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Effect of Sunlight on the Quality of Sachet Drinking Water

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ABSTRACT

Packaged water is touted as hygienic and safe for human consumption. However, several studies have reported a change in water quality due to some environmental factors. In the case of plastic-packaged drinking water, the water quality may be affected by sunlight due to the possibility of leaching petroleum hydrocarbons from the plastics into the water. Total Petroleum Hydrocarbon (TPH) describes a large family of several chemical compounds that originates from crude oil and are known to cause varied ailments including cancer. The study therefore aimed at elucidating the effect of sunlight on TPH levels, of packaged drinking water sampled in the Tamale Metropolis. In all, sachet water from five different brands was exposed to sunlight for seven days and five-set as control under room temperature. Extraction of the TPH from the sachet water collected was done using liquid-liquid extraction techniques followed by Solid-Phase Extraction purification at the Ghana Standard Authority. Target components were analytically determined with Gas Chromatography-Flame Ionisation Detector (GC-FID) and quantified by the area counts. The total amount of TPH identified ranged from 1.6×10^{-3} μgl^{-1} *to* 2.3×10^{-3} μgl^{-1} *in the control water samples whilst that of the exposed water ranged from* 2.1×10^{-3} μgl^{-1} *to* 3.1×10^{-3} μgl^{-1}*. The mean concentration of TPH in exposed samples revealed 25% increase in the TPH levels. Comparing the study to recommendations from the World Health Organisation, TPH must be absent from drinking water hence the sachet water samples are not safe for drinking. There is, therefore, the need for education of vendors and consumers on the safe storage of sachet water for the safety of consumers.*

Key words: *sachet water, quality, sunlight, leaching, Total Petroleum Hydrocarbons.*

INTRODUCTION

Access to safe drinking water has remained inadequate globally particularly in the developing world. The World Health Organisation estimates that, - there is limited access to safe drinking water for more than 2.2 billion people globally (WHO, 2018; Stoler, Tutu & Winslow, 2015).

A significant latest reaction to the gap in urban water supply in Ghana is the proliferation of packaged water, recognised on the road by the more suggestive product name ' pure water, ' which is single-served 500 ml polyethene drinking water bags.

It is perceived as pure and safe with low detectable contaminants and is usually in two forms; bottled and sachet water (Dada, 2011; Johnston & Amoako-Mensah, 2014; Aslan, Beslin, Poole, Anderson, Gallard & McGowan, 2016). About (63%) of urban and rural dwellers in Ghana rely on this source of water (Wardrop et al., 2017). The intention of making water portable for consumers is laudable, but it has been observed that prolonged exposure of packaged drinking water to certain environmental parameters like temperature, leads to significant changes in its chemical composition (Manley, 2013).

Total petroleum hydrocarbon (TPH) is a term used to define a wide family of several hundreds of chemical compounds originating in crude oil. TPH is ubiquitous and is used in many operations and the manufacture of numerous products, including plastics used in water packaging. Significantly high levels of petroleum hydrocarbons in water sources may result in elevated levels of TPH in available potable drinking water (Sung, Kim & Park, 2013).

The International Agency for Research on Cancer has declared some fractions of TPH such as benzene, benzo (a) pyrene and naphthalene as carcinogenic with global cancer data indicating that,- the worldwide burden of cancer has risen to 18.1 million annual instances and 9.6 million fatalities (IARC, 2018).

Furthermore, it is known to be bioaccumulative and noxious for reproduction, endocrine system disruption, developmental abnormalities, polyneuropathy and possibly death if exposure is high enough (Crone & Tolstoy, 2010). -Due to the widespread sources of TPH, the cost of technology in treating it when found in water, its short-term or long-term effects and their inherent trait of carcinogenicity and mutagenicity, it has garnered widespread concern from public health experts, civil society organisations and the general public (Zhang, Chaohai, Chunhua, Zhe, Man, Bo, Pingan & Jiamo, 2015; Ramesh, Archibong, Hood, Guo & Loganathan, 2011; Zelinkova & Wenzl, 2015; Sanches Filho, Luz, Betemps, Silva & Caramão, 2013).

Regulatory bodies lay less emphasis on the presence and acceptable levels of TPH in packaged drinking water. Again there is little research conducted on the influence of sunlight on package water quality particularly, with the leaching of TPH to serve as a baseline for reference as well as aid in promoting good health to the public.

This study specifically tested three hypotheses: The temperatures and length of days that are likely to cause a leach, the influence of sunlight in the leaching of TPH from the sachet rubber into the water, the health risks posed by the levels of TPH in water exposed to sunlight. The study helps deepen the understanding of total petroleum hydrocarbon leach into packaged drinking water to ensure the development and -effective enforcement of policies to improve packaged drinking water quality as the demand for it is continuing to increase in developing countries particularly, Ghana

MATERIALS AND METHODS

The study was conducted in the Metropolitan Assembly of Tamale. A total of 5 packs of packaged sachet water from five (5) brands were randomly bought from production sites and stored at averagely 30ºC room temperature. The purchasing of the samples was between the hours of 7 am and 9 am. In all, five (5) bags of packaged drinking water from five (5) brands were collected and protected from direct sunlight-the samples were purchased early in the morning when the sun was not intense and was covered with unbleached cotton to shield it from the sun’s rays (Abidi, N., Cabrales, L., & Hequet, E., 2009).

Five (5) pieces of sachet water from each brand were randomly selected and exposed to sunlight and five (5) kept as a control for 7 days. Control samples were kept in welldefined environment under ambient conditions (temperature, humidity) where the sunlight rays could not reach and without any devices to alter the room temperature. The sachet water samples were covered under the names Brand 1, Brand 2, Brand 3, Brand 4 and Brand 5. They were labelled as Tc and T_E (those set as control and exposed to sunlight respectively). The temperature of both the samples and the ambient air was taken daily at an equal interval of hours, four times daily. These hours are time ranges where the sun's warmth is much felt. The temperature was taken from 9 am till 5 pm at an interval of two hours using a liquid-in-glass thermometer (mercury thermometer). One tip of each of the sachet water brands selected for exposure and control was opened with scissors and the thermometer was inserted into it for three minutes.

Readings were observed and recorded every two hours each day. A new piece of sachet water samples was selected from the thirty-piece pack for temperature measurement with samples selected for TPH analysis left unchanged. The ambient air temperature was taken at the same time by exposing the thermometer to the atmosphere for three minutes. The complete oil hydrocarbons leached into water specimens were analysed using standard analytical instruments. The sample was analysed for multiresidues by Gas Chromatography –Flame Ionisation Detector. One thousand millilitres of the water sample was transported to a separating funnel of 2 L capability after filtration. Then 30 ml of a saturated solution of sodium chloride was added. The water sample was partitioned with 100 ml of dichloromethane (thrice), shaking the separating funnel for 2-3 minutes at a time and releasing the pressure intermittently.

The layers were allowed to separate and the dichloromethane extract layer was drained. A silica cartridge (10000 mg/ 6 ml) with 2 g sodium sulphate coating on top has been prepared with dichloromethane (10 ± 0.2 ml). The extract was loaded onto the cartridge from 8.1 (ca.1 ml). The elute was gathered in a round bottom flask of 100 ml. twenty millilitres of dichloromethane was used to elucidate the column. Using the rotary evaporator below 40 ° C, the eluent gathered was focused only on dryness. Ethyl acetate was re-dissolved by adding 1ml by pipetting. The extract was transferred into 2 ml, a standard opening vial to be quantified by GC-FID. The extracts are stored frozen until quantitation was achieved.

A survey was conducted on ten shops in Nyankpala area to determine among others, the number of days that bags of sachet water are stored before consumers purchase. Questionnaires were designed and distributed among ten (10) sellers.

Statistical Analysis

The Social Sciences Statistical Package (SPSS) software (version 20) was used to analyse data obtained from the simple social survey. The data obtained from the respondents were coded by assigning numbers to responses so that raw data can easily be analysed. Means of levels of TPH in the water for both control and exposed samples were compared using an independent sample t-test. Descriptive statistics were performed to calculate frequencies, means and percentages of temperature for both ambient air and sachet water. Results were interpreted with tables and graphical representations, as well as the correlation between temperature and the levels of TPH, calculated using Microsoft Excel 2013.

RESULTS AND DISCUSSION

Length of days for exposure and the temperature ranges

The survey was conducted on ten (10) retailers, randomly selected and questionnaires were given to them to respond. It was revealed from the respondents that the largest quantity of sachet water purchased by sellers is above 25 packs , that is, 20% with the lowest being less than 25 packs as shown in Table 1 below. Eighty percent (80) normally purchase less than 25 packs. Six of the respondents representing 60% store their packs outside their shops with 4 respondents (40%) keeping them inside. All of the respondents store the sachet water between 5 days to weeks. Packaged water is supplied by the various companies in open trucks. Again most of the respondents store the sachet water between 5 days to weeks as shown in Table 1. An average of the number of days for the exposure was calculated and approximately, seven (7) days were obtained. The exposure days of the sachet samples have a direct impact on the levels of Total Petroleum Hydrocarbons recorded in the sachet water samples as confirmed by the study Zmit and Belhaneche-Bensemra (2019) who observed that, Antimony concentrations in plastic bottle exposed to a specified range of temperature recorded higher concentrations in 18 days than in 10days of exposure (Westerhoff, Prapaipong, Shock & Hillaireau, 2008).

Table 1: Profile of Sachet water sellers (*n*= 10) in Nyankpala

Characteristics	Variable	Frequency	Percentage	%Total
Market experience	Less than a year	8	80	100
	More than a year	2	20	
Quantity purchased at a goal	25 packs and less	8	80	100
	More than 25 packs	2	20	
Means of transport	In a cover truck	3	30	100
	In an open truck	7	70	
Location of suppliers	Tamale	10	100	100
Place of storage for new stock	Inside a shop	4	40	100
	Outside a shop	6	60	
Length of storage before selling	Day(s)	6	40	100
	Week(s)	4	40	100

High temperatures averagely, were recorded for the exposed sachet water during the hours between 11 am to 12:59 pm, that is 43.1 °C with its equivalent ambient temperature being 34.9 °C followed by hours between 1 pm to 2:59 pm at 41.4 °C with its and lowest in the evening when the sun is about setting at 35.6 °C and the mornings between 9 am to11 am followed at 39.9 °C as shown in Figure 1. The temperatures of the samples and Ambient air as shown in Figure 1 shows a significant difference (p-value, 0.00403<0.05) between the intervals. Temperatures of both room and control samples equally showed a significant difference (p-value, 0.00447<0.05). The temperature of the control samples and room temperature recorded showed a different pattern in the temperature per the time interval as seen in the samples exposed to direct sunlight. Higher room temperature was recorded between the hours of 3 pm and 5 pm (30.9 °C) in contrast with 11am to 12:59 for the exposed samples. The lowest temperature recorded between 9 pm and 11 pm (29.6 °C). Between 11 pm to 12:59 pm and 1 pm to 2:59 pm, 30.4 °C and 30.5 °C was respectively recorded.

With control samples, temperatures: of 28.5 °C, 28.6 °C, 29.06 °C and 29.6 °C were recorded between 9 pm to 11 pm, 11 pm to 1 pm, 1 pm to 3 pm and 3 pm to 5 pm respectively. Comparing the recordings of ambient air and exposed samples, the temperatures of the sachet water were higher than the ambient air temperature. The temperature difference was wide between the hours of 1 pm and 3 pm, recording a temperature difference of 8.7 °C which represents 11.7% and the lowest being 4.6 °C representing 6.9% between 3 pm to 5 pm. The room temperature seemingly opposes the ambient air and exposed samples' temperatures. A negligible difference in temperatures were recorded between room and samples kept as control. This difference is as result of the heat retention strength of water. Water is noted to have a high heat holding capacity. This property of water is the reason for the difference in the temperature pattern. It absorbs about 4, 184 Joules of heat to increase by 1 °C, this heat absorbed is released gradually over a considerable number of hours (Evenson, Orndorff, Blome, Böhlke, Hershberger, Langenheim & Weyers, 2017). This is observed for the hours between 3 to 5 pm-hence the reason why the water had a higher temperature compared to the ambient air which is influenced by other atmospheric factors. High temperatures are noted to reduce the oxygen content of water resulting in the formation of chemicals substances and breaking down important physiochemical constitutes. Research by Muzenda, Ramatsa, Ntuli, Belaid and Tshwabi (2011) reveals that temperature encourages the rates of leaching. Temperatures between 30 °C and 50 °C are more likely to cause leaching (Borra, Pontikes, Binnemans & Van Gerven, 2015). With the temperature recorded which falls within the observed ranges by Borra et al. (2015) the TPH levels observed are influenced by the temperature ranges.

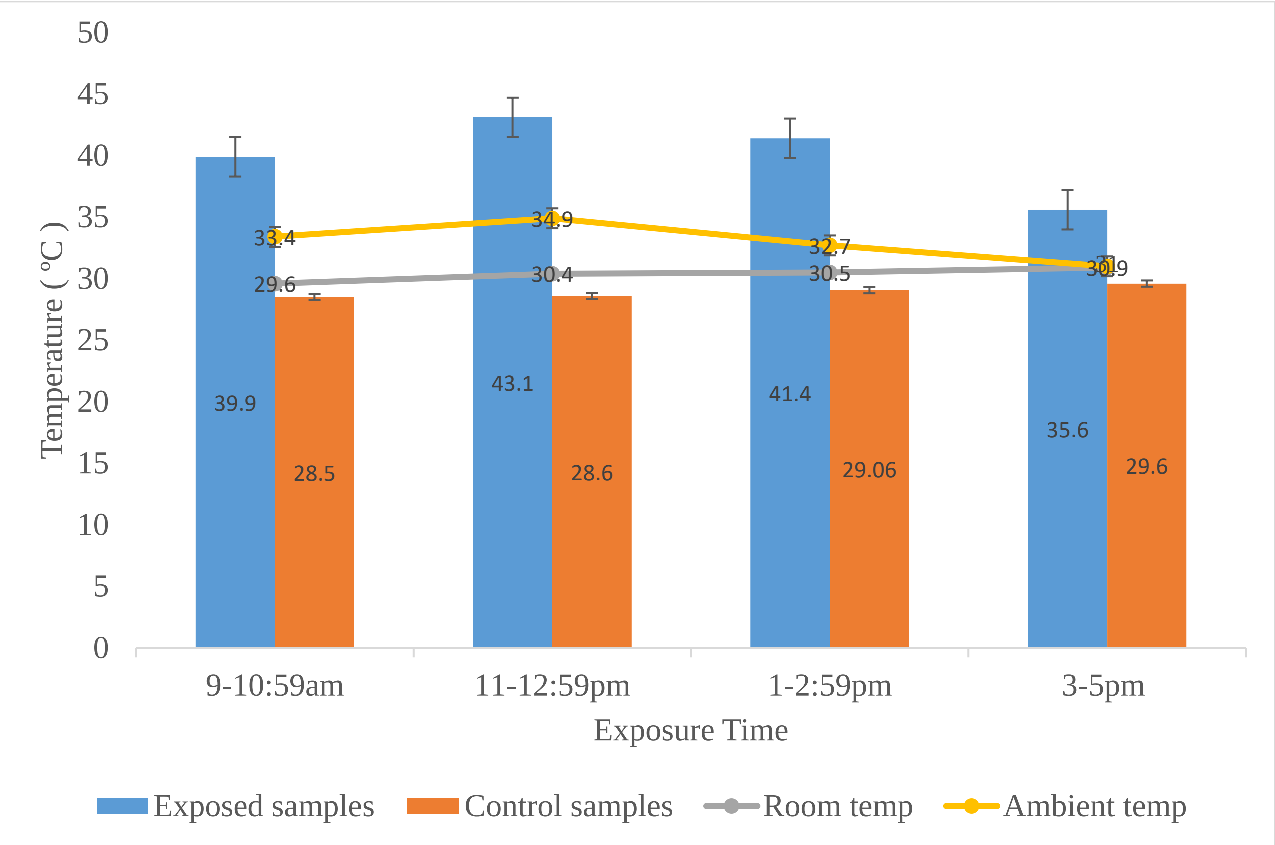

Figure 1: Ambient Air and sachet water temperatures.

TPH levels in sachet water

Amongst the sachet water set as to control, levels of TPH were discovered even under room temperature. It was recorded that, Brand 5 had the highest levels of total petroleum hydrocarbons (2.3×10^{-3} μgl^{-1}), and Brand 3 recorded the least levels of the total petroleum hydrocarbon with a concentration of (1.6×10^{-3} μgl^{-1}). Brand 2 and Brand 4 however recorded the same levels of TPH, $1.7\times 10^{-3}\mu gl^{-1}$ as shown in table 2. It was found that the levels of TPH in sachet water had increased to a considerable concentration after it was exposed to the sunlight. The findings revealed that, Brand 4 had the highest levels of TPH (3.1×10^{-3} μgl^{-1}), while Brand 3 recorded the least levels of the TPH with a concentration of (2.1×10^{-3} μgl^{-1}). Brand 1 and Brand 2 recorded the same levels of TPH as shown in table 2. Comparing the control and exposed samples, the study observed that, Brand 4 recorded the highest increase of 1.4×10^{-3} μgl-1 representing 42.4 % out of the total increase levels with the least being Brand 5 which recorded no increase in the levels of total petroleum hydrocarbons. In all, an average increase of 26.4 % was realised as shown below.

The findings of the study emphasised that, there was a leach of Total Petroleum Hydrocarbon even at room temperature into the sachet drinking water. The study indicates that the levels of TPH present in sachet water are less considered by manufacturers. This confirms the world vision report, 2008, which observed that water provided to homes, trade and businesses in most developing countries particularly sub-Sharan Africa, does not meet drinking standards. Approximately 48 percent of Africa's total population lack access to safe drinking water, including those packaged and sold in various forms and regions. After exposing samples to sunlight for seven (7) days, there was a considerable change in the levels of TPH in the water. This indicates that sunlight had a considerable effect on the increase in the TPH levels in the sachet, however, statistically, the difference was insignificant. Yet there is a positive correlation (0.428) between the temperature and the total petroleum hydrocarbon levels. That is, increase in temperature directly increases the TPH levels in the water samples. The influence of temperature which is mostly affected by the intensity of sunlight,- increases the efficiency of degradation of Petroleum Hydrocarbons (Aung, 2018). Higher temperatures increase the rate of reaction, thus the formation and dissociation of bonds. The difference that exists in the TPH levels when exposed to the sunlight is much attributed to the type of plastic used in the packaging of the water as reported by Kongsgard, Anders, Oien, Inger-Ann and Bruum, 2010 who observed all plastics containers and closure systems leach chemical compounds to some extent. But some types of plastics leach higher amounts (at some range of temperature) of compounds than others into substances. This is shown by Brand 5 which recorded no TPH leach when it was exposed to the sunlight under the same conditions. Brand 4, on the other hand, recorded a higher leach of TPH indicating a different version of the plastics used in the packing of the sachet drinking water. The study also observed that, on the 5^{th} day of the exposure printing on the sachet had faded, plastics softened and consequently burst. Inks used in printing are made of chemicals including hydrocarbons like toluene which can find their way into the water as the plastics expand. A strong correlation between the temperature and TPH levels indicates that the sunlight effect has a direct association with the levels of the TPH identified in the sachet water.

Table 2: Level of TPH in sachet packaged drinking water

Brand	Control (T_C)	Exposed (T_E)	Increase	% Increase
1	$1.9\times10^{-3}\mu gl^{-1}$	$2.5\times10^{-3}\mu gl^{-1}$	$6.0\times10^{-4}\mu gl^{-1}$	18.2
2	$1.7\times10^{-3}\mu gl^{-1}$	$2.5\times10^{-3}\mu gl^{-1}$	$8.0\times10^{-4}\mu gl^{-1}$	24.2
3	$1.6\times10^{-3}\mu gl^{-1}$	$2.1\times10^{-3}\mu gl^{-1}$	$5.0\times10^{-4}\mu gl^{-1}$	15.2
4	$1.7\times10^{-3}\mu gl^{-1}$	$3.1\times10^{-3}\mu gl^{-1}$	$1.4\times10^{-3}\mu gl^{-1}$	42.4
5	$2.3\times10^{-3}\mu gl^{-1}$	$2.3\times10^{-3}\mu gl^{-1}$	$0.0\mu gl^{-1}$	0.0
Total			$3.3\times10^{-3}\mu gl^{-1}$	100
Average % increase				26.4

The health risk posed by the identified levels of TPH

Ramesh et al. (2011) reported that most hydrocarbon compounds have been identified to cause toxicity and cancer in species including humans. TPH primarily, can cause skin, lung, breast, scrotum, bladder, colon and other cancers. Besides the capacity of hydrocarbons to cause reproductive, developmental and neurotoxicity has reached the centre phase (Ramesh et al, 2011). TPH has several carcinogenic components, including naphthalene and benzene. Clean and safe drinking water should be free of contaminants, including chemical sources, according to the (WHO, 2011) Maximum contamination Level of TPH in water. This study has revealed the presence of TPH levels in sachet water when exposed to direct sunlight which has the potential to cause cancer and other related diseases. Technological ways of detecting petroleum products in water, have provided a sound foundation for evaluating the prospective health hazards associated with large-scale drinking water contaminated by petroleum products, however this study did not observe the individual hydrocarbons, yet there is a tendency that some harmful hydrocarbons might be included in the TPH. The difference in TPH components cannot be identified owing to restricted technology and the large number of components that make up the TPH. However, the United State Environmental Protection Agency has established a maximum contaminant limit for a few identified and dangerous components such as naphthalene, benzene and ethylbenzene. Higher levels of TPH is likely to be recorded in sachet water when exposed beyond the seven (7) days. According to WHO recommendations, sachet water containing a TPH is not safe for drinking particularly with long-term consumption as it can lead to cancer growth.

CONCLUSIONS AND RECOMMENDATIONS

The primary aim of this research was to assess changes in Sachet drinking water's chemical constituents when subjected to sunlight. The temperature has a significant role in various chemical reactions. They speed up bond breaking and formation. The total ranges of temperatures of the sachet water increased when the intensity of the sun increased hence a direct effect of sunlight on temperature. This causes more reactions and led to the fading of labels printed on the sachet of drinking water. The concentration levels of the Total Petroleum Hydrocarbons identified were estimated and further comparison was made between the levels present in the categories of the sachet drinking water sold in the Tamale metropolis. On average, it was identified that T_E recorded had a higher level of TPH than T_C but the difference was not statistically significant yet both samples showed a considerable level of TPH at a percentage increase of 24.6. A correlation was drawn between temperature and the levels of TPH. Temperature and the levels of TPH in the sachet water had a positive correlation, thus the effect of temperature has a direct increase in levels of the TPH leached into the sachet water.

Health wise, WHO proposes that water should be free from TPH. Various constituents of TPH may be able to be detected by higher application of technology for numbers of known hydrocarbon constituents making up the TPH. USEPA however has set Maximum Contaminant Limit (MCL) for a few identified and carcinogenic constituents. Per WHO recommendations, the sachet water containing TPH is not safe for drinking especially with long-term intake because it can lead to the development of cancer.

The study recommends that proper treatment and chemical analysis should be done before packaging sachet water for consumption or distribution to prevent the introduction of TPH into sachet drinking water. Again, plastics used in the packing of sachet water should be of good quality to reduce the levels of TPH that may leach into the packaged drinking water.

Finally, sachet water should be stored away from direct sunlight to prevent the leaching of TPH into the water.

REFERENCES

Abidi, N., Cabrales, L., & Hequet, E. (2009). Functionalization of a cotton fabric surface with titania nanosols: applications for self-cleaning and UV-protection properties. *ACS applied materials & interfaces*, *1*(10), 2141-2146.

Aslan, A., Beslin, C. J., Poole, A. L., Anderson, K., Gallard, J., McGowan, K., ... & Afriyie- Gyawu, E. (2016). Microbiological Assessment of Sachet Water in Ghana, West Africa.

AUNG, M. T. M. (2018). Study on Aquatic Coastal Ecosystem Management in Tropical and Temperate Areas Using Microbiological Function Measurement Approaches.

Borra, C. R., Pontikes, Y., Binnemans, K., & Van Gerven, T. (2015). Leaching of rare earths from bauxite residue (red mud). *Minerals Engineering*, *76*, 20-27.

Crone, T. J., & Tolstoy, M. (2010). Magnitude of the 2010 Gulf of Mexico oil leak. *Science*, *330*(6004), 634-634.

Dada, A. C. (2011). Packaged water: optimizing local processes for sustainable water delivery in developing nations. *Globalization and Health*, 7, 24. http://dx.doi.org/10.1186/1744-8603-7-

Edition, F. (2011). Guidelines for drinking-water quality. *WHO chronicle*, *38*(4), 104-8.

Evenson, E. J., Orndorff, R. C., Blome, C. D., Böhlke, J. K., Hershberger, P. K., Langenheim, V. E., ... & Weyers, H. S. (2013). *US Geological Survey Water Science Strategy--observing, Understanding, Predicting, and Delivering Water Science to the Nation*. US Department of the Interior, US Geological Survey.

International Agency for Research on Cancer. (2018). Latest global cancer data: Cancer burden rises to 18.1 million new cases and 9.6 million cancer deaths in 2018. *IARC: Lyon, France*.

Johnston, R., & Amoako-Mensah, S. (2014). Water Quality Module of the Ghana Living Standards Survey VI: Monitoring Household Drinking Water Quality Through a Household Survey. Water and Health–Where Science Meets Policy. *Water and Health—Where Science Meets Policy. Chapel Hill, NC: University of North Carolina*.

Kongsgaard,E.U.,Anders,A.,

Oien,M.,Inger-Ann,Y.O.,& Bruum, I. L. (2010). *Leaching effects caused by high temperature steam sterilisation of prefilled plastic syringes. BMC Nursing*. 10(86) 472-695

Manley, G. (2013). Public Access NIH Public Access. *71*(2), 233–236. https://doi.org/10.1038/mp.2011.182.doi

Muzenda, E., Ramatsa, I. M., Ntuli, F., Belaid, M., & Tshwabi, P. M. (2011). An Investigation into the Effect of Temperature on the Leaching of Copper-Matte. *molecules*, *2*(43), 3.

Ramesh, A., Archibong, A. E., Hood, D. B., Guo, Z., & Loganathan, B. G. (2011). Global environmental distribution and human health effects of polycyclic aromatic hydrocarbons. *Global contamination trends of persistent organic chemicals*, 95-124.

Sanches Filho, P. J., Luz, L. P. D., Betemps, G. R., Silva, M. D. R. G. D., & Caramão, E. B. (2013). Studies of n-alkanes in the sediments of Colony Z3 (Pelotas-RS-Brazil). *Brazilian Journal of Aquatic Science and Technology. Itajaí, SC. Vol. 17, n. 1 (2013), p. 27-33*.

Stoler, J., Tutu, R. A., & Winslow, K. (2015). Piped water flows but sachet consumption grows: The paradoxical drinking water landscape of an urban slum in Ashaiman, Ghana. *Habitat International*, *47*, 52-60.

Sung, K., Kim, K. S., & Park, S. (2013). Enhancing degradation of total petroleum hydrocarbons and uptake of heavy metals in a wetland microcosm planted with Phragmites communis by humic acids addition. *International journal of phytoremediation*, *15*(6), 536-549.

Wardrop, N. A., Dzodzomenyo, M., Aryeetey, G., Hill, A. G., Bain, R. E., & Wright, J. (2017). Estimation of packaged water consumption and associated plastic waste production from household budget surveys. *Environmental Research Letters*, *12*(7), 074029.

Westerhoff, P., Prapaipong, P., Shock, E., & Hillaireau, A. (2008). Antimony leaching from polyethylene terephthalate (PET) plastic used for bottled drinking water. *Water Research*, *42*(3), 551-556.

World Health Organization (WHO). (2018). Food and Agriculture Organization of the United Nations (FAO). IPCS International Programme on Chemical Safety. INCHEM, Chemical Safety Information from Intergovernmental Organization. 2015.

Yang, Y., Woodward, L. A., Li, Q. X., & Wang, J. (2014). Concentrations, source and risk assessment of polycyclic aromatic hydrocarbons in soils from Midway Atoll, North Pacific Ocean. *PLoS One*, *9*(1), e86441.

Zelinkova, Z., & Wenzl, T. (2015). The occurrence of 16 EPA PAHs in food–a review. *Polycyclic aromatic compounds*, *35*(2-4), 248-284.

Zhang, W., Chaohai, W., Chunhua, F., Zhe, Y., Man R., Bo, Y., Pingan, P., & Jiamo, F. (2011). *Distribution and health-risk of polycyclic aromatic hydrocarbons in soils at a coking plant. Journal of Environmental Monitoring, 13:3426-3*

Zmit, B., & Belhaneche-Bensemra, N. (2019). Antimony leaching from PET plastic into bottled water in Algerian market. *Environmental monitoring and assessment*, *191*(12), 749.