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Recyclable Potential of Car Wash Effluent for Concrete Production

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Abstract

The need to find sustainable ways to reuse water to ensure its continued supplies has been in the forefront of water conservation discuss globally. Increasing population and high standard of living as evidenced in the increased purchase of cars by the middle class leading to more water being utilised for washing and cleaning of the exterior and interior compartments of cars. This study investigates the potential of car wash effluent to be employed for concrete production thereby reducing the burden of water extraction for construction purpose. Car wash effluent was collected from selected car wash enterprises in the Ugbowo area of Benin City. The first and second wash effluent were subjected to physicochemical, setting time tests, slump tests and compressive strength tests. The results showed that the first wash effluent understandably contains alkaline compounds with high concentration of most of the anions and cations. The highest setting time value of 248mins was notice for the first wash while the second wash effluent had a final setting time of 208mins less than even the control setting prepared with cement and potable water. All the slump values meet the minimum criteria for concrete even as the first wash effluent gave the highest setting time. The compressive strength of the first and second wash effluents were 65.38% and 44.74% respectively of the control concrete compressive strength produced with potable water. This fell short of its adoption for concrete production as stipulated in ASTM C1602. Consequently, it is recommended that car wash effluent, particularly the first wash effluent that has high concentration of soap or detergent should not be used for concrete production in its untreated state

1. Introduction

In the pursuit of sustainable solutions to addressing environmental challenges occasioned by water scarceness or indiscriminate drilling of borehole, the treatment and reuse of wastewater have gained traction globally. The automobile industry, renowned for its substantial water consumption and discharge, has emerged as a focal point for exploring innovative approaches to wastewater management. Automobile wastewater, considered to be complex and challenging due to its high composition heavy metals, oils, solvents, and suspended solids, is now being explored for its potential applications in construction [1, 2].

The repurposing of automobile wastewater in Benin City for construction offers several potential appeals to reduce plumage from the groundwater reservoir thereby reducing the industry's water footprint [3]. The treated automobile wastewater can contribute to soil stabilization and dust control measures on construction sites, providing an alternative to traditional water-based methods [4]. The effective treatment of automobile wastewater to meet construction standards and regulations is crucial [5]. Advanced treatment processes, such as coagulation, flocculation, and filtration, are necessary to remove contaminants and achieve suitable water quality [3]. Additionally, the long-term environmental and health impacts, as well as the economic viability and scalability of these practices, require careful consideration [4].

While some studies abound on the application of car wash effluent for construction such as building and roads as well as in other ancillary uses, generalization of the output may not be feasible considering that each jurisdiction, by virtue of culture, may define its unique soap quantity and washing methods that differentiate the nature of chemical constituents in the wastewater [6-9]. Hence a study that is localized to deliberately study the reusable potential of car wash effluents for construction in Benin City was conceived. The aim of the study is to investigate the potential of car wash effluent as replacement for potable water in concrete related works.

Mujumdar *et al.* [6], it has been noted that a significant amount of water is consumed when washing cars, and the waste water produced by the operation is simply dumped into the local drainage system. Thus, the treated water can be repurposed for car washing, reducing the need for fresh water, and discharged onto the same area to raise or sustain ground water levels. According to Baddor *et al.* [10], car wash facilities in Aleppo City have a harmful impact on the environment, contaminating the air, water, and soil with Treatment measure investigated to improve the vehicle wash effluent's quality to a point where it could be recycled, reused for the same purpose, and safely disposed of by recycling and beneficial use

According to Asha *et al.* [11], investigated the efficacy of the treatment of waste water from car service stations using chemical and physical approaches. Alum was used for chemical treatment, and locally accessible natural resources like sawdust and sugarcane bagasse were utilized for physical treatment. The study revealed that natural materials are effective at removing oil and grease and COD from the automotive effluent compared to physical and chemical techniques of treatment. Torkashvand *et al.* [12] pinpointed some of the main drawbacks of Carwash wastewater treatment procedures to include low water recovery rates, quick and severe fouling, sludge generation, energy consumption, and unfavorable changes in effluent such a drop in pH and an increase in dissolved solids. Therefore, crucial elements of on-site treatment and reuse of Carwash wastewater include short treatment times, maximum effectiveness, operational conditions, and high-water recovery ratios.

According to Mathurin *et al.* [7], evaluated the impact of the utilization of wastewater from soap production on the physical and mechanical characteristics of concrete. The experimental outcomes suggest that substituting soap factory wastewater for tap water in concrete formulation leads to diminished values in concrete’s subsidence at the Abrams cone, delays cement setting initiation, reduces compressive strength, and triggers early-stage pore formation in the concrete matrix. According to Mathurin *et al.* [7] whose primary focus was on characterizing car wash wastewater and its impact on concrete properties, analysis of chloride and Sulphate presence in car wash wastewater was compared to ASTM standards (ASTM C33). The results suggest that car wash wastewater’s pH ranged from 8.8 to 10.6, slightly higher than tap water. However, Sulphate and chloride content aligned with ASTM and BS standards. At 10% car wash wastewater, compressive strength, tensile strength, and modulus of elasticity decreased; 20% and 30% led to increasing values, but beyond 30%, the values declined. Based on compressive strength and modulus of elasticity outcomes, 20% car wash wastewater is recommended as a suitable fresh water replacement in concrete mixes. Al-Jabri *et al.* [13] conducted a study where automobile wastewater was utilized for concrete production. Experimental issues indicated that the strength of concrete incorporating auto marshland wastewater was similar to the control blend.

1.2 STUDY AREA

Ugbowo is one of the areas of intense commercial and industrial activities in Benin City. It is located in Egor local government area of the metropolis with its population making it a significant political hotspot during electioneering. It is home to the famous University of Benin and the University of Benin teaching hospital in Egor Local Government Area of Edo state. Other landmark development includes the Police Barack, the popular Evareke and Uwelu spare part markets and the Uselu markets known for the purchase of affordable foodstuff. The area often witnesses high level of construction and demolition activities towards new facility developments. Facilities that form the bulk of recent developments include but not limited to shopping complexes, eateries, petrol/gas refilling stations, hostels and educational facilities especially for private schools. The Ugbowo-Lagos Road on which most of these development and commercial activities is a high traffic volume road that usually experienced traffic congestion at almost all daylight period and this may be worsen during heavy downpours or due to the breakdown of heavy-duty trucks along the carriageway. Figure 1.1 shows the location map of Ugbowo in Benin City, Edo state.

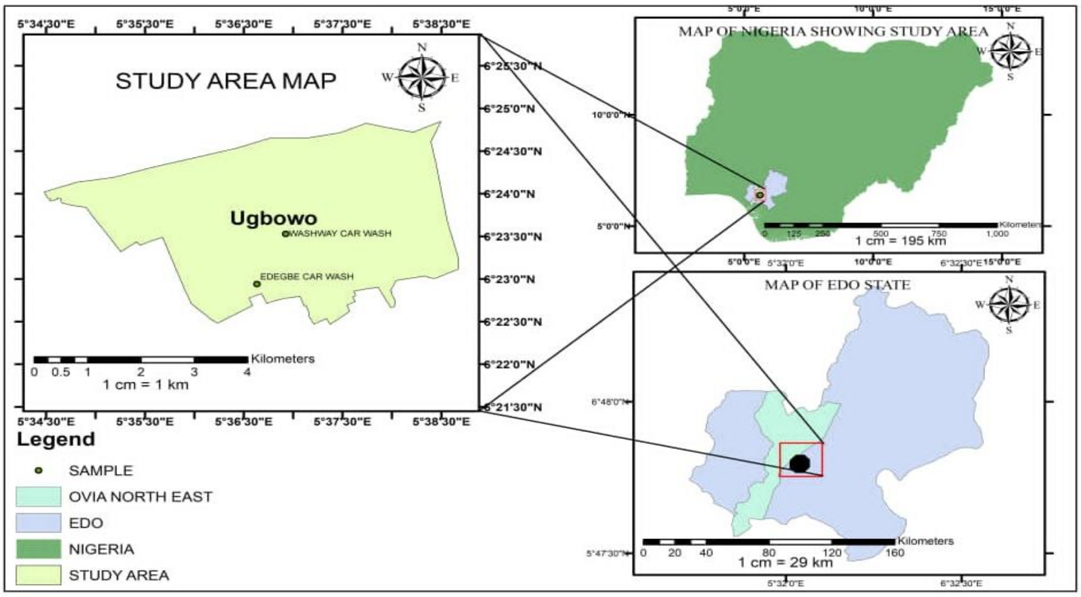

Figure 1: Map of Ugbowo in Benin City

2.0 Materials And Methods

2.1 Sampling

The car wash effluent samples were collected from two car wash enterprises tagged A (N 6°23’31.66188’’, E 5°36’55.404’’) and B (N 6°24’28.42704’’, E 5°36’25.2738). Preliminary studies indicate that the method of car wash is generally similar and groundwater is the major source of solvent for the soap solution in the study area. At the Sampling Points, car wash effluents were collected using grab sampling during or after the washing operation. Samples were collected after the first washing (FW) of the car and also after the second washing or rinsing (SW) of the car. The FW sample was prepared with copious addition of detergent or other soapy agents to attempt to remove as many tough stains and dirt on the car. SW sample is done where the FW was not adequate enough to remove sufficient dirt or attempt is made to enhance the cleaning of the vehicles. This often requires reduced amount of soap and plentiful amount of water. Therefore, the FW samples for the two sampling enterprises were labelled A_{FW} and B_{FW} while the SW samples were labelled A_{SW} and B_{SW} respectively. The samples were then taken to the laboratory for testing and analysis. Figures 2.1 to 2.3 show the process of collection of car wash effluent for this study.

1.1 Figure 2: Sample collection at sample site A

1.2 Figure 3: Sample Collection at Sample site B

Figure 4: Samples Collected

2.2 Laboratory Evaluation

The laboratory evaluation on the collected samples was restricted to physico-chemical analysis only which is in alignment with the aim of the study. Some of the tests carried out include pH, Turbidity, Salinity, Electrical conductivity, Colour, TDS, TSS, COD, NO_2^-, NO_3^-, Cl^-, P^-, SO_4^{2-}, HCO_3^{2-}, NH_4N, Mg, Ca, K, Na, Fe, Mn, Zn, Cu, Cr, Cd, Ni, Pb, V, THC. The BS EN 1008:[14] method of laboratory evaluation was adopted for the determination of these parameters from the samples collected.

2.3 Preparation of Concrete Cubes

The sample with the most critical combination of physicochemical parameters was used for the preparation of concrete to determine the influence of car wash effluent on concrete. Locally sourced coarse, fine aggregates and cement was used for the production of the concrete. This commenced with the concrete mix design and followed by the tests performed on the concrete such as slump test, setting time test and compression test.

2.4 Concrete Mix Design

Design Mix was carried out for a concrete of characteristic strength of 20N/mm^2 using the method stipulated in the COREN Concrete Mix Design Manual [15] **[15]**from locally sourced materials with the car wash effluent are shown in Table 1. Concrete mix design was carried out in Six (6) stages to determine the combination of materials that can provide the target strength of concrete. Table 2.2 and Table 2.3 shows the computed design ratio by mass and volume respectively of the materials that can provide the targeted strength of concrete. The characteristic strength of 20N/mm^2 was so selected being the minimum acceptable strength of concrete used for low-cost construction. From the mix design with the car wash effluent, the proportion of materials by volume to achieve the target strength was 1: 1.2: 2.60 of cement, fine aggregate and Coarse aggregates.

Table 1: Mix Design for Grade 20 Concrete (Using Grade 42.5 Cement)

S/NO	ITEM	Units	Values
1	**STAGE 1**		
1.1	Characteristic strength	MPa	20
1.2	Standard deviation	MPa	8
1.3	Margin	MPa	10.24
1.4	Target mean strength	MPa	30.24
1.5	Cement grade		42.5
1.6	Aggregate type: coarse		Crushed
1.7	Aggregate type: fine		Uncrushed
1.8	Free water/cement ratio		0.44
1.9	Maximum free water/ cement ratio		NONE
2	**STAGE 2**		
2.1	Slump	mm	30 – 60
2.2	Maximum aggregate size	mm	20
2.3	Free-water content	Kg/m^3	210
3	**STAGE 3**		
3.1	Cement content	kg/m^3	478
3.2	Maximum cement content (specified)	kg/m^3	
3.3	Minimum cement content (specified)	kg/m^3	
3.4	Modified free-water/cement ratio		
4	**STAGE 4**		
4.1	Concrete density	kg/m^3	2400
4.2	Total aggregate content	kg/m^3	1712
5	**STAGE 5**		
5.1	Grading of fine aggregate		Zone 11
5.2	Proportion of fine aggregate	%	34
5.3	Fine aggregate content	kg/m^3	525
5.4	Coarse aggregate content	kg/m^3	1130
6	**STAGE 6- Trial Mix quantities**	100mm cube	
6.1	Water (kg)		0.44

S/NO	ITEM	Units	Values
6.2	Cement (kg)		0.21
6.3	Fine aggregate		0.525
6.4	Coarse aggregate		1.13

Table 2: Mix Design by Weight

Quantities	**Cement**	**Water**	**Fine aggr**	**Coarse aggr.**
			(Kilogram)	
Per m^3 to the nearest kg	440	210	525	1130
Ratio	1	0.5	1.2	2.6

Table 3: Mix Design by Volume

Quantities	**Cement**	**Water**	**Fine aggr**	**Coarse aggr.**
			Cubic millimetres x 10^6	
Mix Ratio	1	0.7	1.2	2.6
Per 100mm cube (modified)	0.187	0.131	0.226	0.491

2.5 Setting Time Test

The setting time of cement using the car wash wastewater was investigated in this study. This included the two main types of setting times viz initial setting time and final setting time. The initial setting time is the time taken for the cement to begin losing its plasticity and become rigid after mixing with water. The standard initial setting time for ordinary Portland cement is around 30 minutes. Final setting time is the time it takes for the cement to fully set and harden. The standard final setting time for ordinary Portland cement is approximately 600 minutes (10 hours). The test was carried using the Vicat apparatus (including the Vicat needle), Stopwatch, graduated glass plate and Trowels (see Figure 5).

1.3 Figure 5: Setting Time Test

2.5.1 Setting Time Test Procedure

The setting time of cement was determined for the concrete produced from potable water as well as car wash effluent samples using the procedures stipulated in BS EN 1008:2002 and ASTM C191.

2.6 Slump Test Procedure

The slump test was carried out to measure the consistency of freshly mixed concrete produced from the carwash effluent. It gives details of the workability of the concrete pertinent to its ease of handling and placement. A higher slump value indicates a more workable and fluid mix while a lower slump value indicates a stiffer and less workable mix of concrete. The test is preferably performed immediately after mixing the concrete to obtain better results (see Figure 6).

1.4 Figure 6: Slump Test on Concrete in Action

2.7 Concrete Batching and Curing

Concrete cubes were produced from cement, fine and coarse aggregates using potable water as control and car wash effluent. The car wash effluents were subjected to compressive strength tests at 7, 14 and 28days intervals accompanied by adequate curing. Figure 7 showed concrete cubes produced in mould in the laboratory. A total of eighteen cubes were produced for which comprising nine cubes from samples FW and SW. The mould of dimension 100mm x 100mm x 100mm were cleaned and placed on a flat surface for which fresh concrete using the designed mixed ratio were poured on the mould and levelled with the aid of a hand trowel. The cubes produced were placed were allowed to cured for the periods purposed for compressive strength testing. All curing was done using potable water only. Figure 8 shows the concrete cubes positioned for curing operations.

Figure 7: Casting and Vibration of concrete moulds.

Figure 8: Curing of sample Concrete cubes.

2.8 Compressive Test on Concrete Cubes

Compressive strength test on concrete cubes is a standard test method used to determine the compressive strength of hardened concrete. The strength and durability of concrete structures are significantly influenced by the concrete cube's compressive strength as a measure of the cube's capacity to withstand compression. The test was conducted in a laboratory using the using the method enshrined in ASTM C1602 [16] and the outcomes compared to the mix design strength. Figure 9 shows one of the concrete cubes being subjected to compressive strength in the laboratory.

Figure 9: Testing the Compressive Strength of the Concrete Cubes

3. Results and Analysis

3.1 Physico Chemical Analysis of Car Wash Effluent

Table 3.1 shows the chemical properties of the collected waste water from the sample car wash outlets. Three crucial chemicals' properties such as TDS, Cl and HCO_3 had some of the highest concentration and from BS EN 1008:200, chemical limits were provided for which a comparison can be done to determine those parameters that exceeded extant limit. Though the value of pH and SO_4 were not in high concentration, they were also provided for in British Standard BS EN 1008

[17] and ASTM C1602 [16], hence their inclusion. The table showed that the first wash effluent was alkaline while the second wash effluent was acidic.

From table 4 also, above standards were inserted as limits for immediate comparison and it could be seen that none of these parameters which are known to have effects on concrete were exceeded. Thus, the water samples taken from both samples' sites were within the standard limits and would not need further treatment in order to be used for concrete production.

Table 4: Physicochemical Properties of Car Wash Effluent Samples.

Parameters		AFW	ASW	BFW	BSW	Limits
pH		9.1	6.7	8.8	6.6	≥4.0
Turb	(NTU)	1.8	0.8	1.3	0.5	
Sal	(g/L)	1.43	0.41	1.40	0.35	
EC	(µS/cm)	3167	908	3087	781	
Col.	(Pt. Co)	2.5	1.0	2.0	0.8	
TDS		1581	453	1531	390	≤50000
TSS		3.8	1.9	3.1	1.0	
COD		164.8	34.4	57.8	34.4	
NO_2		0.143	0.082	0.132	0.063	
NO_3		0.901	0.410	0.813	0.380	
Cl		177.3	141.8	159.5	109.5	≤1000
P		0.170	0.083	0.140	0.072	
SO_4	(mg/L)	3.31	1.45	2.651	1.23	≤3000
HCO_3		389.1	128.1	311.1	128.1	≤600
NH_4 N		0.821	0.45	0.651	0.370	
Mg		8.70	1.73	6.13	1.40	
Ca		15.11	4.73	13.12	3.38	
K		1.74	0.61	1.55	0.55	
Na		4.33	0.94	3.90	0.80	
Fe		1.48	0.83	1.01	0.73	
Mn		0.66	0.28	0.53	0.21	
Zn		0.93	0.51	0.80	0.42	
Cu		0.30	0.17	0.27	0.15	
Cr		0.21	0.11	0.20	0.10	
Cd		0.13	0.07	0.11	0.04	
Ni	mg/L	0.09	0.04	0.09	0.03	
Pb		0.17	0.09	0.15	0.07	
V		0.06	0.02	0.04	0.02	
THC		1.41	0.83	1.33	0.71	

3.2 Results of Setting Time Tests

Table 4 shows the result of the setting time test carried out on cement using **AFW** sample while table 5 shows the initial and final setting time for moulds made using **ASW**. Table 6 gives information on the Initial and Final Setting time of control concrete made with potable water. As noticed in table 3.4, average initial and final setting times for **AFW** -cement mix were 86mins and 248mins respectively. The same pair of setting values for **ASW**-cement mix were 65mins and 208mins respectively. The initial and final setting time using potable water with cement were 112mins and 216mins respectively.

Table 4: Initial and Final Setting Time for Moulds using First Wash.

Setting Time	Mould 1 (min)	Mould 2 (min)	Mould 3 (min)	Av. Setting Time (min)
Initial	84	86	88	86
Final	240	256	248	248

Table 5: Initial and Final Setting Time for Moulds Made using Second Wash.

Setting Time	Mould 1 (min)	Mould 2 (min)	Mould 3 (min)	Av. Setting Time (min)
Initial	65	63	68	65
Final	211	202	212	208

Table 6: Initial and Final Setting time for moulds using Potable Water

Setting Time	Mould 1 (min)	Mould 2 (min)	Mould 3 (min)	Av. Setting Time (min)
Initial	108	113	116	112.3
Final	223	213	212	216

Consequent upon the above, it can be seen that the initial setting time of the moulds made using both the first wash and second wash experienced a decrease of 27.73% and 45.38% respectively in comparison to that of the cement mix made with potable water. However, the Final setting time of the moulds made using the first wash experienced an increase of 14.81% while that of second wash experienced a decrease of 3.70% indicating that the former experienced a longer setting time than the latter. This may have been occasioned by the difference in composition and concentration of detergents between the first wash and second wash effluents. Since the first wash effluent was alkaline and the second wash effluent was acidic, an increase in the alkaline content of cement will delay the final setting time, reduce the compressive strength, and rapidly reduce workability [18]. This may have accounted for the reason why the final setting time of the cement made with the alkaline first wash effluent experienced more delays.

3.3 Results Of Slump Tests

Table 7 shows the result of the slump tests carried out on the concrete mix using potable water and first and second car wash effluents. it is evident from the slump test results that the slump values correspond to the degree or concentration of detergents in the water used being that the first wash which contains more detergent has higher slump value than that of second wash with the lowest slump value seen in the concrete made with potable water. It is worthy of note that, the concrete produced with all car wash effluent meets the specified and tolerance criteria stated in ASTM C94M-09 [19]

Table 7: Results of Slump Tests

Water Type	Slump Value(mm)
Potable water	10
First wash	18
Second Wash	15

3.4 Results of Compression Test

Tables 8 to 10 show the results of compression tests of concrete cubes produced with potable water, first and second car wash effluents. Each of the compression tests were performed after 7, 14 and 28 days of curing. The average compressive strength of the concrete cubes produced from potable water showed consistently increasing strength from 19.53 to 23.14N/mm^2 between 7days and 28days periods of curing. The concrete cubes produced with the first wash effluent gave compressive strength values ranging from 9.43 to 14.82N/mm^2 whereas, the compressive strengths obtained from the cubes produced with the second wash was between 8.74 and 11.00N/mm^2 from 7days to 28days interval of curing. These showed that the percentage decreases of concrete strength for the first wash and second wash compared to the control concrete were 34.61% and 55.25% respectively at 7days whereas the decreases were 35.96% and 54.75% respectively at 28days interval of curing.

The results further strength the reasoning that the high concentration of detergent in the first wash could have played a role in the dip in the compressive strength at 14days interval of curing. Overall, the high compressive strength noticed in the first wash concrete compared to the second wash effluent was unexpected given the high concentration of detergents in the first wash effluent used for the production of the concrete cubes.

Table 8: Compression Test Result using Potable Water.

Days	Sample	Weight (kg)	Density of cubes (kg/m^3)	Failure load (KN)	Comp strength (N/mm^2)	Average density (kg/m^3)	Average comp strength (N/mm^2)
7	W_1	2.56	2560	213.07	21.31	2553.33	19.53
	W_2	2.56	2560	193.25	19.33		
	W_3	2.54	2540	179.59	17.96		
14	W_1	2.54	2540	210.35	21.04	2550.00	21.52
	W_2	2.53	2530	229.73	22.97		
	W_3	2.58	2580	205.64	20.56		
28	W_1	2.57	2570	236.32	23.63	2576.67	23.14
	W_2	2.57	2570	228.22	22.82		
	W_3	2.59	2590	229.74	22.97		

Table 9: Compression Test Result using First Wash

Days	Sample	Weight (kg)	Density of Cubes (kg/m^3)	Failure load (KN)	Comp Strength (N/mm^2)	Average Density (kg/m^3)	Average Comp. Strength (N/mm^2)
7	W_1	2.49	2490	135.30	13.53	2473.33	12.77
	W_2	2.40	2400	108.89	10.89		
	W_3	2.53	2530	138.88	13.89		
14	W_1	2.44	2440	98.47	9.85	2463.33	9.43
	W_2	2.39	2390	91.83	9.18		
	W_3	2.56	2560	92.73	9.27		
28	W_1	2.51	2510	148.88	14.89	2496.33	14.82
	W_2	2.52	2520	156.90	15.69		
	W_3	2.45	2450	138.66	13.87		

Table 10: Compression Test Result using Second Wash

Days	Sample	Weight (kg)	Density of Cubes (kg/m^3)	Failure load (KN)	Comp Strength (N/mm^2)	Average Density (kg/m^3)	Average Comp. Strength (N/mm^2)
7	W_1	2.59	2590	89.82	8.98		

Days	Sample	Weight (kg)	Density of Cubes (kg/m³)	Failure load (KN)	Comp Strength (N/mm²)	Average Density (kg/m³)	Average Comp. Strength (N/mm²)
	W_2	2.57	2570	83.59	8.36	2563.33	8.74
	W_3	2.56	2560	88.92	8.89		
14	W_1	2.46	2460	114.49	11.45	2496.67	11.00
	W_2	2.51	2510	103.10	10.31		
	W_3	2.52	2520	112.39	11.24		
28	W_1	2.38	2380	84.42	8.44	2480	10.47
	W_2	2.71	2710	121.38	12.14		
	W_3	2.35	2350	108.29	10.83		

As per ASTM C1602, it is specified that a sample concrete must attain a limit of ≥90% of the mean strength of the control concrete (here produced with potable water) to be adjudged adequate. It is can be deduced in this instance that the compressive strength of the concrete cubes produced from the first wash and second wash yielded 65.38% and 44.74% respectively of the compressive strength of the control concrete which is less than the prescribed value. Therefore, the automobile waste water is deemed not suitable for concrete production in its untreated state. Figure 10 is the summary of compressive strength tests for potable water and different car wash effluents.

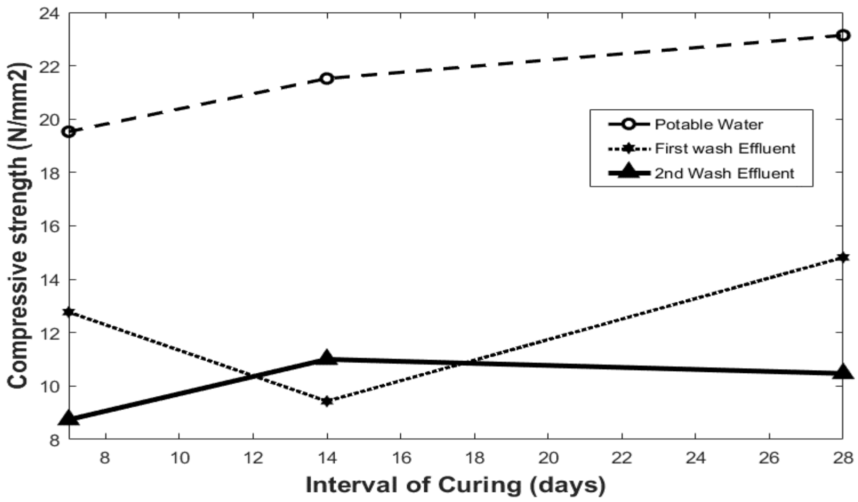

Figure 10: Graphical Representation of the Compressive Test Results

4.0 Conclusion

Evaluation of the quality of car wash effluent as a reusable material for the production of concrete for construction purpose gave valuable insights in this study. Car wash effluents were obtained from two car wash outlets in Egor Local Government Area of Benin City and subjected to physicochemical evaluations. Wastewaters were obtained after the first and second washing operations of the exteriors and interiors of the car excluding the engine compartment. The first was effluents tended to have a high concentration of soap or detergent deliberately so to remove tough stains or dirt in the car. The second effluent which may be described as a rinse water has reduced detergent concentration. The car wash effluents were then used to produced cement mix and concrete that were examined for the setting time, slump value and compressive strengths.
From the study, the first wash effluents generally showed high alkaline content while the second wash sample showed acidic characteristics. Other notable cations and anions showed high

concentration in the first wash effluent compared to the second wash effluent. The final setting time was longest in the first wash sample and shortest in the second wash sample. The sample produced with potable water gave intermediate results. The increased setting has the adverse effects of reducing workability due to its high alkaline content. All the slump values passed the minimum criteria for suitable concrete even though the first wash slump value was highest among the lot. The compressive strength of the first and second wash effluents were 65.38% and 44.74% respectively of the control compressive strength which fell short of the relevant criteria to access its suitability as useful concrete for construction endeavours.

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