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Insights into the factors influencing the use of plastic products for water packaging and their sustainable recycling potential

Eyere Emagbetere[a]*, Joseph Oyetola Oyekale[a], Oluwasina Samuel Omotoso[a], Benjamin Ufuoma Oreko[a], Omonigho Benedict Otanocha[a]

[a] Department of Mechanical Engineering, Federal University of Petroleum Resources, Effurun, Nigeria
*Corresponding Author- emagbetere.eyere@fupre.edu.ng

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Abstract

Plastic waste negatively affects our environment, and an assessment of their usage would be beneficial for promoting sustainable recycling. The extent of plastic use for water packaging and influencing factors were investigated in this work. Data were obtained via questionnaires and oral interviews with 700 randomly sampled respondents in Effurun, Nigeria. Basic descriptive statistics, Analysis of Variance and correlation coefficient were used to explore the data. It was found that more than 65 and 95 % of respondents consume plastic-packaged water at home and away from home, respectively, and an average of 4 sachets of 60 cl is consumed daily. There was a weak correlation (all values less than 0.31) between the demographics such as age, education, sex, income, and employment type with respondents' responses. However, significant variations were observed in the preference for sachets or bottles for different education classes and employment types. Also, the quantity that different age groups or education classes may consume varies significantly. To conclude, the population of locals can easily be used to quantify obtainable waste from plastic water packages regardless of demographics. However, consideration should be given to age and education distribution for proper planning or citing a recycling.

1. Introduction

There are several harmful environmental effects associated with plastic waste. Such effects include the release of toxins to the soil as they degrade with time, deaths of marine lives due to indigestion or suffocation from their intake, adverse health effects for man and animals resulting from leached chemicals, underground water pollution and blockage of canals [1, 2]. To alleviate these effects, several attempts have been made to reduce plastic usage, and they include sensitization [3], government regulations such as high taxes, bans and incentives [4] and creating other alternatives [5]. These attempts seem futile because plastics are relatively cheap [6]. Recycling them may be the way to go, as it has excellent economic prospects. Notwithstanding, the economic benefits from plastic recycling must outweigh associated problems for wider adoption. Recycling plastics for reuse or converting them to new products can be beneficial, but the availability of used ones could be a major setback.

One way of addressing issues with plastic wastes is to reuse them for purposes other than the reason they were made without any reprocessing. There are reports of plastics being used as asphalt binders

for road construction. It improves the nature of the street by lessening dampness assimilation and porousness on the street surface. Thus, it is added to bitumen for road construction [7, 8]. Likewise, they are used for creating floor or wall tiles, as they contain properties that can serve as good anti-porous agents [9]. Plastics have also been reportedly used for stabilizing soil, mainly to improve some of its properties [10, 11], but it is argued that the large quantity needed has greatly reduced its application [12]. A last area of application is developing composite materials [13]. However, most of these researched application areas are still in their early stages and are not being implemented yet.

Converting plastic wastes to other valuable products is another way of reducing their adverse environmental effects. The mechanical method can be used to produce grains of plastics and later new products via sorting, washing, shredding, melting, extruding, pelletizing, and remoulding [14, 15, 16, 17]. On the other hand, chemical recycling converts plastic waste into chemical feed stocks that can later be used to manufacture virgin-quality polymers. It involves processes such as pyrolysis, solvolysis, and high concentration acid method, supercritical fluid de-polymerization or hydrolysis [18, 19]. Plastic wastes are also converted to electrical or heat energy by burning them with incinerators [20, 21]. There are also other unpopular techniques, such as high voltage fragmentation and fluidized Bed disintegration: a thermal technique used for fibre recovery from thermosetting plastics [18]. The mechanical recycling technique is the most environmentally approachable technology for recycling; it does not produce toxic gases and chemicals into the atmosphere [18], and it can be deployed profitably. However, specific questions about the sustainability of pursuing local waste plastic recycling remain unanswered.

The economic viability of mechanical recycling of plastic waste materials has been investigated by Geetha et al. [22]. They focused on the effect of cost resulting from sorting. However, a lot has been reported on sorting techniques, namely: manual [23], NIV (Near Infrared) and MIR (Mid-wavelength Infrared) technologies [24], electromechanical mechanisms [25], and Radio Frequency Identification (RFID) based technology [26]. Thus, one can say that there is sufficient information as to which sorting procedure would help reduce product price.

Product availability is also a factor to be considered regarding sustainable plastic waste recycling. The use of plastics, particularly polythene materials, for water packaging is the widest single-use case. As a result, the bulk of plastic wastes littering our environment today is from water packages, including sachet and bottled water products. It has been demonstrated that a large proportion of residents in the United Arab Emirates use plastics for water packaging and are willing to participate in recycling exercises [27]. Also, it was reported that the quantity of polythene bags used on the Nigerian campus correlates with academic and business activities [28]. Related investigations bothering on the usage and disposal of plastics have been reported for several study areas, including Kerala [29], Wardha City [30], Southwestern Ethiopia [6], Kerala [29], Yemen [31], and Turkey [32]. Nevertheless, there is a need to probe further the quantity of local plastic waste obtainable from water packaging and the influencing factors.

This article investigates the use potential of plastic materials for water packaging and some demographic factors that may influence their usage in the Niger-Delta region of Nigeria. Water and drink packaging are the most severe single-use case of plastics materials, constituting a significant part of plastic waste locally [27]. As a result, waste polythene bags can be found littered in the streets of many cities. Information on the availability of polythene wastes may be helpful for sustainability planning of its recycling; such information would be useful for sighting recycling plants and preparing a recycling business plan.

2. Methodology

2.1 Description of the study area

This research was carried out in Effurun, a town in Delta state of Niger Delta region, Nigeria. It is one of the most populated towns in the region [39]. It is a multi-ethnic town comprising people of different religions, tribes, and demographics. There are numerous portable water producing companies within the town, as it has no central source of water supply. The town's geographical coordinates are 5^{o} 33' 0" North 5^{o} 47' 0" East. The region is faced with two distinct weather seasons, dry and wet seasons.

2.2 Survey form

The survey in this study was carried out by questionnaire distribution and oral interviews. The questionnaire contains questions that bothers on demographic factors (gender, residence location, nationality, age, education, income, and occupation), mode of disposal, the quantity of water taken per day (per 60 cl), preferred water packaging, the degree to which residents travel and attend social events, and quantity and type of water packaging taken during a social outing, on a journey or at work. The information gathered was then sorted, collated and analyzed statistically. Overall, 652 out of 700 questionnaires were valid for the analysis. Also, information on the different materials and their properties used for water packaging and quantities sold per day were also obtained from four different producers.

2.3 Statistical analysis of results using ANOVA and descriptive statistical tools

Various statistical tools in MATLAB® version 2019 were used to analyze and explored the data. Descriptive statistical tools and appropriate graphics first were used to explore the data set. Then, Analysis of variance (ANOVA) at a confidence level of 5 % was used to access the variation in the data set, followed by correlation analysis using the Person correlation coefficient.

3. Results and Discussion

3.1 Demographics of respondents

Stratified random sampling was used to appropriately represent the societal classes or demographic population. A total of 700 people were interviewed or surveyed, with the number of respondents distributed demographically. Six hundred and fifty-two (652) out of the seven hundred (700) respondents' questionnaires were properly filled out and fit for the analysis. Figure 1 shows the age distribution and sex of the different respondents surveyed. There were more male respondents for all age groups. The highest number of respondents was observed for respondents in the age group of 18-25 years, while the lowest was for those under 17.

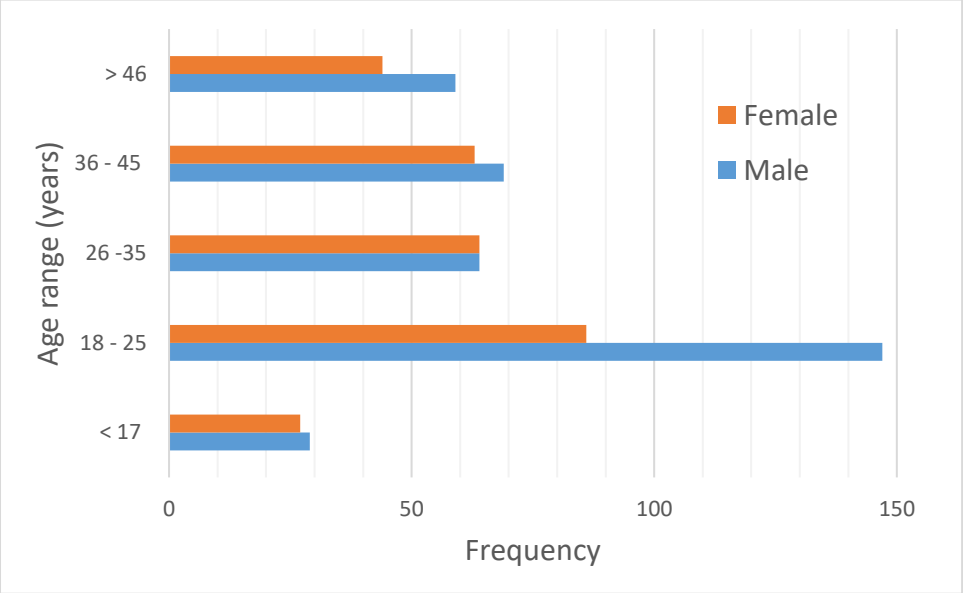

Figure 1. *Number of respondents per age group for male and female respondents*

Overall, 43 % of the respondents indicated that they were married, as shown in Figure 2. This is consistent with the report given by Statista [33], which indicated that about 39 million out of 93.4 million people were married as of 2020.

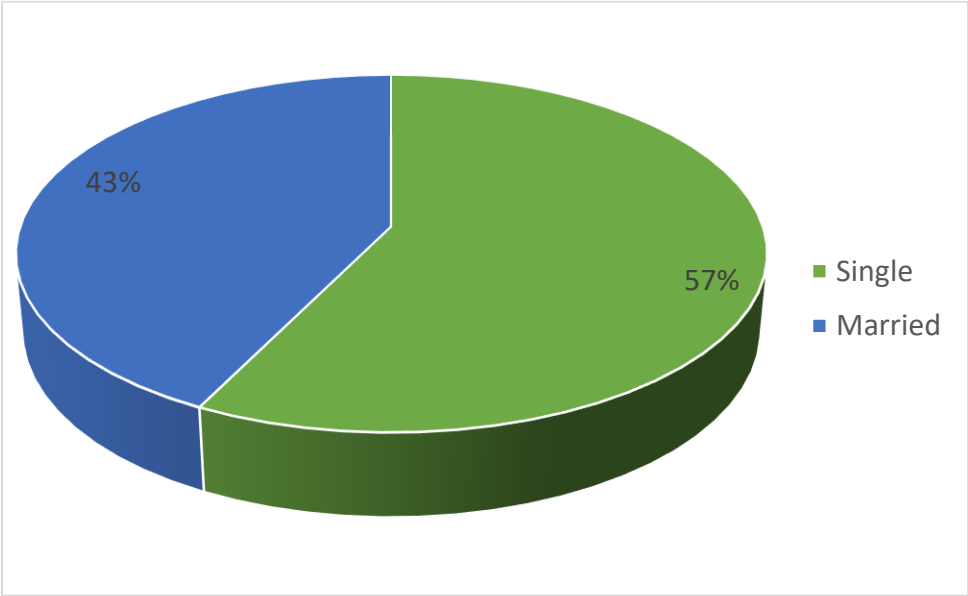

Figure 2. *Marital status of respondents*

The majority of the respondents had at least secondary education, as only 8 % possessed just primary education, as shown in Figure 3. Also, 25 % were educated up to university, while just about 15 % had postgraduate education. All respondents have at least primary education because it is free and compulsory for Nigerians [34]. Additionally, secondary education is also free, but a few persons may not be able to complete their secondary education, probably because of poverty or health issues. But overall, about 92 % of the respondents had at least a secondary education, with 53% owning a university degree.

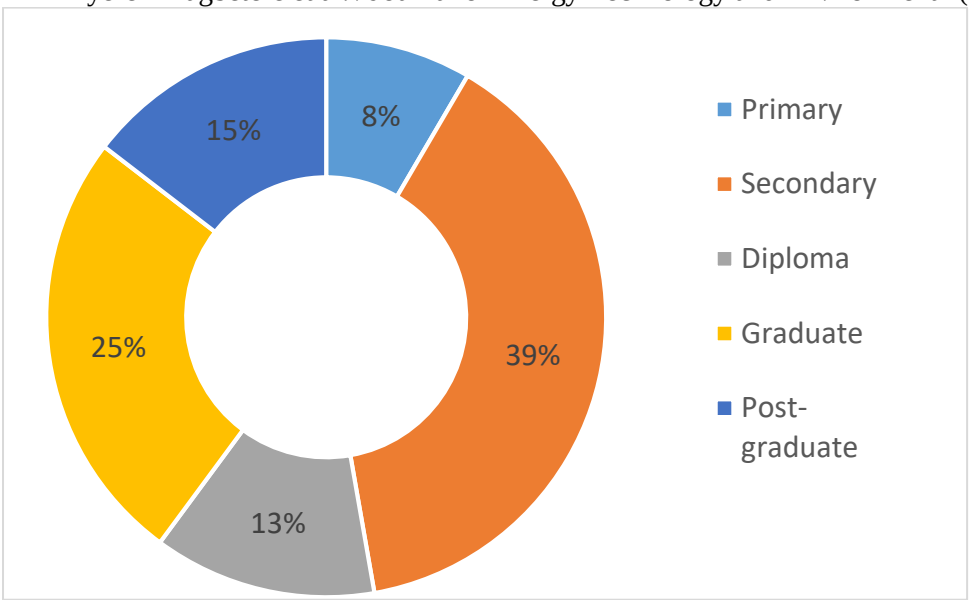

Figure 3. *Education distribution of respondents*

The respondents reported various employment engagements, as displayed in Figure 4. Those self-employed toped the chat, being 41 % of all employment types. The self-employed categories are those who are doing any form of business or own a shop where they trade. Meanwhile, about 29 % of the respondents were unemployed, constituting a large number of the younger population. Respondents engaged with confirmed employment status were about 23 % in all. The last categories were those who were probably students or dependent and formed about 7% of the respondents.

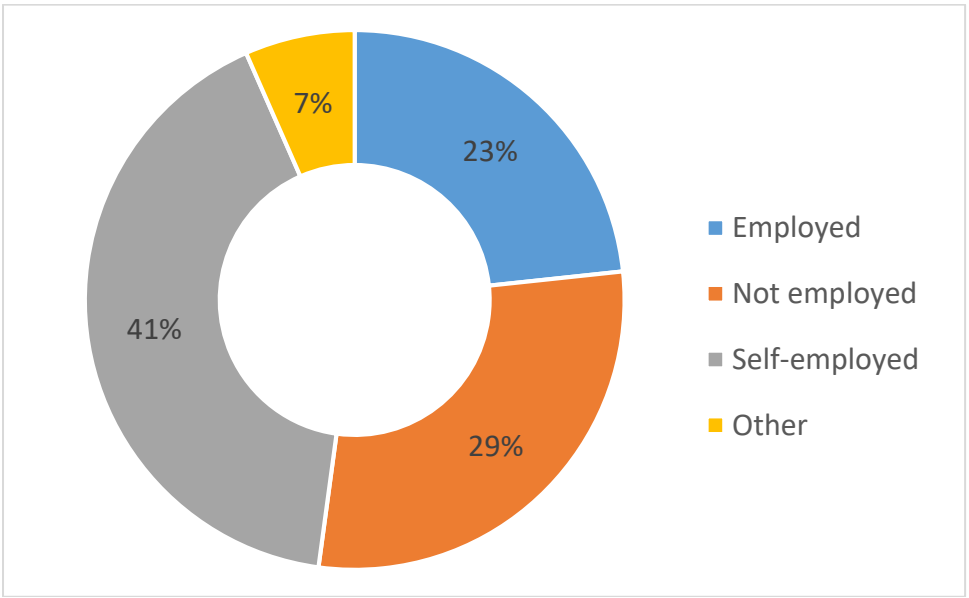

Figure 4. *Distribution of Employment of employment types for respondents*

Figure 5 shows the income of the different respondents. Up to 43 % received below forty-five thousand Naira (N 45,000) per month. These categories of individuals are the largest in the population, and it is in line with a recent report that many Nigerians live in poverty [35]. Just about 13 % earns more than two hundred thousand Naira, which may be considered high income in Nigeria. Overall, the population per income class decreases as the value increases.

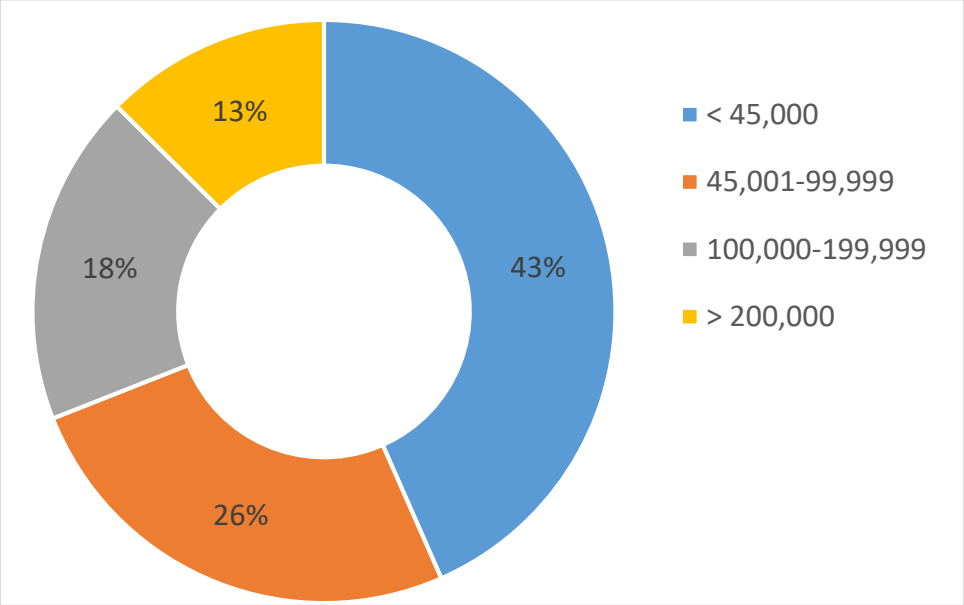

Figure 5. *Income distribution of respondents*

3.2 Water consumption pattern by respondents

There are three categories of water consumption classes considered for this investigation. The first group is the type consumed at home, the second is the type taken at work, and the final class is that taken on a journey, as presented in **Error! Reference source not found.**. Many respondents would consume water packaged with polythene sachets at home and work. It is the cheapest portable water source, thus widely taken at home. The proportion of respondents who take sachet water at home and work are 55 and 66 %, respectively. Therefore, that quantity of wastes sachets could be recovered from homes and workplaces. Most respondents would take water packaged with polythene bottles when on a journey. The reason given for this is primarily hygiene, as it is generally opined that the bottled water is better processed and may be more hygienic to trust when the particular brand is not tested and trusted. This suggests that a large volume of plastic bottle wastes can be recovered from transport vehicles. Only about 29 and 12 % of respondents, at home and work, respectively, take water from sources other than those packaged with polythene materials. Other sources here may include water obtained directly from taps, water dispensers, or other local sources. However, not many respondents would drink water from a regular source when travelling on a journey, as they would either buy sachet or bottled water on the way. So, public buses could be a significant source of waste polythene materials, as most people would buy water packaged with a can or sachet when on a journey. However, a more significant proportion would opt for bottled water because it is assumed to be purer than sachet water.

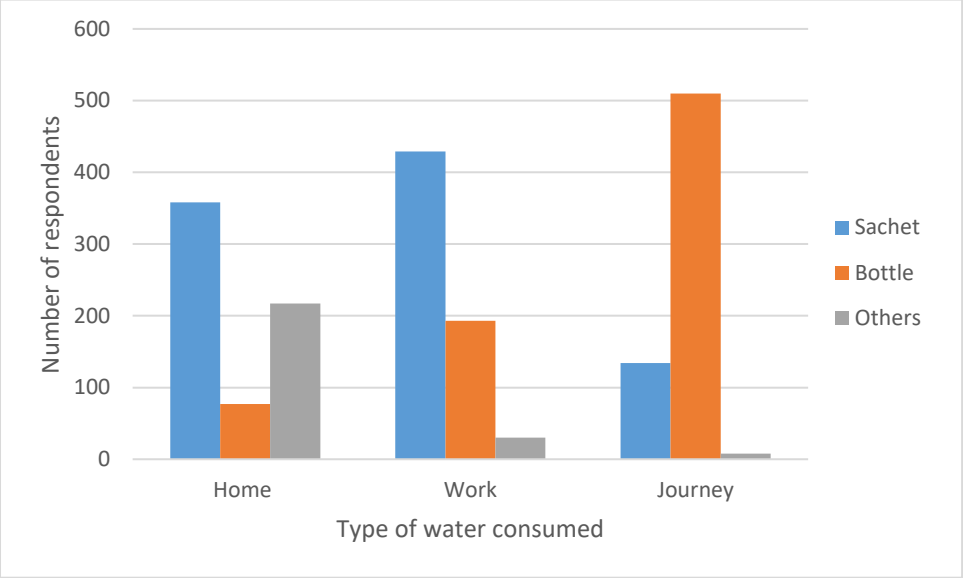

Figure 6: *Type of water package taken by respondents*

The amount of water consumed by respondents per day is shown in Figure 7. As can be observed, up to 40 % of the respondents takes about 5 to 6 sachets or bottles of water of 60 cl daily, and about the same amount drinks up to 4 sachets or bottles daily. The average daily water consumed was reportedly 2.1 and 2.8 cl for females and males, respectively [36]. So consumption of 3-6 60cl sachets/cans would amount to about 1.8-3.6 litres per day, which is consistent with the report of Altun et al. [36], and the recommended daily water consumption for females and males, respectively [37]. Only a tiny proportion drinks less than two sachets or bottles per day. The proportion who drinks this few is for those who may consume water from other sources and would take sachet or bottled water only if there are limited choices. One can thus deduce that about 2.7 litres, the average volume of water consumed by respondents, would give about five waste sachets per individual since a sachet or small bottle contains about 60 cl of water.

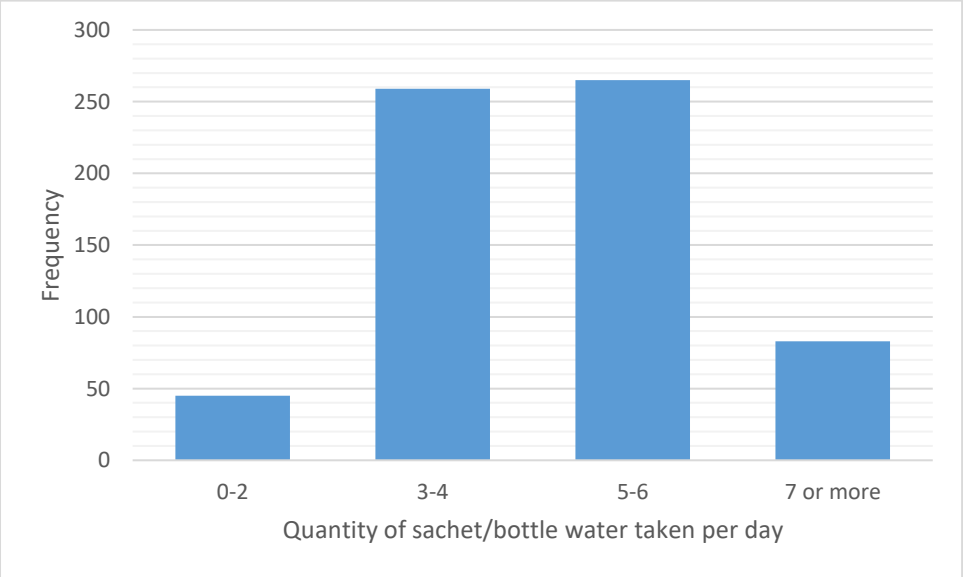

Figure 7. *Amount of sachets/bottles of water taken per day*

3.3 Means of disposal of respondents

The preferred method of disposal by respondents is shown in Figure 8. Most respondents dispose of their used polythene responsibly by trashing them. This is an indicator that it may be easy to collate most waste materials for recycling. This finding is not strange as it has been reported that people are very likely to support good environmental practices for plastic waste disposal and recycling [27]. Only a few would gather them to resell, burn or just litre it. Reselling and burning were the least practices among respondents.

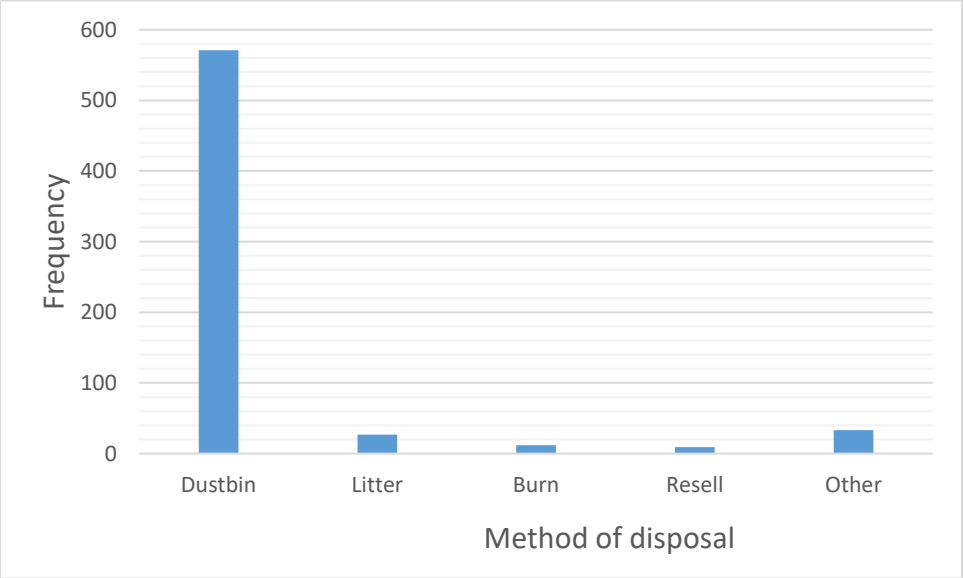

Figure 8. Histogram showing the frequency of disposal methods by respondents

3.4 Analysis of Variance

For different demographic factors (education, employment, income and age), some critical responses (packaging preference, daily consumption and mode of disposal) were arranged in groups. Then the variance was analyzed using ANOVA at a 5% confidence level. The goal of the analysis was to ascertain the variance in the responses as affected by these demographic factors. The result obtained is summarized in

Table 1. The result showed calculated values of the sum of squares (SS) which measures the deviation from the mean, the degree of freedom (df) which is a number less than the number of items per group, both of which were used to determine the mean squares (MS). Larger deviations were obtained for the preferred method of packaging compared to other responses considered. Relatively small values of SS and MS were obtained for all responses in the income categories indicating that income would very likely affect the responses the least.

Although the F and F-crit values can be used to determine the significance of each variation, the p-value also tells the same story. So the p-values were used to identify which responses had significant variations for the selected demographic factors investigated. As can be observed, the type of package preferred varies significantly for different classes of education and employment, having p-values less than 0.05. The quantity of water consumed by day significantly differs for respondents with different education and age groups, as these also had p-values less than 0.05. Mode of disposal showed significant variation for respondents of different levels of education and age.

Table 1. ANOVA results for various demographic factors

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Education and packaging preference	49.37	4	12.34	16.13	1.34E-12	2.39
Education and daily water consumption	7.30	4	1.82	2.91	0.021142	2.39
Education and mode of disposal	116.65	4	29.16	31.65	4.23E-24	2.39
Employment and packaging preference	9.95	3	3.32	4.02	0.00754	2.62
Employment and daily water consumption	3.00	3	1.00	1.58	0.193361	2.62
Employment and mode of disposal	4.98	3	1.66	1.76	0.153797	2.62
Income and packaging preference	2.69	3	0.90	1.07	0.360954	2.62
Income and daily water consumption	4.06	3	1.35	2.14	0.093907	2.62
Income and mode of disposal	3.71	3	1.24	1.31	0.27039	2.62
Age and packaging preference	497.16	4	124.29	1698.31	0.073027	2.39
Age and daily water consumption	11.09	4	2.77	4.46	0.001463	2.39
Age and mode of disposal	8.42	4	2.11	2.24	0.063296	2.39

3.5 Correlation analysis

Pearson correlation coefficient was determined for the different demographic factors and responses. The result is captured in
Table *2*. As can be seen, none of the factors showed strong correlation with any of the responses since all the values of correlation coefficient are closer to zero than one, so it may be difficult to develop models that could be used to predict such outcomes based on the demographic factors. However, the age and income of respondents are weakly correlated with the sort of water taken at home and the sort of water taken on a journey, having correlation coefficients between 0.2 and 0.3 for all cases. Also, education was weakly correlated with water preferred at home, outside the home, such as at work and on a journey. All other factors had no significant correlation with responses, having very low values of correlation coefficient. Most of the factors showed weak correlation because it has become cultural for many to take packaged water in the absence of access to pipe-borne water [38].

Table 2. Result of correlation analysis for the different demographics

	Gender	***Age***	***Marital Status***	***Education***	***Employment***	***Income***
Sort of water at home	0.0928	0.3054	0.2753	0.1535	-0.0467	0.2682
Quantity of water taken a home	-0.0277	0.0002	0.0016	-0.0066	0.0616	0.0026
Disposal method	-0.0238	-0.1206	-0.1006	0.0146	-0.0339	-0.0705
Sort of water on a journey	0.0283	0.2175	0.1586	0.2527	0.0410	0.2496

Sort of water outside home	-0.0819	0.0900	0.0007	0.2077	-0.1416	0.1908
Sachet water intake rate	-0.0150	-0.0527	-0.0538	-0.0997	0.0489	-0.1277
Bottle water intake rate	-0.0052	0.0592	0.0259	0.1509	-0.0584	0.1509

3.6 Product description and assessment of Factors that affects consumption from the Manufacturers' Perspective

Information on the packaged water products from four different factories is shown in Table 3. The average volume as written on the label was noted for different categories of water products, as well as the mass of the pack itself. It was informed by the vendors via direct interview that the major factor which affects their total volume of sales per day is the weather condition. The average number of packs sold per day was then computed for all four companies and recorded. The variation in the number of packs dished out per day varies significantly for the year's season, having a p-value less than 0.05, with higher sales recorded for dry/hot seasons.

Table 3: summary of products from four different companies

S/No	Category	Volume (cL)	Average Mass of package (g)	Average daily sales in wet season (packs)	Average daily sales in hot season (packs)
1	Sachet	60	2	350	480
2	Bottle	60	13	170	220
3	Bottle	120 or 150	22	55	85

4. Conclusion

In order to determine the prospects for plastic waste recycling from water packages, a total of 652 questionnaires regarding the use of plastic materials for water packaging were examined. At least 55 % of a similar population would yield about five used sachets or bottles per day from work and home water consumption. These figures could be higher during the dry season, and the demographics of the populace cannot be used to predict them. Also, many waste plastic bottles can be recovered from travelling vehicles. Meanwhile, many people would present a favorable attitude toward gathering plastic waste. Finally, there would be significant variation in the packaging preference for populations with different education or employment classes. The quantity of waste obtainable could vary for people of different education or age. Therefore, utmost consideration must be given to the obtainable quantity of wastes from a given population for planning or citing a recycling plant that would depend on water packaging waste.

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Appendix: Survey questionnaire

FEDERAL UNIVERSITY OF PETROLEUM RESOURCES
P.M.B. 1221 EFFURUN, DELTA STATE, NIGERIA.

DEPARTMENT OF MECHANICAL ENGINEERING

This questionnaire is a part of a research of a Final Year Student research aimed to ascertain the level of use sachet and bottled water. Be rest assured that every piece of information provided will be kept anonymous and remain undisclosed.

THANK YOU!

1. What is your gender? ◯ Male ◯ Female
2. Which age category do you belong? ◯ 17 or younger
   ◯ < 17 ◯ 18 – 25 ◯ 26 – 35 ◯ 36 – 45 ◯ > 45.
3. What is your marital status? ◯ Single ◯ Married

4. What is your highest educational qualification?
◯ Primary school ◯ Secondary school ◯ Diploma ◯ Graduate ◯ Post-graduate

5. Which of the following best describes your employment status?
◯ Employed ◯ Not employed ◯ Self-employed ◯ Other.
6. What is your average monthly income?
◯ < 45,000 ◯ #45,001 - #99,999 ◯ #100,000 - #199,999 ◯ > #200,000
7. What sort of drinking water do you take at home?
◯ Sachet ◯ Bottled ◯ Others
8. If at home throughout, on the average, how many sachets/can of water do you drink daily?
◯ 0 ◯ 1 - 3 ◯ 4 - 6 daily ◯ 7 and above.
9. At home, after you have finished drinking water, what do you do with the sachet/can? ◯ Dustbin ◯ Litter ◯ Burn ◯ Resell ◯ Other.
10. If you are on a journey what sought of water would you buy to drink?
◯ Sachet ◯ Bottle ◯ Others
11. How often do you travel per month average?
◯ 0-2 ◯ 3-5 ◯ 6 or more
12. What sought of water source do you take outside your home (work/school as the case may be)? ◯ Sachet ◯ Bottle ◯ Others
13. Would you drink Sachet water, if offered on a social gathering (party/outing with friend)?
[yes] [NO] / Bottle [YES] [NO]
14. If yes, on an average, how often do you go out for such events monthly?
◯ 0-2 ◯ 3-5 ◯ 6 or more