BIOCHEMICAL OXYGEN DEMAND (BOD) AND UV VISIBLE CHARACTERISATION OF FILLED WATER IN POLYETHYLENE TEREPHTHELATE (PET) BOTTLE UPON EXPOSURE TO DIFFERENT ENVIRONMENT

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Abstract— Bottle bevarages filled Polyethylene Terephthalate (PET) bottle are in demand for drinkable bottle due to excellent characteristic such as neligible permeability to carbon dioxide, can withstand high temperature, non-toxic nature, high mechanical strength and high transparency. New developed formulation can be made to impart degradable properties to PET. Research was carried out by using masterbatch of degradable Polyethylene Terephthelate (PET) and they are blow moulded through injection blow moulding technique. Chemical content of filling liquid such as mineral water and coke were investigated through Biochemical Oxygen Demand test and uv-visible test. BOD values for each sample in different exposed condition were determined to investigate the presence of bacteria on the bottle. Test was carried out by taking the initial value (before exposed at different condition) of two type of water which is mineral water and carbonate drink. Result showed that mineral water has highest BOD value compared to carbonated drink which is 7.56 mg/L and 1.32 mg/L respectively. Liquid were tested at three different conditions which are at room temperature, exposure to sunlight and in fridge for four week and result was taken. BOD exhibited lowest value for fridge storage beverages. It shows that BOD depends on the temperature of storage or exposure; lower temperature can inhibit microorganism growth. UV-Visible spectroscopy as used to investigate the amount of aldehyde and ketones group in the beverage that had been exposed at different exposed condition. No appreciable UV absorption between 280 to 200nm of liquid was found for room temperature and fridge condition PET sample as compared to sunlight exposed. UV absorption started to develop significant absorption after 2 weeks whereas fridge and room temperature only showed negligible absorption even after 4 weeks.

Keywords— Polyethylene Terephthalate (PET), Biochemical Oxygen Demand (BOD), UV-Visible Spectrometer Analysis.

I. INTRODUCTION

Polyethylene Terephthalate (PET) has become the most favourable packaging material world-wide for beverages. The reason for this development is the excellent material properties of the PET material, especially its unbreakability and the very low weight of the bottles compared to glass bottles of the same filling volume [1]. Nowadays, PET bottles are used for soft drinks, mineral water, energy drinks, and ice teas as well as for more sensitive beverages like beer, wine and juices. For a long time, however, a bottle-to-bottle recycling of post-consumer PET packaging materials was not possible, because of the lack of knowledge about contamination of packaging polymers during first use or recollection. In addition, the decontamination efficiencies of recycling processes were in most cases unknown. During the last 20 years, PET recollection as well as recycling processes made a huge progress [1]. PET is basically is a thermoplastics resin composed of phthalate [2]. PET materials do not degrade and are mostly recycled, so that it will not be decomposed [3]. Addition of natural additives was incorporated into PET resin formulation for enhancing PET degradability [4]. When the resin was blow moulded, testing of related strength and performance of PET bottles need to be investigated and taste of filled beverage need to be evaluated to maintain its quality. Nowadays, the virgin of PET bottles has high tensile test, drop test and good texture and can withstand different temperature without compromise its function [5]. Therefore, this testing will assist to investigate that the new formulation of PET bottles will have similar taste to water or filled beverages contained in the bottle and also to investigate the PET properties itself upon storage after liquid filling. The migration of aldehyde group into the beverages will cause effects the shelf – life and quality for beverages in the PET bottles [6].

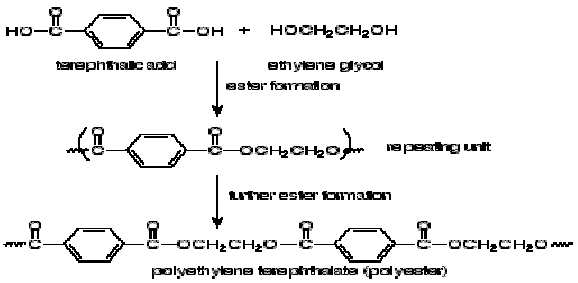


Fig.1. Reaction process during Polyethylene Terephthalate Manufacturing

II. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

The materials and methodology examined in this project are stated below

a) Polyethylene Terephthalate (PET) preform

The PET preform was prepared via injection moulding and then will be blow moulded. Then, this preform will be blown to form 1.5 litre bottle shapes.

b) Mineral Water

All the mineral water will be filled up to 1 litre bottle of mineral water 3 set condition. One condition are for bottles filled with 1 litre mineral water. One bottle is for BOD sample and another bottle is for exposed filled PET bottles testing. Determinations of the filled water content were performed for mineral water bottle stored at different temperatures and exposed to sunlight.

c) Carbonated Water

The carbonated water also were also prepared for three 3 different condition using namely COKE for carbonated drink. The effects of alkali water towards the filled beverage after storage at different temperature and exposed to sunlight were performed.

d) Testing of filled beverages in PET bottles

All the bottles will be exposed to 3 sets of condition, under Sunlight, room temperature and fridge ~ 10°C for maximum of 4 weeks. Every week, the beverage will be tested by using UV – Visible spectrometer to determine the migration of aldehyde into the beverages.

III. RESULTS AND DISCUSSION

A. Microbiological Test (BOD*)*

The BOD value before the bottles were exposed was mentioned in table 1. The mineral water shows highest BOD value compared than Coke which is 7.56 and 1.32 respectively. BOD values for Coke show lowest because it contain high amount of carbonated content thus lowering the amount of oxygen demand in the bottles.

Table 1 BOD value before exposed for mineral water and coke

Type of water	Mineral Water	Coke
Reading	7.56	1.32

Final Day (After Exposed) For Mineral Water and Coke

Table 2: BOD value after exposed for mineral water

Condition	Reading (mg/L)			Average	BOD Value (1st day-Final Day)(mg/L)
	1st	2nd	3rd		
Room Temperature	6.79	6.78	6.77	6.78	0.78
Fridge	7.44	7.45	7.45	7.45	0.11
Sunlight	6.11	6.09	6.09	6.09	1.47

Table 3: BOD value after exposed for coke

Condition	Reading (mg/L)			Average	BOD Value (1st day-Final Day)(mg/L)
	1st	2nd	3rd		
Room Tempera-ture	0.97	0.96	0.96	0.96	0.36
Fridge	1.09	1.07	1.06	1.07	0.25
Sunlight	0.55	0.53	0.51	0.53	0.79

Table 2 and table 3 show the BOD value after exposed at different condition for mineral water and Coke. BOD value for exposing the beverages at sunlight shows the highest values which are 1.47mg/L for mineral water and 0.79mg/L for Coke compared than stored at room temperature and Fridge. BOD values after exposing at sunlight were highest because the microorganism in these bottles is able to grow due to their active temperature [7]. According to United States Department of Agriculture Food Safety and Inspection Service, the active temperature of bacteria towards food and beverage are in the range between 30 °C – 60 °C [8]. Therefore, it required high amount of oxygen to oxidize the amount of inorganic material. During storage in the fridge, the BOD value shows 0.11mg/L for mineral water and 0.25mg/L for coke which is the lowest value because temperature in the fridge had inhibited the growth of microorganism. However, BOD values at these different conditions were do not shown a risk for users to use these bottles. The samples are classified as risk when the BOD value exceeds 700mg/L. According to Cristina Bach and Xavier Dauchy (2014) stated that Polyethylene terephthalate bottles water that had exposed into sunlight will have a migration of formaldehyde and aldehyde [9] and this showed that samples of PET bottle is safe for use.

Graph BOD Value vs. Condition

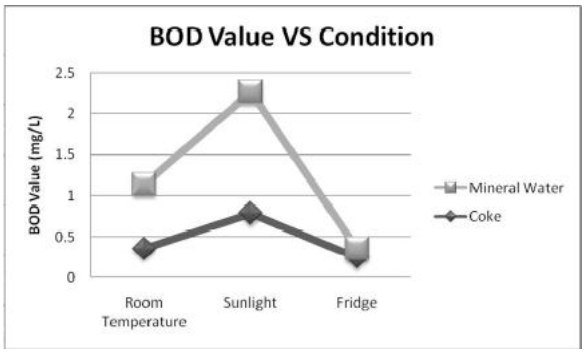


Fig.2. BOD value at different condition for mineral water and coke.

B. UV – VISIBLE SPECTROMETER ANALYSIS

The UV – Visible test was conducted to determine the absorption of the organic compound in the mineral water and *COKE* after exposing at sunlight and two different conditions for four weeks. Besides that, UV – Vis measure the amount of light absorb at each wavelength of the UV and Visible. The UV ranges are between 200 nm – 400 nm and visible range are between 400 nm – 800 nm. The wavelength range are selected above 200 nm because the component that adsorb in the below range of 200 nm are weak. Because of that, it is difficult to adsorb in the spectrum and mentioned in the graph. In this testing, the different bond will produce difference absorption due to different molecular chain that they

have. The absorbance by a compound at a particular wavelength increase with increasing number of molecules undergoing transition which is from ground state to excited stated. These samples were scan at the maximum wavenumber from 700 nm to 200 nm. After that, the results were analyzed as shown below.

The Effects of Mineral Water after Exposed 4th Weeks

Figure 3 to 7 shows graph of the effects of mineral water after exposing at different conditions for maximum 4 weeks. The maximum absorbance shows at the wavelength range between 282nm – 290nm after 1st week exposed. After exposing the bottles containing mineral water for 1 week, the migration of aldehyde and ketones groups were found to slightly migrate into the beverage under sunlight and fridge. These absorbances were occurred at the wavenumber between 284 nm and 287 nm for sample under sunlight and 284 nm for sample in fridge. These absorbance can be seen in the figure 4, figure 5, figure 6 and figure 7 below whereas it is a wavenumber for aldehyde and ketones group as mentioned in literature review. The carboxyl group of saturated aldehyde and ketones give a weak absorption bond in the range between 270 nm – 300 nm. However, there are no absorbances after 1 weeks exposed for mineral water at room temperature. But, after second week exposing, the sample at room temperature exhibited absorbance at range 270 nm – 300 nm. These migrations were too slow compared to the others because it does not have any possible migration of carboxyl group at the room temperature. The samples at sunlight have fast migration due to the deterioration of the degradable additive plus the presence of UV light. There is possibility of organic material to migrate into water. There are slightly different after the following weeks as is seen in the absorbance of the carboxyl group, however, it still in the range of 270 nm - 300 nm.

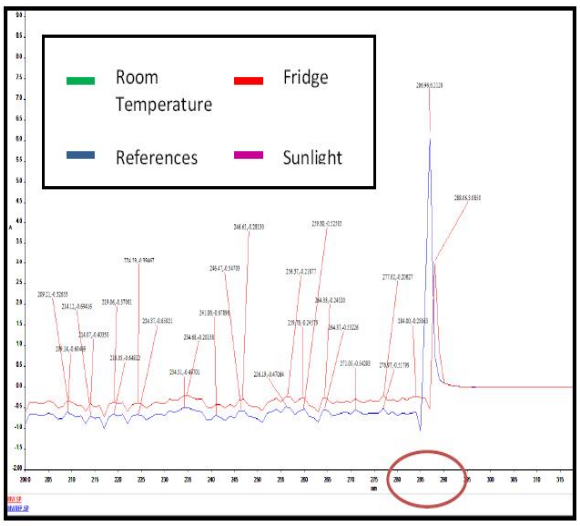


Fig.3. The absorbance in sample of mineral water before exposed

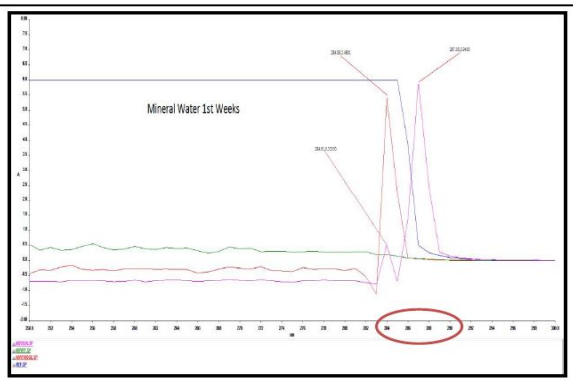


Fig.4. The absorbance in sample of mineral water after exposed 1weeks

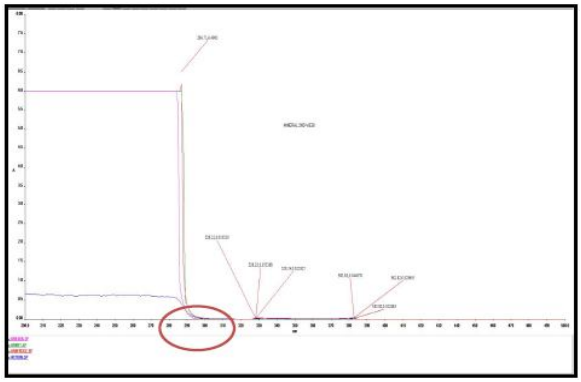


Fig.5. The absorbance in sample of mineral water after exposed 2 weeks

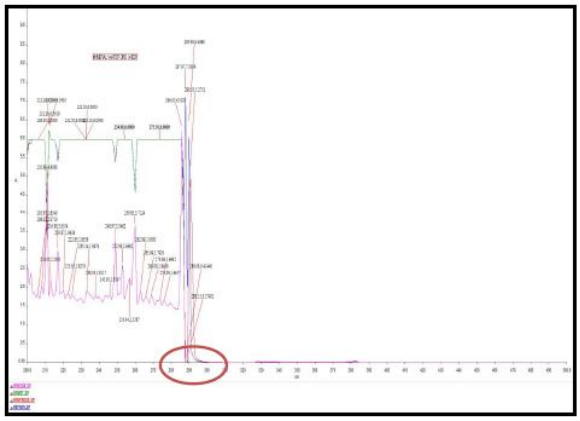


Fig.6. The absorbance in sample of mineral water after exposed 3 weeks

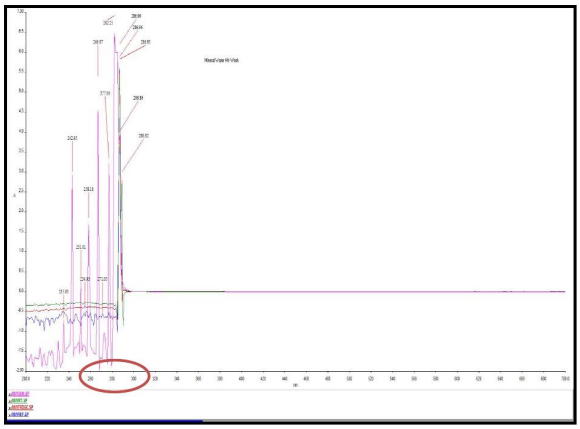


Fig.7. The absorbance in sample mineral water after exposed 4 weeks

Table 4: The wavenumber for aldehyde and ketones group in UV-Vis

Wavenumber (nm)	Absorbance Group
270-300	Aldehyde and Ketone

The Effects of Coke after Exposed 4th Weeks

Figure 8 to 12 shows graph of the effects of coke after exposing at different conditions for maximum 4 weeks. There are slightly different in their absorbance peak due to different mineral content in their composition. According to lee et al., (2007) Coke has more sugar, carbon dioxide, caffeine as natural flavors and caramel in its composition [10]. The absorbance of the coke sample at different condition was found to be unchanged until the third weeks. The maximum peaks before exposed exhibited absorbance at wavenumber between 350 nm – 430 nm. Slight wavenumber changes were observed to 380 nm – 440 nm. The possible compound that absorb in this range is conjugated aldehyde group due to presence of high double bond in their chain. At third weeks, the maximum peaks show at 434 nm which for sample at room temperature while maximum peak for sunlight showed presence at 385 nm. Unfortunately, the maximum peak for fridge cannot be measured due to excess the limit absorption in this instrument which is more than 6.

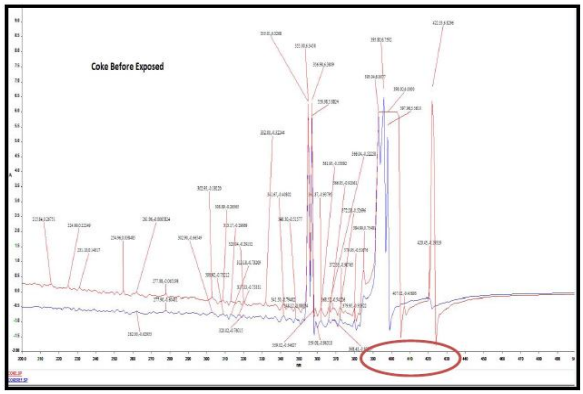


Fig.8. The absorbance in sample of Coke before exposed

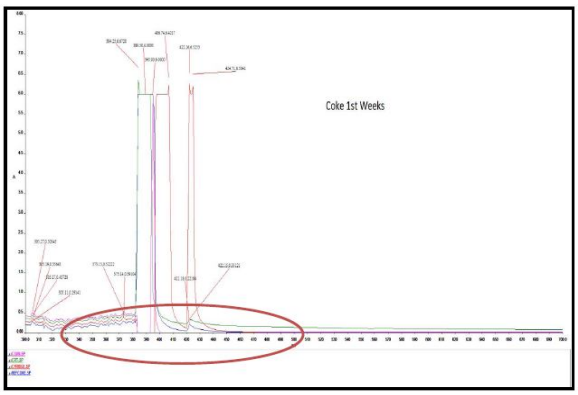


Fig.9. The absorbance in sample of Coke after 1week exposure

Table 5: The wavenumber for aldehyde and ketones group in UV-Vis in sample coke

Wavenumber (nm)	Absorbance Group
380-450	Unsaturated aldehyde

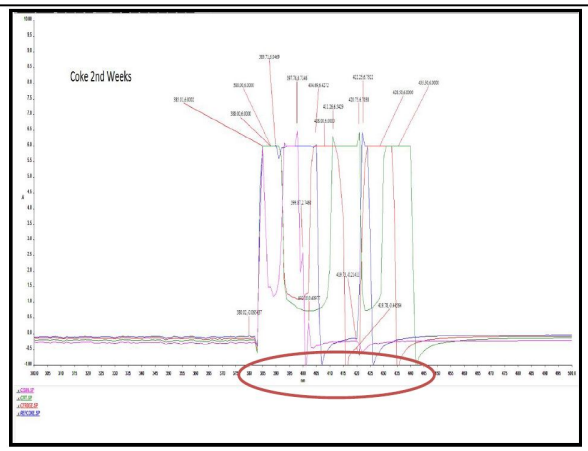


Fig.10. The absorbance in sample of Coke after exposed 2weeks

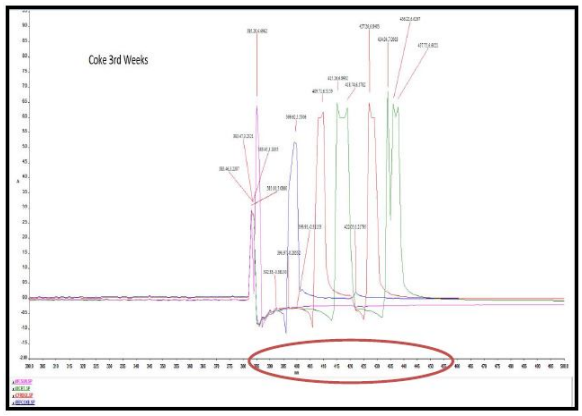


Fig.11. The absorbance in sample of Coke after 3 weeks exposure

For the last week, the peaks for sample at fridge and room temperature were too sharp and narrow compared to previous weeks. The sharp peak was observed due to high absorption or high bonding in the chain. These bonds are not attacked by surrounding temperature. In contrast, the sample at sunlight had diminished their peaks and no absorbance found at 395 nm. The possible reason is the conjugated saturated aldehyde was diminished by the reaction with the acid in the Coke after initiation by presence of UV – light. This peak can be seen in the figure 12 as shown below.

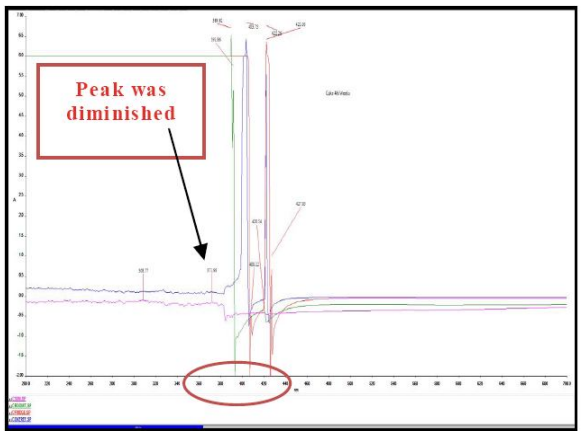


Fig.12. The absorbance in sample of Coke after exposed 4 weeks

CONCLUSIONS

The study has indicated that the sample at sunlight showed higher amount of BOD level due to presence amount of bacterial activity, high BOD in the water sample. However, the sample water in fridge did not indicated as much. Hence, from BOD level test, the bacteria did not originated from the degradable additive degradation but actually, due to different type of exposure condition. Therefore, it can be said this degradable additive did not give any effects to the quality of beverages for users.

The additives migration into both mineral water and coke were too slow at room temperature or fridge condition compared to the others because it does not have any possible migration of carboxyl group at the passive low temperature without exposure to sunlight.

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REFERENCES

[1] Welle, F. (2011). Twenty years of PET bottle to bottle recycling—an overview. *Resources, Conservation and Recycling*, *55*(11), 865-875.J. U. Duncombe, "Infrared navigation—Part I: An assessment of feasibility," IEEE Trans. Electron Devices, vol. ED-11, pp. 34-39, Jan. 1959.

[2] Frounchi, M., Mehrabzadeh, M., & Ghiaee, R. (1997). Studies of Recycling of Polyethylene Terephthalate Beverages Bottles.

[3] Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: challenges and opportunities. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *364*(1526), 2115-2126.

[4] Hanlon, J. F., Kelsey, R. J., & Forcinio, H. (1998). *Handbook of package engineering*. CRC press.

[5] Ros-Chumillas, M., Belissario, Y., Iguaz, A., & López, A. (2007). Quality and shelf life of orange juice aseptically packaged in PET bottles. *Journal of Food Engineering*, *79*(1), 234-242. Jing, L., & Mattiason, B. (2002). Microbial BOD sensors for wastewater analysis. Journal of Water Research.

[6] Bach, C., Dauchy, X., Severin, I., Munoz, J. F., Etienne, S., & Chagnon, M. C. (2014). Effect of sunlight exposure on the release of intentionally and/or non-intentionally added substances from polyethylene terephthalate (PET) bottles into water: Chemical analysis and in vitro toxicity. *Food chemistry,162*, 63-71.

[7] Lund, V., & Hongve, D. (1994). Ultraviolet irradiated water containing humic substances inhibits bacterial metabolism. *Water research*, *28*(5), 1111-1116.

[8] Kubin, A. (2012). *Landfilling in tropical climates: an analysis of issues to be solved*. na.

[9] Bach, C., Dauchy, X., Severin, I., Munoz, J. F., Etienne, S., & Chagnon, M. C. (2014). Effect of sunlight exposure on the release of intentionally and/or non-intentionally added substances from polyethylene terephthalate (PET) bottles into water: Chemical analysis and in vitro toxicity. *Food chemistry,162*, 63-71.

[10] Lee, T., Chang, P. K., Talebi, F., Zaniewski, T. A., Garcia, M. A. A., & Chen, H. (2007). *U.S. Patent Application No. 11/686,305*.

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