

ORIGINAL ARTICLE

Environmental Risks of Burn-Out Fluorescent Lamp Tubes (BFLTs) in Nigeria

^{1,2}Ayejuyo Olusegun*, ¹Nwume, Michael, ¹Alani Rose and ¹Akinrinade, Olumide.

¹Department of Chemistry, Faculty of Science, University of Lagos, Akoka, Nigeria

²Department of Chemistry, College of Science and Technology, Covenant University, Ota, Nigeria

*Email: oayejuyo@unilag.edu.ng,

ABSTRACT

Fluorescent lamps (FLs) are favourites in terms of energy efficiency, brightness and durability. However, fluorescent lamp tubes (FLT) are of health and environmental concern due to the presence of metallic mercury which aids their functionality for light production. Burn-out fluorescent lamp tubes (BFLTs) are carelessly handled and indiscriminately disposed in landfills. In the present study, the exposure level of mercury in BFLTs was investigated using Mercury Drum-Top Crusher Test model. The average mercury exposure level was between 0.46 mg/m³ and 0.74 mg/m³ in a closed drum. These concentrations attenuated thereafter, and eventually remained unchanged at a certain threshold level leaving residual mercury vapour. Accidental or deliberate breakage of FLTs in a closed environment will, therefore, require enough ventilation to remove the residual mercury vapour. The mercury exposure level was significant, though the concentration could be lower in a larger or opened environmental space. Reduction in mercury concentration was a signal that mercury vapour gradually pollutes the ambient air during the Drum-Top Crusher usage and the accumulated concentration could pose harm to the environment. There is need for urgent public awareness on the potential risk of FLTs. Laws banning indiscriminate dumping of fluorescent tubes in landfills should be advanced and supported with proper recycling technologies.

Keywords: Fluorescent lamp, Drum-top crusher, Mercury determination, Human exposure and environmental risks

Received 21.03.2019 Accepted 13.05.2019

© 2019 AELS, INDIA

INTRODUCTION

Incandescent light bulbs, compact fluorescent lamps (CFLs) and fluorescent lamps (FLs) are commonly used electrical lighting systems in Nigeria. However, with a continuous acute power supply and a need to fall in line with the general global campaign for energy conservation, there is a need for a lighting system with maximum energy efficiency usage without compromising (or with better) brightness and durability. CFLs and FLs fit into the requirements leading to general acceptance and increasing popularity of the lamps. The basic operation of FLs require some doses of metallic mercury, the mercury produces ultraviolet radiation which is transformed to visible light by the phosphorescent powder coated on the inner side of the glass [3, 12]. Mercury is considered to pose serious environmental and health risks, it could lead to a number of diseases ranging from headache to a severe memory loss depending on the levels of exposure. About 80% of inhaled mercury is absorbed or transported by the blood to the brain and other target tissues. It is persistent in the environment, forming methyl mercury which is more toxic than mercury itself, and bio-accumulate through the food chain. Although, the body has a potential of gradually eliminating the metal, the cumulative exposure can aggravate the amount in the body [3, 14, 17]. The use of mercury has been restricted to a maximum concentration of 10 mg per lamp in FLs according to the regulations in directive 2002/95/EC on the Restriction of the use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS). This was confirmed by some investigations, though some tubes contain more than their indications [2, 9]. Most of the mercury in lamps remained either as a component of phosphor powders which are attached inside the lamp or in glass matrices; Phosphor powder has greater than 80% of mercury amount in burn-out fluorescent lamp tubes (BFLTs) and about 15% of mercury amount in glass matrix, while the rest 5% may exist in vapour phase inside the tube. Phosphor powder is, therefore, considered as a hazardous waste while base-cap and glass are classified as non-hazardous wastes. By washing and eliminating all phosphor powder attached to the glass surface it is possible to classify the glass as a non-hazardous waste [7, 10, 13, 14]. The mercury

concentration in a phosphor powder sample with 103 mg kg⁻¹ of mercury is about 6.6 mg kg⁻¹ and by retorting the phosphor powder at optimal conditions, it can also be considered to be non-hazardous wastes [6, 11]. The distributions of mercury in the vapour phase, phosphor powder, and glass matrix are the same for both new and spent fluorescent tubes [8]. While most studies' targets are on occupation areas, some studies have implicated non-occupation areas for intensive mercury poisoning after mercury vapours are released from damaged devices such as FLs [14], hence mercury is classified as a house hold hazardous waste priority chemical and the quality of indoor air and the resultant risk associated with accidental exposure to volatilized metallic mercury are major concerns for building occupants [1, 15]. Mercury lamps are handled carelessly, resulting in breakage during storage packing or disposal in landfills. They are sometimes deliberately broken for them to fit into disposal bins and children commonly play with them. SFLT's are transported and dumped directly in landfills where most of them get broken along the way or in the landfills posing health risk to the surrounding occupants and environmental workers. Little work has been recorded on current state of affairs in the environmental management of discarded SFLT's. Several possible means of storing, transporting and recycling spent fluorescent lamps have been advanced [16], but a significant adoption involves the use of drum top lamp crushers, where the BFLT's are stored or crushed to reduce solid waste volume and avoid mercury exposure in landfills or storage facilities. The present study is aimed at determining the exposure level of mercury from spent broken fluorescent tubes in Nigeria. The drum top lamp crushing procedure is modified in this study to examine the potential mercury concentration released from broken fluorescent lamps; their fate, and persistence were assessed by evaluating the mercury exposure over time.

MATERIALS AND METHODS

Sampling:

Three commonly used brands of burn-out fluorescent lamp tubes (BFLT's) were selected for this investigation. Fifty five pieces of different brands of the linear tubes were carefully collected from dumpsites, door steps of offices and homes, and individual donations in Lagos, Nigeria. Tubes were thoroughly observed for minor breakages and leakages.

Materials:

Burn-out linear fluorescent lamp tubes

208 L thermoplastic drum

Rubber tubes

Lamp crushing kit

Gastec gas sampling pump set (Model GV-100S) with standard detection tubes

Methods:

A modified Mercury Lamp Drum-Top Crusher Test [2, 16] was employed using three set of thermoplastic drums in isolated laboratories for lamp crushing and gas measurement. This was used to simulate the deliberate or accidental lamp breakage in an enclosed environment with minimum air current. The 208-L drum was appropriately washed, cleaned and dried. A rubber tube of 2 m long and 3 mm diameter was inserted into a port previously drilled on top of the thermoplastic drum and the entry point was sealed with a black rubber tape. The diameter of the port was ensured to be suited for the rubber and both were properly fixed. At about four-fifth length of the drum, another port of 12.7 mm was made to fit in the Gastec gas sampling pump set for direct reading instrument used for the measurement of mercury vapour concentration. The procedure was undertaken at room temperature of 26.5^oC.

Initial reading was taken to determine the blank mercury vapour concentration in the empty drum prior to the measurement. Five BFLT's were randomly picked for each lamp brand and fed singly into the entry rubber tube. For each introduction, the outer part of the rubber tube was sealed off and the lamp was broken mechanically when it had made meaningful entry into the tube. The glass fragments, phosphor powder and shards were properly discharged into the drum air space. Tube breakings were done with some levels of attention for relatively constant operational forces. Concentration of the 5 BFLT's were determined and evaluated for average exposure model. The drum was opened and the contents were properly discharged into sealed bags. The procedure was repeated for the other two brands. Blank levels were always determined for possible residual mercury content.

To investigate mercury exposure rate in the drum air space, readings for 10 BFLT's of each tube brand was taken as a function of time (hr) at every 2 hours for 36 hours.

RESULTS AND DISCUSSION

The average mercury exposure in the drum air space is dictated by the specifications or brand of the lamp and it is independent of tubes length and diameter (Table I). The value ranges from 0.46±0.32 - 0.74±0.71

mg/m³. The results are consistent with 1.44 mg/m³ determined by Aucott *et al.* [2] for two broken fluorescent tubes at 85°F. The different concentrations obtained from different brands have been attributed to factors such as product design, mercury content as metallic or amalgam and duration of usage [2, 15]. The results did not specify the amount of mercury in vapour phase, phosphor powder, glass matrix and end caps. There was a significant relationship in the average mercury concentration for every set of the procedure and could be used to predict the exposure risk at every point of tube breakage. The potential risk is clearly significant, especially in enclosed environment caused by accidental breakage or deliberate as in the case where children make funs with them and where adults crumble tubes to fit into waste bins. Exposure rate is directly proportional to the number of lamp crushes. The investigation mimicked the condition of an enclosed environment; the exposure trend in an open environment with higher ventilation and temperature [2, 16]. Mercury concentration decreased with increase in the initial concentration level (Table II), which is also dependent on the specifications of the brand but not on the dimension of the tubes. Mercury levels attenuate with time irrespective of the specifications (Fig. 1). This could be due to settlement of the mercury vapour with the particles or release from the drums as reported in USEPA [16]. The two possibilities indicate potential environmental risks. In the first case, the condensed mercury could volatilize into the environment or leached into soil where it could be further transferred to aquatic environment causing harms. The second possibility indicates that Drum-top crushers (DTC) used for recycling of SFLT's are exposure route for mercury in the environment and could lead to increase in ambient air mercury concentration which may be harmful to the workers and populace. It has been suggested by USEPA [16] that the DTC should be located outside the residential areas during recycling processes. The constant concentration observed for all the brands (Tables 3-5) are related to the operational physico-chemical parameters of mercury vapour in the drum space and this signifies a residual volume of mercury when released in an enclosed environment. Breakage of tubes where there is limited mass transfer of air is environmentally risky and could be mitigated by aeration.

Table I: The specifications of linear fluorescent lamps

S/N	Manufacturer/ Country	Model	Length (Ft)	Diameter (mm)
1	Phillips/ Holland	TLD 18W/54	2	2.0
2	Sylvania/Germany	F40W/154-IRS	4	2.0
3	Tungsram/ Hungary	F74/M11	4	1.5

Table II: Average concentration of mercury in different lamp brands

Model	Diameter	Blank conc. (mg/m ³)	Average conc. (mg/m ³)
TLD 18W/54	2.0	0.00	0.73±0.57
F40W/154-IRS	2.0	0.00	0.46±0.32
F74/M11	1.5	0.00	0.74±0.71

Table 3: Trend in exposure levels of mercury in 10 tubes of brand TLD 18W/54

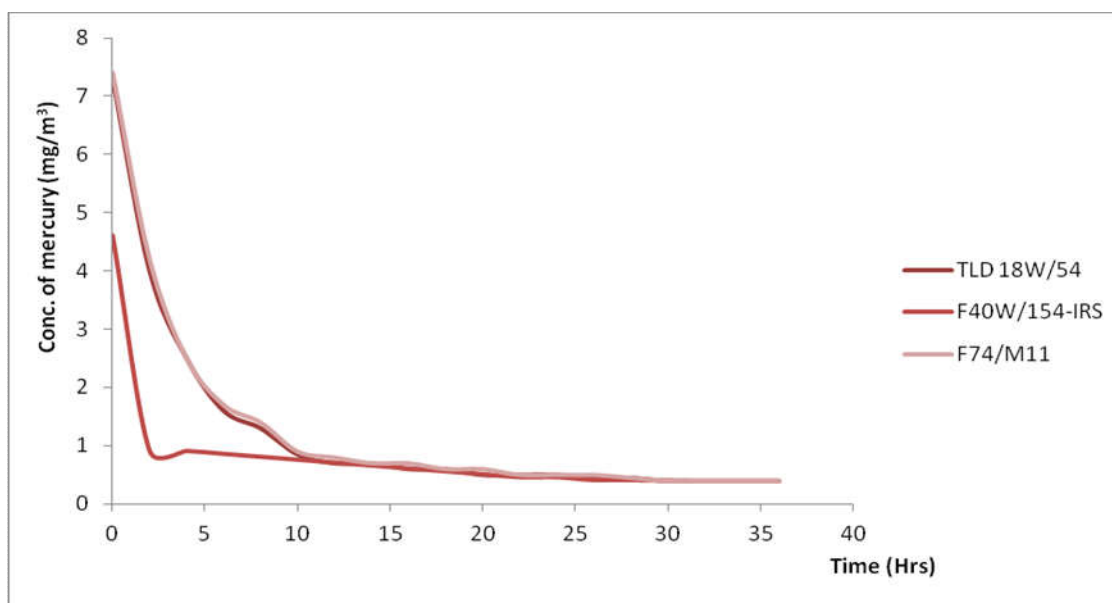
Time (Hrs)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Conc. (mg/m ³)	7.30	4.00	2.50	1.60	1.30	0.85	0.70	0.70	0.60	0.60	0.50	0.50	0.50	0.45	0.45	0.40	0.40	0.40	0.40

Table 4. Trend in exposure levels of mercury in 10 tubes of brand F40W/154-IRS

Time (Hrs)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Conc. (mg/m ³)	4.60	0.90	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.45	0.40	0.40	0.39	0.38	0.38	0.38

Table5: Trend in exposure levels of mercury in 10 tubes of brand F74/M11

Time (Hrs)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Conc. (mg/m ³)	7.40	4.20	2.50	1.70	1.40	0.90	0.80	0.70	0.70	0.60	0.60	0.50	0.50	0.50	0.45	0.40	0.40	0.40	0.40

**Fig. 1:** Decrease of mercury concentration with time**CONCLUSION**

The results of the investigation indicated a significant level of mercury in fragments of broken fluorescent lamp tubes (BFLTs) and the associated and the potential environmental and health risks. The mercury exposure level decreases with time in an enclosed environment but remain constant beyond certain concentration with the implication that exposed mercury vapour from BFLTs or other sources in enclosed environment could leave a residual level of mercury. BFLTs could serve as air-borne exposure route of mercury into the body; the exposure is severe in enclosed environment.

The general public have to be properly enlightened on the effects of mercury and its presence in fluorescent lamp tubes; information should also be extended on how to handle the tubes. Where there is accidental breakage, the environment should be evacuated and maximum ventilation should be allowed. Environmental laws and policies disallowing breakage of fluorescent tubes and disposal of fluorescent tubes in land fills should be properly put in place. For appropriate waste management, special boxes or bags may be designated for the carrier, storage, and disposal of FLTs. There is urgent need for the construction and adequate usage of recycling facility.

ACKNOWLEDGMENT

Prof. Olusegun Opeyemi Ayejuyo Olusegun has spent the last twenty years contributing to research in the field of Analytical/Environmental Chemistry with particular emphasis on method development and determination of additives/toxicants in the environment as an application. As an analyst, he has developed and validated some simple and fast analytical techniques for the determination of different analytes in water, food and drug samples. . He has published over 50 articles in reputable local and international journals such as Journal of Applied Science, Environmental Monitoring and Assessment, International Journal for Food and Nutrition, The Environmentalist, Journal of Environmental Science and Technology, Journal of Chemical Society of Nigeria. NWUME MICHAEL Michael is a graduate student in the Department of Chemistry University of Lagos and he holds an MSc degree in Environmental Management. ALANI ROSE PhD Rose is a Senior Lecturer in in the Department of Chemistry University of

Lagos, Nigeria. She is currently working in the area of Air Quality Monitoring and Assessment. He is widely travelled and a prolific writer and has over twenty publications to her credit. AKINRIMADE OLUMIDE Olumide is a Doctoral Student in the Department of Chemistry University of Lagos, Nigeria currently working of trace pollutants in Nigeria air environment. He is on Royal Society of Chemistry scholarship in UK due September this year.

REFERENCES

1. Asari, M., Fukui, K., and Sakai, S. (2008). Life-cycle Flow of Mercury and Recycling Scenario of Fluorescent Lamps in Japan. *Sci Total Environ.* 393(1), 1-10.
2. Aucott, M., McLinden, M. and Winka, M. (2003). Release of Mercury from Broken Fluorescent Bulbs. *J. of air and waste manage. Assoc.* 53(2), 143-151.
3. Batenburg, B., Essers, P., van Lieshout, R. and Tromp, S. (2010). Round Robin Test Report: Mercury Determination in Fluorescent Lamps. Netherlands: European Lamp Companies Federation.
4. Baughman, T.A. (2006). Elemental Mercury Spills. *Environ Health Perspectives* 114(2), 147-152.
5. Directive 2002/95/EC on the Restriction of the use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS).
6. Durão, W.A. Jr, de Castro, C.A, and Windmöller, C.C. (2008). Mercury Reduction Studies to Facilitate the Thermal Decontamination of Phosphor Powder Residues from Spent Fluorescent Lamps. *Waste Manag.* 28(11),2311-2319.
7. Figi, R., Nagel, O., Schreiner, C. and Hagendorfer, H. (2015). Determination of Non-gaseous and Gaseous Mercury Fractions in unused Fluorescent Lamps: A Study of Different Lamp Types. *Waste Manag.* 33(3), 295-299.
8. Hobohm, J., Krüger, O., Basu, S. Kuchta, K., van Wasen, S. and Adam, C. (2017). Recycling Oriented Comparison of Mercury Distribution in New and Spent Fluorescent lamps and their Potential Risks. *Chemosphere* 169, 618-626.
9. Hu, Y. and Cheng, H. (2012). Mercury Risk from Fluorescent Lamps in China: Current Status and Future Perspective. *Environ Int.* 44, 141-50.
10. Jang, M., Hong, S.M. and Park, J.K. (2005). Characterization and Recovery of Mercury from Spent Fluorescent Lamps. *Waste Manag.* 25(1), 5-14.
11. Park, H.S. and Rhee, S.W. (2016). Estimation of Retorted Phosphor Powder from Spent Fluorescent Lamps by Thermal Process. *Waste Manag.* 50, 257-63.
12. Rey-Raap, N. and Gallardo, A. (2012). Determination of Mercury Distribution inside Spent Compact Fluorescent Lamps by Atomic Absorption Spectrometry. *Waste Manag.* 32(5), 944-948.
13. Rhee, S.W., Choi, H.H. and Park, H.S. (2014). Characteristics of Mercury Emission from Linear Type of Spent Fluorescent Lamp. *Waste Manag.* 34(6),1066-1071.
14. Roda, E. Giampreti, A., Vecchio, S., Apostoli, P. and Coccini, T. (2016). Mercury Vapour Long-Lasting Exposure: Lymphocyte Muscarinic Receptors as Neurochemical Markers of Accidental Intoxication. *Case Report in Meds.* 2016, 1-8. Article ID 9783876
15. Singhvi, R., Taneja, A., Patel, J. R., Kansal, V., Gasser, C. J. and Kalnicky, D. J. (2011). Determination of Total Metallic Mercury in Compact Fluorescent Lamps (CFLs). *Environmental Forensics.* 12, 143-148.
16. United States Environmental Protection Agency (2006). Mercury Lamp Drum-Top Crusher Study (EPA530-R-06-002) —*Memorandum*; Office of Solid Waste and Emergency Response. Assessed on 10th February, 2017; from <http://www.epa.gov/epaoswer/hazwaste/id/univwast/drumtop/drum-top.htm>
17. World Health Organization (2016). Fact sheet: Mercury and Health. Assessed on 10th February, 2017; from <http://www.who.int/mediacentre/factsheets/fs361/en>.

CITE THIS ARTICLE

Ayejuyo Olusegun, Nwume, Michael, Alani Rose and Akinrinade, Olumide. Environmental Risks of Burn-Out Fluorescent Lamp Tubes (Bflts) In Nigeria. *Res. J. Chem. Env. Sci.* Vol 7 [3] June 2019. 09-13