures designed to control CFLs in their countries, which includes safety standards or requirements, efficiency standards or labelling requirements and minimum energy performance standards (MEPS). In the Philippines, passing both MEPS and labelling requirements are mandatory for CFL units. The national standard, PNS 603-2- Amd. I:2001 are based on the International Electrotechnical Commission (IEC) standard 60969, which covers testing of product performance. Though the Philippines require mandatory testing for CFL safety requirements under IEC 60968, it only tests the unit for mechanical issues and integrity or fit of CFLs—not its mercury content. Thus, the term "CFL quality" is now more commonly used to refer only to overall CFL performance including: testing, efficacy, lifetime, color rendering and color temperature, start- up time, lumen maintenance and warranty [1, 17].

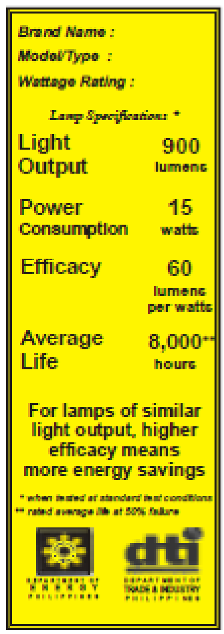

Figure 4. Energy Labelling Program Standard for CFLs in the Philippines [15]

DOE, through its Consumer Welfare and Promotion Office, launched its Energy Labelling Program in 2004, with the goal of providing information to consumers on the energy efficiency performance of the product. The main objectives of the program are [15]:

- To eliminate the least efficient lighting system in the local market;
- To reduce monthly electric bill;
- To protect consumers from mislabelling;
- To encourage manufacturers to improve product efficiency, and;

- To reduce greenhouse gas emissions.

Since the CFL promotional strategy of the government is heavily based on perceived reduction in energy demand and carbon emission, the issue of mercury gets diluted in the equation. CFL's sold in other countries' markets sometimes have the mercury caution mark in product labels, such as those in India [2]. In the Philippines, however, no brand has the same mark in their labels.

Channels of mercury exposure

Insert figure. Mercury exposure pathway (manufacturing → households → collection → recycling or disposal → environment → bio accumulation and biomagnification)

The relation between CFLs and mercury emission is not limited to the actual mercury content of the CFL bulbs. Different mercury emission pathways have already been identified, starting from the assembly of CFL units. Mercury can be released during the manufacturing process, especially if hand- dosing of liquid mercury is used. It can also be released when the lamp breaks during its distribution from the factory to the retailer to the consumer and eventually to disposal. Specifically, the improper disposal of lamps in dumpsters, rubbish bins, incinerators and landfills, cause the emission of mercury into the atmosphere. Even if lamps get recycled, mercury can evaporate during crushing, mercury- recovery, as well as metal smelting. In the end, all of these instances must be addressed in order to remove and recycle the mercury content of CFL units [9, 23].

Republic Act No. 9003 or the Ecological Solid Waste Management Act of 2000 outlines the specific roles and responsibilities of stakeholders on solid waste management, with provisions on proper waste segregation at source and recycling. Lamp wastes are not directly mentioned in the implementing rules and regulations (IRR) of the act, though it is designated under special wastes [23, 25]. Special wastes coming from both residential and commercial sources should be collected and handled separately from domestic wastes, and not thrown in landfills or burned [24]. Data from the PELMATP have shown that majority of lamp waste sources dispose off their mercury- containing lamp waste together with domestic wastes, which depicts the lack of awareness of the Filipino consumer on handling special wastes which pose a risk to their health and to the environment. A survey conducted by A2D Research Alternatives and Ban Toxics in Cebu, Davao and Marikina show that only one- third of household lighting equipments are stored, whilst the remaining two- thirds are dumped with domestic wastes [28, 29].

Table 1. Percentage of Lamp Waste Disposal [20, 21]

Lamp waste sources	Percentage of Lamp Wastes	
	Disposed with domestic wastes	Sold to Junk shops
Households	88%	1%
Commercial establishments	77%	3%
Hospitals	33%	67%
Offices	9%	9%
Schools	83%	15%

The improper disposal of lamp adds mercury in the waste stream and exposes waste workers to mercury during the process of collection, transportation, dumping and recycling in unregulated conditions. Waste workers are directly exposed to mercury through touching the contaminated waste materials with bare hands and no protective clothing and through breathing the mercury- contaminated air [20].

Informal recycling of lamp wastes which is done to recover recyclable parts in the lamps' filament involves the archaic manner of smashing the lamps with a hammer and thus releasing mercury inside the glass housing. With no proper protective equipment and ventilation, these itinerant recyclers are greatly exposed to the hazards of mercury. On the other hand, spent CFLs not reclaimed by enterprising recyclers would normally end up being dumped in open and controlled dump sites or sanitary landfills. Since landfills and dumpsites are often located in environmentally-critical areas, dumping of CFLs can potentially affect biodiversity through air, water and land pollution. When water trickles through contaminated areas, mercury is released and enters surface water, groundwater and the soil. Surface and groundwater contamination have significant effects on the health of the food chain, damages the wetlands and impair their availability to support a healthy ecosystem in controlling flooding, filtering pollutants during typhoons, and water runoff. Humans and animals bathing or drinking contaminated water, or aquatic fishes ingesting contaminated water can bio- accumulate mercury in their bodies [27, 28]. Mercury found in soil and air can damage plants and animals when they absorb this substance through their roots, ingesting or touching contaminated soil and inhaling contaminated air.

Mercury released as a toxic vapour, during lamp breakage, readily pollutes the air causing harm to anyone who inhales it and adding to the global mercury burden. Mercury vapour in the air goes back down to the ground or water through rain and snow (wet deposition), or when it settles down by itself [25, 26]. Once released, mercury persists in the environment where it circulates between the air, water, sediments, soil and biota in various forms. Bioaccummulation of methylmercury increases concentration in marine organisms at the same time progressively builds up as it moves up the food chain. Since it has the ability to transport in long range far from where it was released, mercury pollution that happens in the community can contribute to global pollution and affect the global fish catch and eventually the food we eat [26]. Dermal exposure of contaminated air can result when it is in contact with the skin. Since plants rely mainly on respiration for growth, they are affected by contaminants transported in the air [27, 28].

The burning of mercury- added products in waste such as mercury lamps emits upwards of 200 tons of mercury in the atmosphere annually [16, 20]. Thus, this deliberately calls for a system for end- of- life management, to prevent mercury- containing lamps from being accidentally broken or improperly disposed off.

Effects of mercury exposure to the environment and health

Mercury is a naturally- occurring element, thus, it cannot be created nor destroyed through chemical means. It exists in various forms: elemental (or metallic), inorganic and organic, each of which has different toxicities and implications for health and for measures to prevent exposure.

Children with Congenital Minamata Disease due to intrauterine methylmercury poisonir
(Harada 1986)
Source: http://www.teratology.org/jfs/Agricultural.html

Figure 5. Effects of Mercury Exposure [23]

Elemental and organic mercury are toxic to the central and peripheral nervous system, with absorption percentages of 80 to 100% of the total amount of mercury form exposed to. The inhalation of mercury vapour can produce harmful effects on the different parts of the body, and specifically targets the nervous, digestive and immune systems, lungs and kidneys. For people with weak immune system and increased vulnerability to heavy metals, mercury exposure may prove to be fatal. Neurological and behavioural disorders may be observed after inhalation and ingestion of different mercury compounds, as observed in the victims of the Minamata incidence in Japan. Symptoms include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunctions. Children are especially vulnerable and may be exposed directly by eating contaminated fish. Methyl mercury bioaccumulated in fish consumed by pregnant women may lead to neuro- developmental problems in the developing fetus. Since the fetal brain is very sensitive, trans- placental exposure is the most dangerous and may lead to neurological symptoms including mental retardation, seizures, vision and hearing loss. In children, a syndrome characterized by red and painful extremities called acrodynia has been reported to result from chronic mercury exposure. Because children have smaller body size, similar levels of exposure to mercury will have a greater effect on them compared to adults [20, 25, and 26].

Since there is no safe level of exposure to mercury from which there are no adverse effects, steps must be taken to eliminate and prevent the risk of mercury exposure especially for women and children [25].

Chapter III: Methodology

Scope and objectives of the study

The study focuses on the determination of the total mercury content of different CFL brands sold in the Philippine urban market, with simultaneous analysis on the mercury burden contribution of these brands versus their efficacy and efficiency as lighting products. Lastly, the study should be able to suggest some policies and practice measures that could be taken up and implemented in order to manage the manufacture, storage and disposal of CFLs and CFL wastes.

The brands of the samples tested are published in the study in order to raise awareness of the consumers on the CFL products being sold in the market, with the aim of providing information on the risks and responsibilities that buying such products entails.

At the empirical level, the objectives of the study are:

a. To determine the total mercury content of 6 brands of CFL bulbs sold in the local urban market;
b. To describe the trend of mercury dosing in CFL bulbs of different wattages and estimate the variance in their mercury concentrations;
c. To assess the divergence in mercury levels of CFLs compared with the globally best known standards; and,

The analysis of the results for the laboratory leads to the following objectives of the report:

a. To present findings to the government, media and the public to raise their awareness and consciousness on the issue;
b. To pressure manufacturers and distributors to address the mercury content in their product; and,
c. To make recommendations to regulators for mercury standards in CFLs, proper product labelling and end- of- life management.

Sampling

Samples of six CFL brands spanning 7 wattage categories were purchased in chosen local urban markets in Metro Manila. Replication was done in order to minimize errors in testing and to address variance analysis. A total of 88 samples were randomly collected, procured and recorded accordingly. The CFL samples were sent to Delhi Test House (NABL accredited lab- ISO/ IEC

17025:2005), A- 62/3, G.T. Karnal Road, Industrial Area, Azadpur, Delhi- 110033 for further analysis of mercury content.

Methodology for the determination of Hg- content in CFLs [2]

The same sample preparation and testing protocols used by Toxic Link- India's study entitled, "CFL: Poison in the Glow" were used. These Standard Operating Procedures (SOP) were developed by Toxics Link and New Delhi House from a few internationally- available SOPs, which includes the determination of mercury in CFL light by ICP- MS.

Inductively- Coupled Plasma Mass Spectrometry or ICP- MS is an analytical technique that measures the mass- to- charge ratio of charged particles, such as metals like mercury, at concentrations as low as one part in 10^{12} (part per trillion). An inductively- coupled plasma is a plasma that contains a sufficient concentration of ions and electrons to make the gas electrically- conductive. Thus, when a sample is aspirated into the center of the plasma toroid, it dissolves instantly, dissociates, vaporizes, atomizes and ionizes. The plasma ejects electrons from the shell resulting to a positively- charged analyte ion. The ions are selected as a function of mass and are measured for determining the mercury content. ICP- MS is chosen for its greater speed, precision and sensitivity, as compared with other atomic absorption techniques [2, 27].

Materials and Equipment

- Ultra- pure acid HNO_3, H_2O_2
- De- ionized water (free from elements) and clean sample preparation environment
- Hot plate, 500 or 1000 mL beakers
- 100 mL volumetric flask
- 0.45 micron membrane filter paper and filtering units
- Final sample solution high- quality containers
- High- quality gloves
- Centripure reference standards for ICP- MS

Standard preparation

1. Prepare stock solutions of 1 ppm from Centripure standard in 2% HNO_3
2. Make the final dilutions to concentrations of 0, 1, 5, 10, 20, 50 and 100 ppb to achieve a linearity of minimum of 6 points.

Sample preparation

1. Put the glass bulb into a glass chamber.
2. Remove the plastic base and metal parts with knife or pliers.
3. Take a beaker containing 50% HNO_3 and 10% H_2O_2 solution and break the bulb inside it.
4. Stir or wash the pieces around the container with a glass rod until no more phosphor comes off from the glass

5. Heat the beaker on a hot plate (90^{0}C for 50 minutes). Cool the solution to room temperature.
6. Transfer the solution into a volumetric flask and make up the volume to 100 mL with de-ionized water.
7. Filter the sample with 0.45 micron membrane filter papers and put the filtrate in the sample containers to be nebulised into the ICP- MS.

Precautions

- Use high quality gloves while adding ultra pure acid into samples.
- Preserve the final sample solution in sample storage rooms if the samples are not getting analyzed immediately after filtration.

Calculations

$$\text{Final Conc. of Mercury (Hg)} = \text{mg per CFL} = \frac{[\text{Measured Conc. x Dilution Factor x Avg. Wt}]}{[\text{Sample Wt. (gm) x 1,000 x 1,000}]}$$

Chapter IV: Results and Discussion

Key Findings

a. The average mercury content per unit of CFL, regardless of wattage category, has been found to be 3.258mg. Mean values for Xin Mey 7W is highest at 7.953mg, and lowest for Osram 11W with 0.688mg. (Table 2)
b. Recorded values for mercury content was lowest for Osram 11W with 0.017mg, and the highest value was 17.47mg for CATA 5W. (Table 2)
c. The average mercury content values per wattage category across brands are: 3.612mg for 5W, 4.516mg for 7W, 4.561mg for 8W, 2.661mg for 9W, 3.429mg for 11W and 2.733mg for 14W. (Table 2)
d. The variance on mercury dosing per brand is highest for GE 8W, with a standard deviation (SD) value of 9.018. The lowest variance value was Osram 13W, with SD value of 0.474.
e. Only one brand, Osram, exhibited decreasing mercury content with increasing wattage. It has a linearity value (R) of 93.83%. Linearity values for the rest of the brands were non-conclusive.
f. Over- all, the mercury content per watt decreases with increasing wattage category. The highest average Hg/ watt value is 0.722mg Hg/W for 5W and the lowest is 0.056mg Hg/W for 13W.
g. Of the samples analyzed, 20.45% were found to have mercury content higher than the EU RoHS standard of 5mg. 28.57% of Philips samples have higher contents than the standard, whilst CATA/ Otaca and Osram only recorded 13.33% of the samples.

h. If a standard of 3.5mg of mercury is used, only 65.77% of the samples will pass. 57.14% of both Philips and GE samples have higher content than the standard, with Osram having 13.33% only.
i. For 2013 RoHS standard of 2.5mg, 53.40% of the samples have mercury content lower than the standard. 57.14% of both Philips and GE samples still have higher content than the standard, with Osram having 26.67% only.
j. Mercury dosing in Philippine CFLs seem to be quite random. Higher wattage units tend to have slightly lesser mercury content compared to those with lower wattage.

Table 2. Mercury Content of CFL brands in the Philippines

Watt	Brand Name	Mercury content per piece (mg)			St Dev (mg)	Hg/ watt
		Min	Max	Mean		
5	CATA	1.426	17.47	6.509	7.419	1.302
	GE	2.81	6.544	4.631	1.869	0.926
	Omni	0.032	11.69	2.983	4.927	0.597
	Osram	1.797	6.312	3.697	2.341	0.739
	Philips	0.134	6.461	3.142	2.812	0.628
	Xin Mey	0.169	1.742	0.709	0.895	0.142
	AVE	**1.061**	**6.703**	**3.612**	**3.377**	**0.722**
7	Omni	0.424	2.545	1.143	1.214	0.163
	Otaca	0.191	3.326	1.453	1.528	0.208
	Xin Mey	4.277	11.26	7.953	3.506	1.136
	AVE	**4.892**	**5.710**	**4.516**	**2.083**	**0.502**
8	GE	0.234	17.42	7.248	9.018	0.906
	Osram	1.069	5.474	2.566	2.519	0.321
	Philips	1.545	5.265	3.868	2.026	0.484
	AVE	**0.949**	**9.386**	**4.561**	**4.521**	**0.570**
9	Omni	0.156	10.39	3.518	4.729	0.391
	Otaca	0.439	7.395	3.598	3.522	0.400
	Xin Mey	0.139	1.35	1.156	0.517	0.096
	AVE	**0.734**	**6.378**	**2.757**	**2.923**	**0.296**
11	GE	0.514	3.952	1.836	1.836	0.170
	Omni	0.094	5.531	2.672	2.353	0.242
	Osram	0.02	3.326	0.688	1.475	0.063
	Otaca	0.154	3.776	2.180	1.797	0.198
	Philips	1.587	7.201	5.182	3.121	0.471
	Xin Mey	0.154	17.07	8.014	7.718	0.729

	AVE	**0.421**	**6.809**	**3.429**	**3.053**	**0.296**
13	Osram	0.031	1.091	0.727	0.474	0.056
14	Philips	0.153	4.875	2.637	2.290	0.188
	GE	0.161	5.212	2.828	2.454	0.202
	AVE	**0.157**	**5.044**	**2.733**	**2.372**	**0.195**

Discussion

The study clearly indicates that the common CFL brands available in the Philippines contain varying amounts of mercury across wattages. On an average, the mercury content per CFL was found to be 3.258 mg, with values ranging between 0.017 mg/CFL to 17.47 mg/CFL) (Table 2). These values are considerably lower than those recorded in the ToxicsLink- India report, with slated average value of 21.21mg of mercury [2]. Most minimum recorded values from the laboratory per wattage category are even recorded to have 100 times lesser amount of mercury than the computed average, with Osram 11W leading the pack with 0.017mg (Table 3).

Table 3. Comparison of Mercury Content per wattage category

Watt	mg of Hg/CFL		Brand Name
5	Min	0.032	Omni
	Max	17.47	CATA
7	Min	0.191	Otaca
	Max	11.26	Xin May
8	Min	0.234	GE
	Max	17.42	GE
9	Min	0.139	Xin Mey
	Max	7.395	Otaca
11	Min	0.017	Osram
	Max	17.07	Xin Mey
13	Min	0.031	Osram
	Max	1.091	Osram
14	Min	0.153	Philips Genie
	Max	5.212	GE

In general, CFL products under the Osram brand have significantly lower mean mercury content of 2mg/CFL, while those from CATA/ Otaca have the highest with 4.46mg/ CFL (Figure 6). Xin Mey products have registered the most number of maximum values per watt category. Both maximum recorded values for7W and 11W categories come from Xin Mey (Table 3).

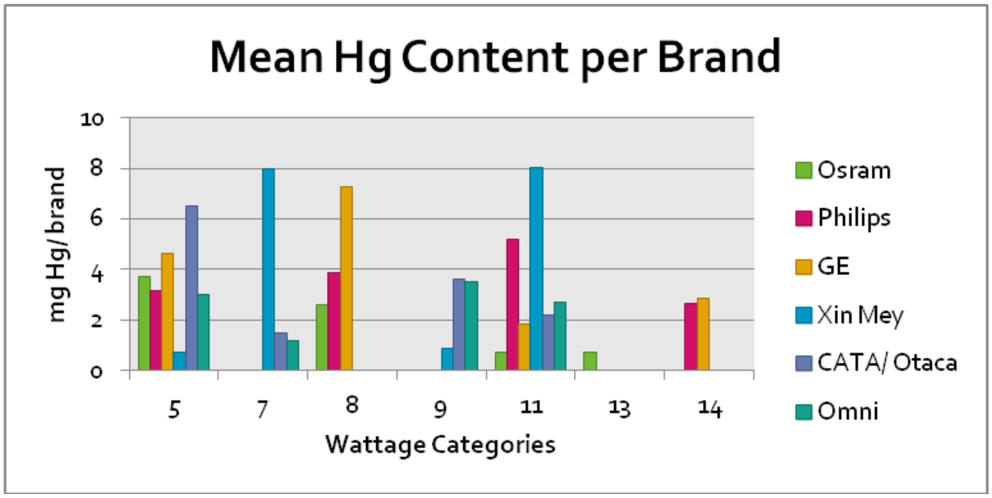

Figure 6. Computed Mean Hg Content per Brand and Wattage Category.

The results of the analysis clearly indicated that, there is no consistency in mercury dosing in CFL. No clear trend was observed in mercury dosing, neither intra brand nor between different brands (Figure 7). The precision of mercury dosing among brands were also computed, based on the standard deviation of the laboratory results on the computed mean. The difference on mercury dosing of GE 8W products was high, with an SD value of 9.018. This means that mercury dosing for this brand tend to be less precise or inconsistent. On the other hand, dosing in Osram 13W units is more precise, with an SD value of 0.474 only (Table 2). Over- all, variance is high for the 5W category, and low for the 13W category.

Among the 6 brands, only Osram exhibited decreasing mercury content with increasing wattage. This correlation has a value of 93.83%. while the other brands have alternating "up- down" values as wattage increases. There are however one distinct pattern observed while compared the analysis wattage wise, i.e. the low wattage (5 watt to 11 watt) CFLs contains higher mercury content than that of high wattage (13watt-14watt) CFLs (Table3).

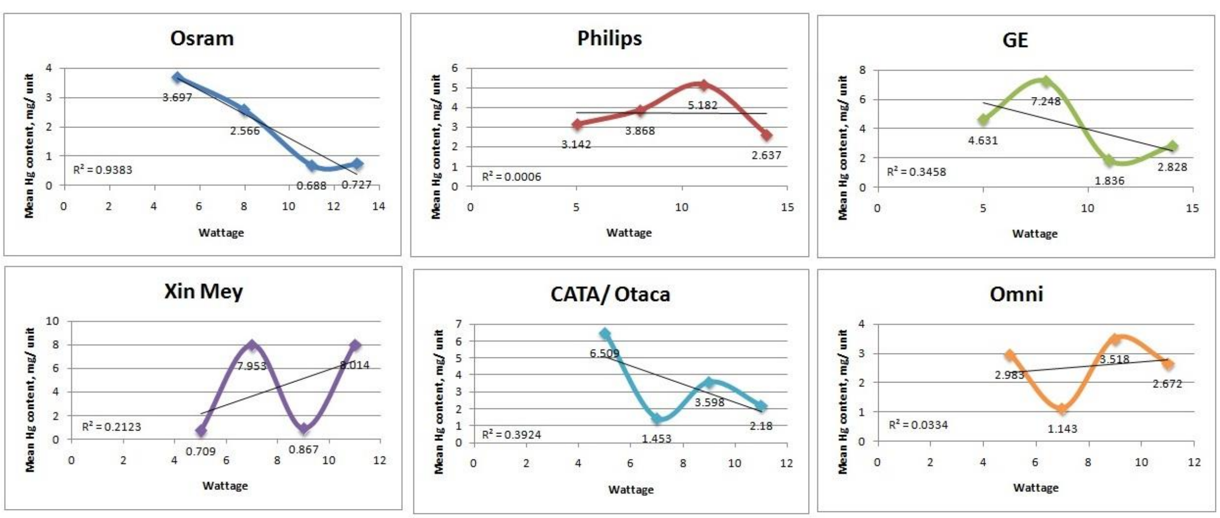

Figure 7. Mercury Dosing within Wattage Categories

Comparing to the current RoHS limit of 5mg of mercury per unit of CFL, four- fifths of the CFL samples have values lower than the standard (Figure 8). On the other hand, the majority of the brands falling over the limit came from Xin Mey and Philips.

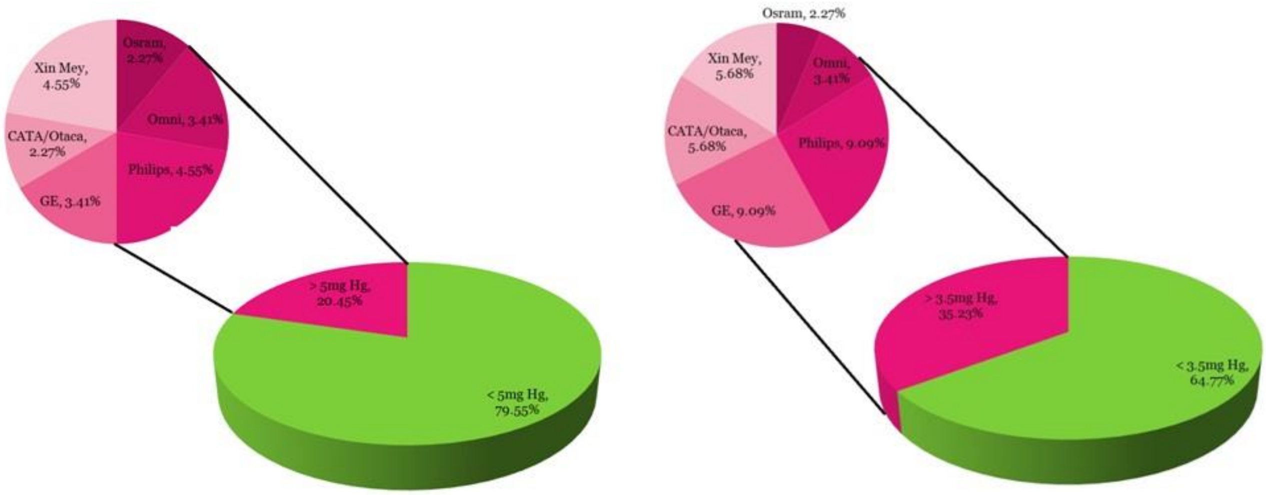

Figure 8. Distribution of CFLs according to (1) 5mg and (2) 3.5mg RoHS limit.

For the year 2012, the EU RoHS prescribes a standard of 3.5mg per CFL unit, to achieve the goal of total reduction of mercury use in lighting equipment. Using this standard, it was computed that among the 88 samples, only 65.77% of the samples have achieved passing values. It was also noted that 57.14% of samples coming from Philips and GE samples have higher content than the standard. Osram still leads the pack with only 13.33% of samples over 3.5mg of mercury.

Furthermore, for the envisioned 2013 RoHS standard of 2.5mg, almost half, or 53.40% of the samples have mercury content lower than the standard. Thus, stricter rules on monitoring mercury content in CFLs must be in place before the year starts.

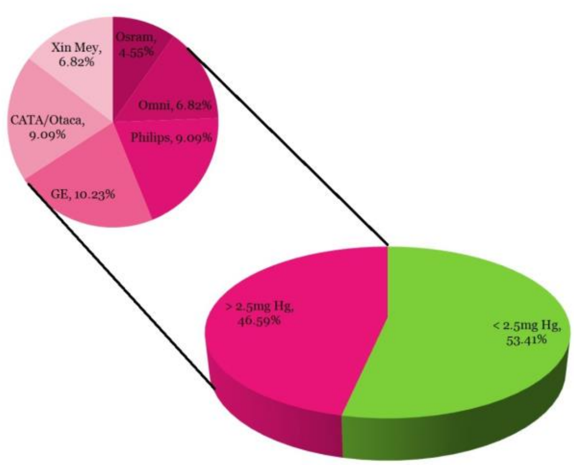

Figure 9. Distribution of CFLs according to 2.5mg RoHS limit

With the results extrapolated, the collective mercury consumption of Metro Manila urban households, with a total of 330, 434, was computed. In a scenario where each household consumes at least one CFL bulb per annum, mercury input ranges from 0.234 Kg/ year if all use Xin Mey 5W, to 2.848 Kg/y if the households use Xin Mey 11W bulbs (Figure 10). Given that some households use up to 9 CFL units a year, this estimate have not yet reflected the multiple numbers of units used [28]. The estimated mercury consumption for CFLs in Metro Manila, Marikina City and Davao City are summarized in Table 4.

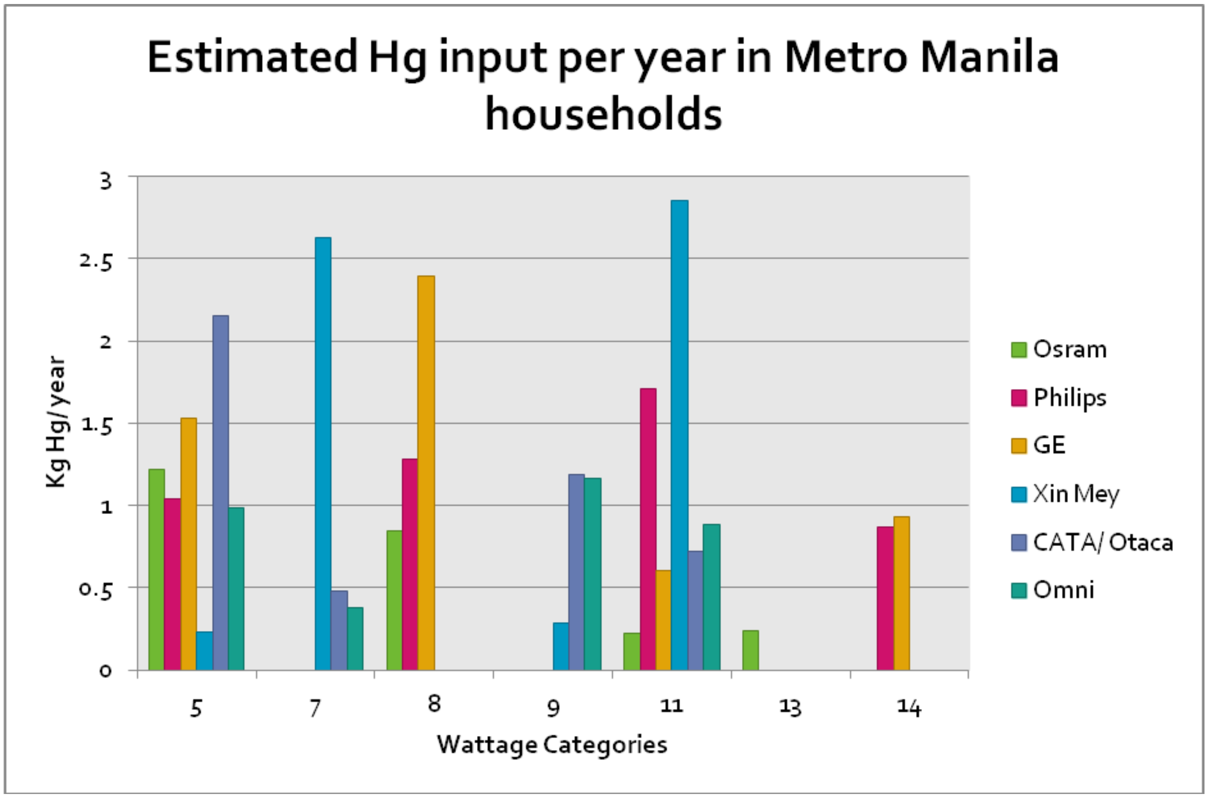

Figure 10. Estimated Hg input in Metro Manila Households (1 CFL per household)

Since higher mercury dosing means higher risk of exposure at households and workplaces, the absence of a sound end- of- life management practice in the country can result to the improper disposal of these products to the waste stream, posing potential risk of contamination to soil, surface and groundwater, and ultimately to biodiversity and wildlife. The absence of mercury warning labels further endangers the Filipino consumers, who are left unaware with the imminent danger lurking in their homes. Since the US EPA charted the acceptable limit of only 0.01mg/ m^3 of mercury vapour concentration in the air, the lack of standard limit for mercury in indoor air set by our own government may prove to be disabling to the consumers and their knowledge in mercury spill management [2]. The bulk of CFL products available in the local market originated from China, and the absence of proper global regulatory rules hinder the implementation of importation policies that safeguards the people on sub-standard products.

Table 4. Estimated Hg consumption per household (1CFL= 1 household)

Brand Name	Wattage	Mean	Hg input/ year (Kg/ y)*		
			Manila (330, 434)	Davao (179, 774)	Marikina (105, 351)
Osram	5	3.697	1.222	0.665	0.389
	8	2.566	0.848	0.461	0.27
	11	0.688	0.227	0.124	0.072
	13	0.727	0.24	0.131	0.077
Philips	5	3.142	1.038	0.565	0.331
	8	3.868	1.278	0.695	0.408
	11	5.182	1.712	0.932	0.546
	14	2.637	0.871	0.474	0.092
GE	5	4.631	1.53	0.833	0.488
	8	7.248	2.394	1.303	0.252
	11	1.836	0.607	0.33	0.064
	14	2.828	0.934	0.508	0.298
Xin Mey	5	0.709	0.234	0.127	0.075
	7	7.953	2.627	1.43	0.838
	9	0.867	0.286	0.156	0.091
	11	8.014	2.848	1.441	0.844
CATA	5	6.509	2.151	1.17	0.686
Otaca	7	1.453	0.48	0.261	0.153
	9	3.598	1.189	0.647	0.379
	11	2.18	0.72	0.392	0.23
Omni	5	2.983	0.986	0.536	0.314
	7	1.143	0.378	0.205	0.12
	9	3.518	1.162	0.632	0.371
	11	2.672	0.883	0.48	0.282

Chapter V: Conclusions and Recommendations

Conclusions

a. CFLs sold in the Philippine market considerably falls under the 5mg limit set by international standards such as the European RoHS and US EPA. However, since models and studies have proven that even lesser mercury content values can still be implemented, the number of CFL brands which showed less adherence to stricter limits, such as the 3.5mg and 2.5mg RoHS may comprise a significant portion of the units available in the market.

Even though the average content value for CFLs fall under the 5mg limit (3.258mg Hg), some units still have a record high 17.47mg, which exceeds the standards three folds.

b. Given that each urban household consume 1 CFL unit per year, the mercury input or consumption may range from 0.234 Kg/ year to 2.848 Kg/y. These values would have a devastating effect on the ecology if improperly disposed or discarded in the waste stream. 0.5 to 1.5g of elemental mercury is enough to contaminate a 20- acre lake to an unsafe level. This is dangerous considering the rapid growth of the CFL market and the implementation of policies to replace ICLs.
c. There is a lack of regulatory framework or standard for limiting mercury dosing in CFLs. Also, the end- of- life management practices are at the conceptual level with a lot of dots that need to be joined. There is no disposal mechanism or infrastructure to deal with the discarded and used- up lamps, which points towards imminent danger of mercury getting released into the immediate environment from these devices. This is a matter of concern considering that the local inhabitants and waste workers might directly get exposed to the mercury released.
d. There is no indication of voluntary action being taken by manufacturers or their associations to cap mercury dosing in CFLs. This counts towards a need for stricer and mandatory standards for mercury dosing in CFLs.

Recommendations

a. The creation of a regulatory framework or standard for limiting mercury dosing in CFLs and end- of- life management practices must be initiated and implemented. These will provide the proper disposal mechanism or infrastructure that will deal with the discarded and used-up lamps, and thus prevent the imminent danger of mercury getting released into the environment and affecting vulnerable populations.
b. Since the Philippines import CFLs from other countries, stricter mandatory standards must be in put into place to force manufacturers to cap mercury dosing in their products. The government must come up with a maximum limit for mercury dosing in CFLs, and they can do so through exploring policies being implemented at the international level such as the European RoHS. Technically, mercury dosing can be limited to 2-3 mg/ CFLs with less than 20 watts. This value is present and available in the market, and thus will also encourage manufacturers to standardize their production process, and to innovate green design.
c. Proper labelling must be made mandatory, which includes a mercury cautionary mark with specific amount present in CFL. The proper regulatory agency must be capacitated with the skills and equipment necessary to undertake random testing for products imported into the Philippines to check compliance of products to limits.
d. Extended producers responsibility (EPR) can be tapped to finance the infrastructure for CFL/ mercury management. This should be done through the joint efforts of the manufacturers, government, regulatory agencies, NGOs and CSOs and other stakeholders. Consumers have the responsibility for the proper disposal of broken and used- up lamps, as set by Philippine laws. They should be informed of the information on how to manage their lamp wastes and the accredited facilities that will do so.

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